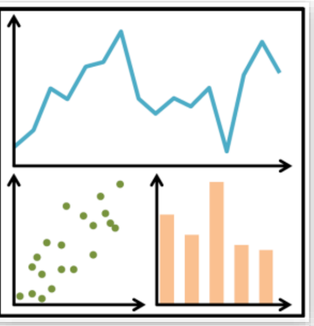
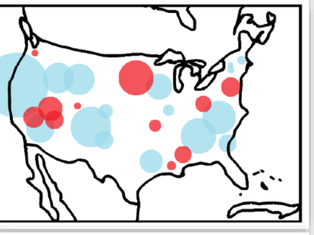
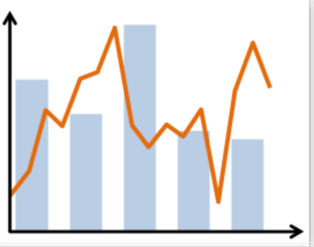
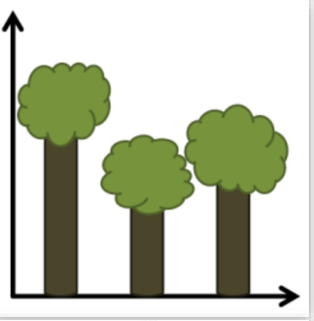
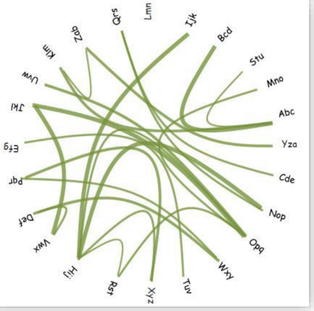






Lecture 10: Color

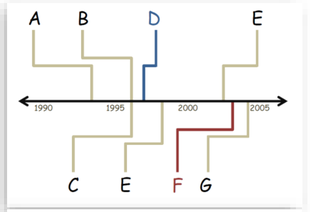
CS 7250

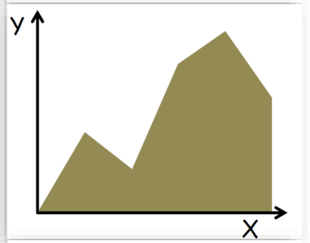
SPRING 2021

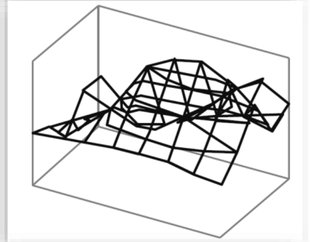
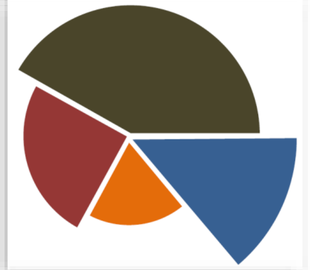
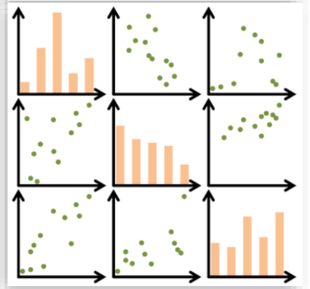
Prof. Cody Dunne

NORTHEASTERN UNIVERSITY

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





Checking In

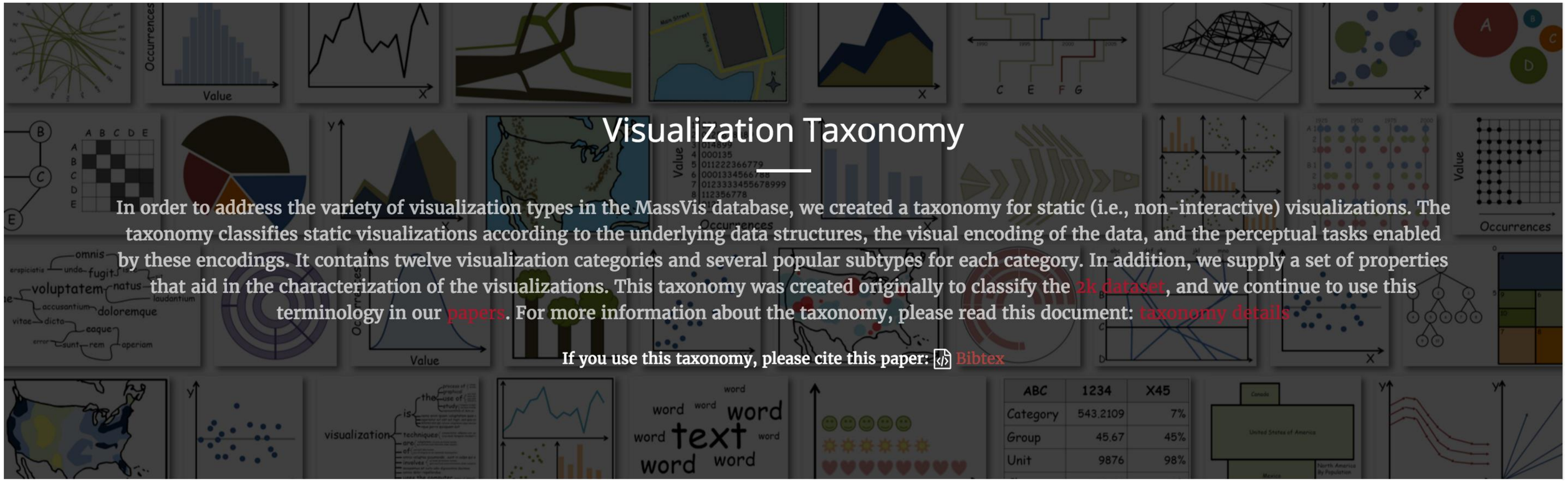
READING QUIZ

Quiz — Color

Password: “drats_another_quiz”

Accept Assignment 7 — D3 Event Handling now!

Visualization Ideas



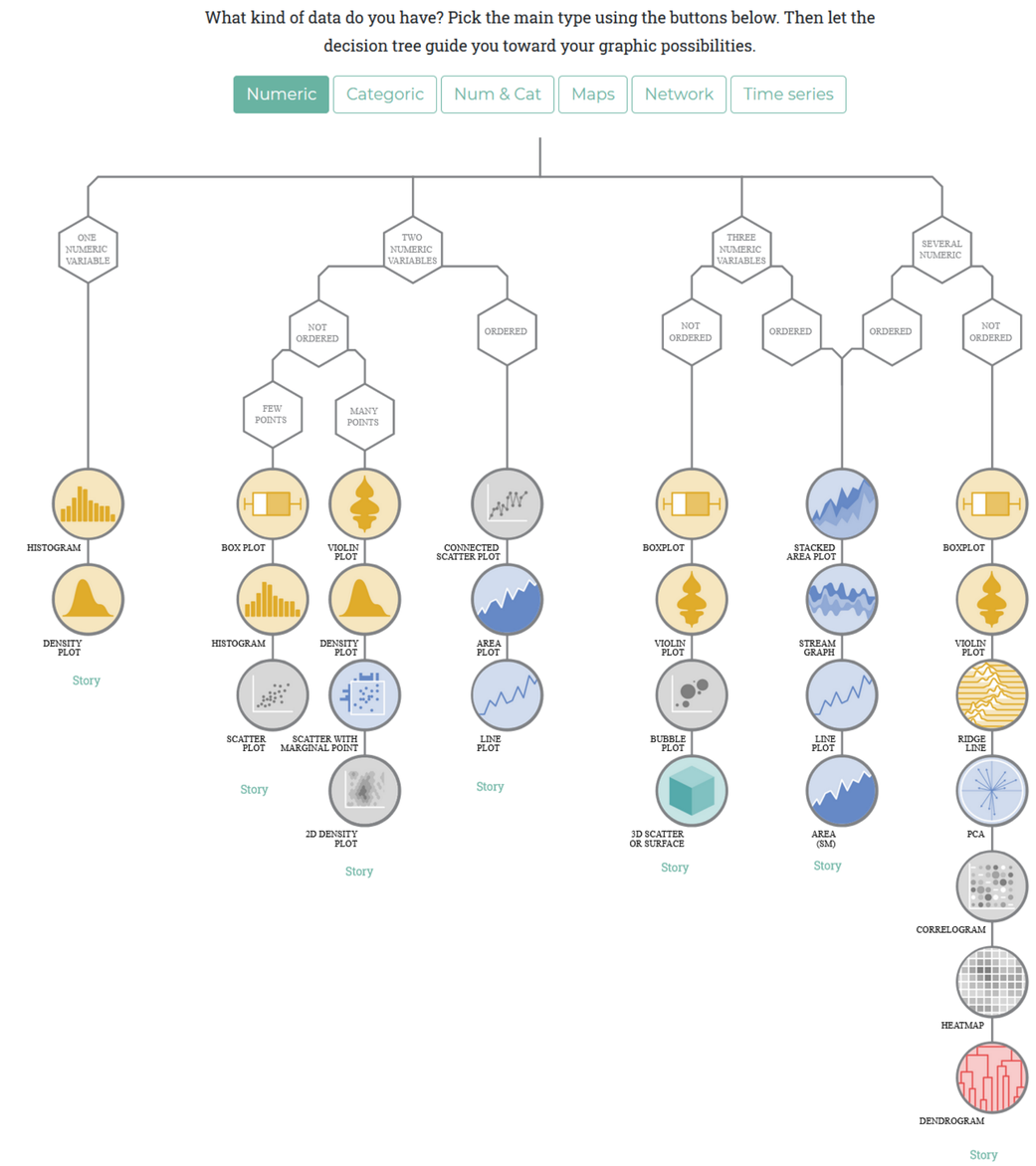
http://massvis.mit.edu/

Borkin, M., Vo, A., Bylinskii, Z., Isola, P., Sunkavalli, S., Oliva, A., & Pfister, H., 2013, "What Makes a Visualization Memorable?", IEEE Transactions on Visualization and Computer Graphics (Proceedings of InfoVis 2013), 19, 12, 2306-2315.

More visualization “catalogs”

Data to Viz

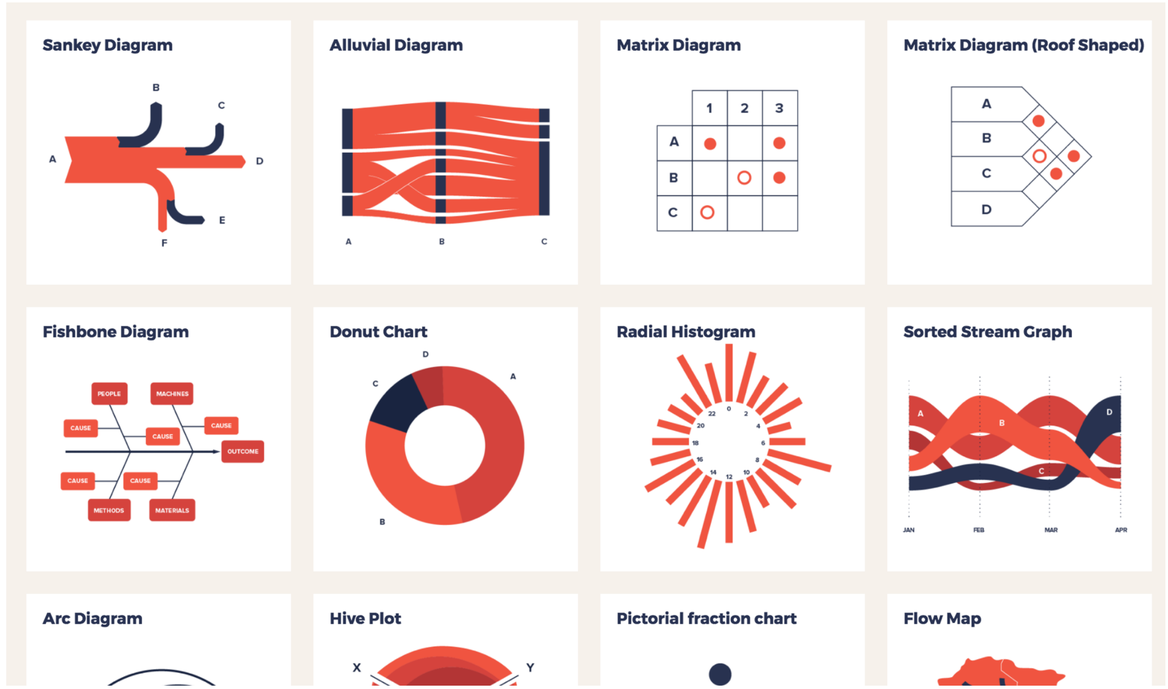
https://www.data-to-viz.com/



More visualization “catalogs”

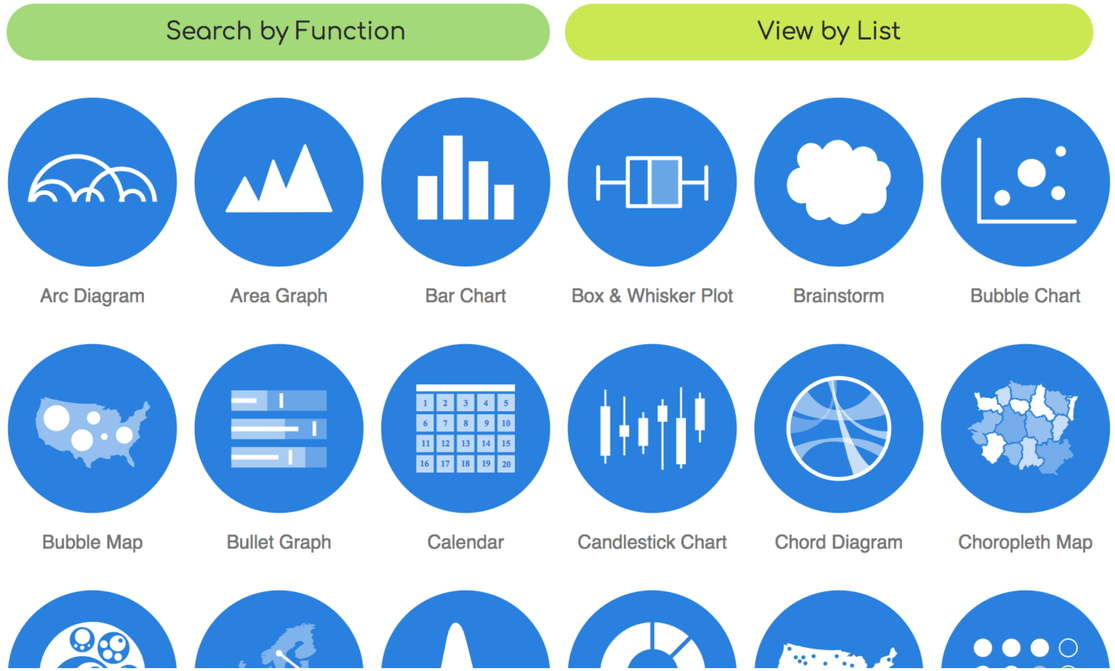
DataVizProject

http://datavizproject.com/



The Data Visualization Catalogue

http://www.datavizcatalogue.com/

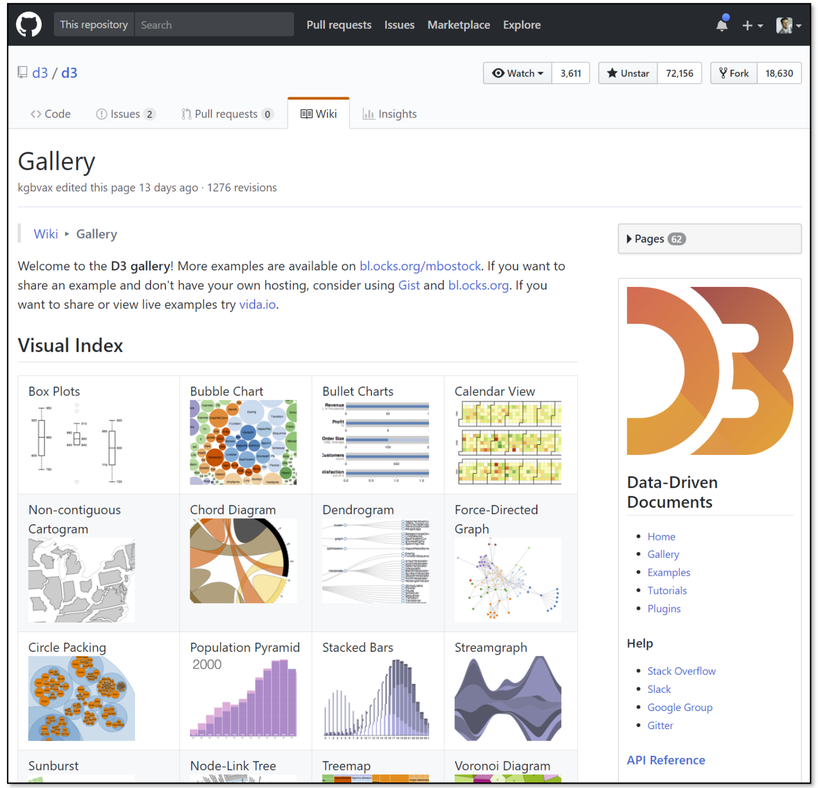


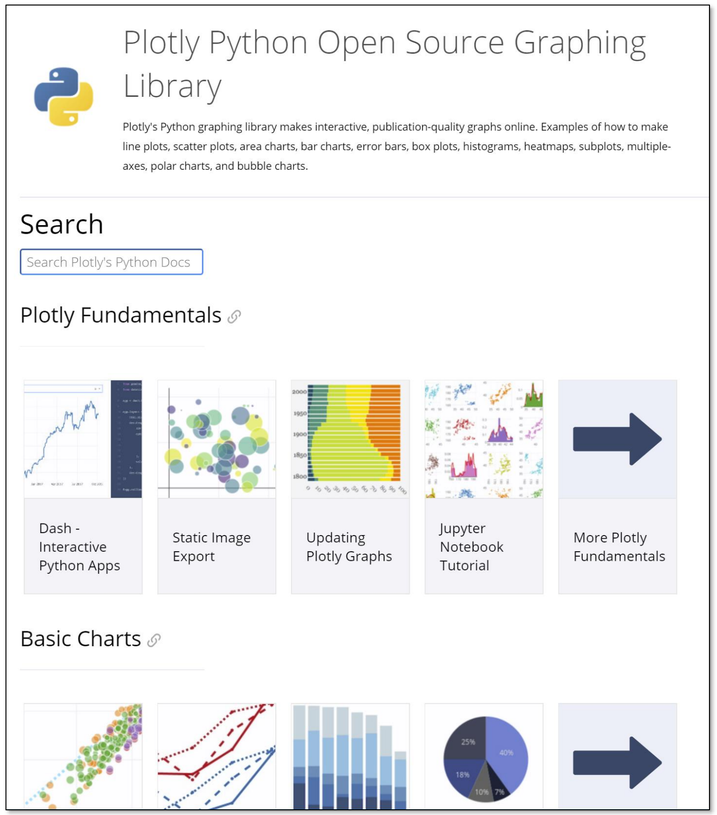
More visualization ideas

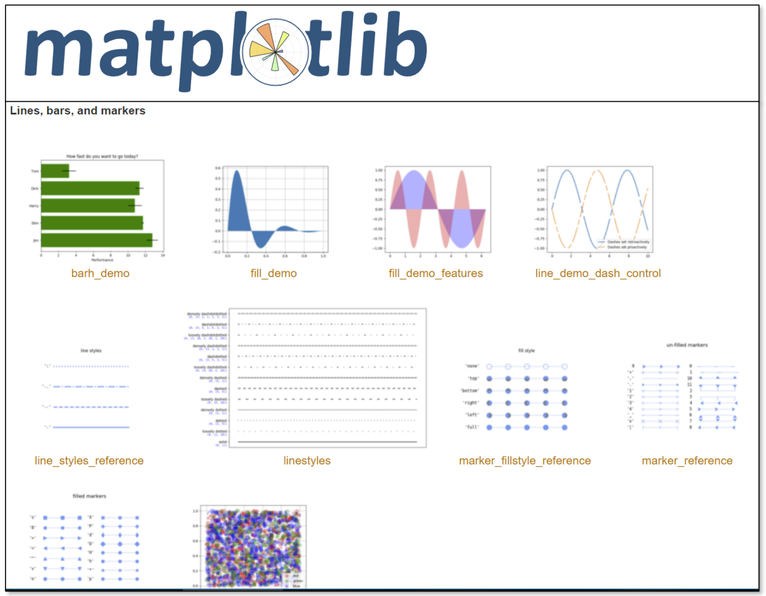
https://matplotlib.org/gallery.html

https://github.com/d3/d3/wiki/Gallery

https://plot.ly/python/







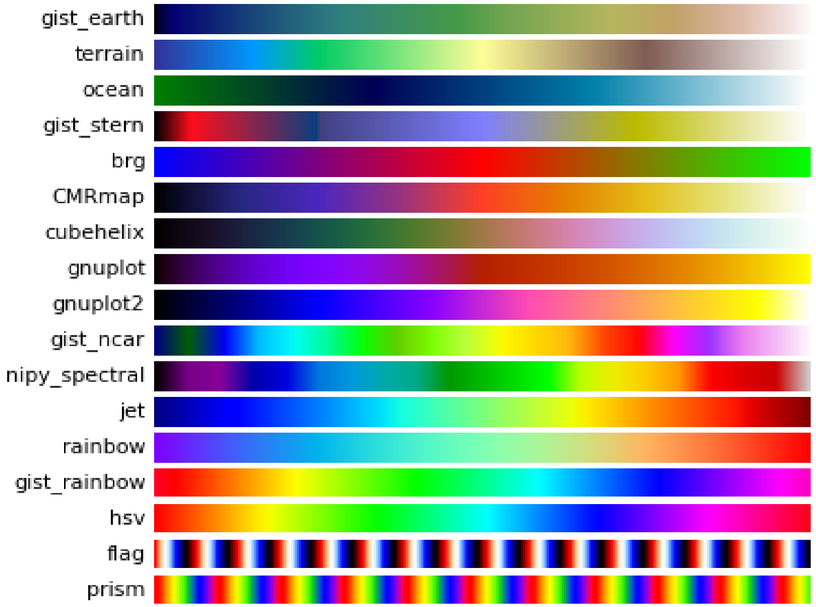
COLOR

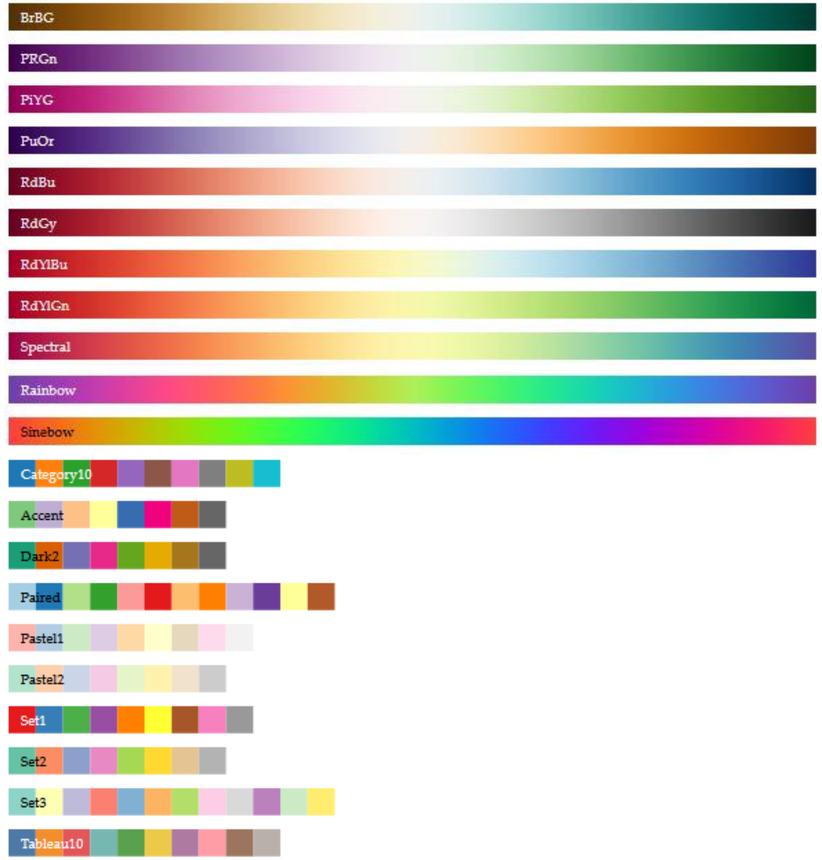
Goals for Today: learn How...

- …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.

Color Maps

Color Map = map between value (domain) and color (range)





Bostock, 2018

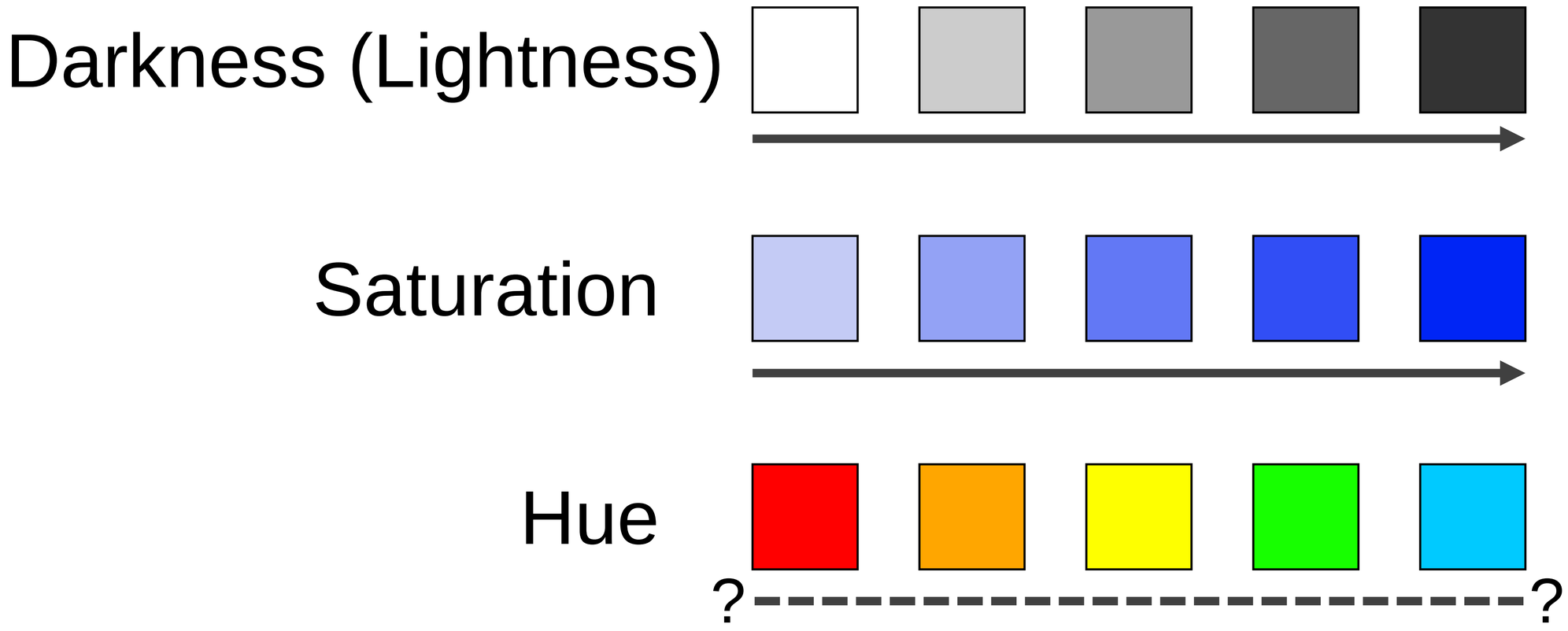
matplotlib

“…avoiding catastrophe becomes
the first principle in bringing color
to information: above all, do no harm.”

-Edward Tufte

Tufte, “Envisioning Information”

Color Vocabulary and Perceptual Ordering



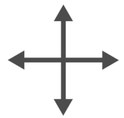
Color

- Color Encoding
  - Hue
  - Saturation
  - Luminance

- Color Map
  - Categorical

  - Ordered
    - *Sequential*
    - *Diverging*

  - Bivariate



Size, Angle, Curvature, ...

- Length

- Angle

- Area

- Curvature

- Volume

Shape

Motion

- Motion
  Direction, Rate, Frequency, ...

Color Maps

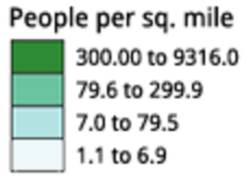
Three Main Types:

Categorical

Does not imply magnitude differences (categorical/nominal data)

Distinct hues with similar emphasis

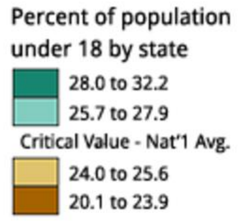
Sequential



Best for ordered data that progresses from low to high (ordinal, quantitative data)

Darkness (lightness) channel effectively employed

Diverging



For data with a “diverging” (mid) point (quantitative data)

Equal emphasis on mid-range critical values and extremes at both ends of the data range

Brewer, 1994

Color Maps

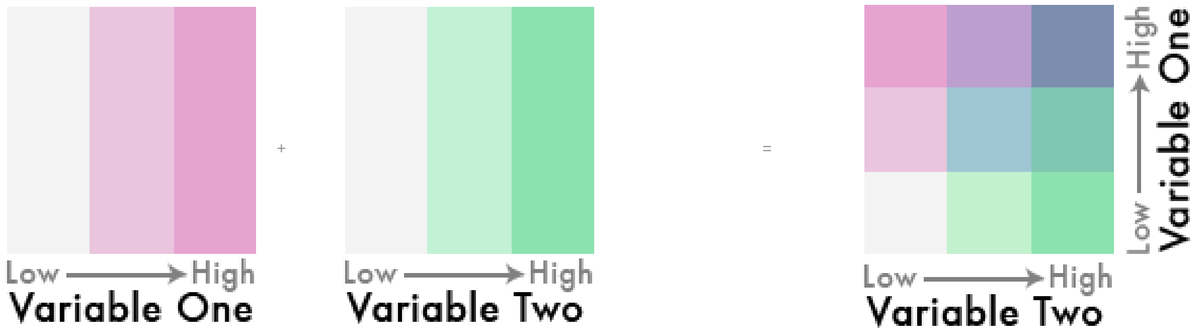
ALSO...

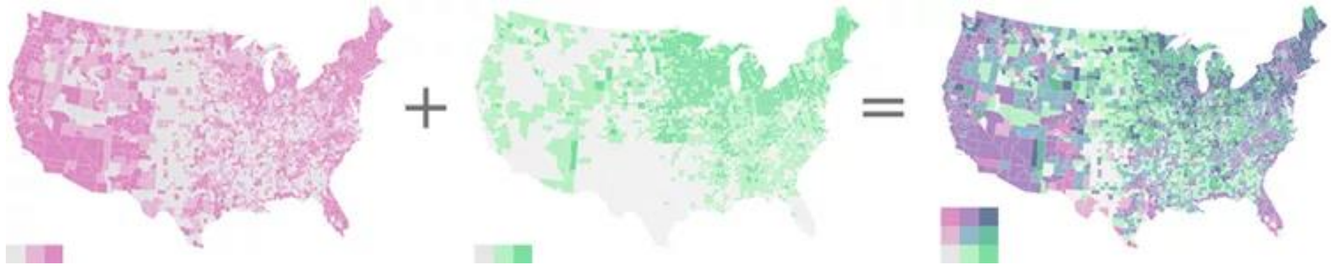
Bivariate

Displays two variables

Combination of two sequential color schemes

These are very difficult to design effectively, make intelligible, and be color blind friendly.

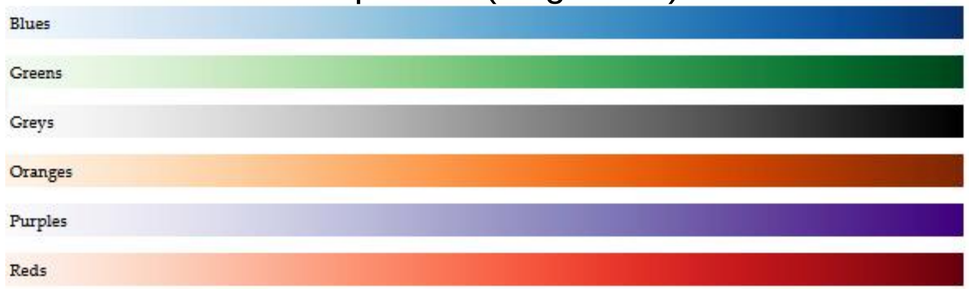




Stevens, 2015

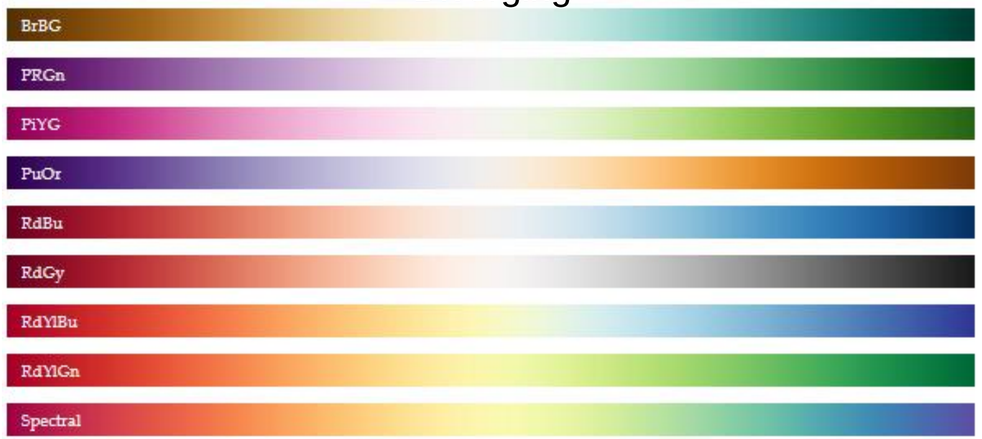
Types of Color Maps

Sequential (single hue)



Sequential (multiple hue)

Diverging

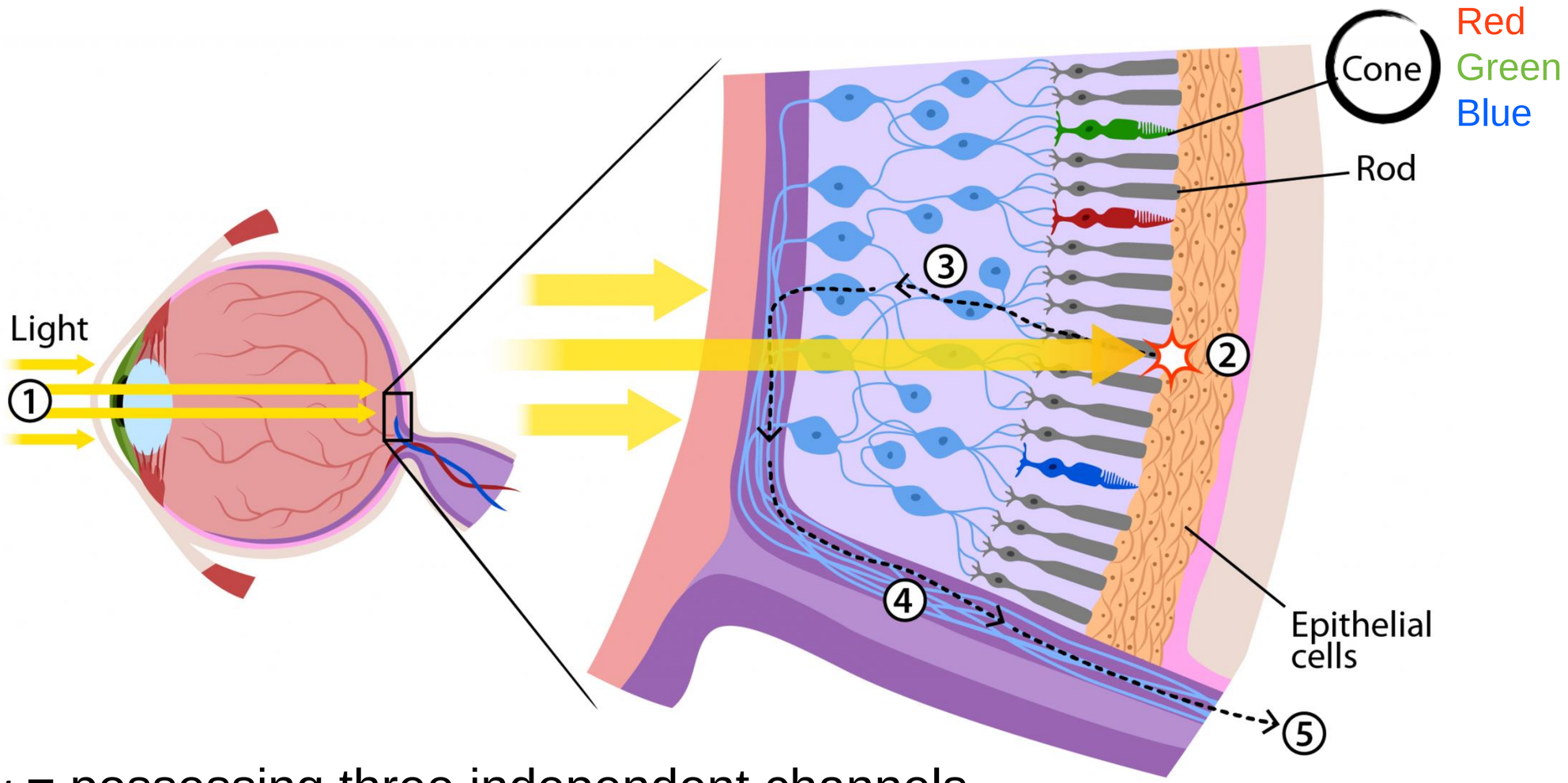


Categorical

Cyclical

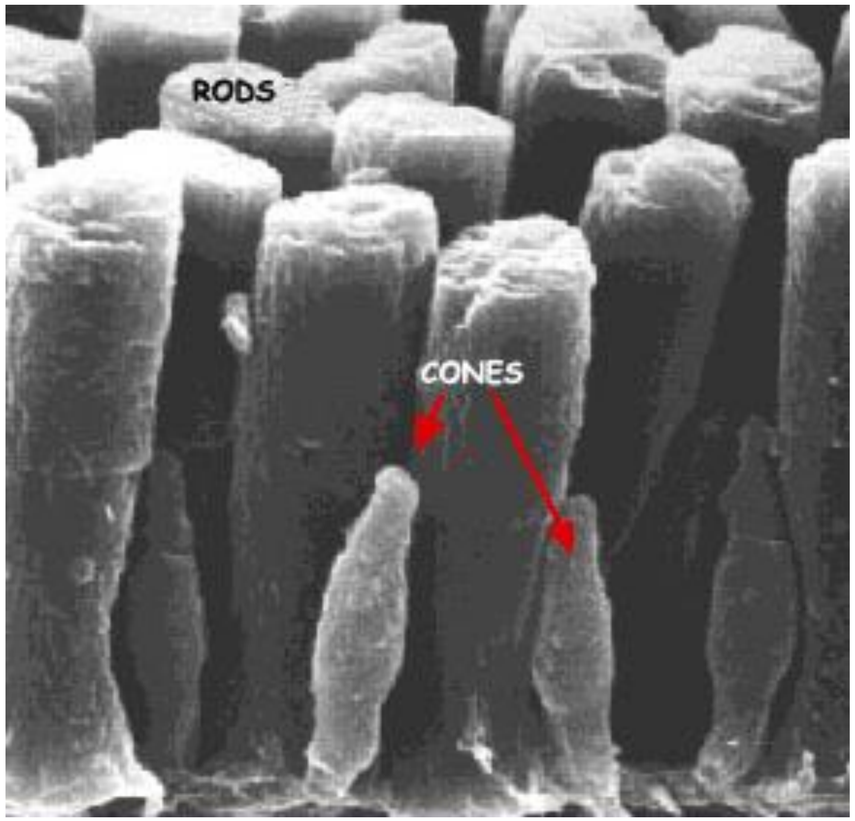
Bostock, 2018

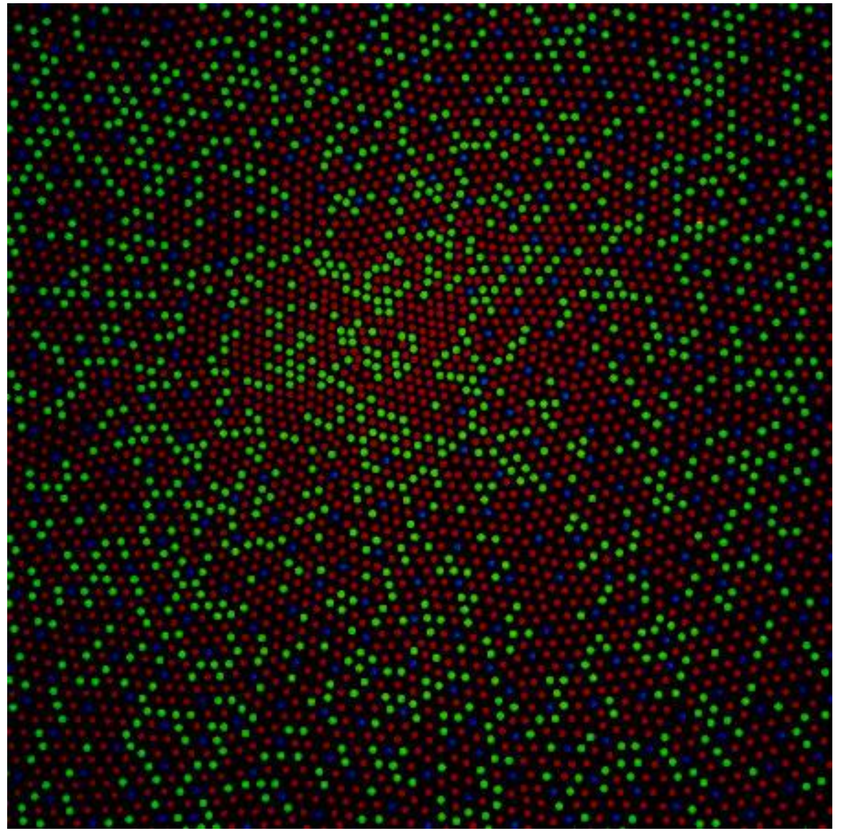
Rods & Cones



trichromacy = possessing three independent channels for conveying color information

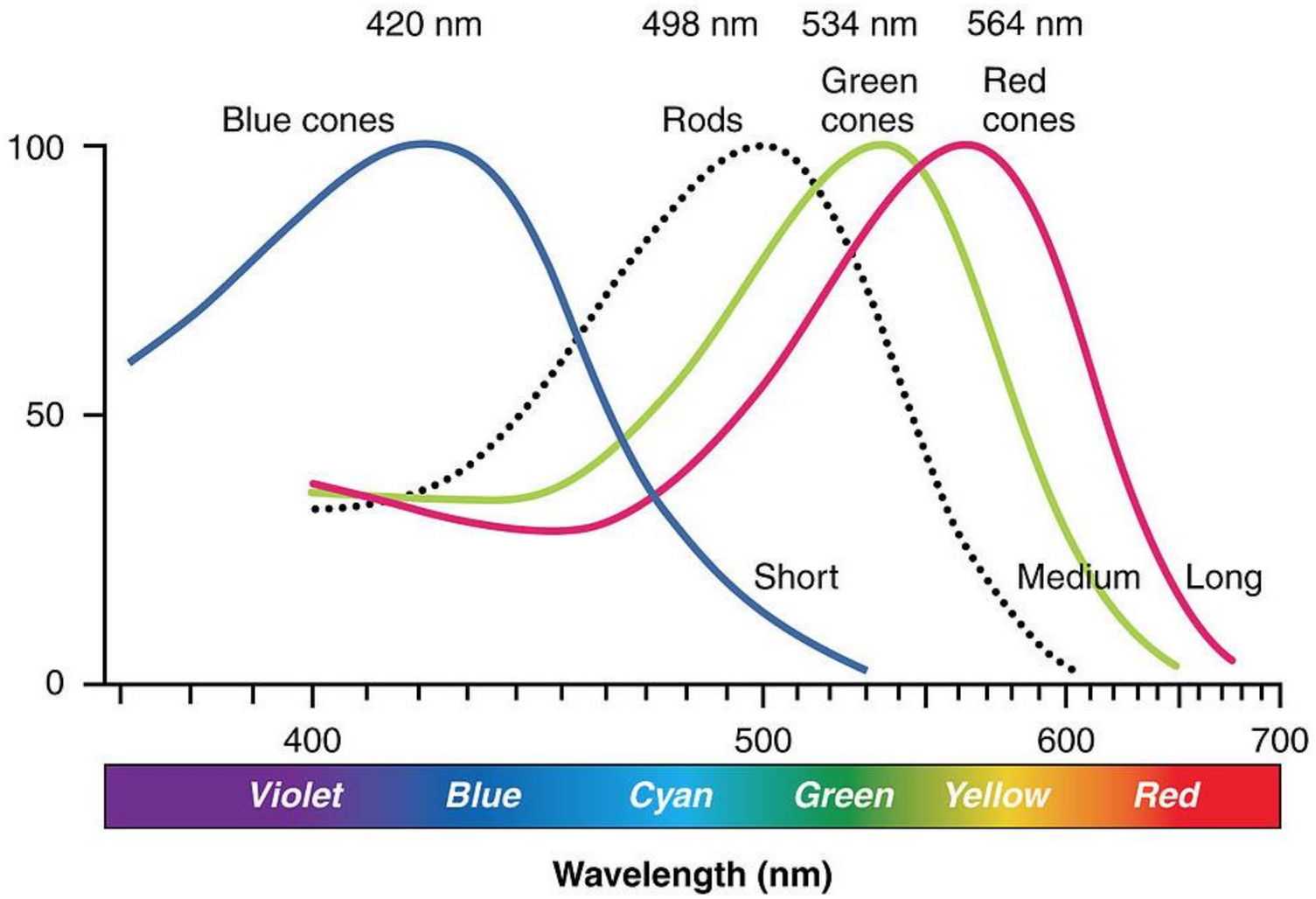
Rods & Cones





http://i.stack.imgur.com/wIbcE.jpg
Dubuc, 2002

Cones & Rods



This is why darkness (lightness) is an effective encoding channel!

Rods:120 million

Cones: 5-6 million

This is why we are so sensitive to red!

Cones:

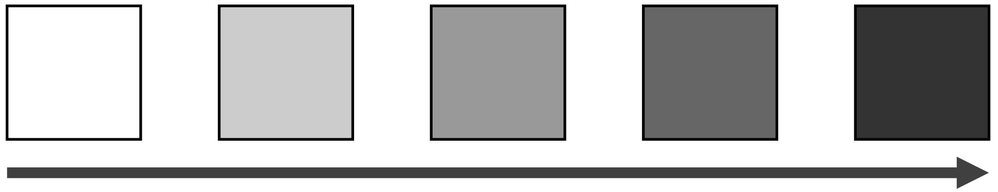
64% red-sensitive

32% green-sensitive

2% blue-sensitive.

Witcombe, 2014

Darkness (Lightness) Channel



- 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

“Get it right in black and white.”

-Maureen Stone

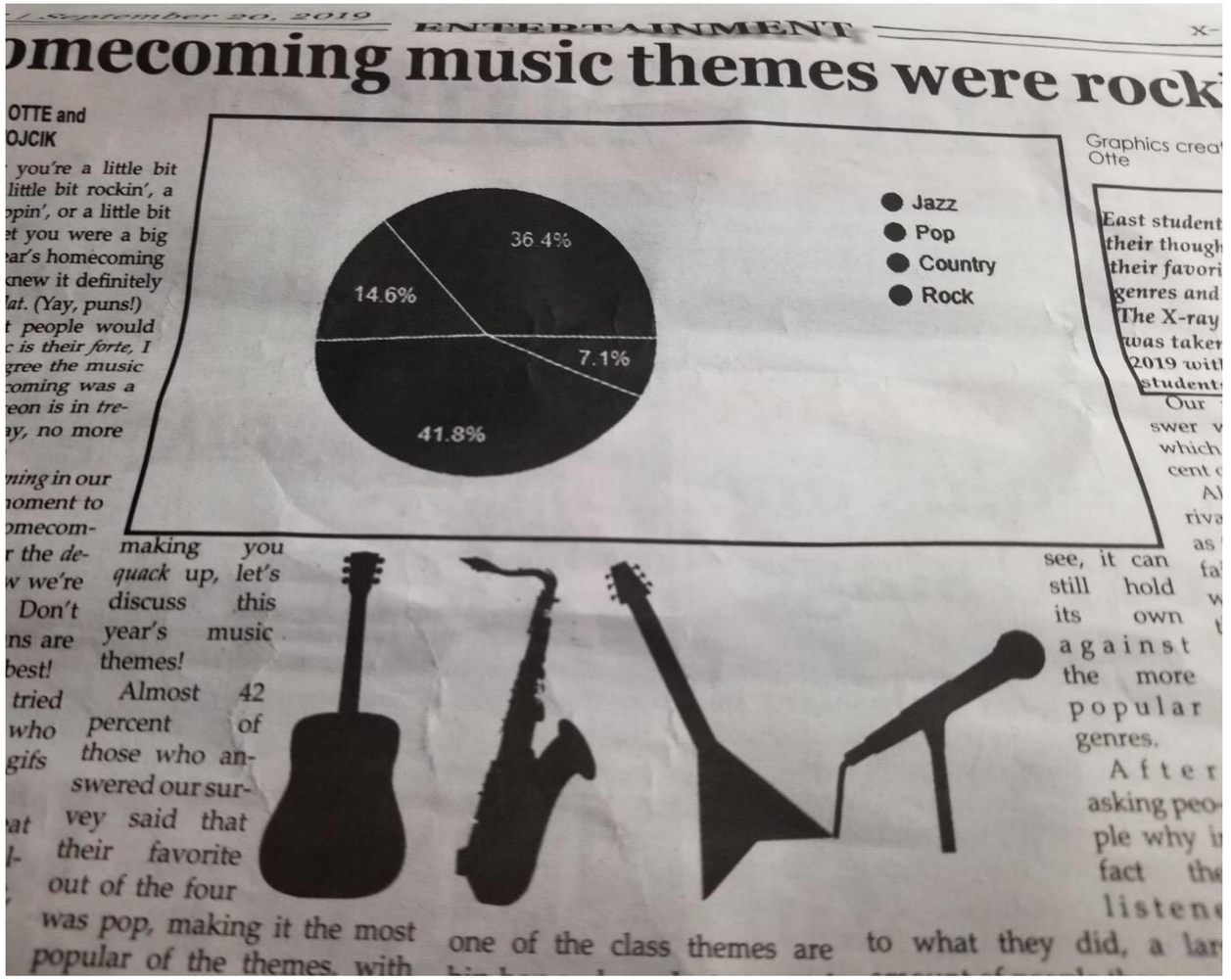
Stone, 2010


Petaluma
Tomales
1
Point Reyes-Petaluma Rd
Point Reyes Station
Novato Blvd
101
121
37
Novato
SAN PABLO BAY
Olema
Sir Francis Drake Boulevard
POINT REYES NATIONAL SEASHORE
San Rafael
80
580
1
PACIFIC OCEAN
Oakland
GOLDEN GATE
0 10 Kilometers
0 10 Miles
San Francisco


Petaluma
Tomales
1
Point Reyes-Petaluma Rd
Point Reyes Station
Novato Blvd
101
121
37
Novato
SAN PABLO BAY
Olema
Sir Francis Drake Boulevard
POINT REYES NATIONAL SEASHORE
San Rafael
80
580
1
PACIFIC OCEAN
Oakland
GOLDEN GATE
0 10 Kilometers
0 10 Miles
San Francisco

Stone, 2010

Understanding your medium matters



September 20, 2019 ENTERTAINMENT

omecoming music themes were rock

OTTE and
OJCIK

you're a little bit
little bit rockin', a
pin', or a little bit
t you were a big
ar's homecoming
new it definitely
lat. (Yay, puns!)
t people would
c is their forte, I
gree the music
coming was a
eon is in tre-
y, no more

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The X-ray
was taker
2019 with
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making you *quack* up, let's discuss this year's music themes!

Almost 42 percent of those who answered our survey said that their favorite out of the four was pop, making it the most popular of the themes, with one of the class themes are

see, it can still hold its own against the more popular genres.

After asking people why i fact the listene to what they did, a lar

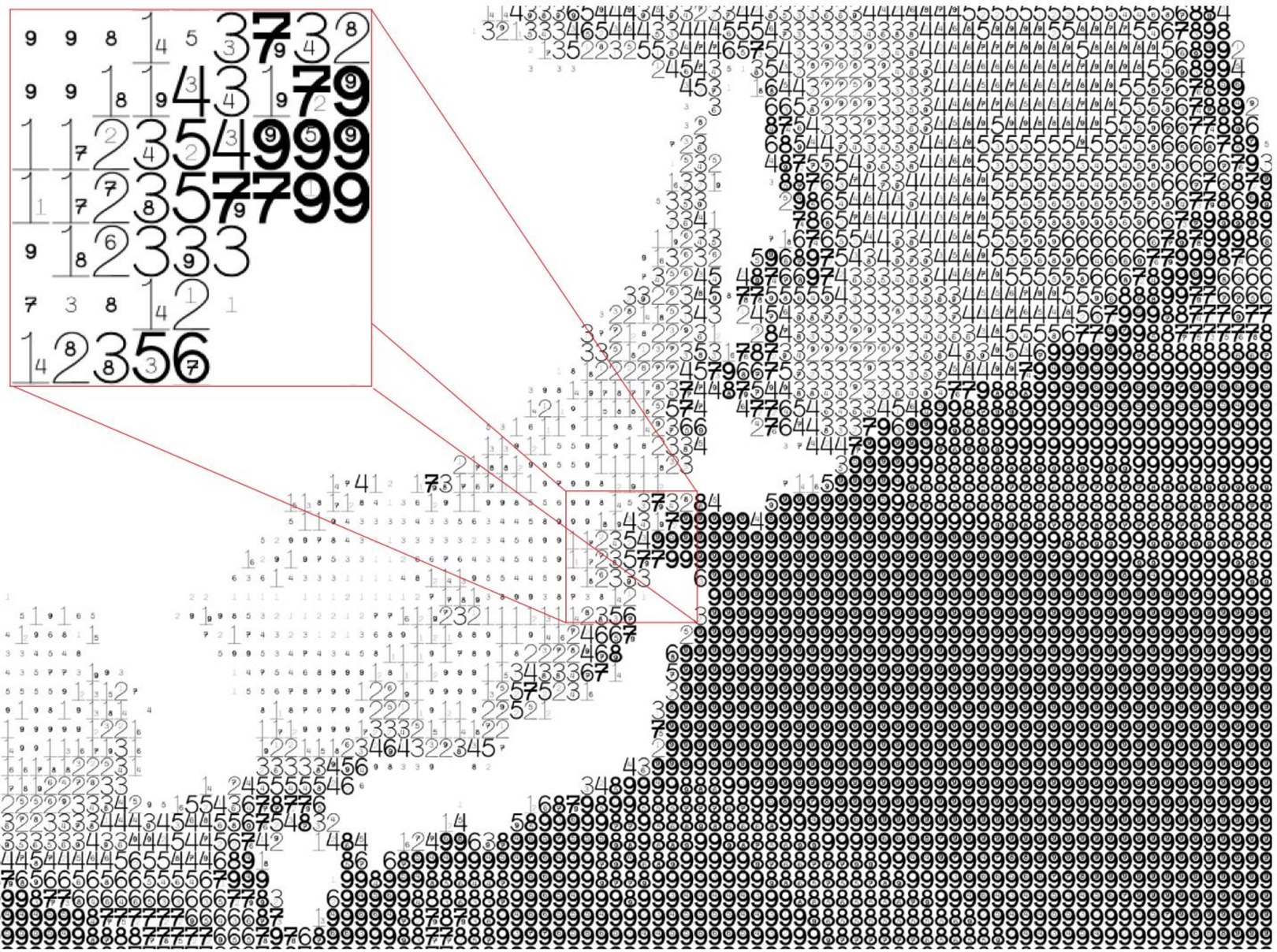
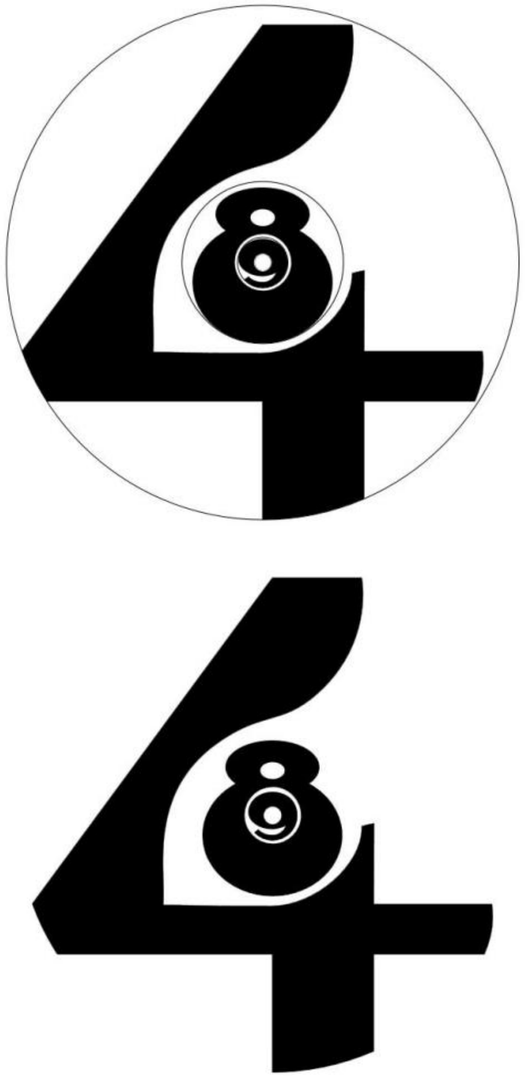


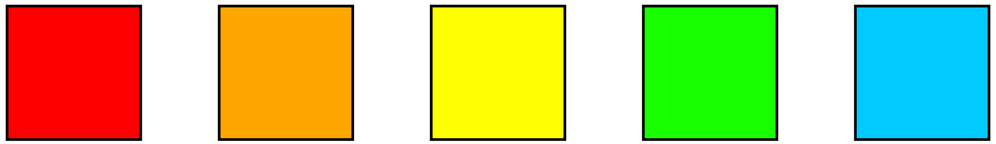
Figure 8: Maximum wave amplitudes for the Japan 2011 tsunami. Amplitudes were clipped at 99cm. Data adapted from NOAA; http://www.noaa.gov/.

FatFonts

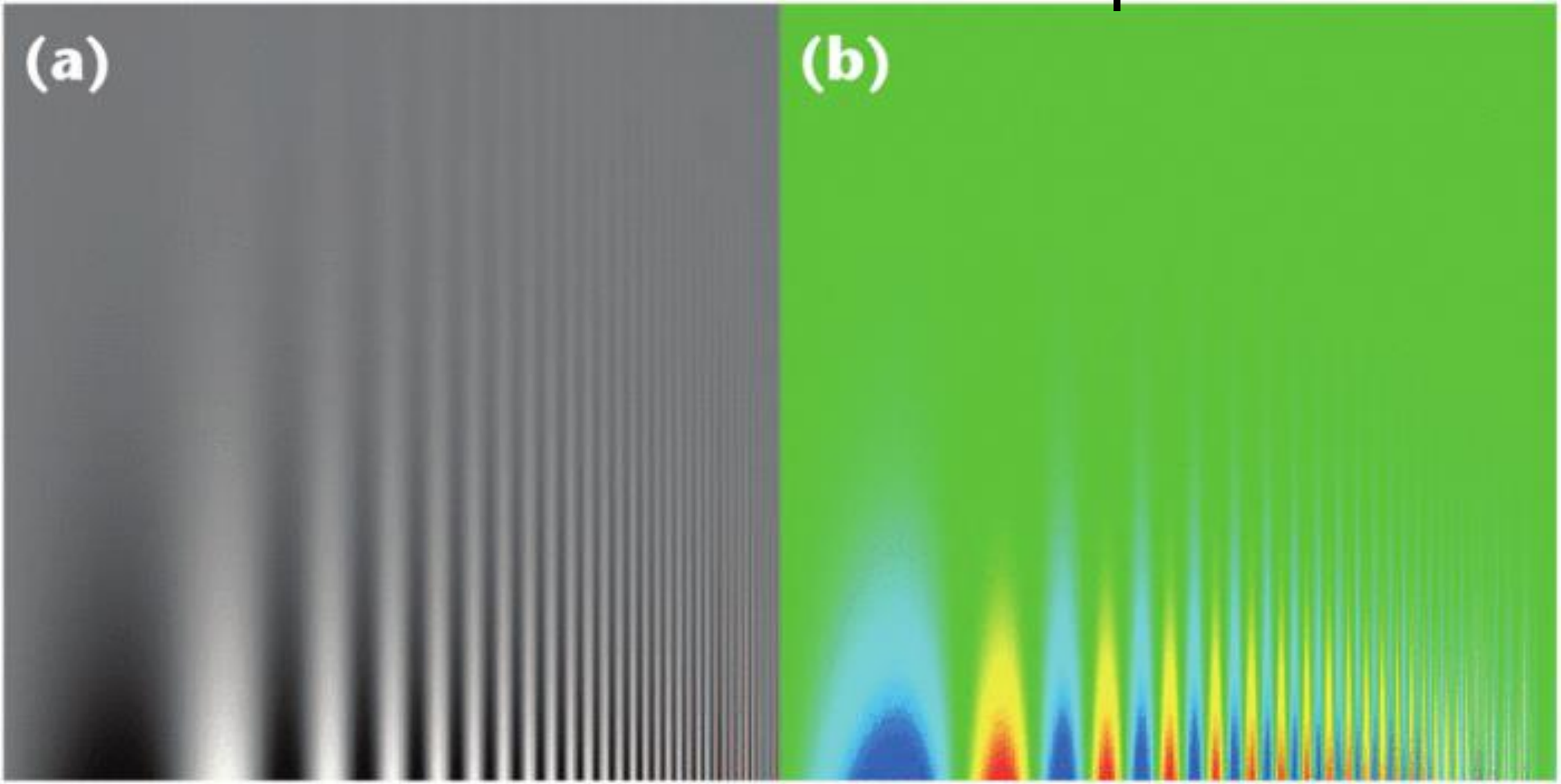


[Nacenta et al., 2012](#)

Rainbow Color Map (Hue)

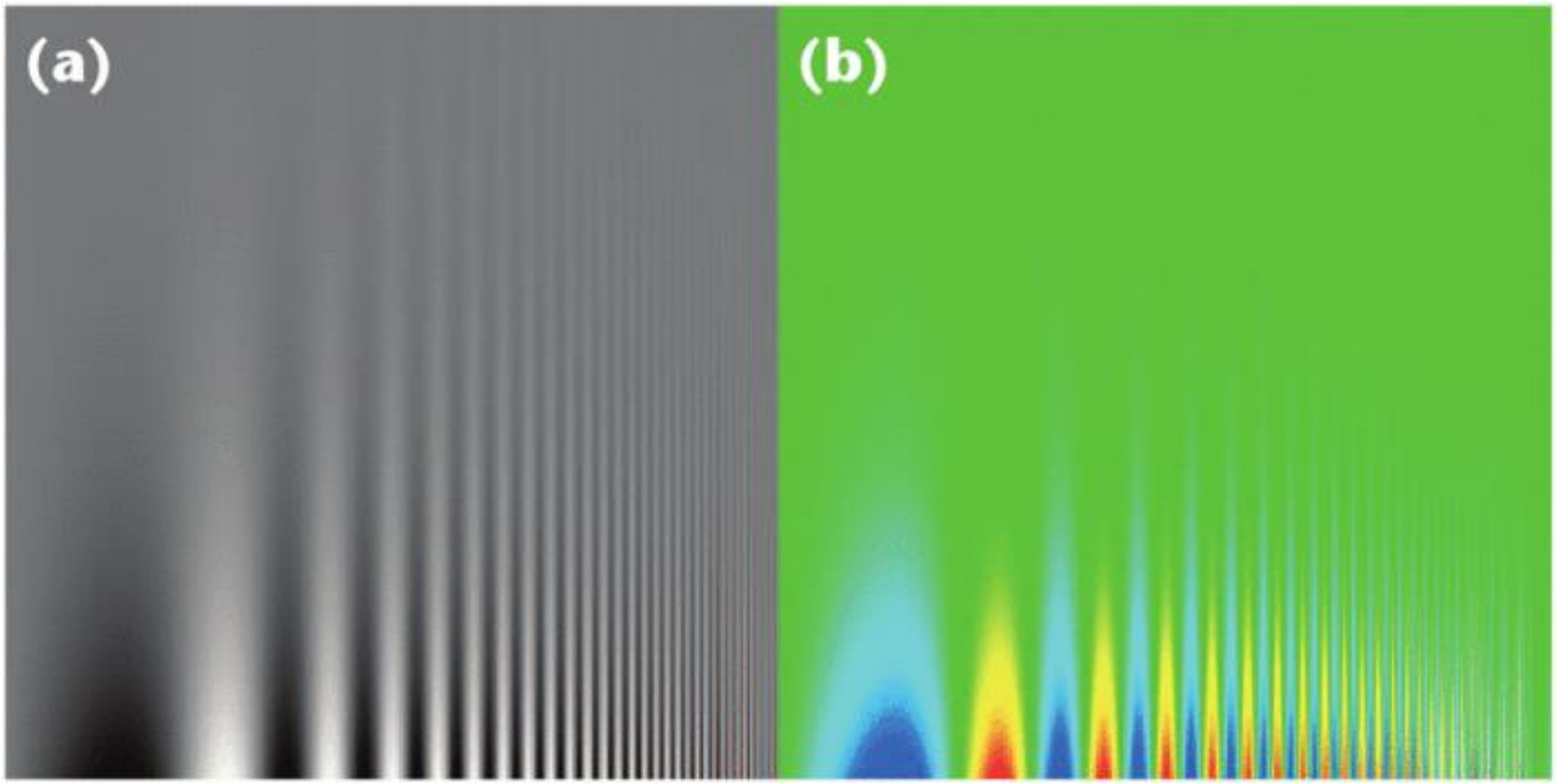


Rainbow Color Map



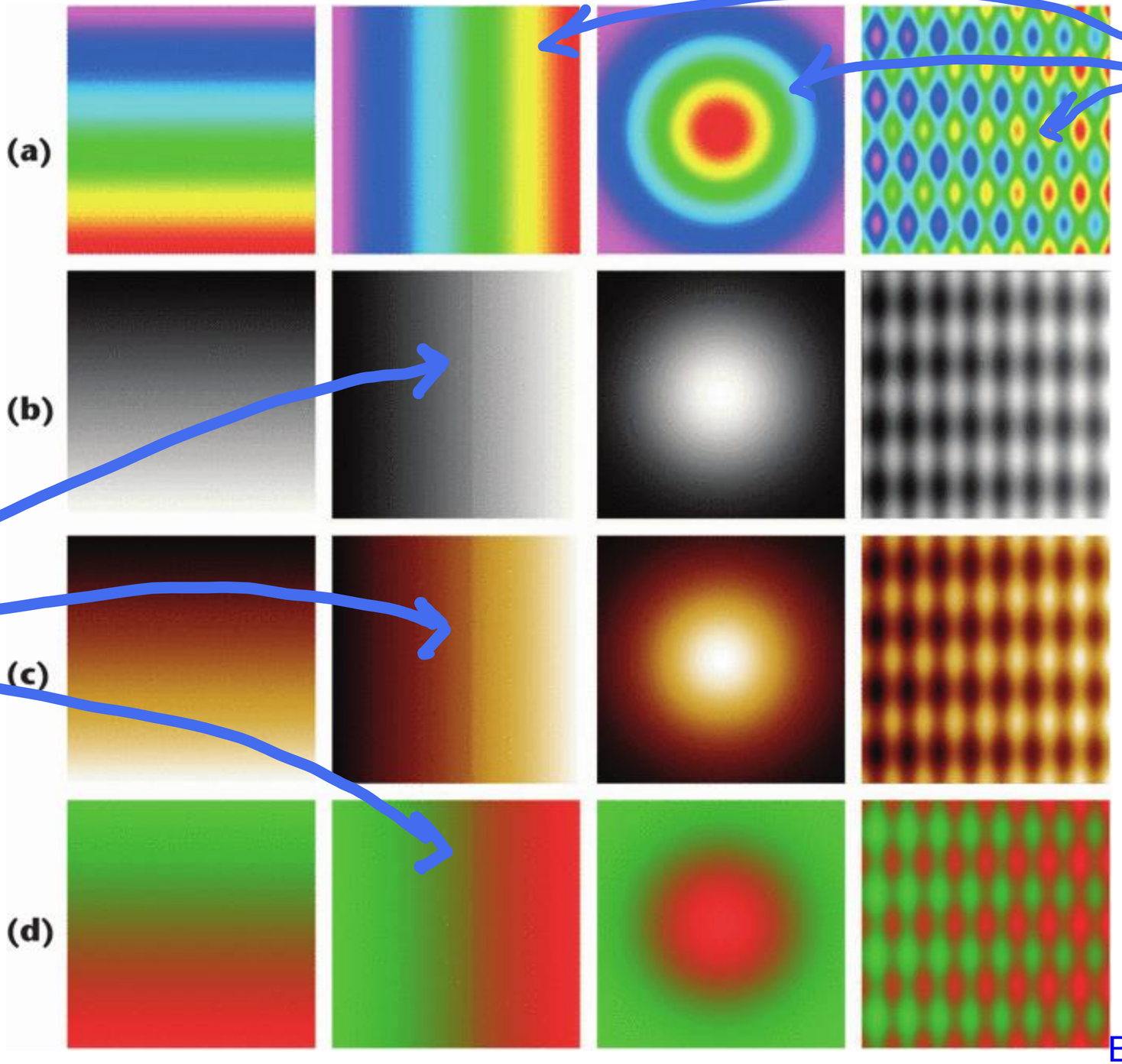
Borkin et al., 2011

Rainbow Color Map



- 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)

Borkin et al., 2011

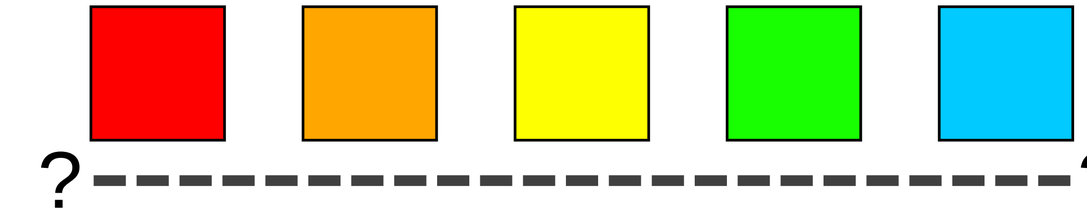


False

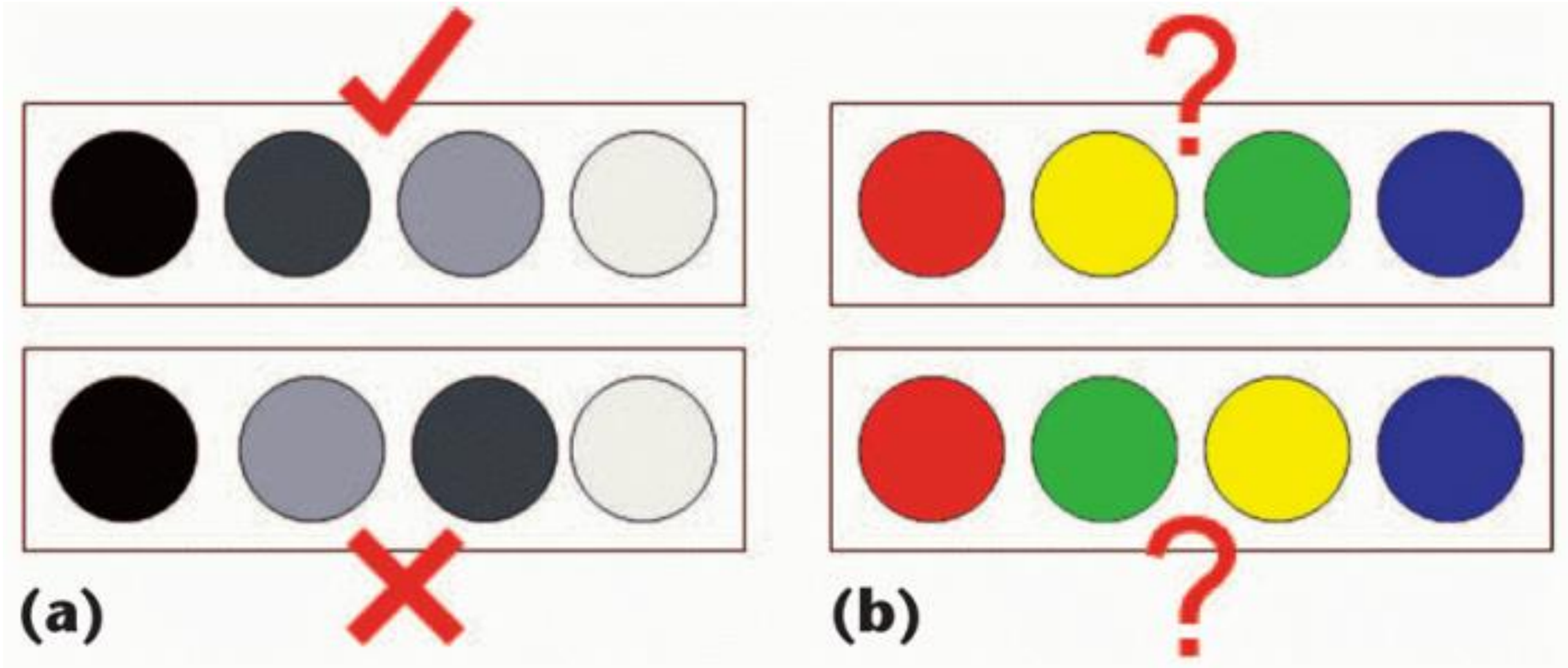
Real!

Borland & Russell, 2007

Rainbow Color Map (Hue)



No perceptual ordering (confusing)



Borland & Russell, 2007

Rainbow Color Map

Rainbow:

3D: 39%

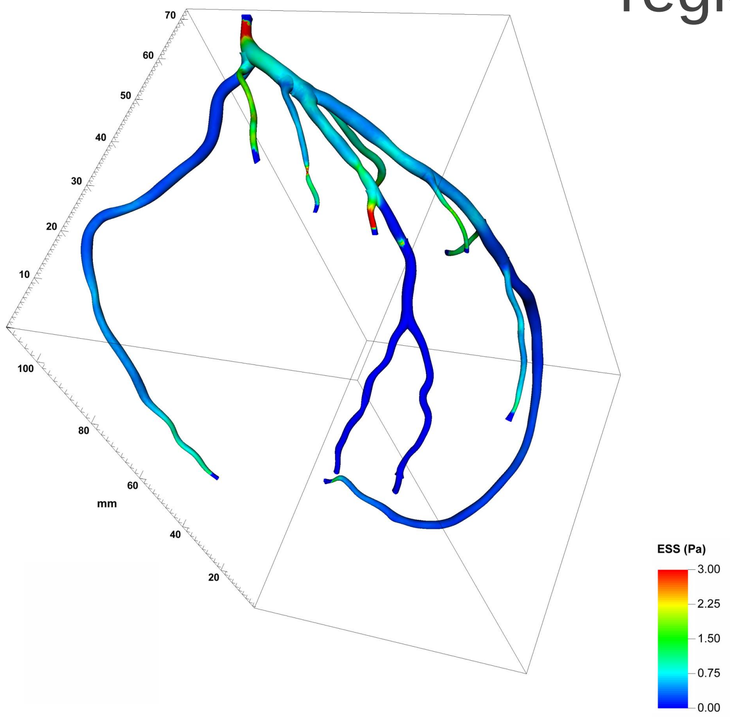
2D: 62%

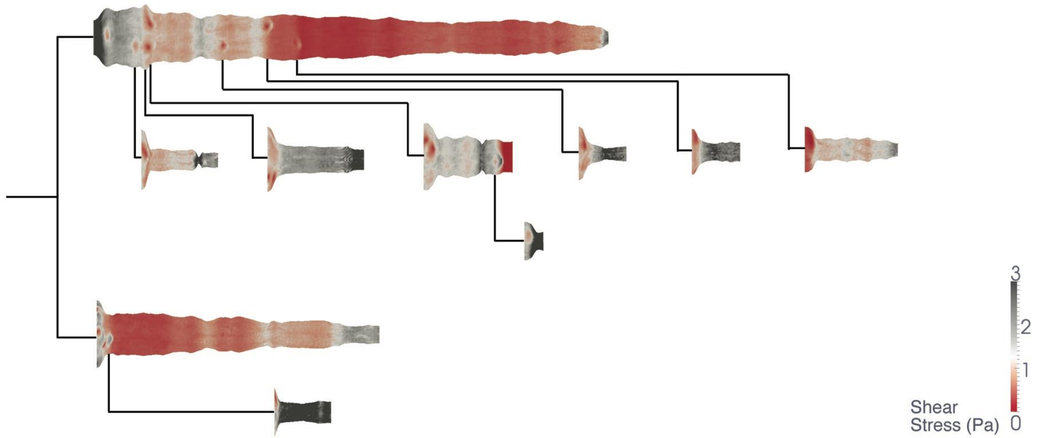
How many diseased regions found?

Diverging:

3D: 71% (*Δ +31%*)

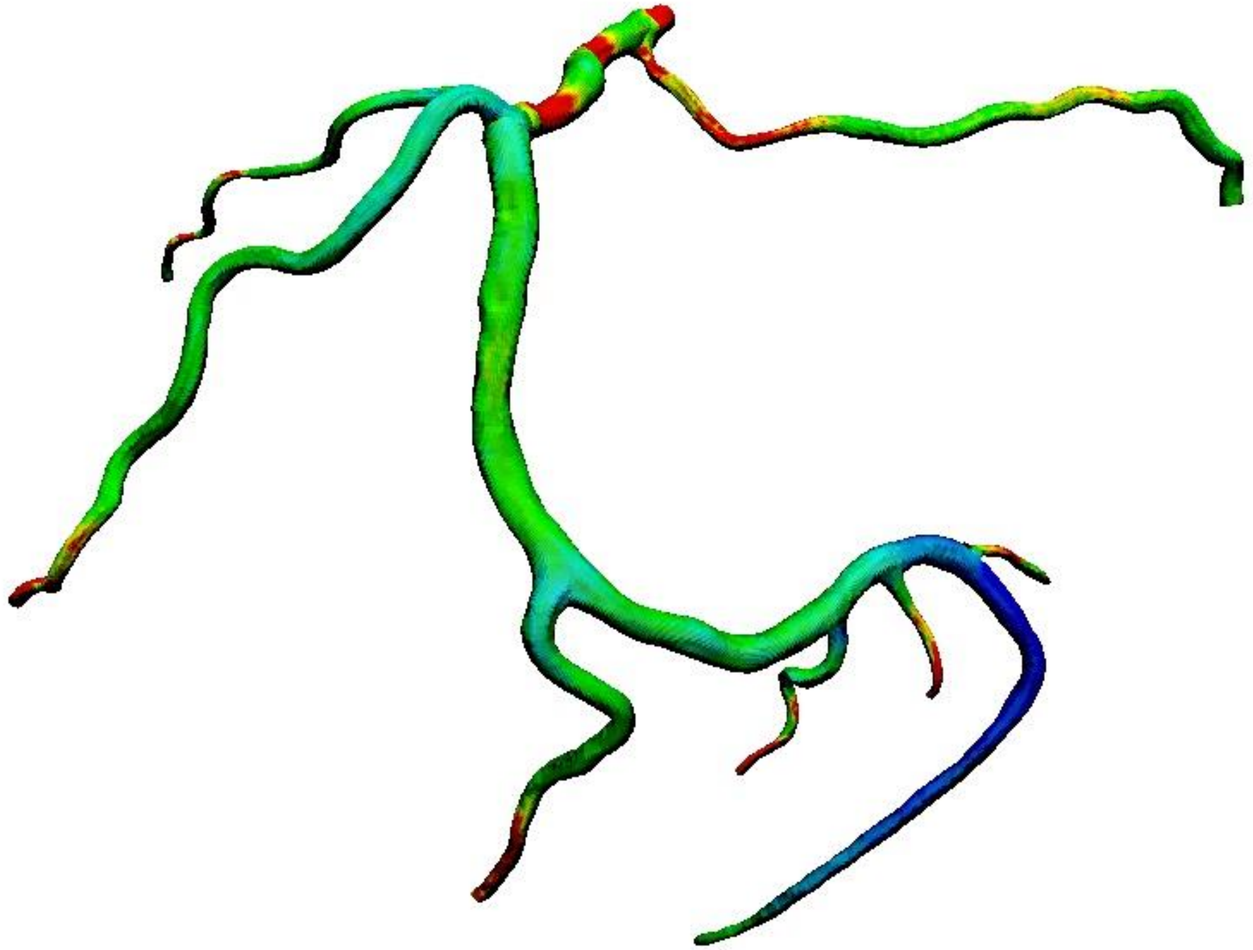
2D: 91% (*Δ +29%*)





Borkin et al., 2011

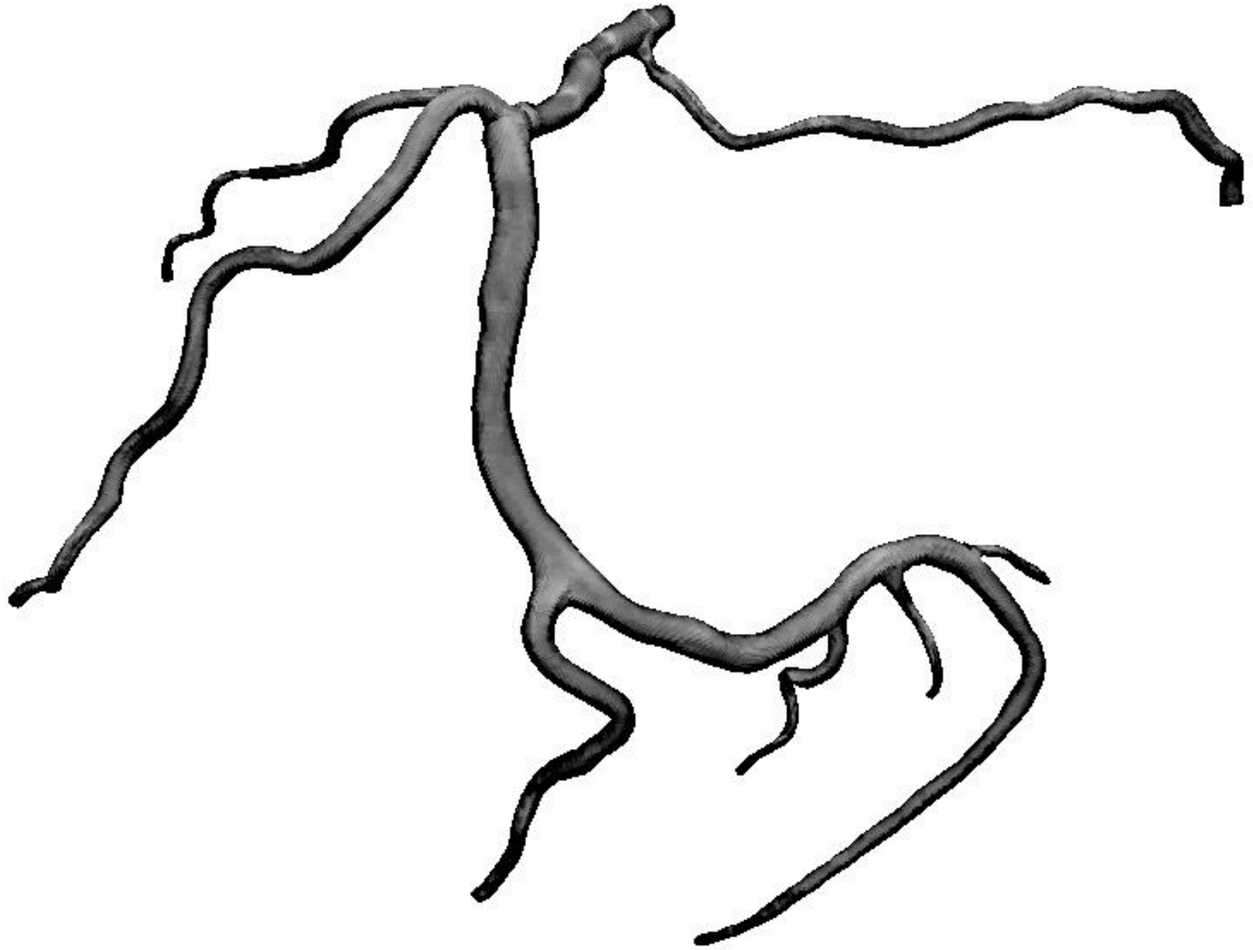
“Get it right in black and white.”



39% Diseased Regions Found

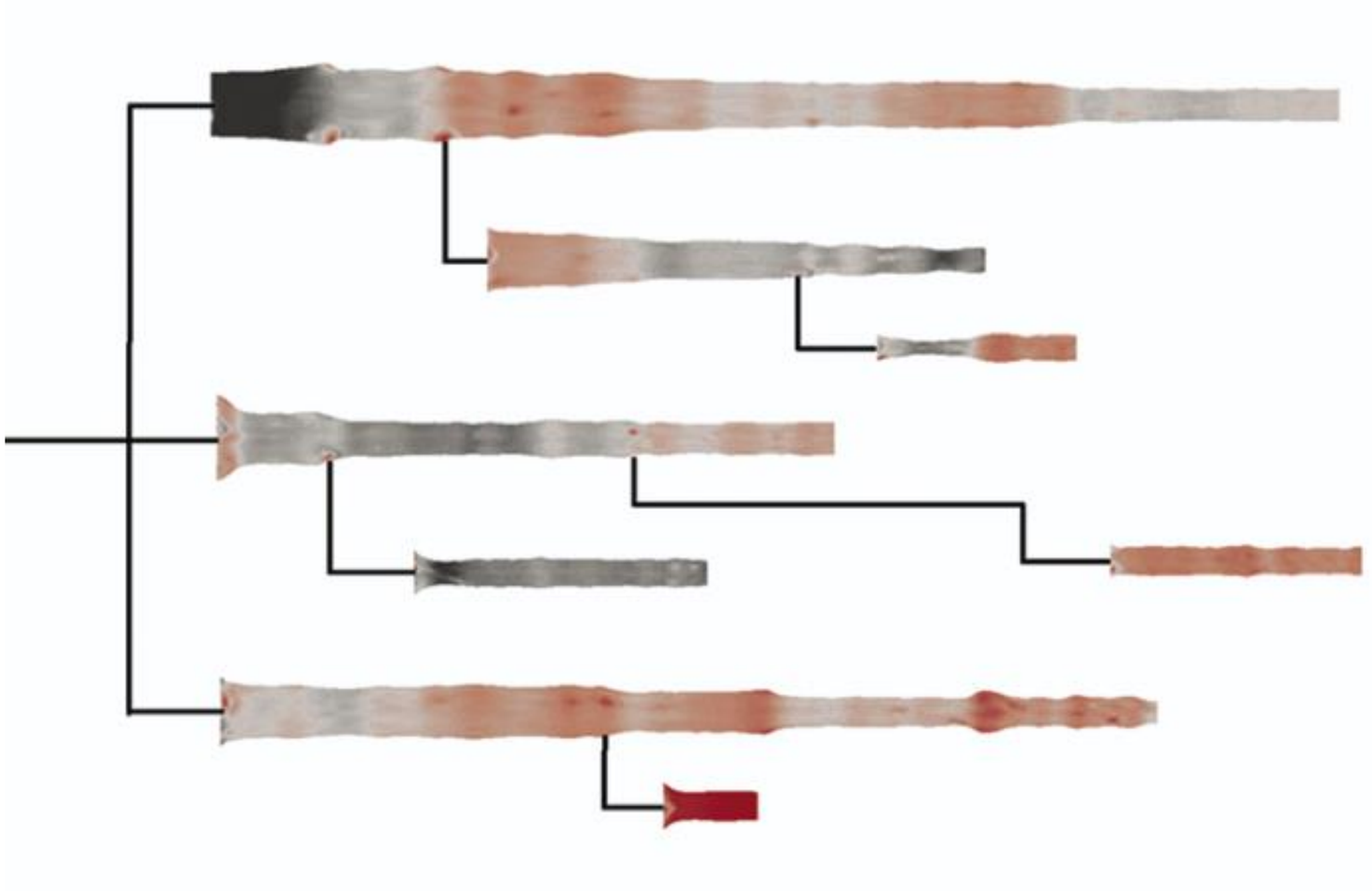
Borkin et al., 2011

“Get it right in black and white.”



Borkin et al., 2011

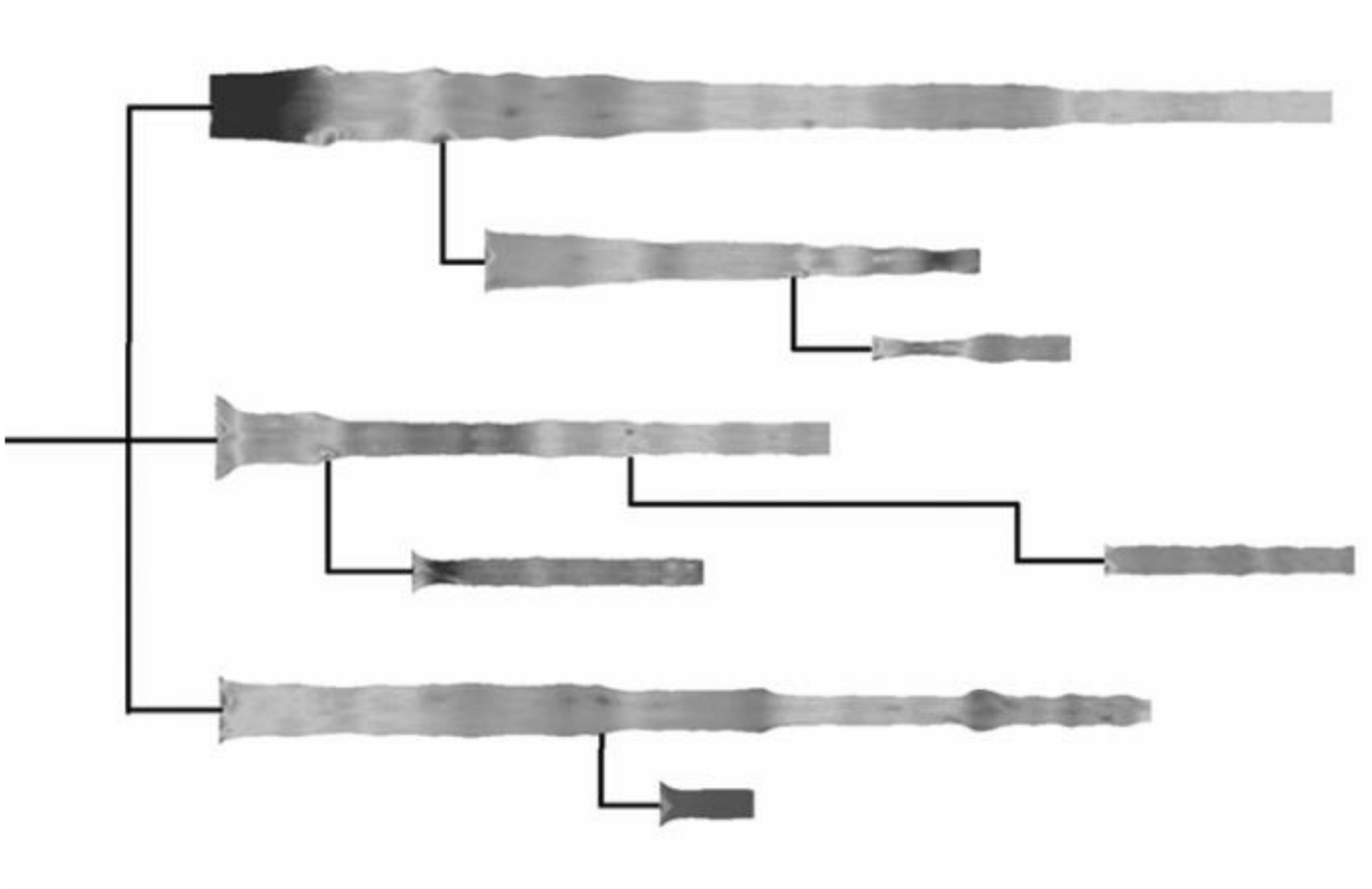
“Get it right in black and white.”



91% Diseased Regions Found

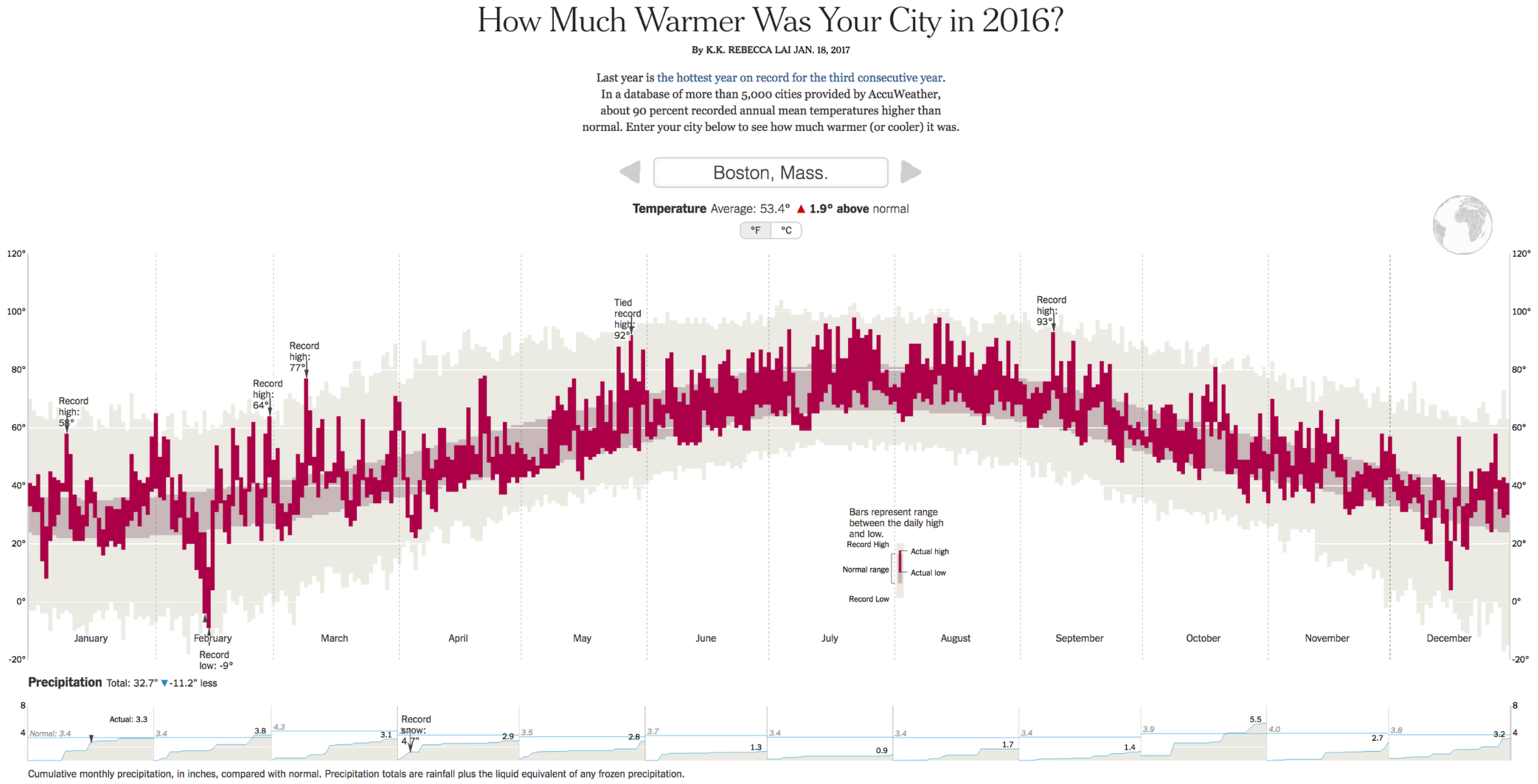
Borkin et al., 2011

“Get it right in black and white.”



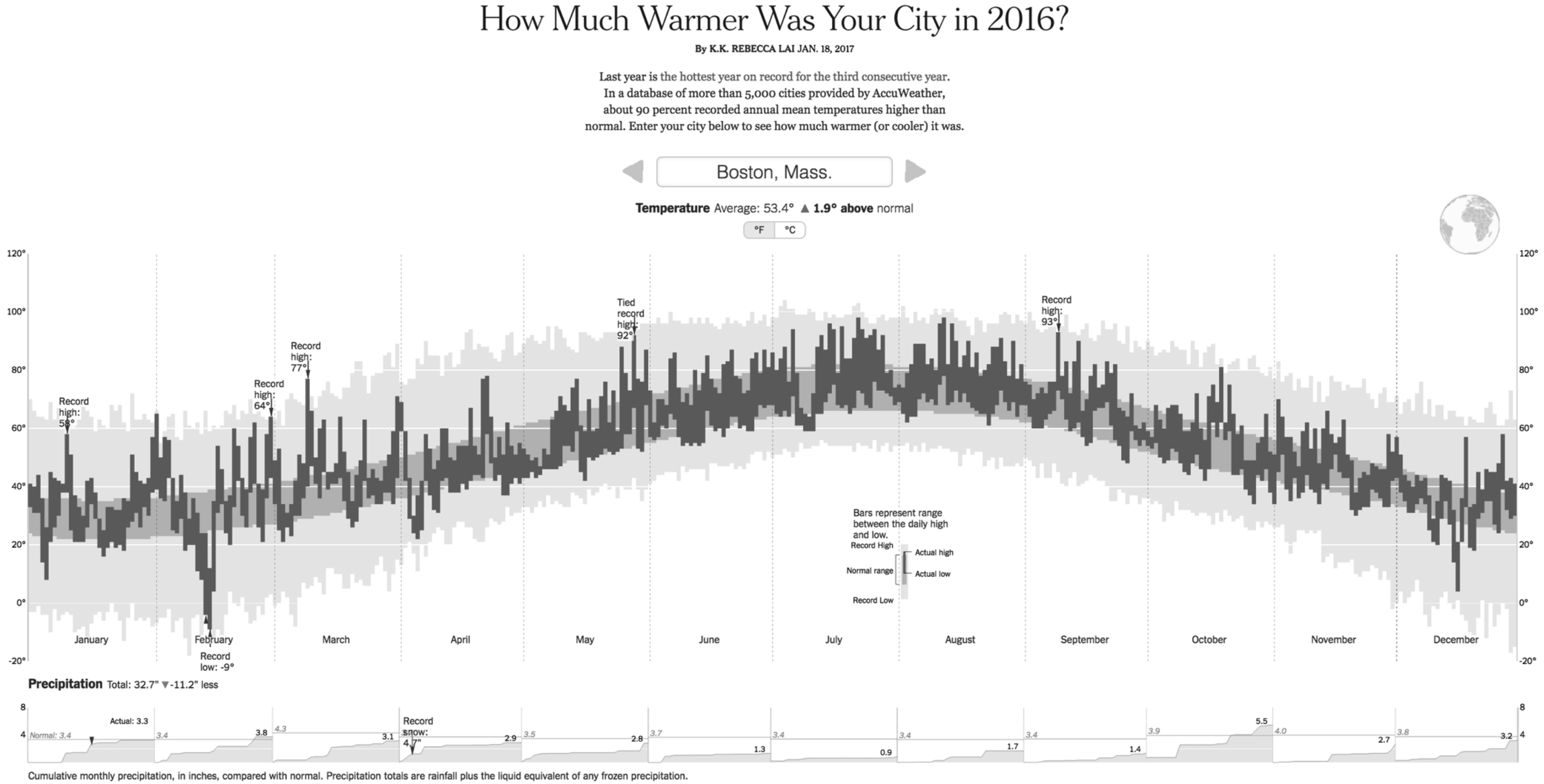
Borkin et al., 2011

“Get it right in black and white.”



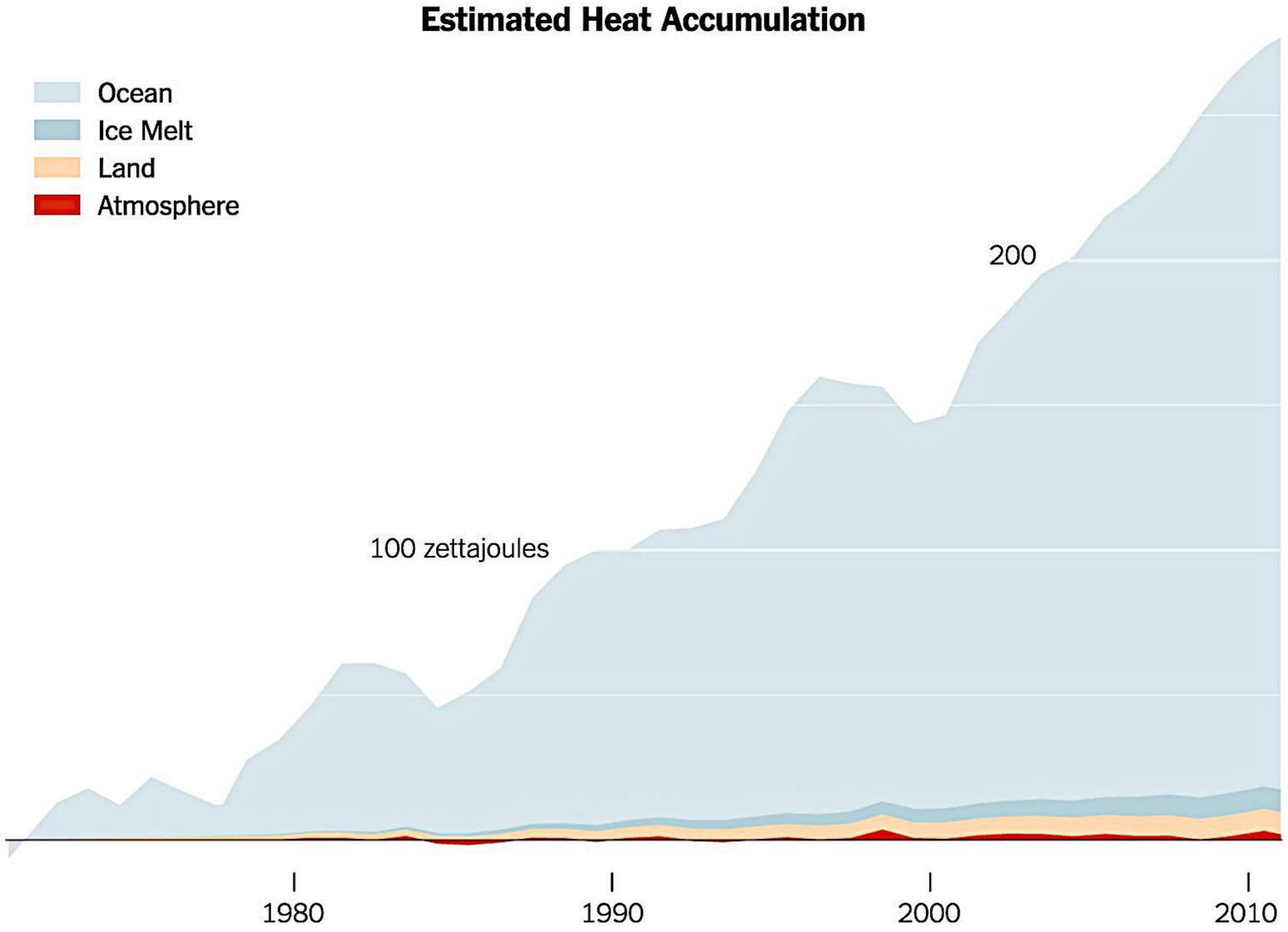
NY Times, 2017

“Get it right in black and white.”

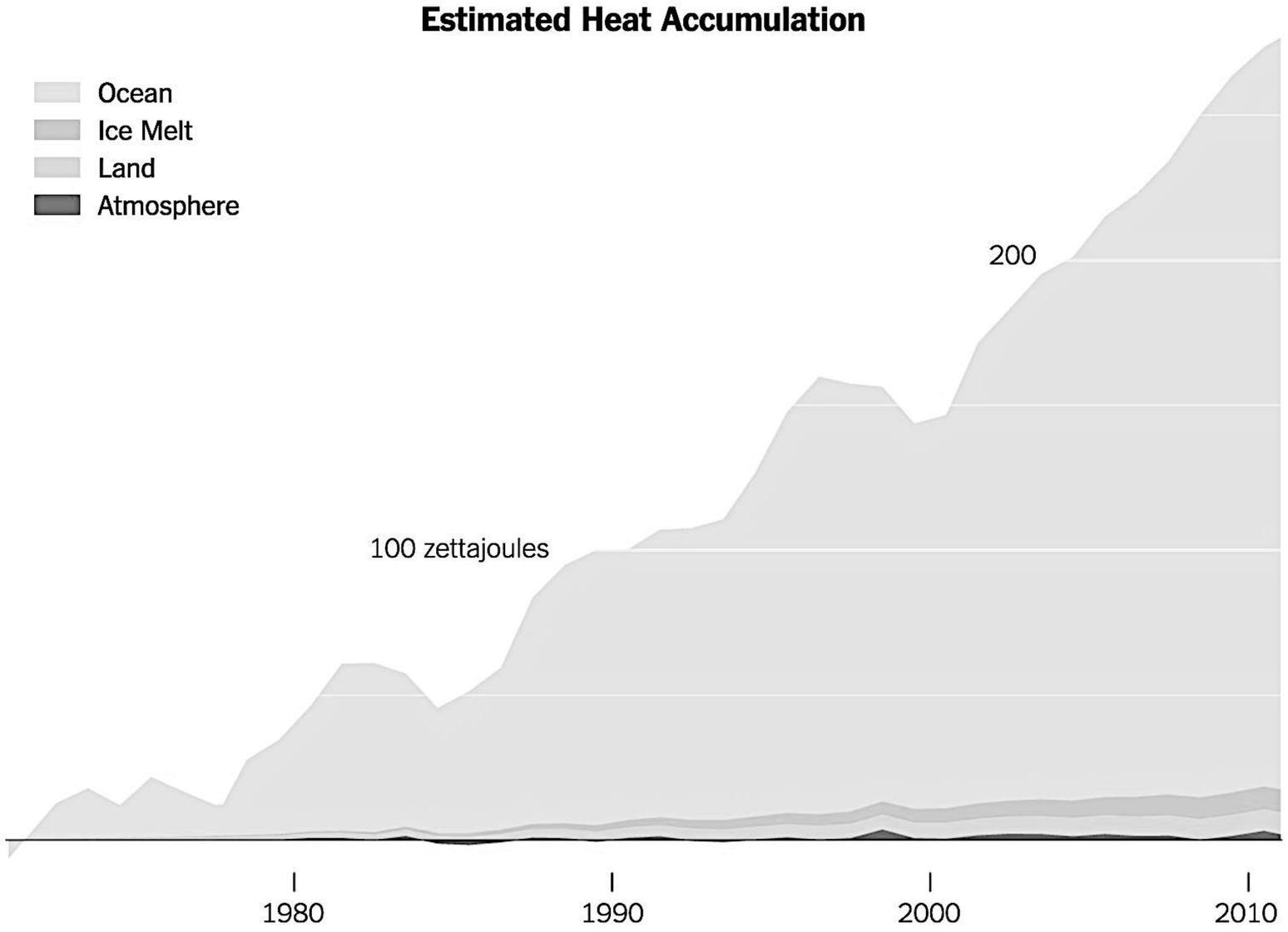


NY Times, 2017

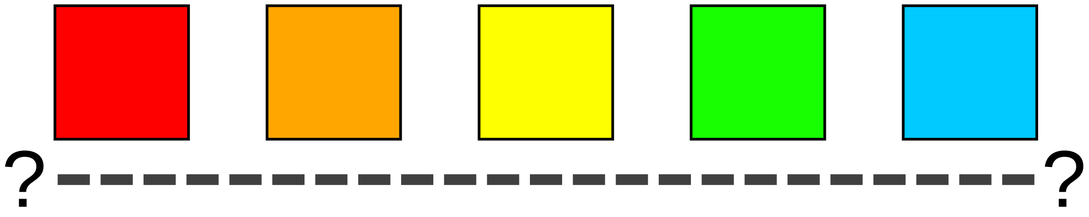
“Get it right in black and white.”



“Get it right in black and white.”



Rainbow Color Map (Hue)

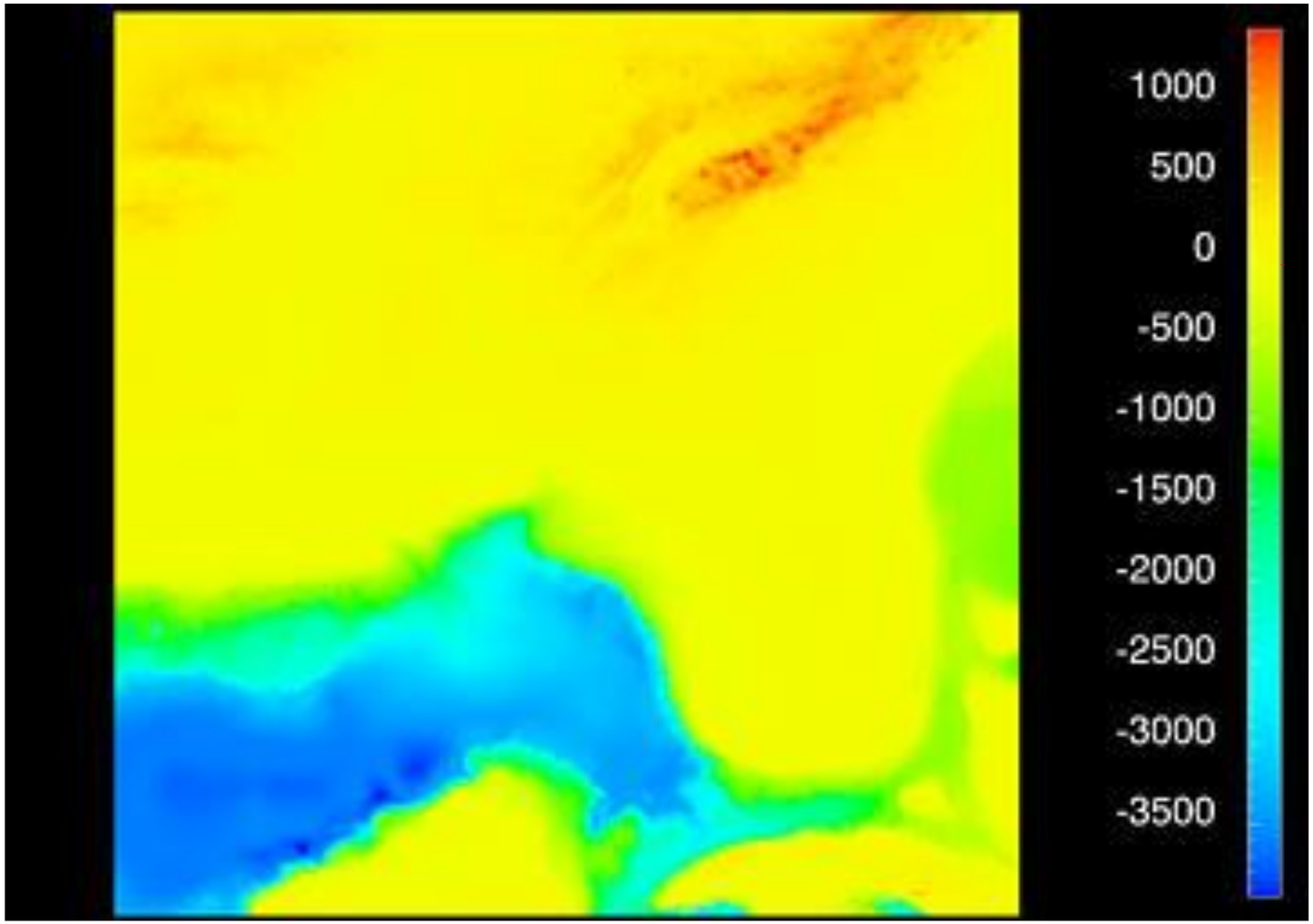


Why this color map is a poor choice for quantitative data…

- 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)

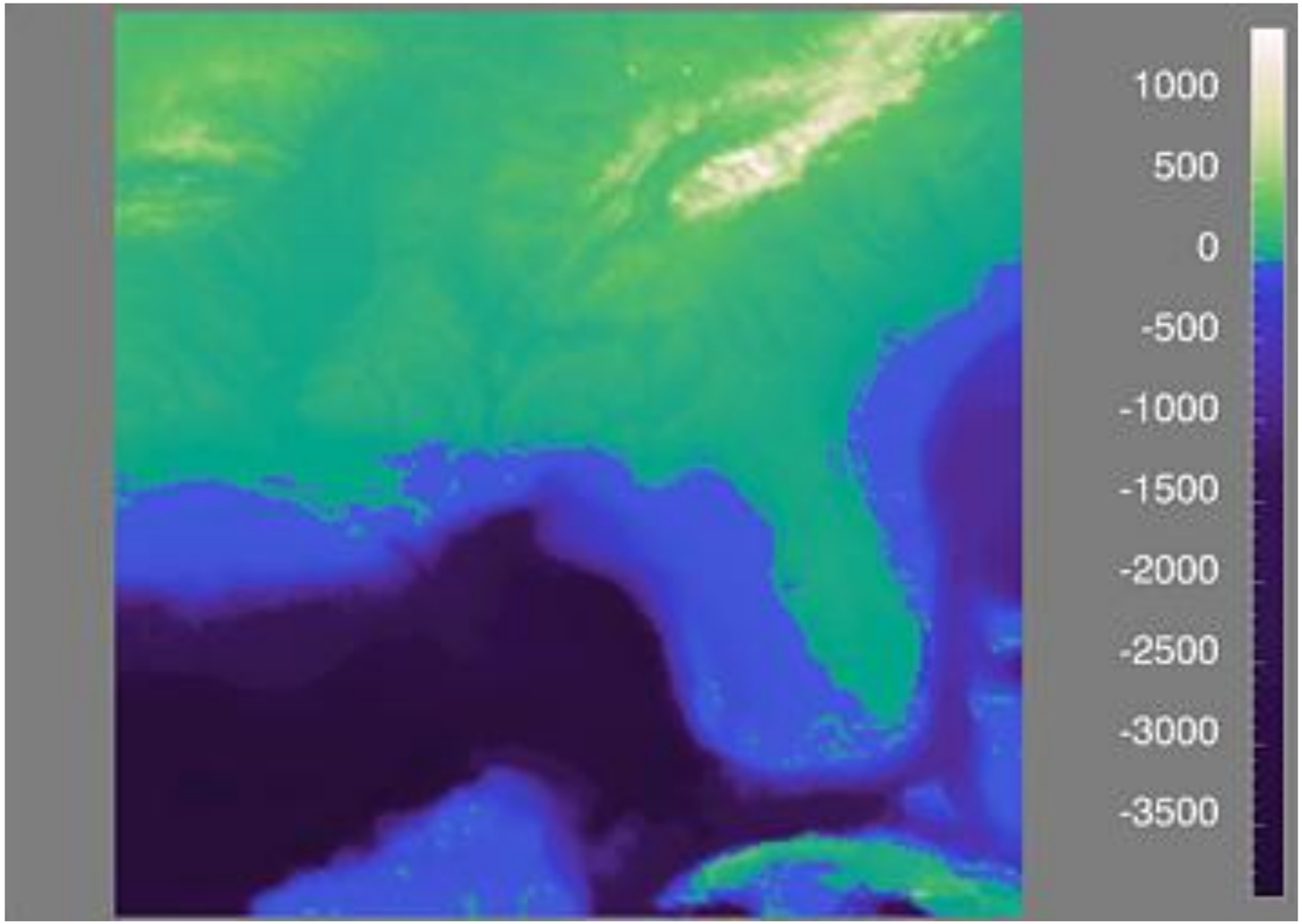
Borland & Russell, 2007

Color Maps



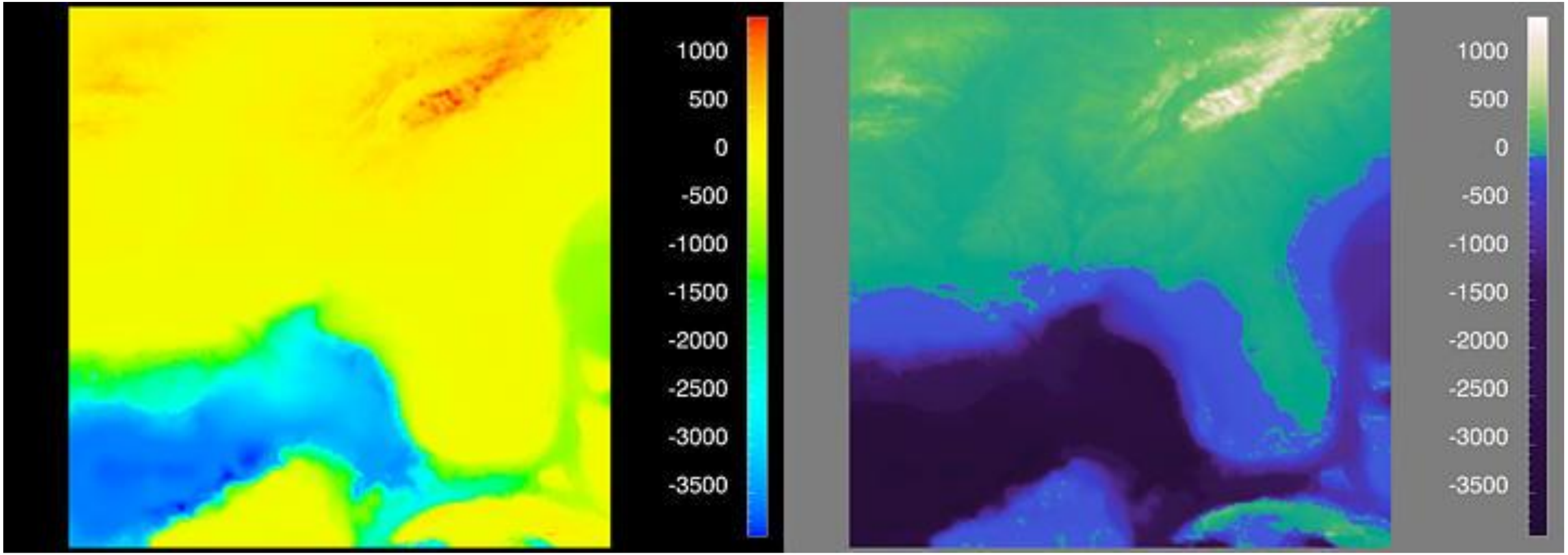
Rogowitz & Treinish, 1996

Color Maps



Rogowitz & Treinish, 1996

Color Maps



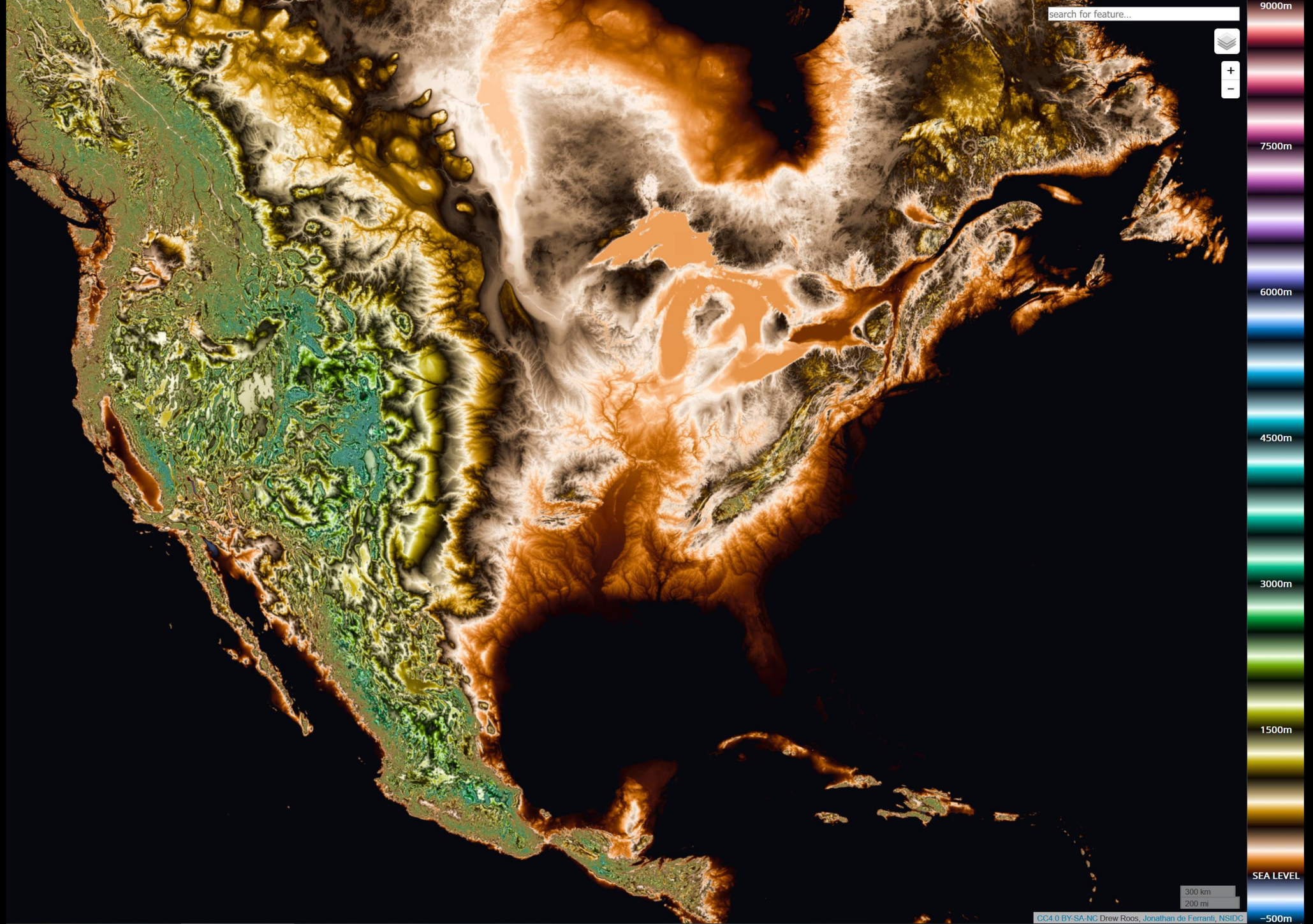
Sequential (possibly wrong)

Diverging

Sequential rainbow (wrong!)

Rogowitz & Treinish, 1996

Roos, 2015

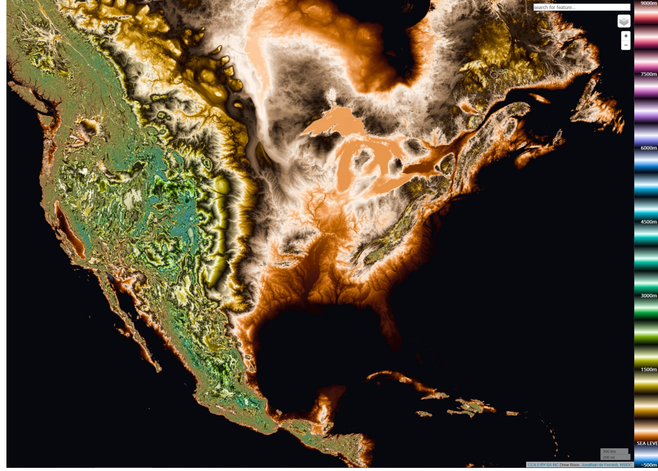

search for feature...
9000m
7500m
6000m
4500m
3000m
1500m
SEA LEVEL
−500m
300 km
200 mi
CC4.0 BY-SA-NC Drew Roos, Jonathan de Ferranti, NSIDC

Roos, 2015

IN-CLASS EXERCISE

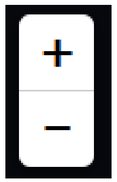
In-class exercise: Oilslick

10m



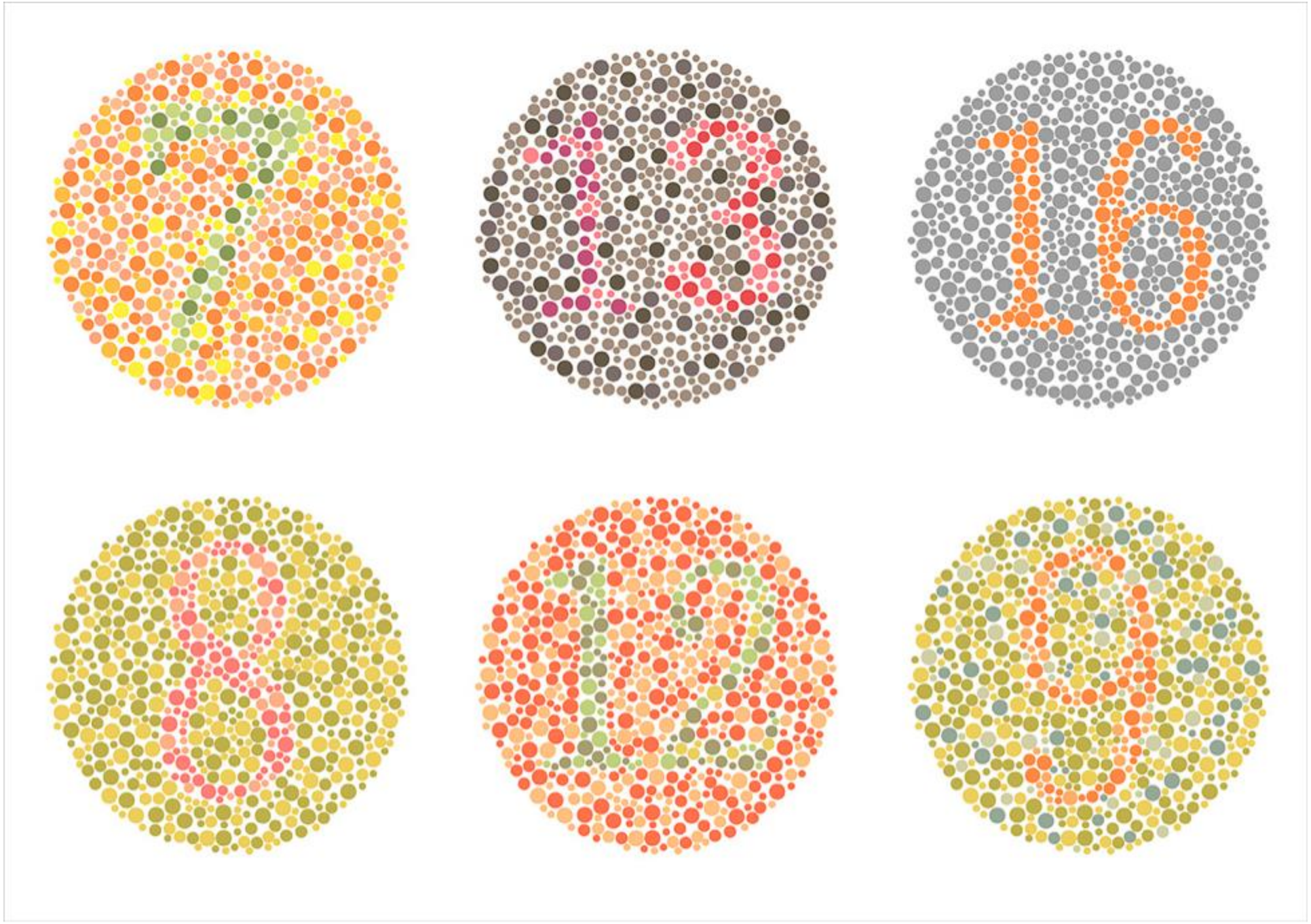
INSTRUCTIONS:

- Working individually, go to https://mrgris.com/projects/oilslick/
- 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.

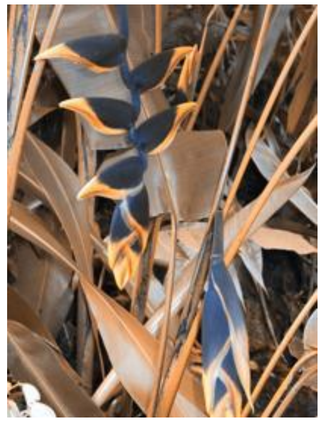


Those with deuteranope color blindness (red/green) will have difficulty seeing the numbers.

Color Deficiencies (Color Blindness)

Person with faulty cones (or faulty pathways):

Protanope = faulty red cones



Deuteranope = faulty green cones

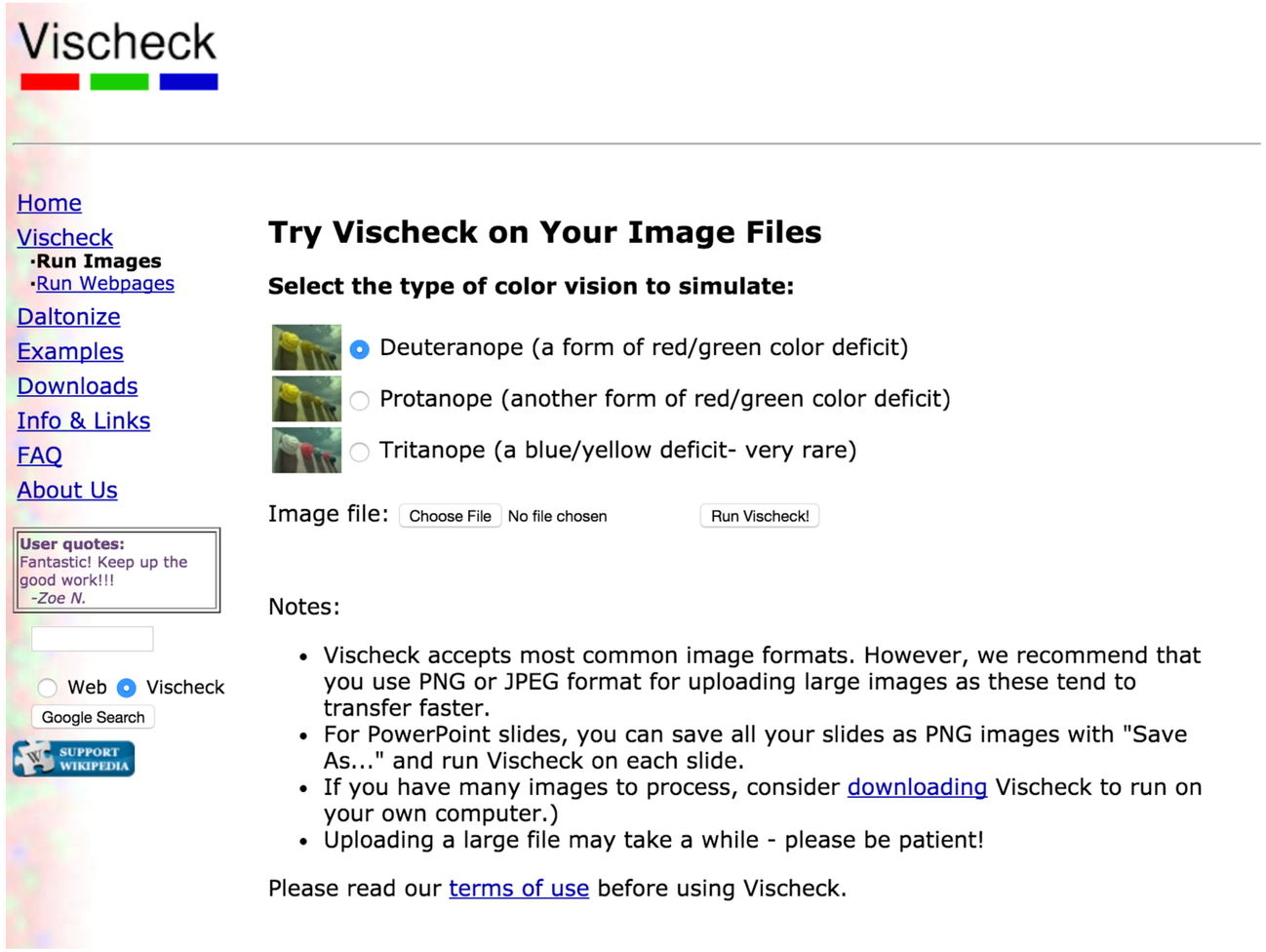
normal

Tritanope = faulty blue cones

Color Deficiencies (Color Blindness)

Based on Slides by Hanspeter Pfister, Maureen Stone

Check your images/colormaps for issues!



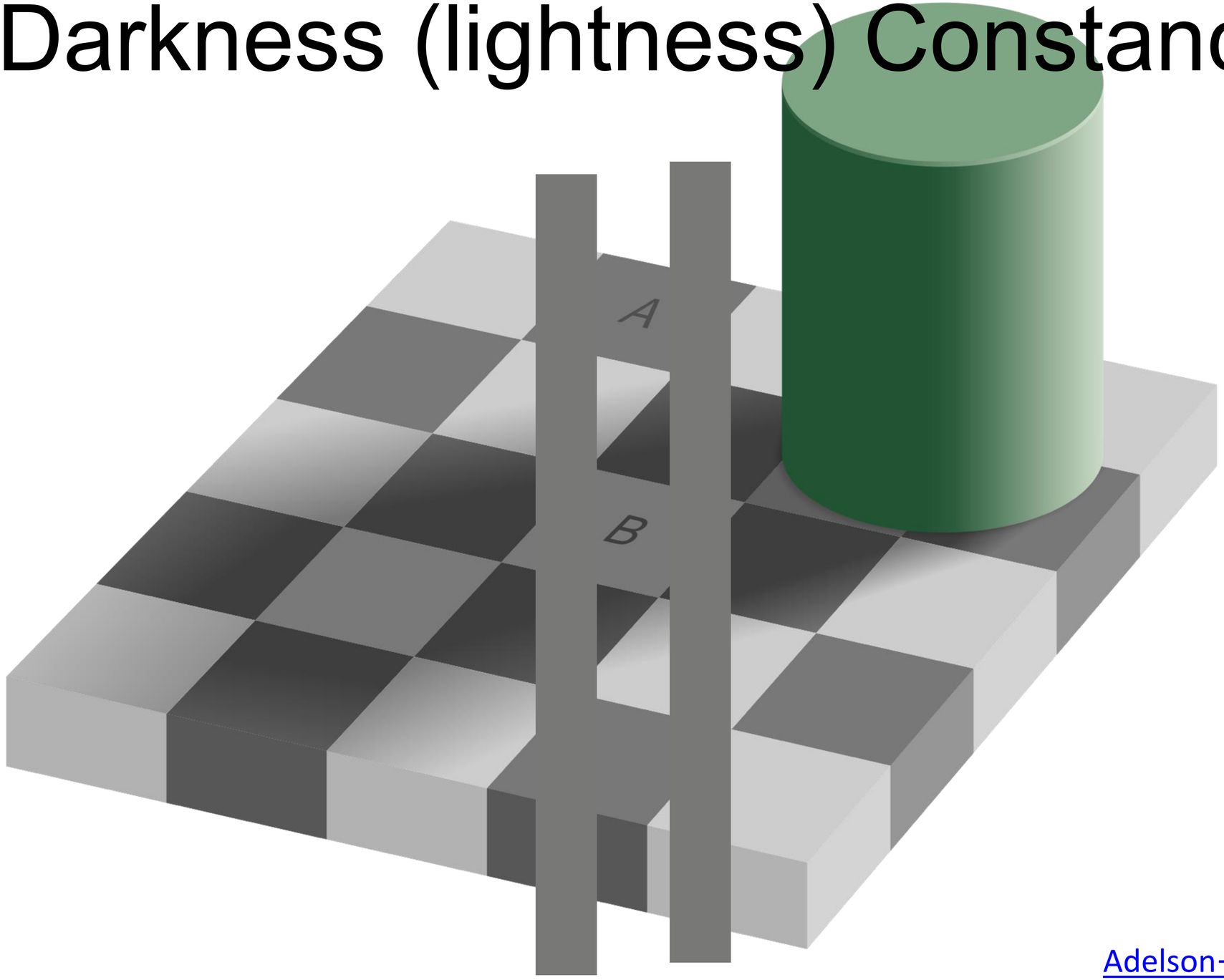
http://www.vischeck.com/vischeck/vischeckImage.php https://www.color-blindness.com/coblis-color-blindness-simulator/

Interactions between Colors and with Lighting

“Lightness Constancy”

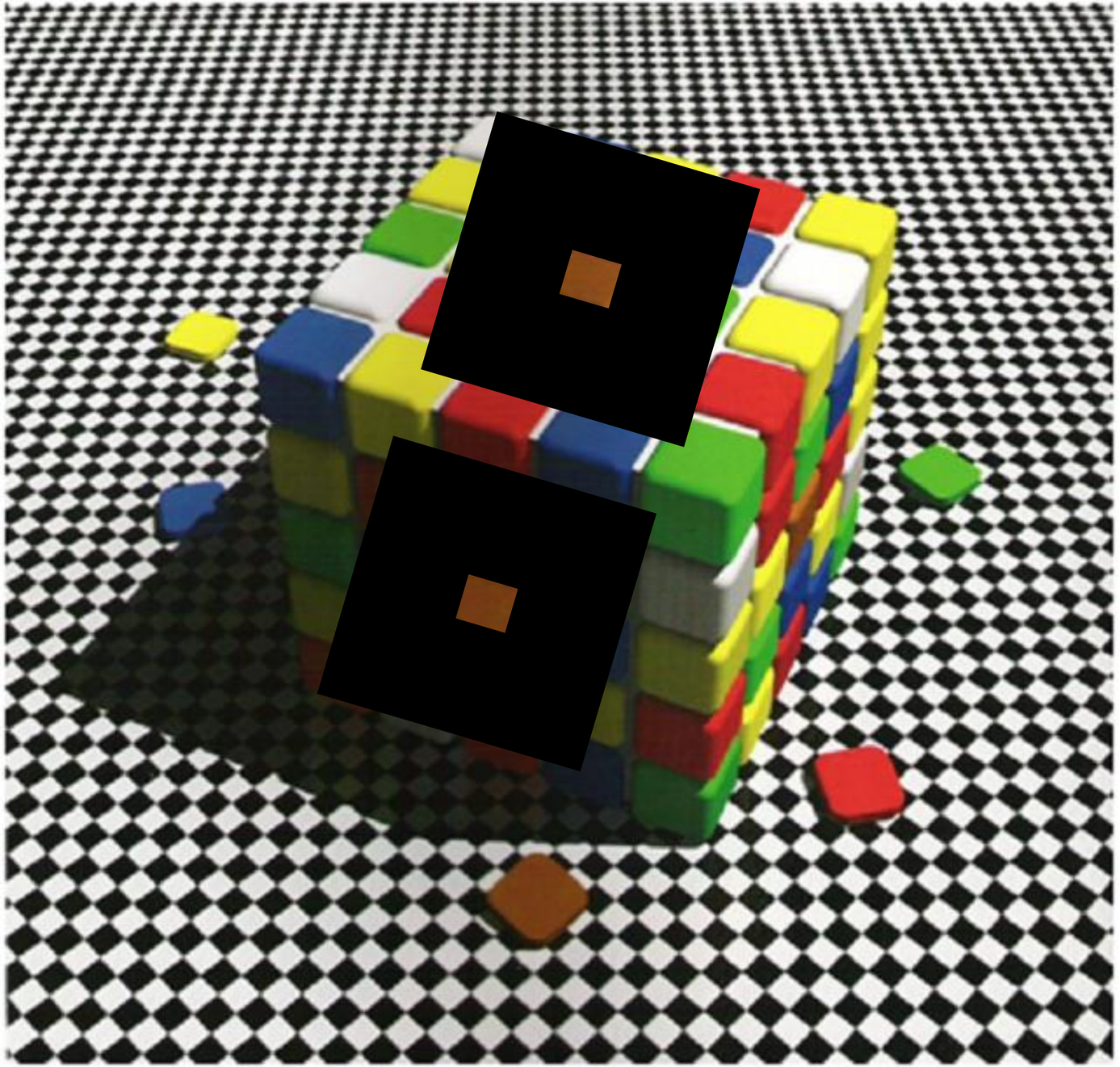
The perception that the apparent brightness of light and dark surfaces remains more or less the same under different luminance conditions is called **darkness (lightness) constancy**.

“Darkness (lightness) Constancy”



Adelson→Pingstone, 2015

“Color Constancy”



Lotto, 2009

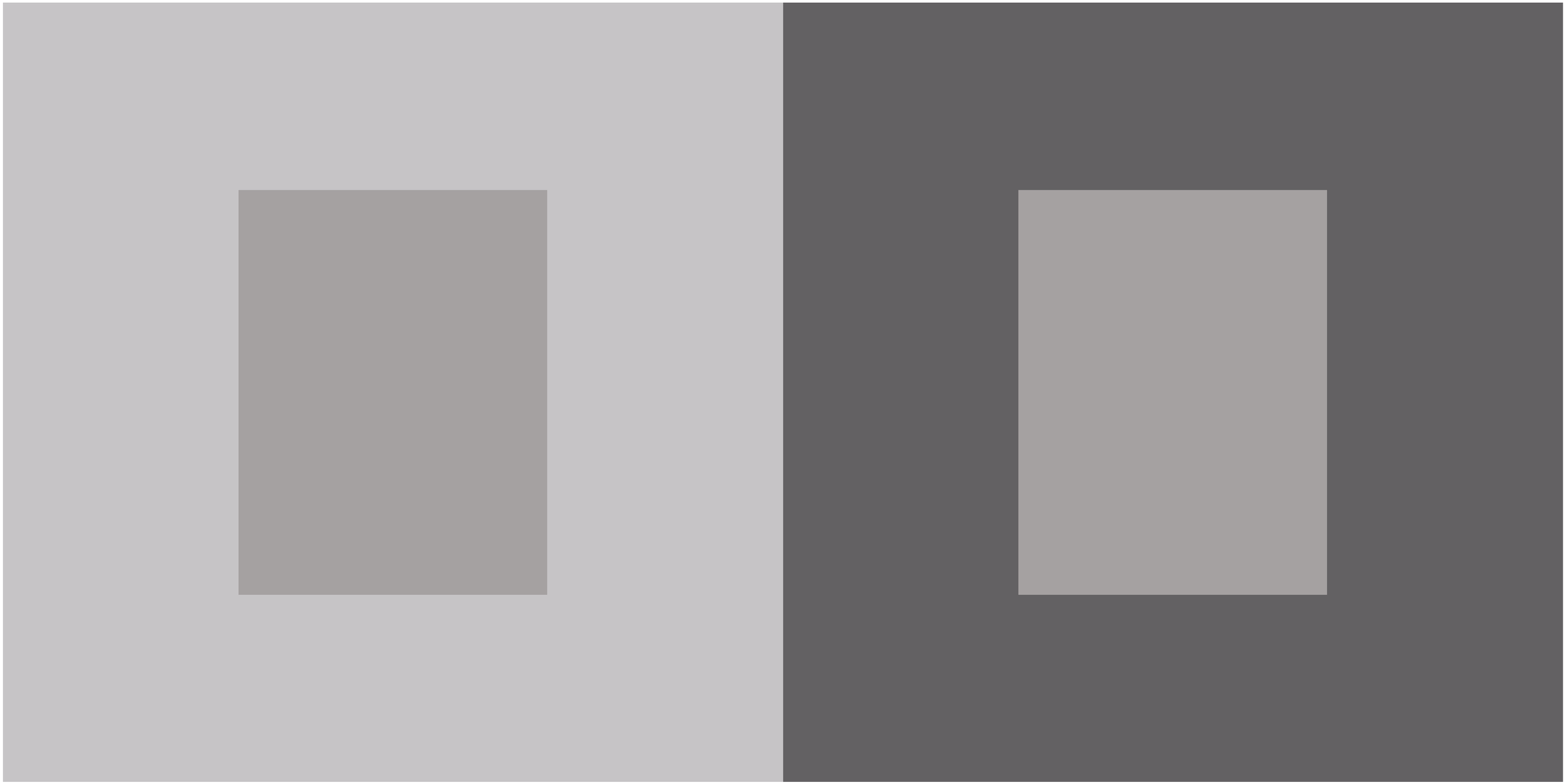
“Simultaneous Contrast”

“Simultaneous Contrast”

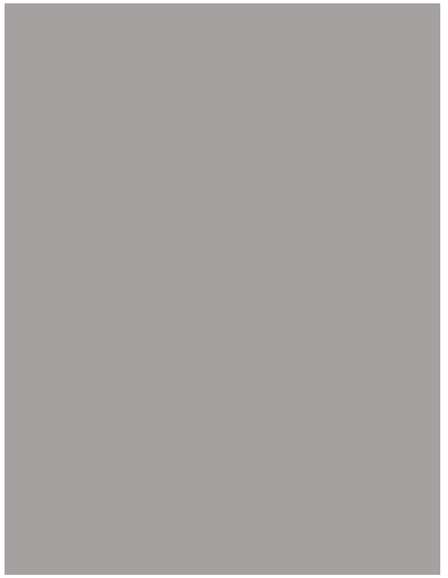
“Simultaneous Contrast”

Avoid gradients as backgrounds or bars!

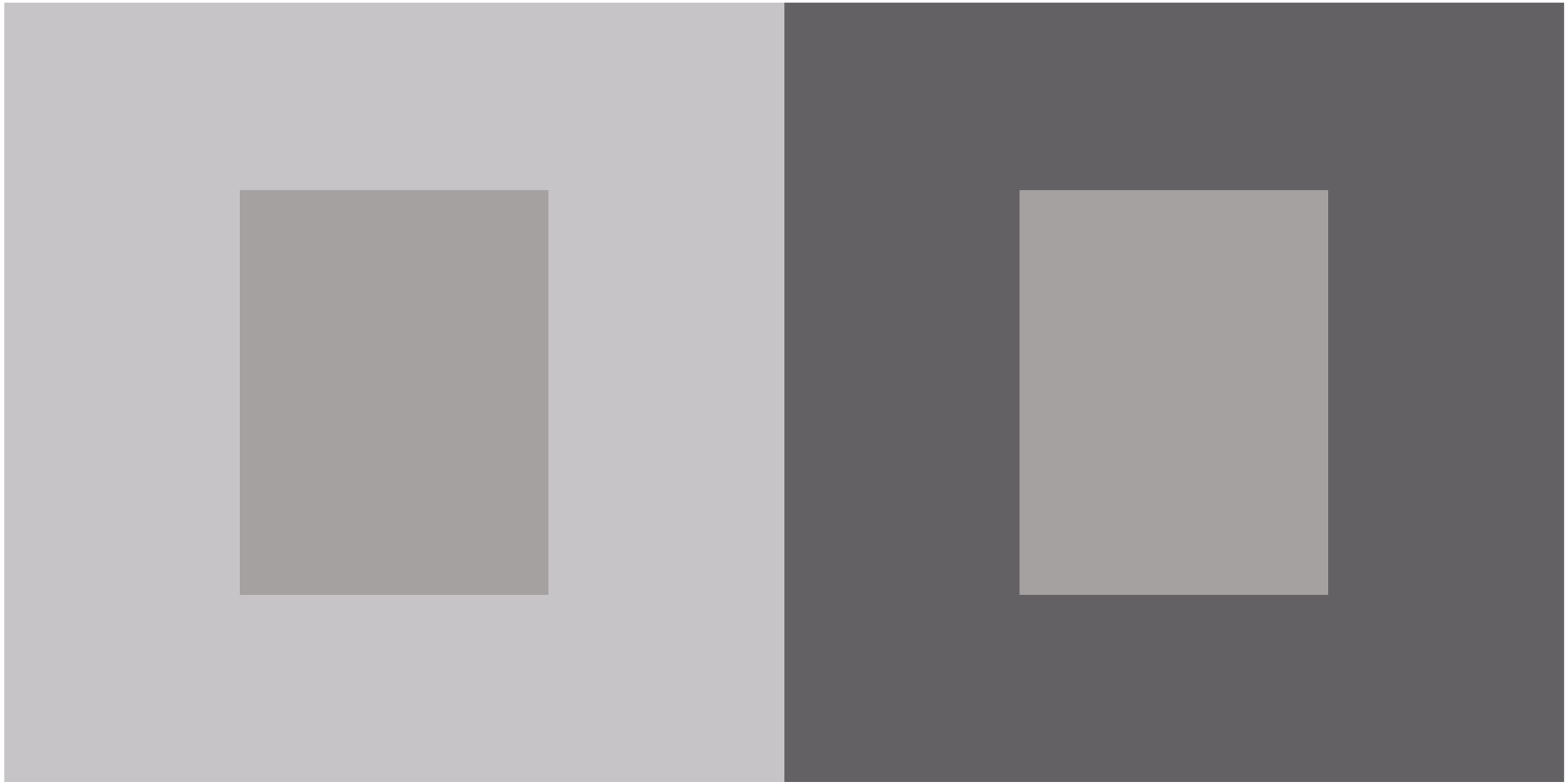
“Simultaneous Contrast”



“Simultaneous Contrast”

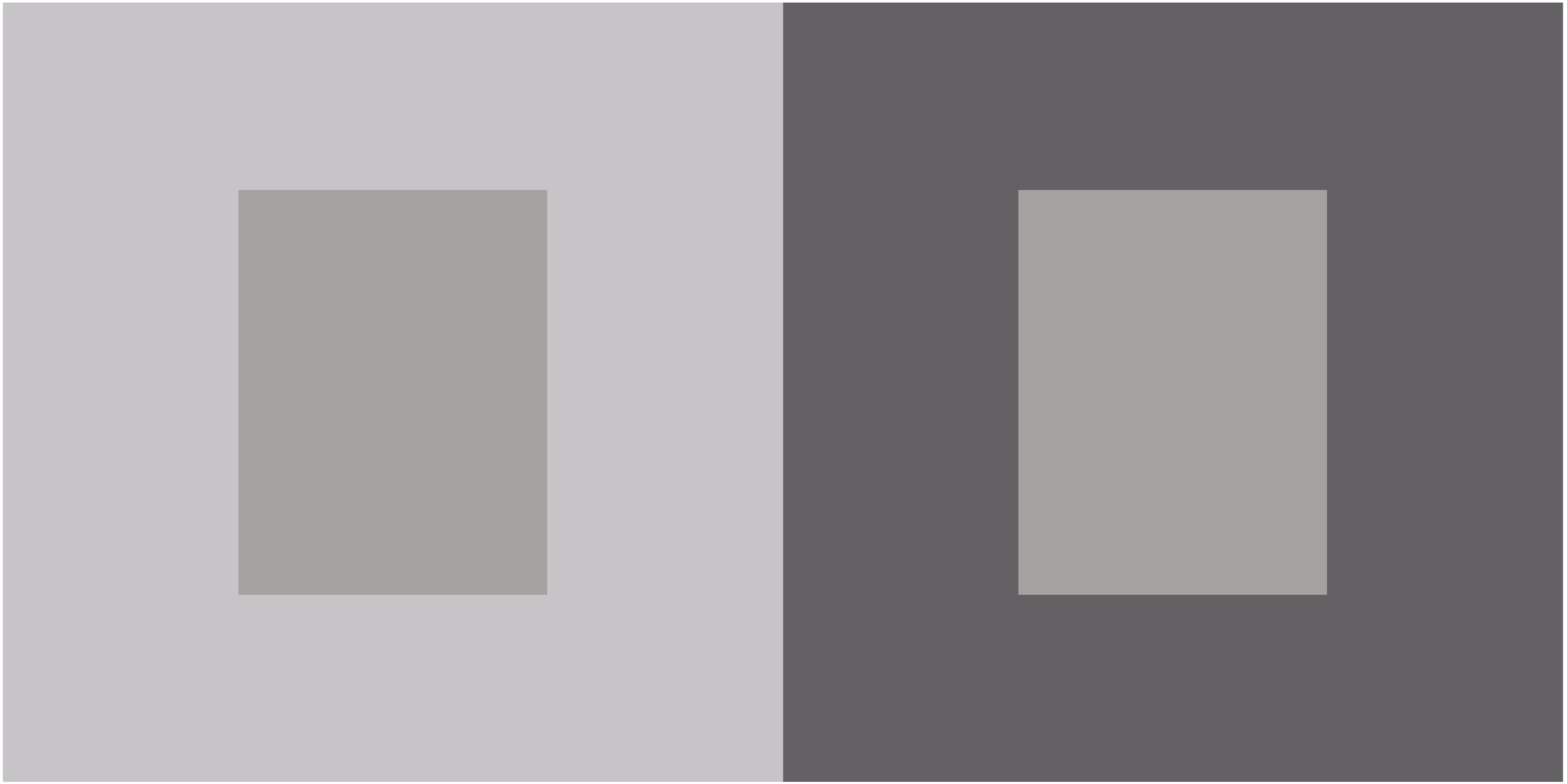


“Simultaneous Contrast”

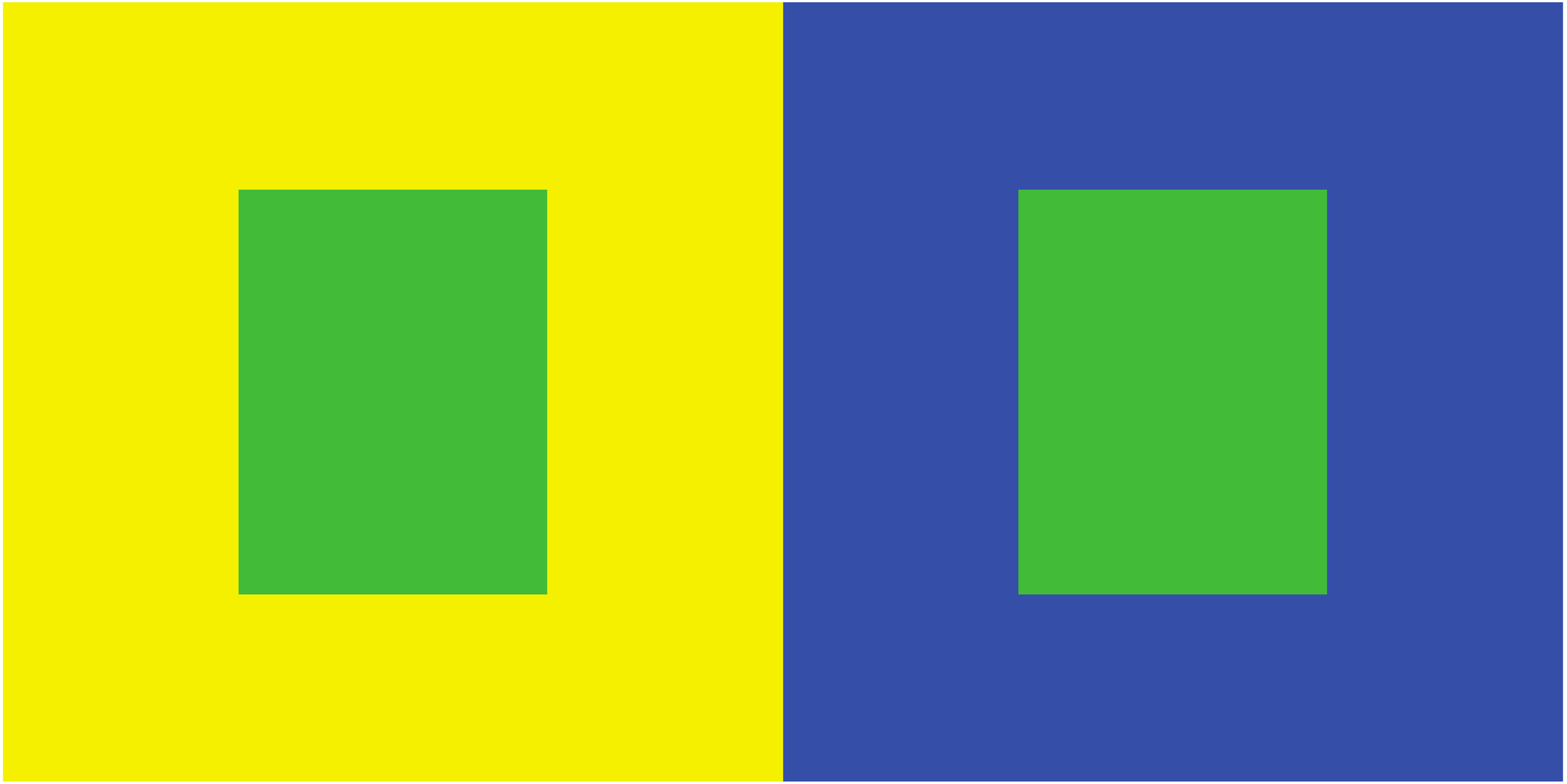


“Simultaneous Contrast”

“Simultaneous Contrast”

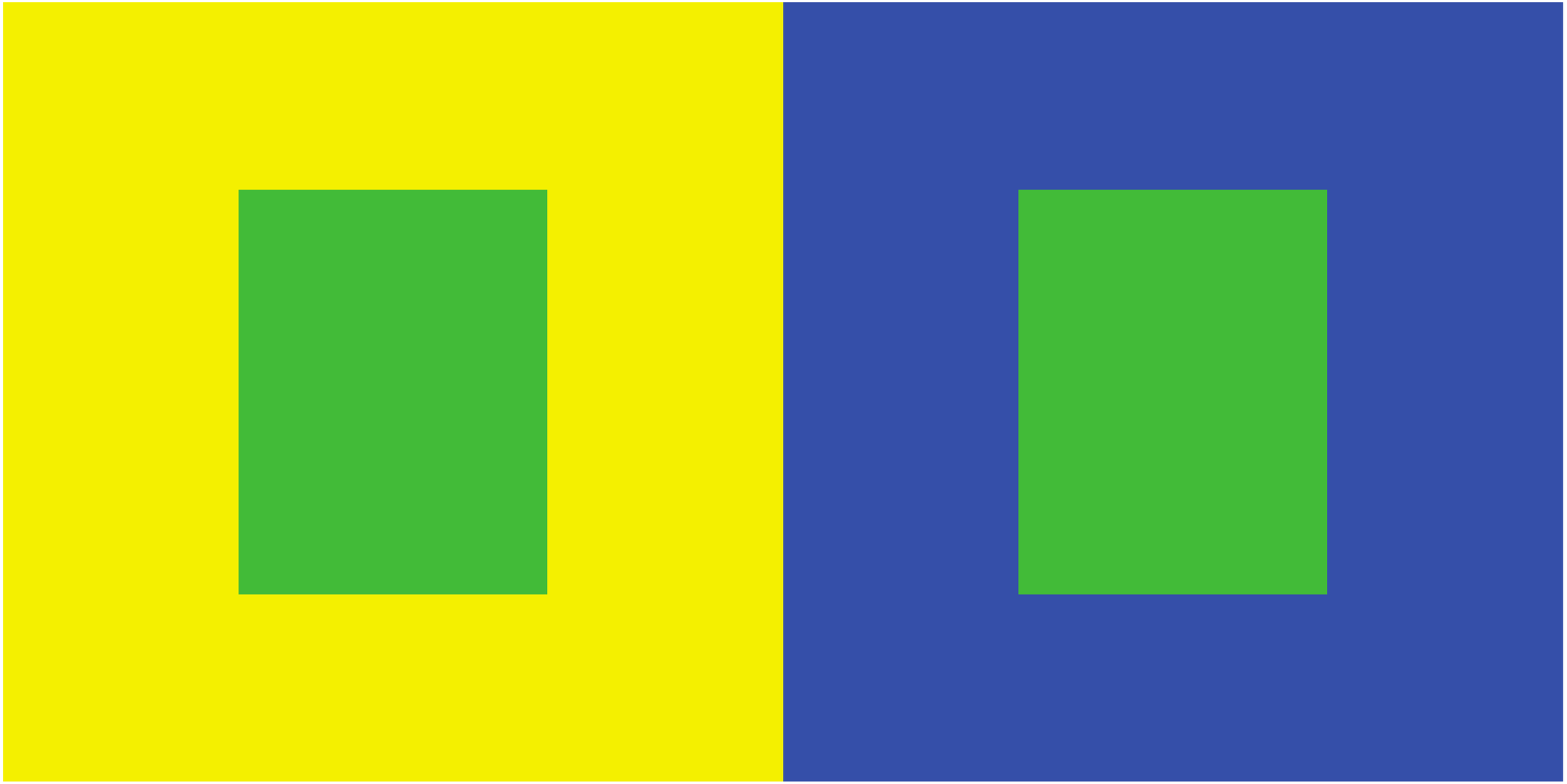


“Simultaneous Contrast”

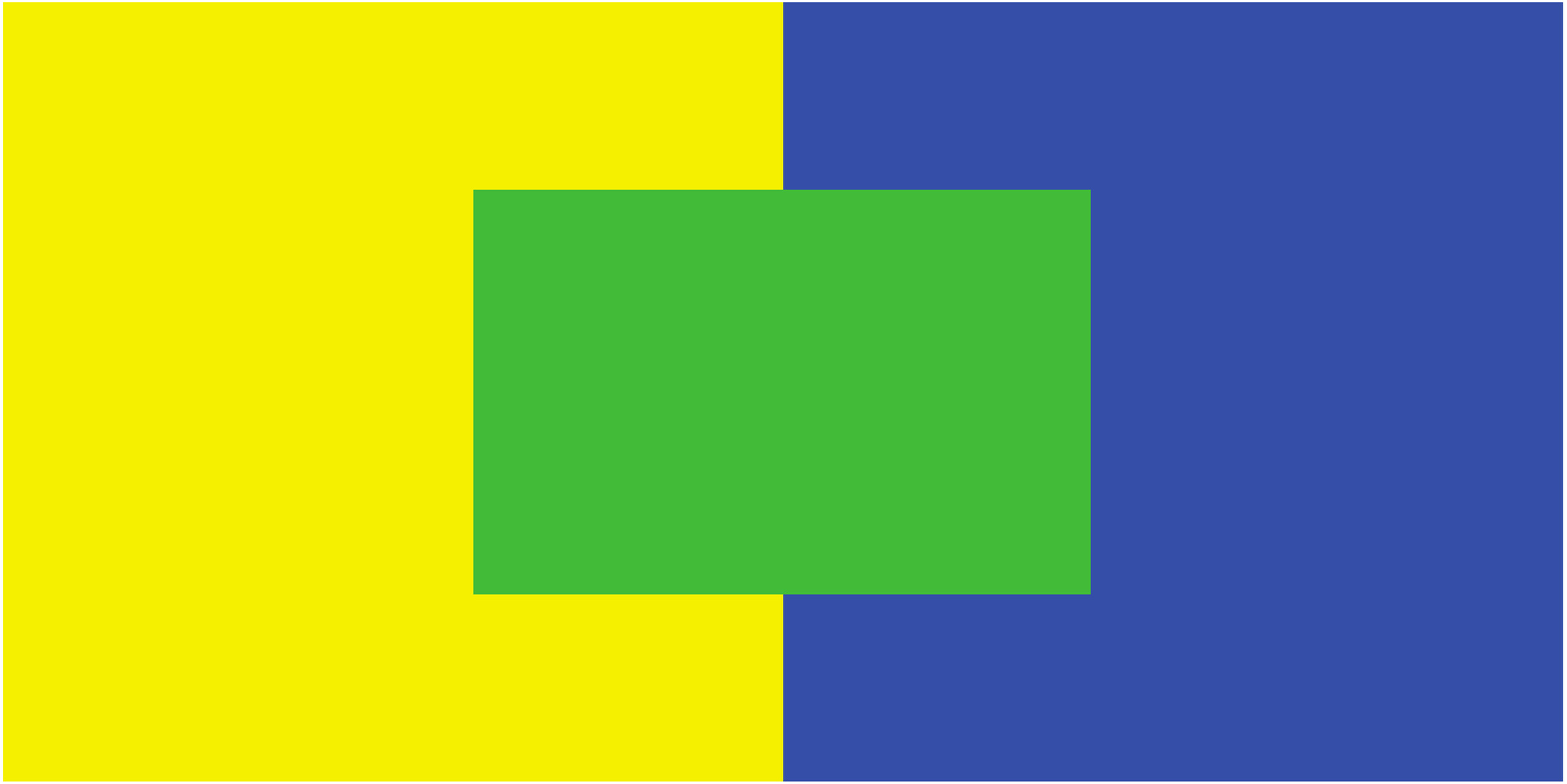


“Simultaneous Contrast”

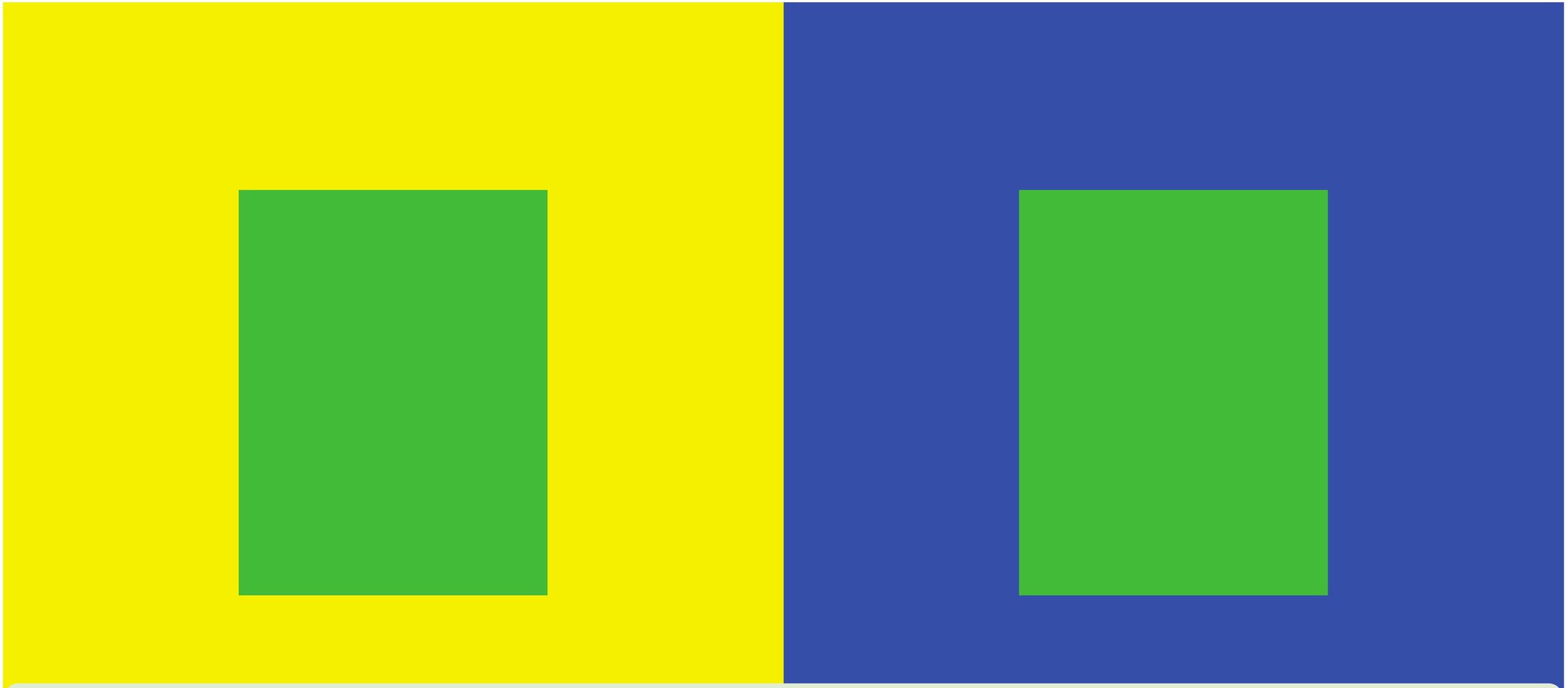
“Simultaneous Contrast”



“Simultaneous Contrast”



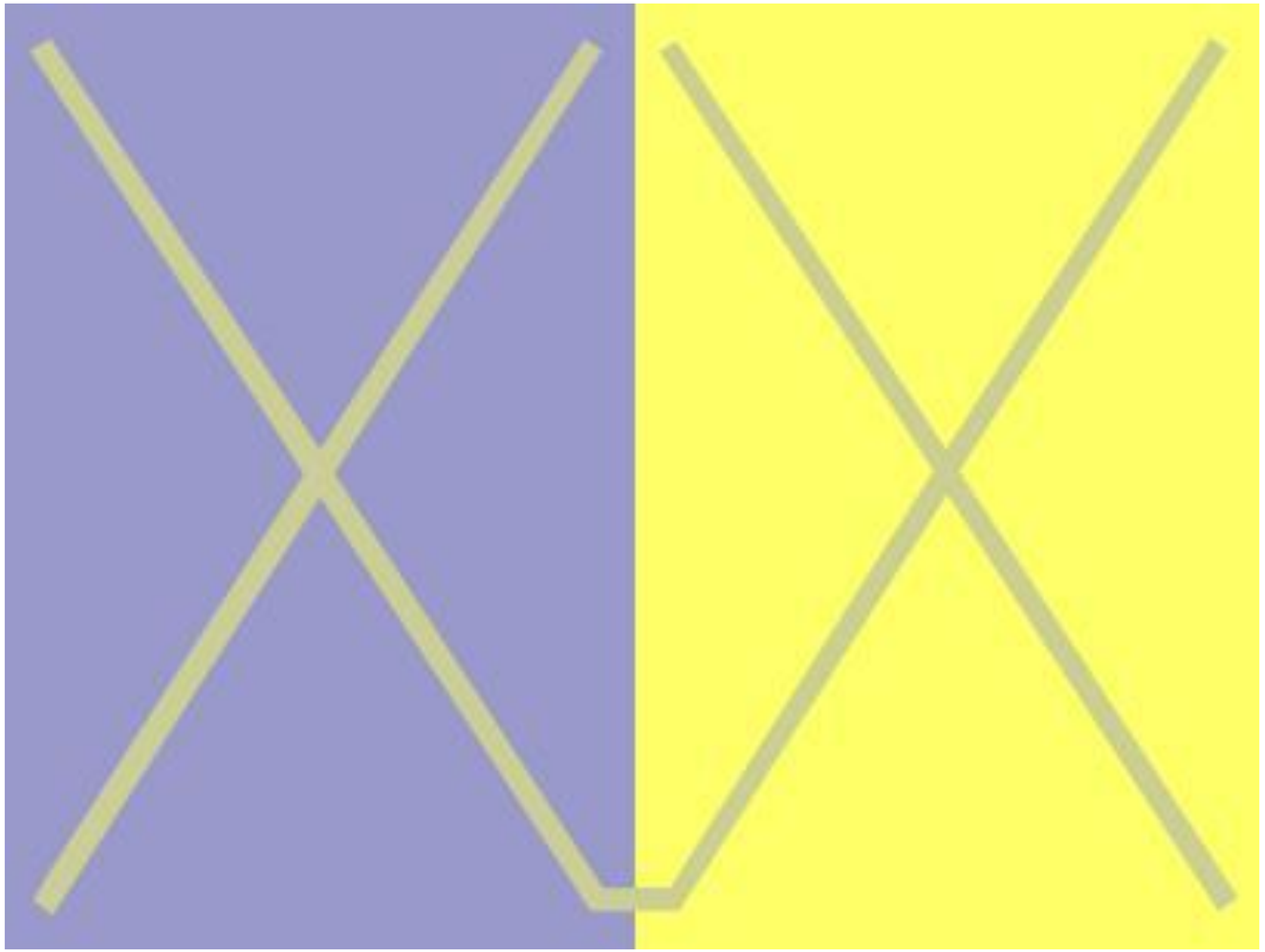
“Simultaneous Contrast”



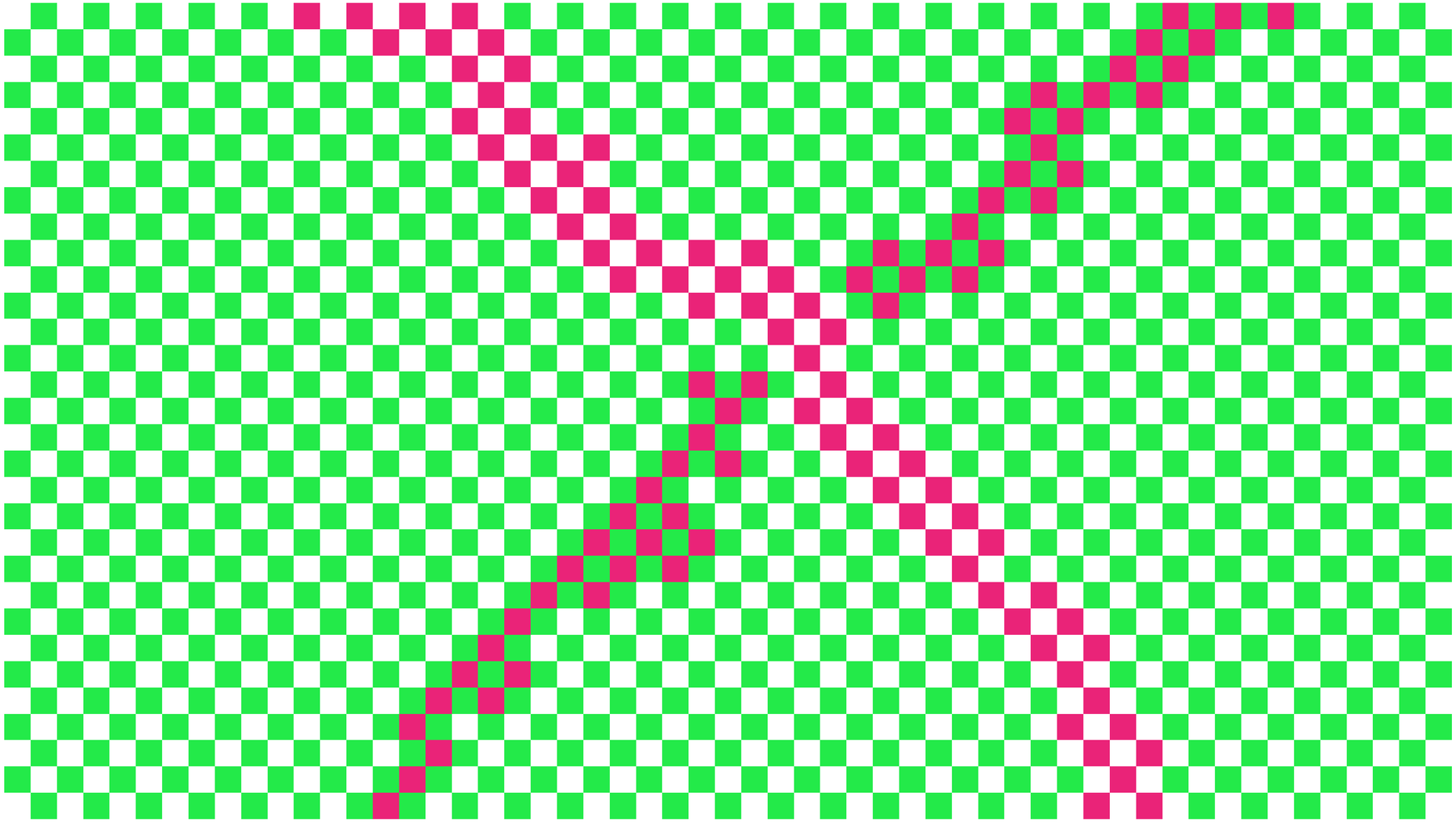
Be careful with bars and scatter plot points - the colors may appear differently with different background colors and neighboring colors!

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

“Simultaneous Contrast”

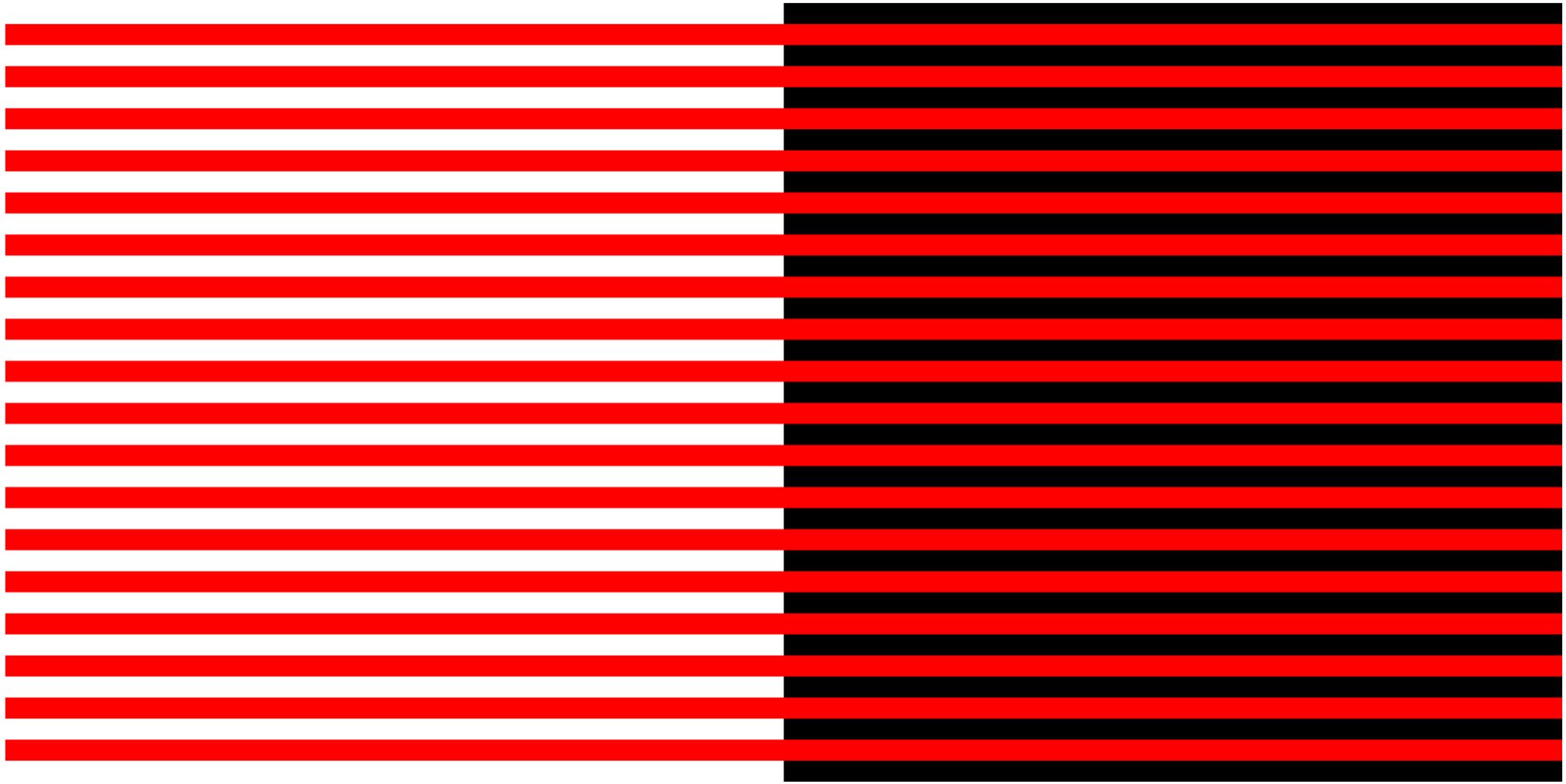


“Simultaneous Contrast”

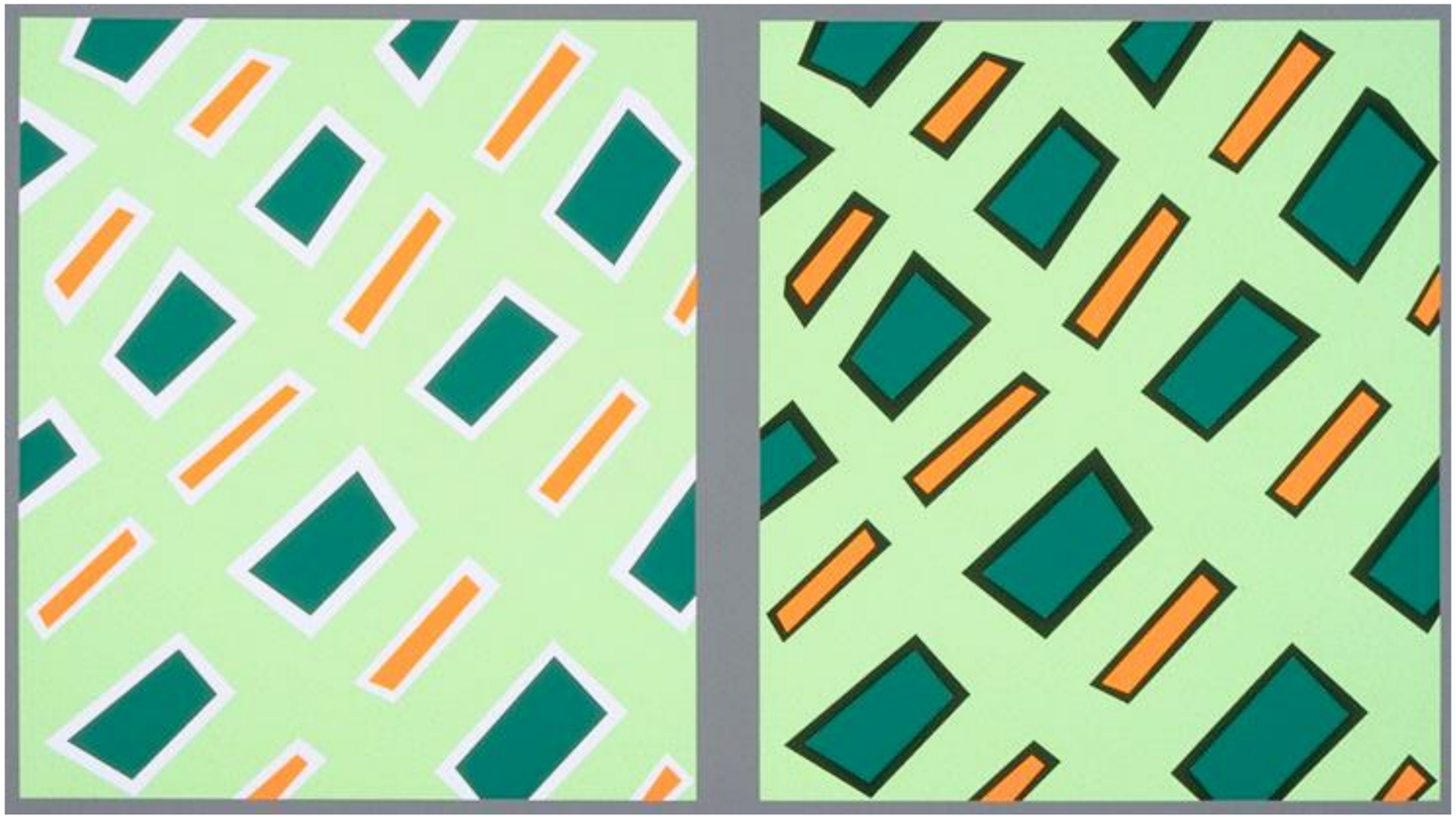


Griffin, 2015

“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)?

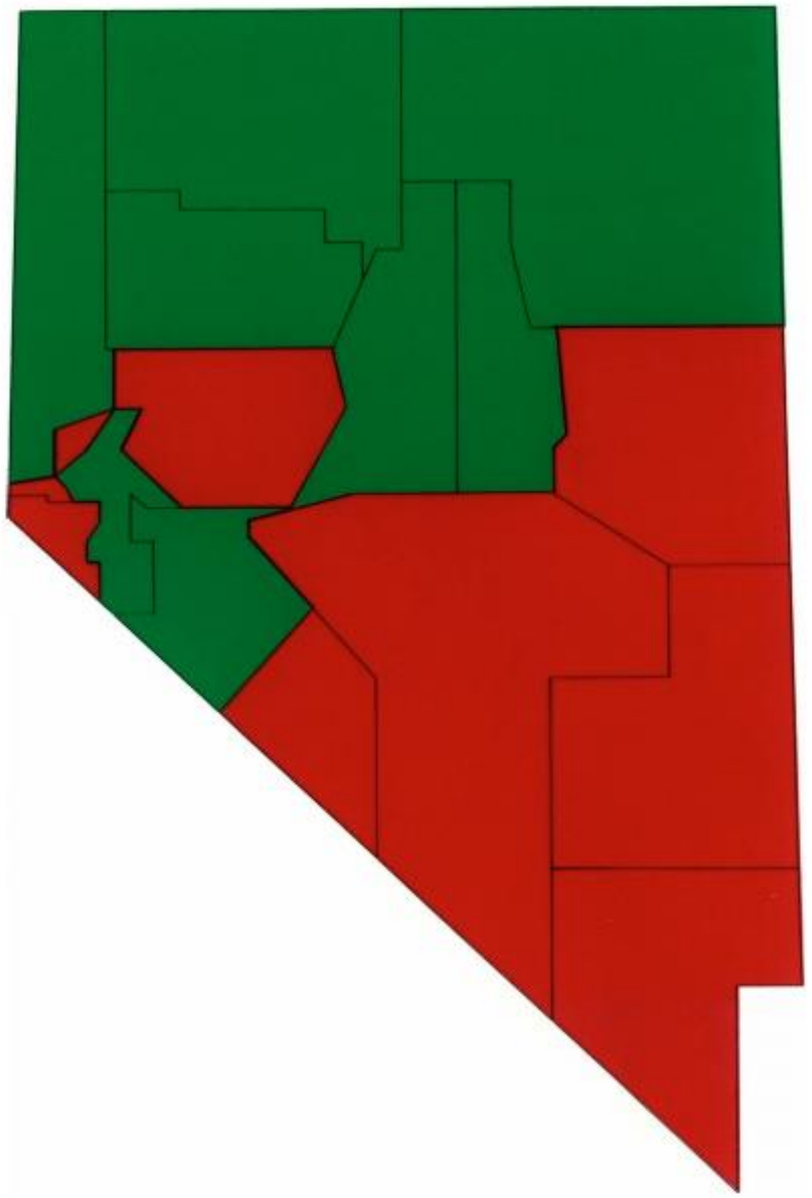


Figure 1. Stimulus From the High-Saturation Group

Cleveland & McGill, 1983

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)

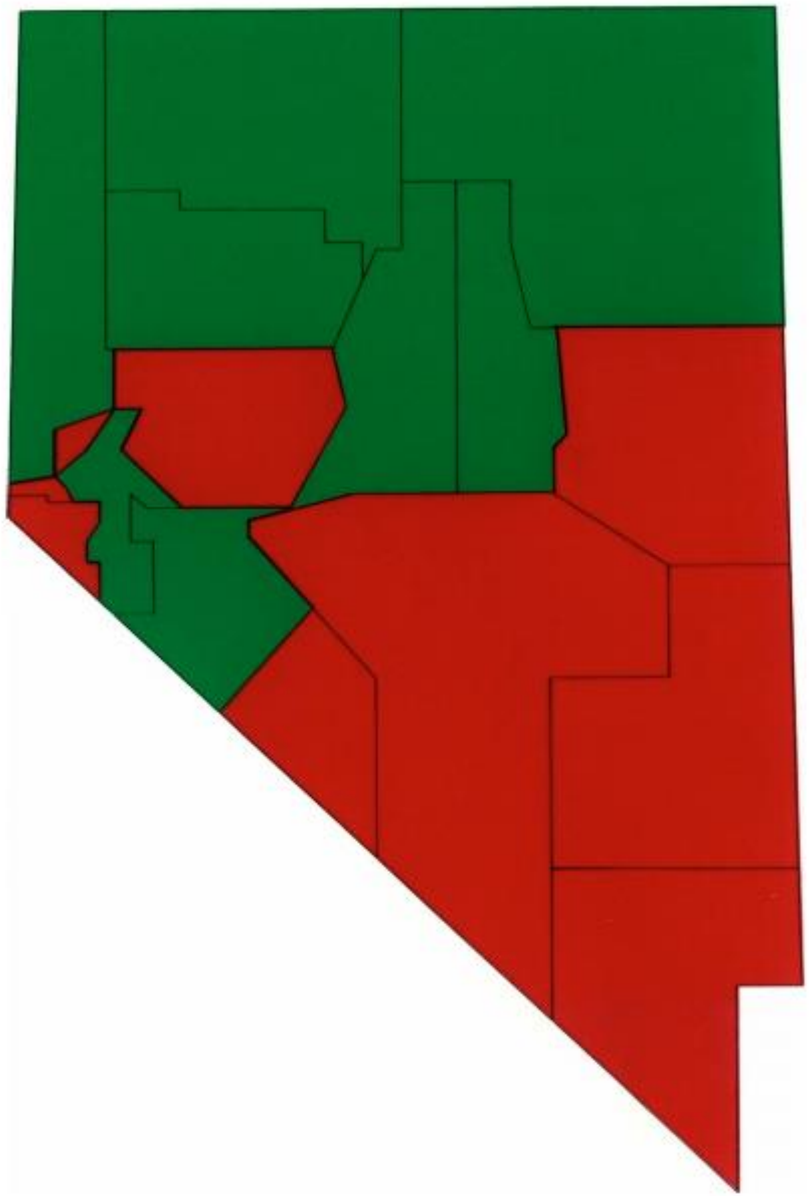


Figure 1. Stimulus From the High-Saturation Group

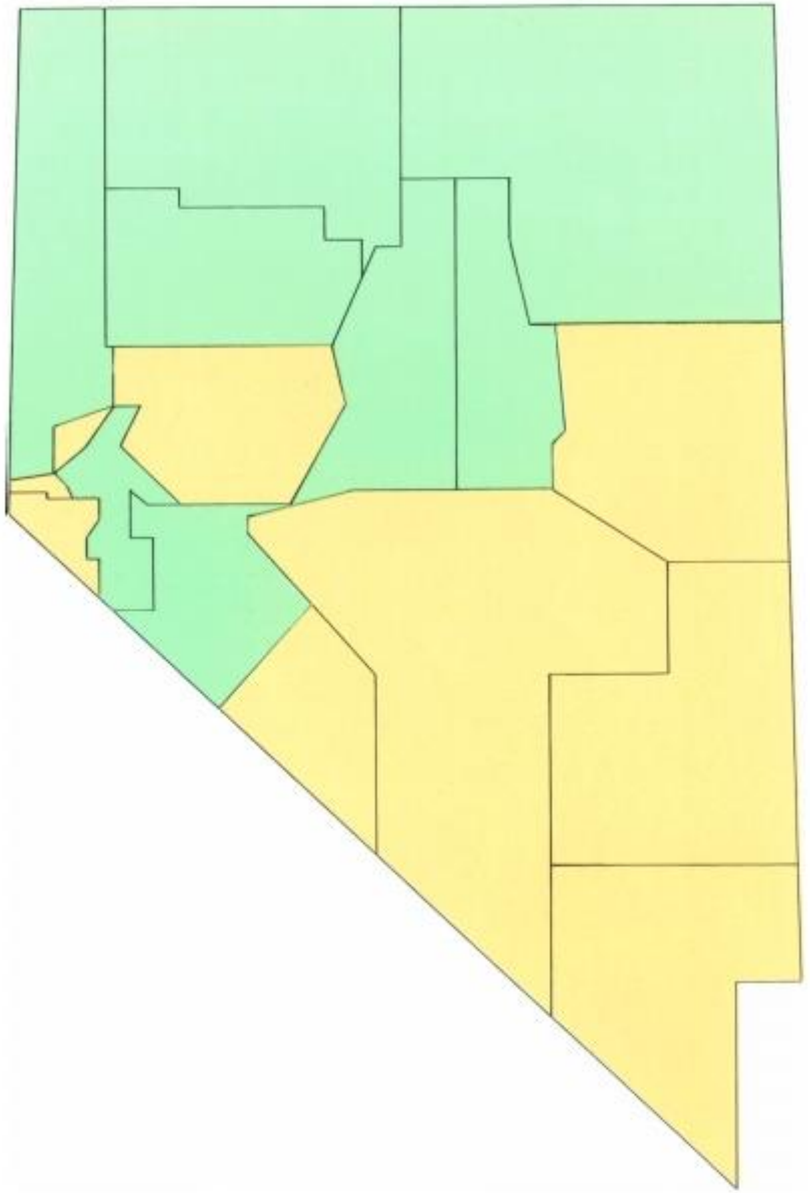
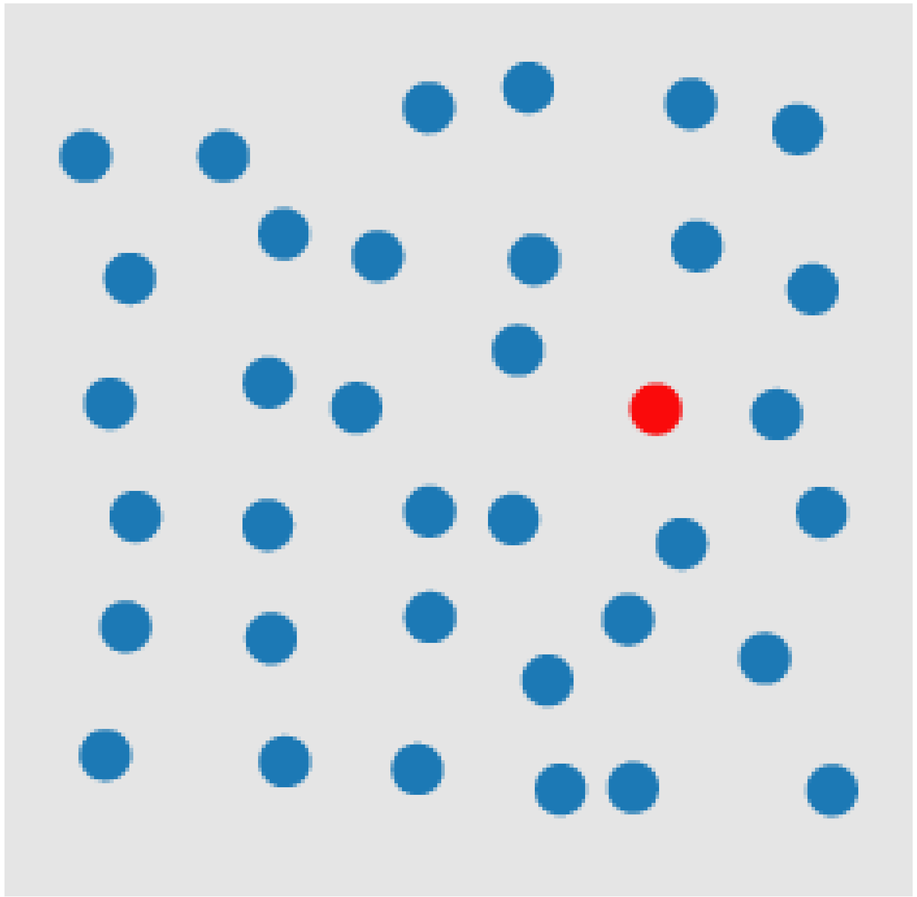
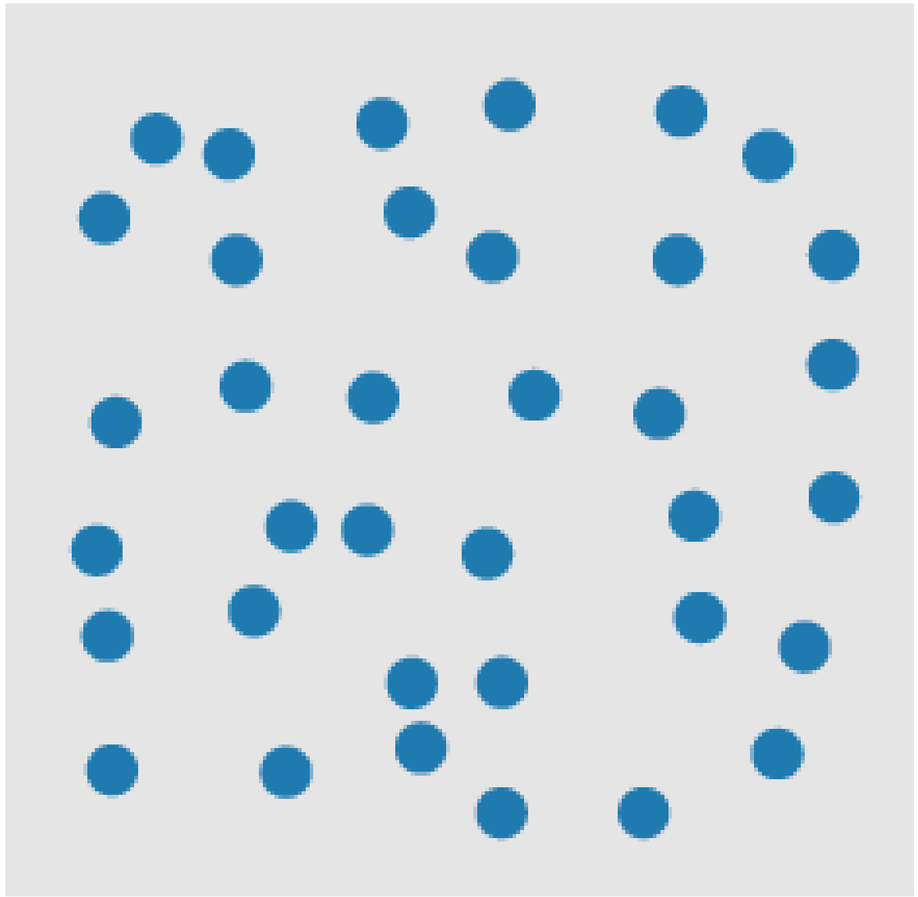


Figure 2. Stimulus From the Low-Saturation Group

Cleveland & McGill, 1983

POP-OUT EFFECTS





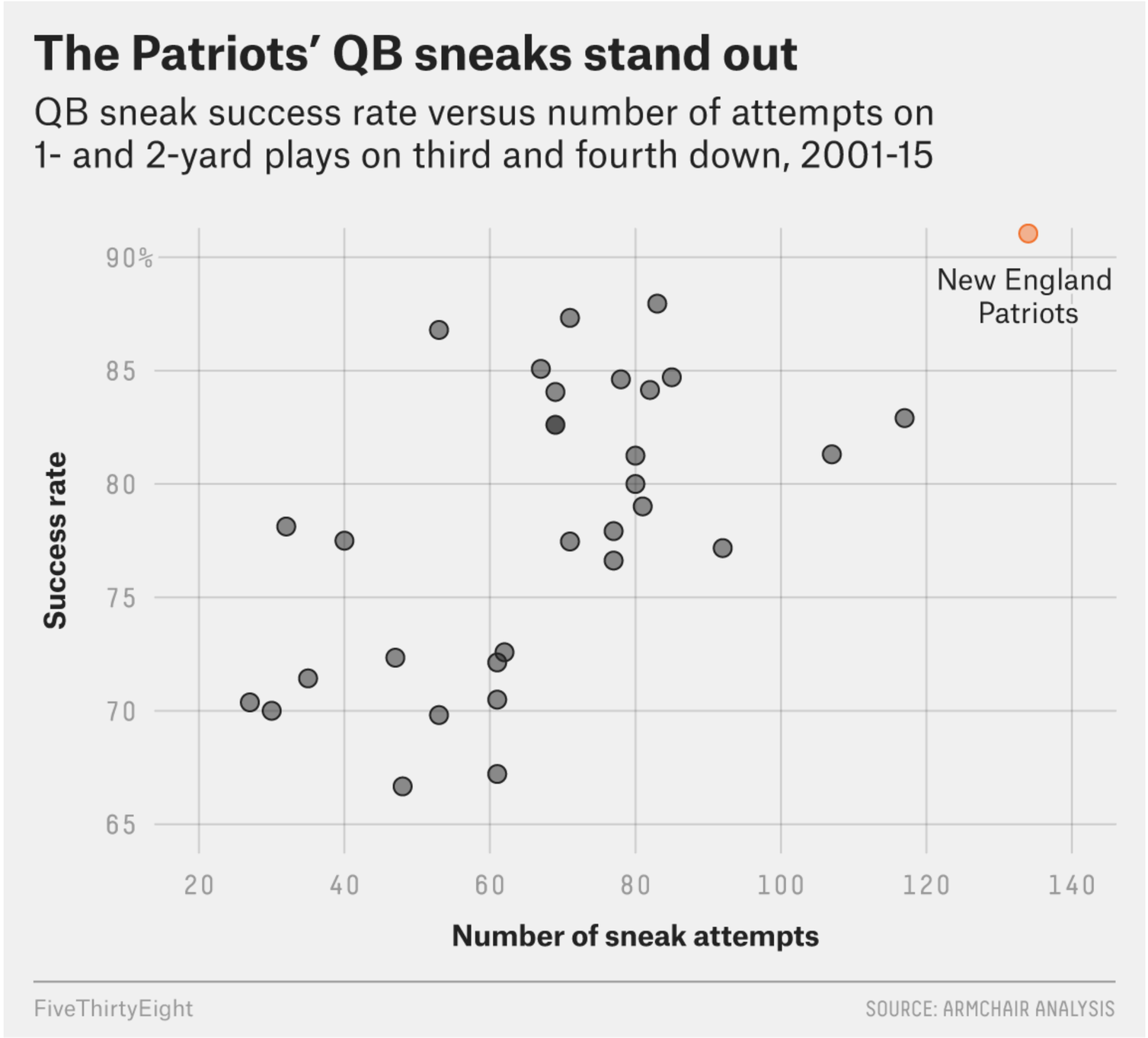
COLOR

Healey, 2012

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_sneak

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



Davis & Lopez, 2017

Desaturated background, light blue

NASA/ESA/Hubble Heritage Team (STScI/AURA) / Hester & Scowen

Color Mixing Pitfalls

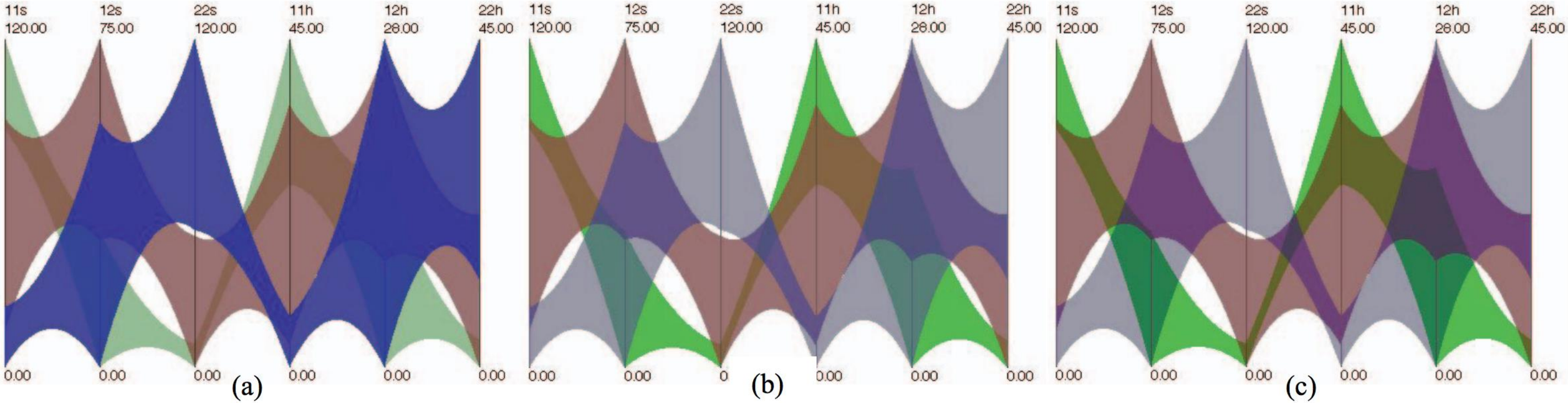


Fig. 12: Illustrative visualizations of a six-dimensional dataset using illustrative parallel coordinates. (a) Ideal visualization with appropriate weightings and color choices, and the use of the local model in overlapping areas. (b) Improper weightings are employed. The blue cluster no longer seems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

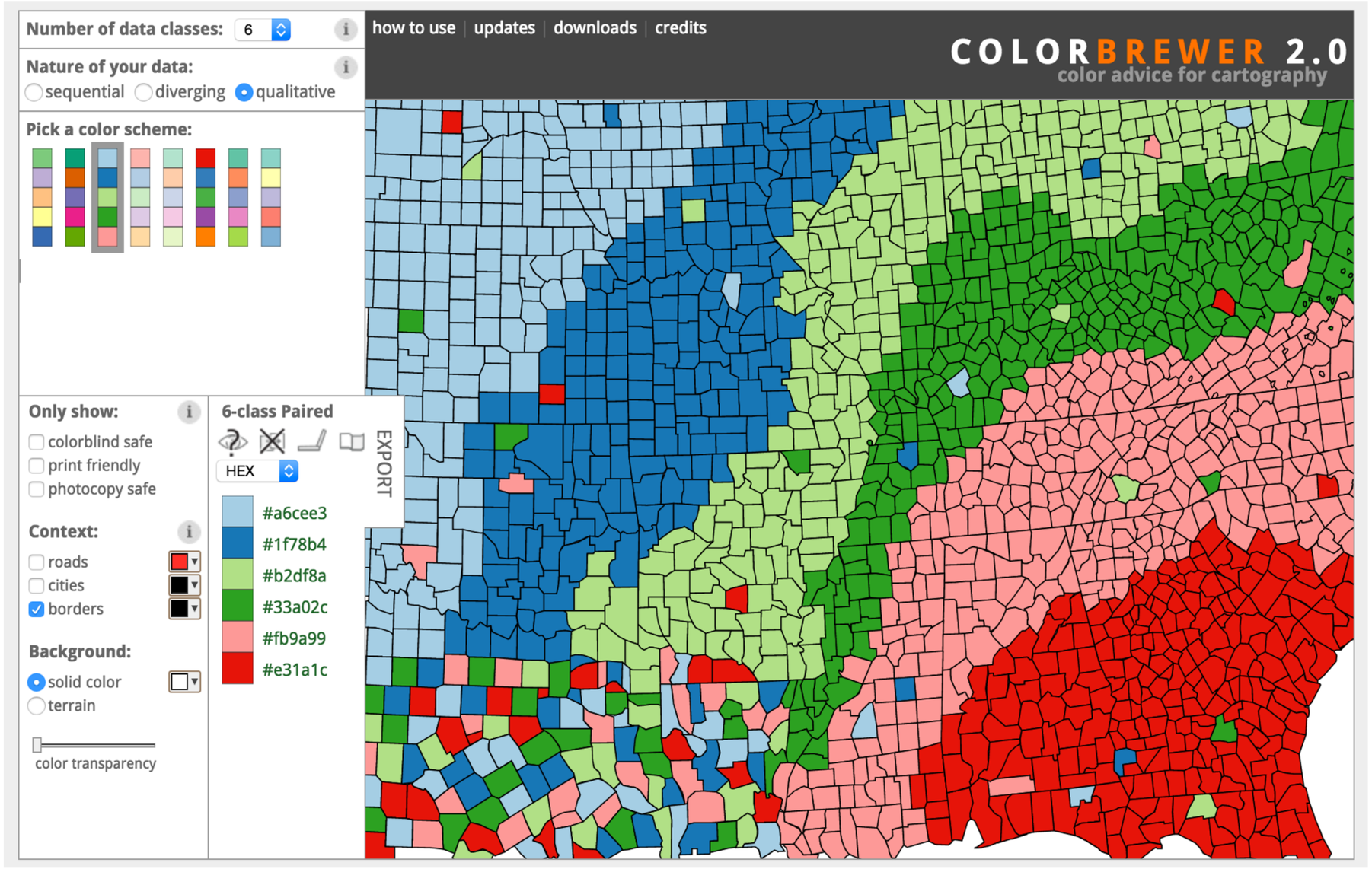
"Aimed at reducing false colors in the overlap regions. …[Reduce] saturation of the color in the rear object only in the overlap region while keeping its lightness."

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

Wang et al., 2008

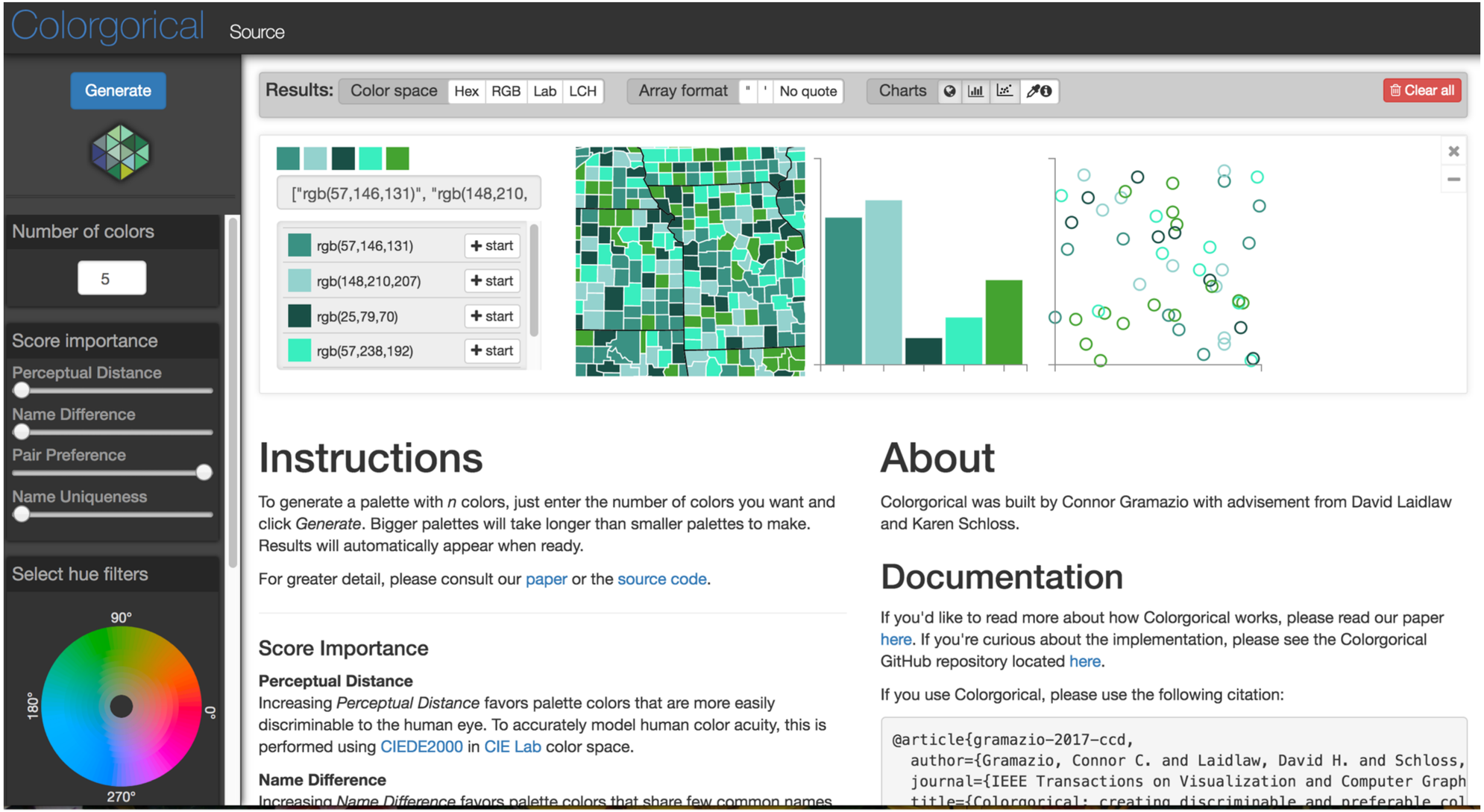
Tools for Picking Colormaps

Color Brewer



http://colorbrewer2.org

Colorgorical



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

Other Useful Tools

- Get a list of colors from an image: https://html-color.codes/color-from-image
- Analyze your palette: https://projects.susielu.com/viz-palette
- 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-color-scales/#combining-bezier-interpolation-and-lightness-correction
- Easy picking a multi-hued color scale: http://tristen.ca/hcl-picker/
- Easily correcting darkness (lightness) for a scale: http://gka.github.io/palettes/
- Do a ton programmatically: https://gka.github.io/chroma.js/
- virdis colors: https://cran.r-project.org/web/packages/viridis/vignettes/intro-to-viridis.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!

Upcoming Assignments & Communication

Look at the upcoming assignments and deadlines regularly!

- Textbook, Readings, & Reading Quizzes — Variable days
- In-Class Activities — 11:59pm same day as class
  - T: Lecture, F: In-class project feedback meetings & work
  - Next T: Lecture, Next F: Lecture
- Assignments & Projects— Generally due R 11:59pm
  - R (6 days):
    - Assignment 7 (D3 Events)
    - **Project 3 — Interview & Task Analysis**
  - Next R (13 days): Project 4 — Data Collection & Exploration, Sketches
  - Next-next R (20 days):
    - Assignment 8 — Brushing and Linking in D3
    - Project 5 — Final "Interactive" Visualization Sketch, Implementation Plan, & Group Charter

Use Canvas Discussions for general questions, email the TAs/S-LTA/instructor for questions specific to you: codydunne-and-tas@ccs.neu.edu. Include links!

If you're emailing about a particular assignment, please **include the URL of the Submission Details page**. (Canvas documentation.)

If you have a project question, **give us your group number**. E.g., include: `Group ## — Topic` with '##' replaced by your group number and 'Topic' replaced by your topic.