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Northeastern University

Color, Illusions

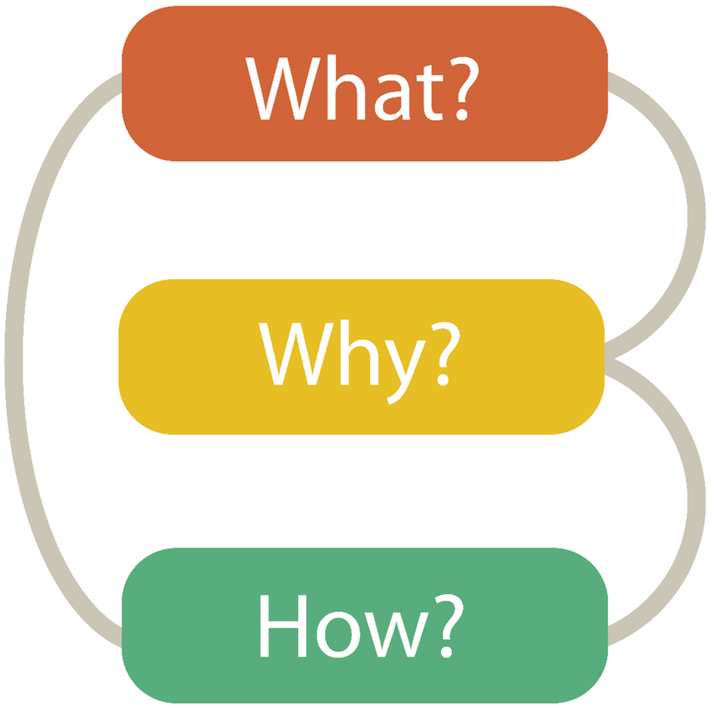
Checking In

Goals for Today: Learn How…

- …task analysis can lead to multiple designs
- …to find visual idioms and ideas for inspiration.
- …to effectively use color as a channel for visual encodings including different colormap types.
- …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.

Task Abstraction → Visual Encoding

Analysis



What data is shown?

DATA ABSTRACTION

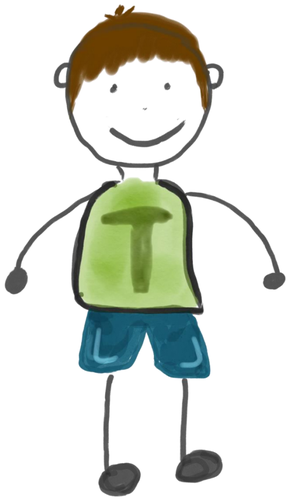
Why is the user analyzing / viewing it?

TASK ABSTRACTION

How is the data presented?

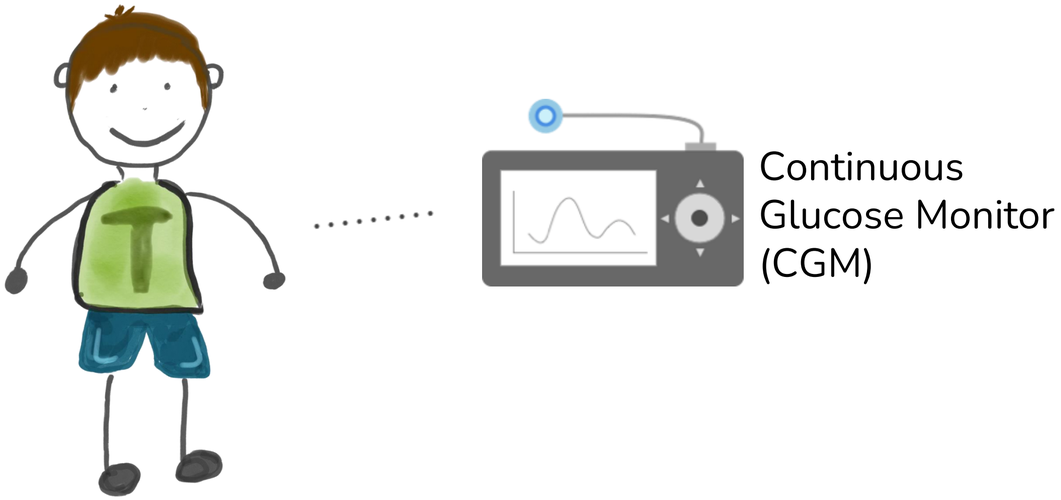
VISUAL ENCODING

Imagine a 10-year-old kid, who has been diagnosed with type 1 diabetes...



Zhang et al., 2018

Imagine a 10-year-old kid, who has been diagnosed with type 1 diabetes...



Zhang et al., 2018

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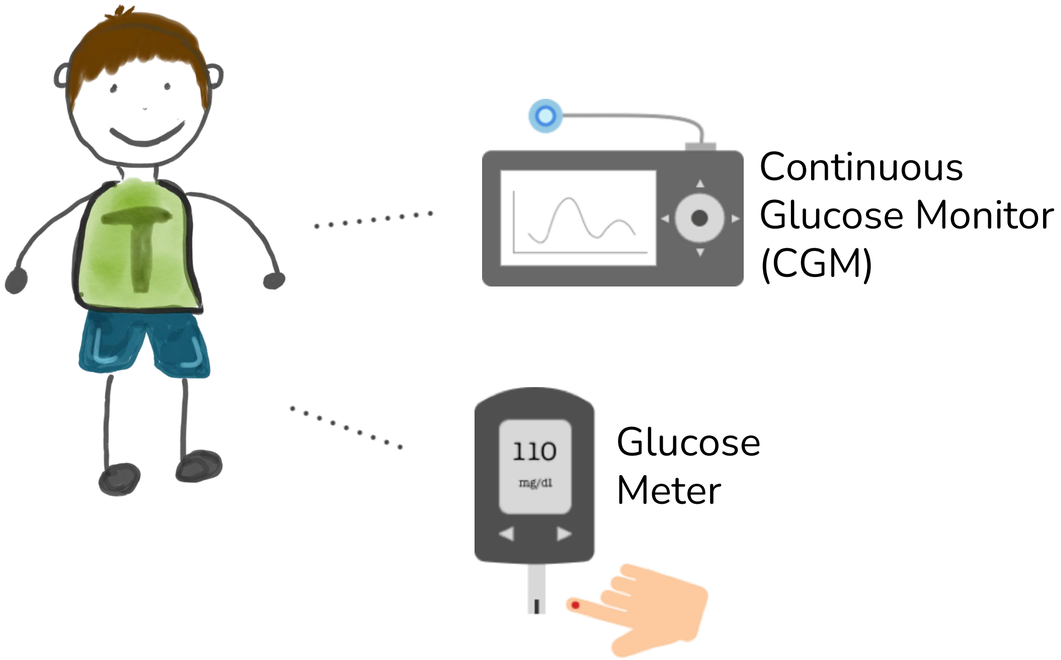

Zhang et al., 2018

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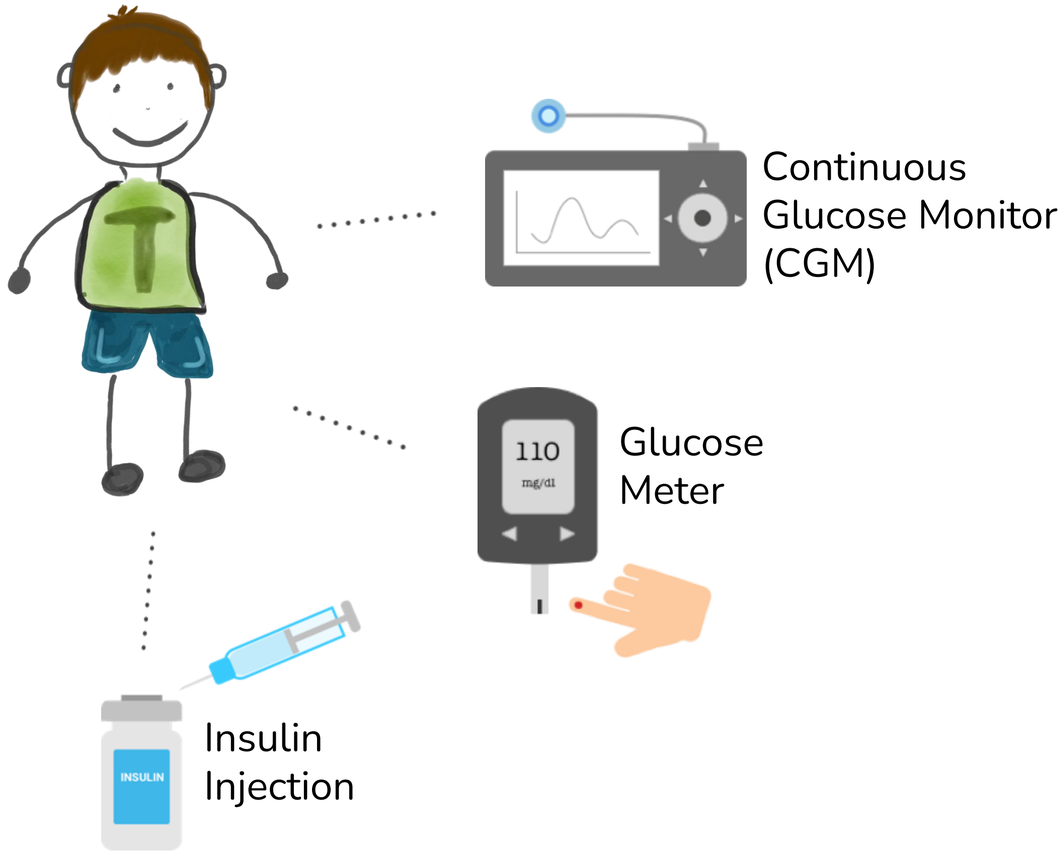

Zhang et al., 2018

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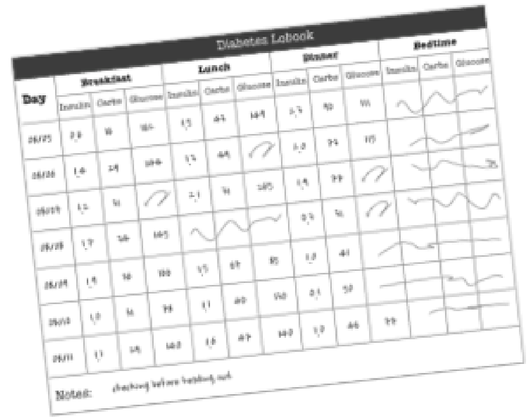
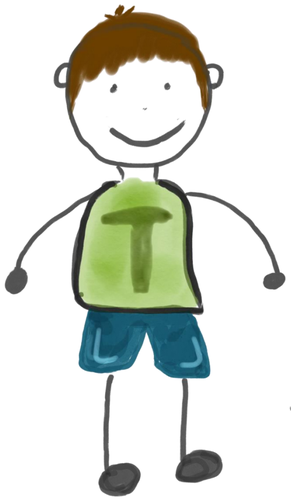
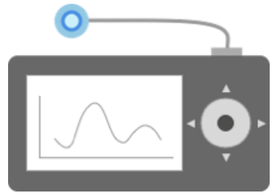


Diabetes Logbook

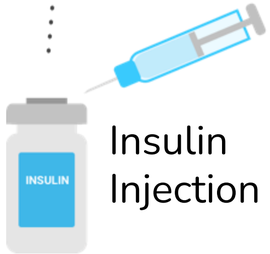
Sickness Food Exercise





Continuous Glucose Monitor (CGM)

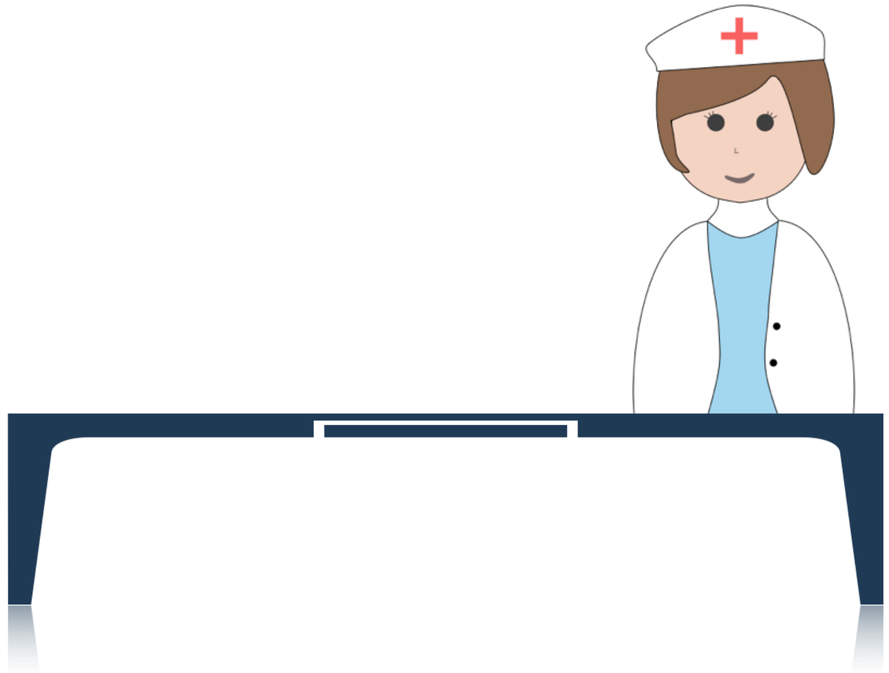
Glucose Meter



Insulin Injection

Zhang et al., 2018

During a clinical visit …



Zhang et al., 2018

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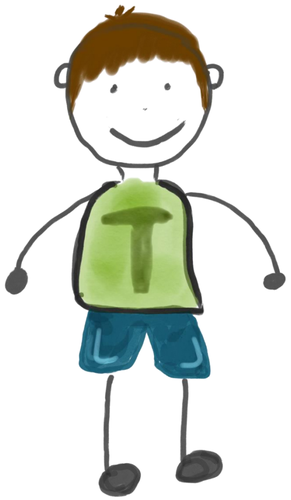

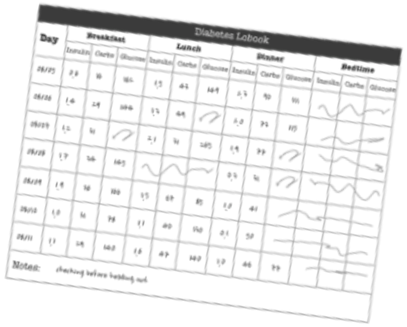

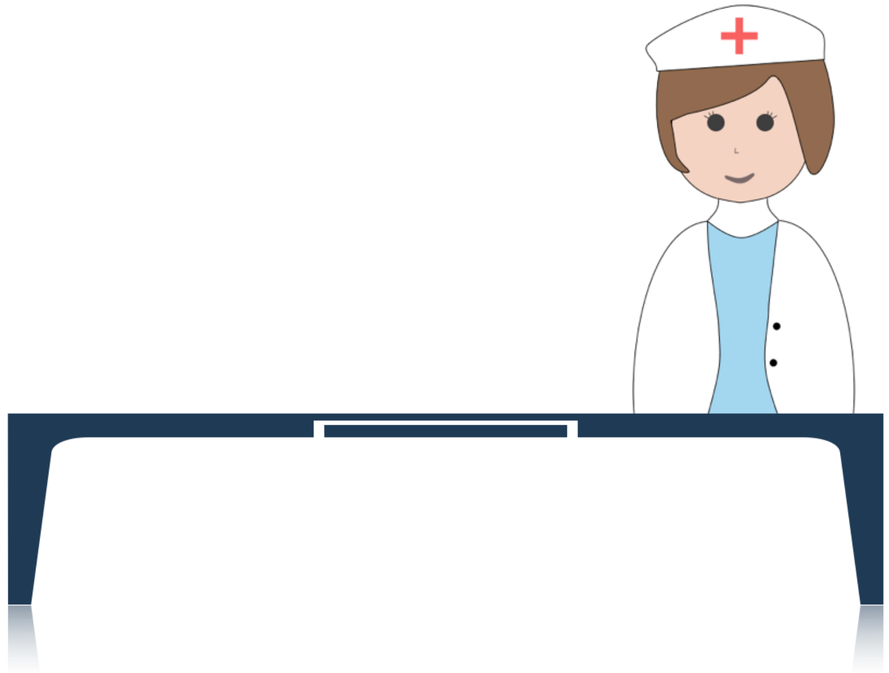

[Zhang et al., 2018]

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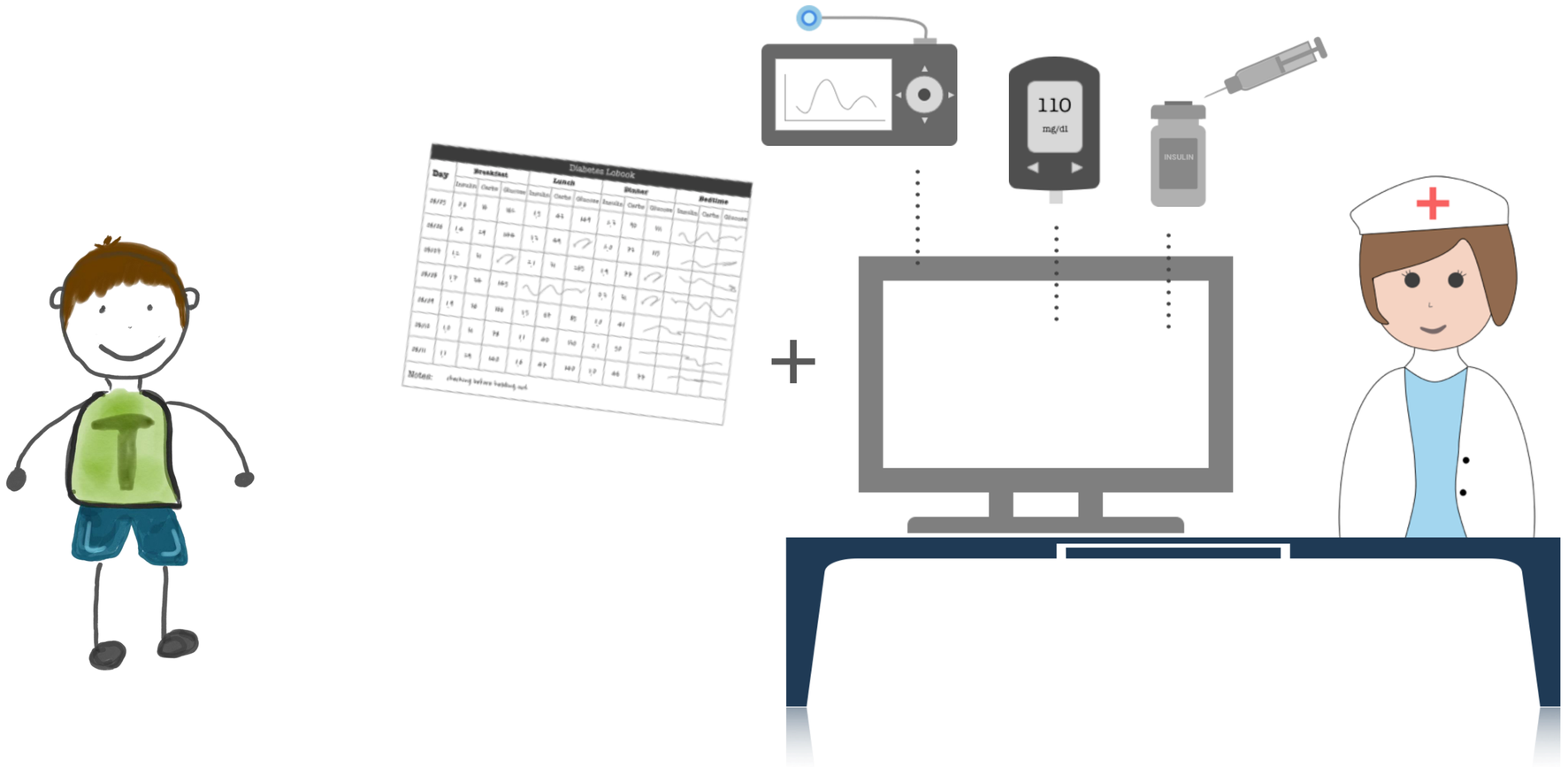

[Zhang et al., 2018]

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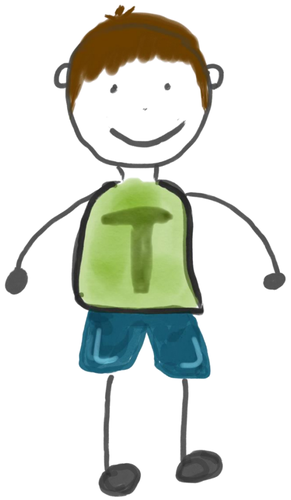
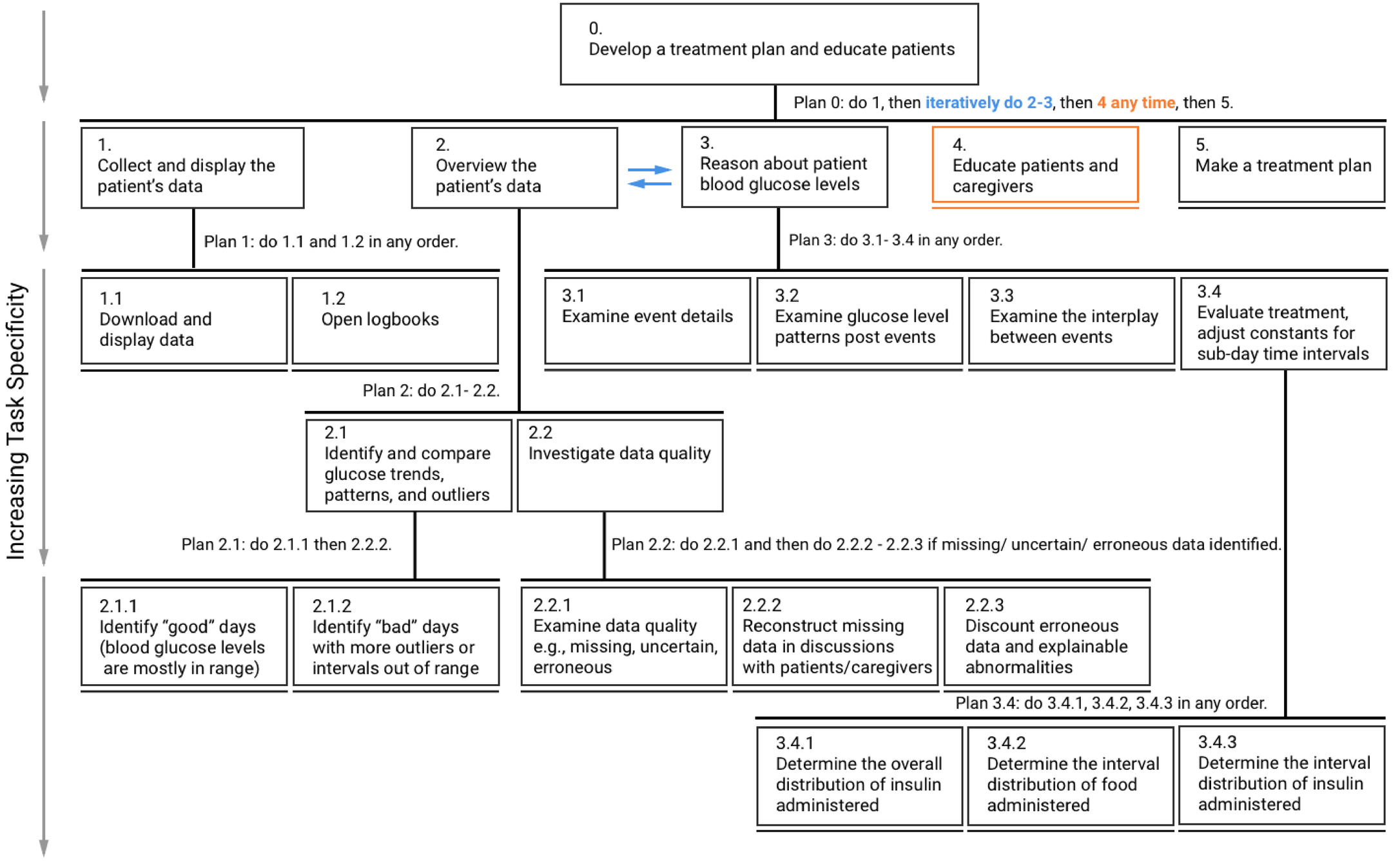
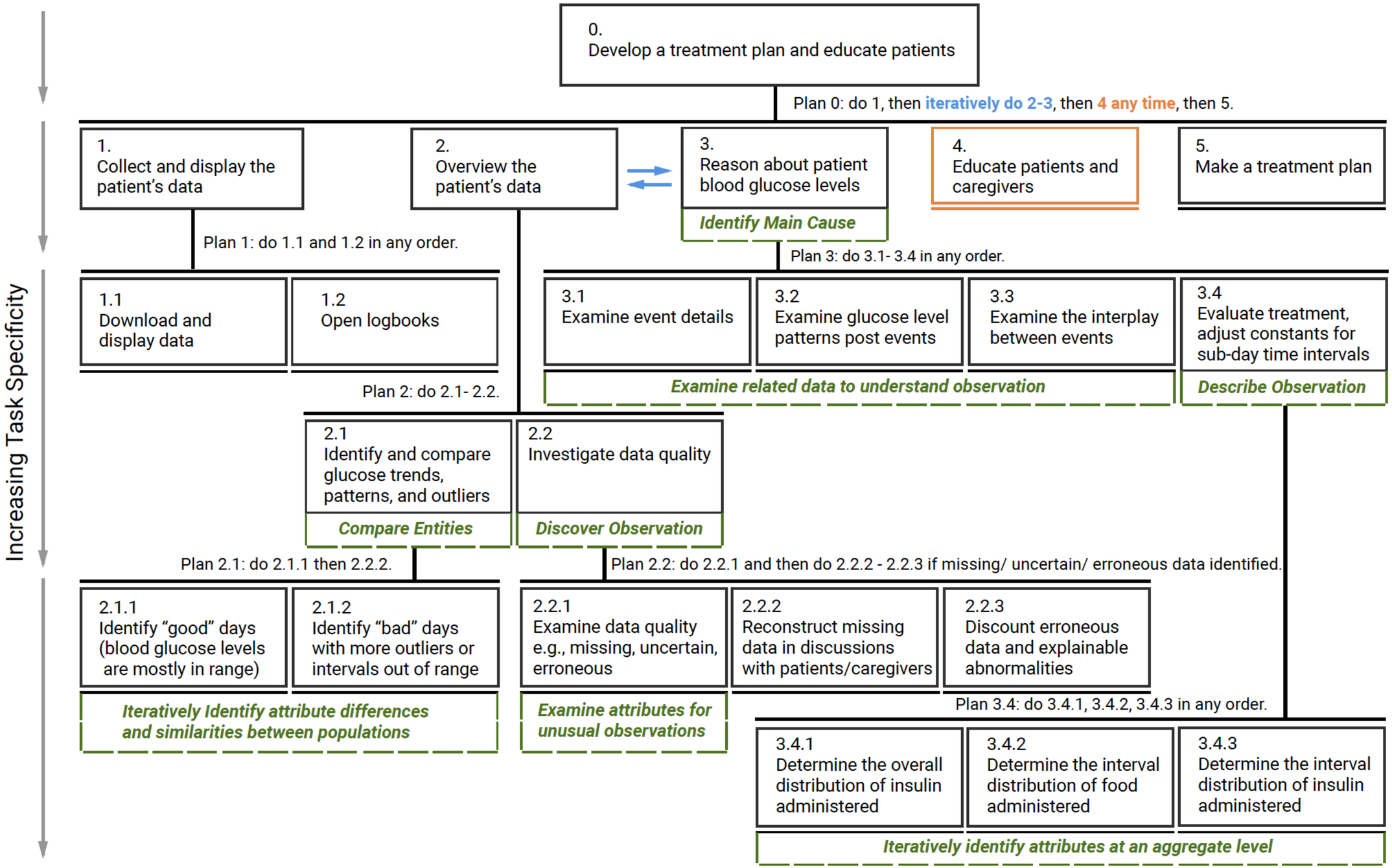




Zhang et al., 2018



Zhang et al., 2018

Design Requirements

- DR1. Composite Visualization of **Integrated** Data
- DR2. Visualization of **Folded Temporal** Data
- DR3. **Align and Scale** Temporal Data
- DR4. **Summary** Statistics

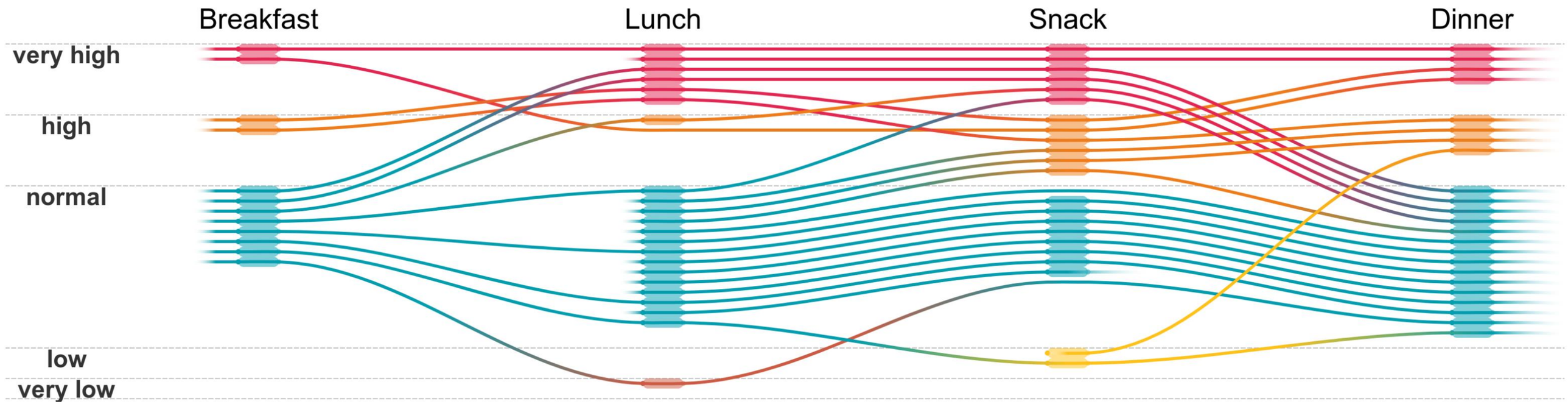
Zhang et al., 2018

14-Day Overview

Detail View

Summary Statistics Panel

Alternate



Di Bartolomeo et al., 2020

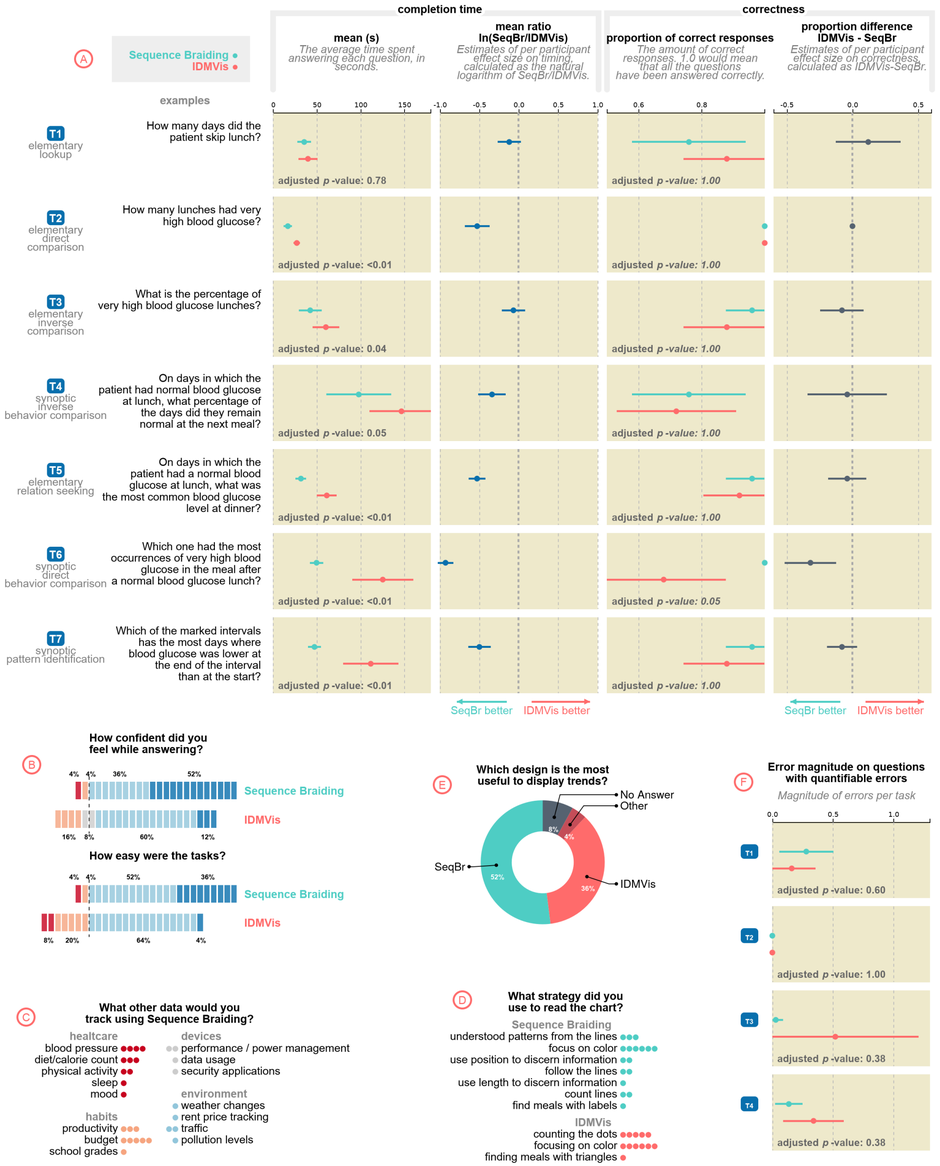
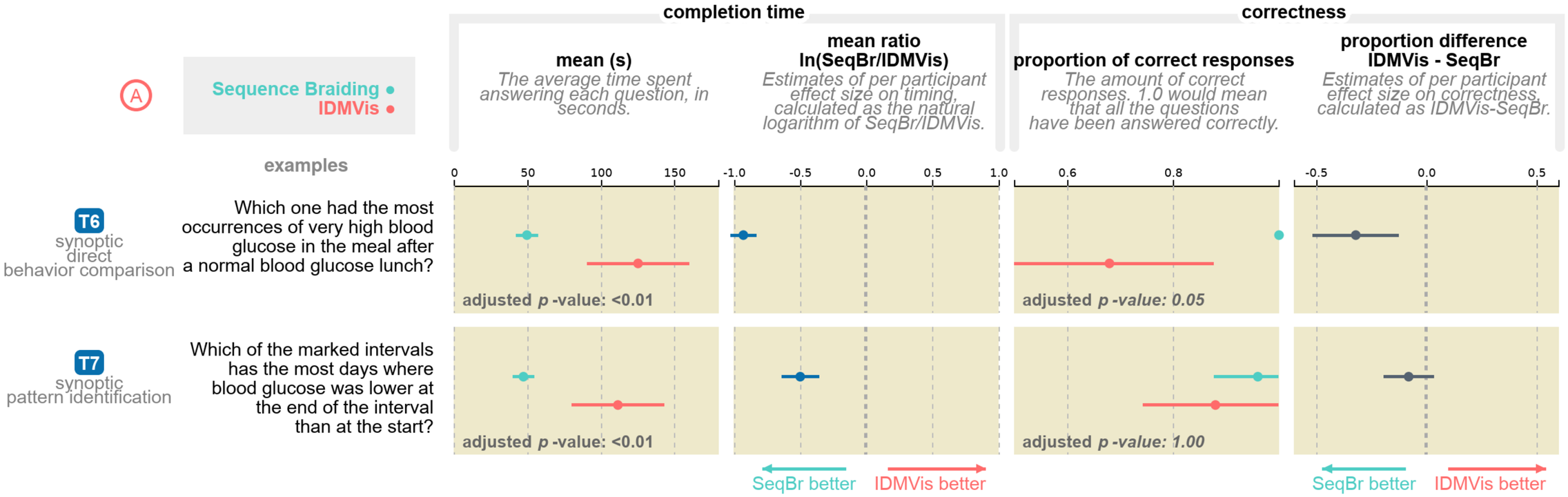
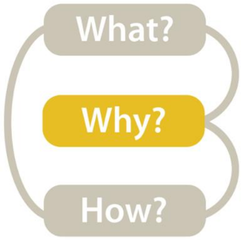


Fig. 9: Results of our evaluation comparing SEQUENCE BRAIDING vs. IDMVis [63]. (A) Completion time and correctness per task. Each row corresponds to the task at left, which is classified based on Andrienko & Andrienko [3]. The specific question instantiating that task for the study is in the second column. (B) Participants' Likert scale responses regarding confidence and ease of use. (C) Participants' answers when asked what other types of data would they use with SEQUENCE BRAIDING. (D) Participants' reported strategies used. (E) Participants' preference for which method was most useful for displaying trends. (F) Error magnitude per task, for those which are quantifiable.

[Di Bartolomeo et al., 2020]


completion time
correctness
A
Sequence Braiding
IDMVis
mean (s)
The average time spent answering each question, in seconds.
mean ratio ln(SeqBr/IDMVis)
Estimates of per participant effect size on timing, calculated as the natural logarithm of SeqBr/IDMVis.
proportion of correct responses
The amount of correct responses. 1.0 would mean that all the questions have been answered correctly.
proportion difference IDMVis - SeqBr
Estimates of per participant effect size on correctness, calculated as IDMVis-SeqBr.
examples
T6
synoptic
direct
behavior comparison
Which one had the most occurrences of very high blood glucose in the meal after a normal blood glucose lunch?
T7
synoptic
pattern identification
Which of the marked intervals has the most days where blood glucose was lower at the end of the interval than at the start?
0
50
100
150
-1.0
-0.5
0.0
0.5
1.0
0.6
0.8
-0.5
0.0
0.5
adjusted p -value: <0.01
adjusted p -value: 0.05
adjusted p -value: <0.01
adjusted p -value: 1.00
SeqBr better
IDMVis better
SeqBr better
IDMVis better

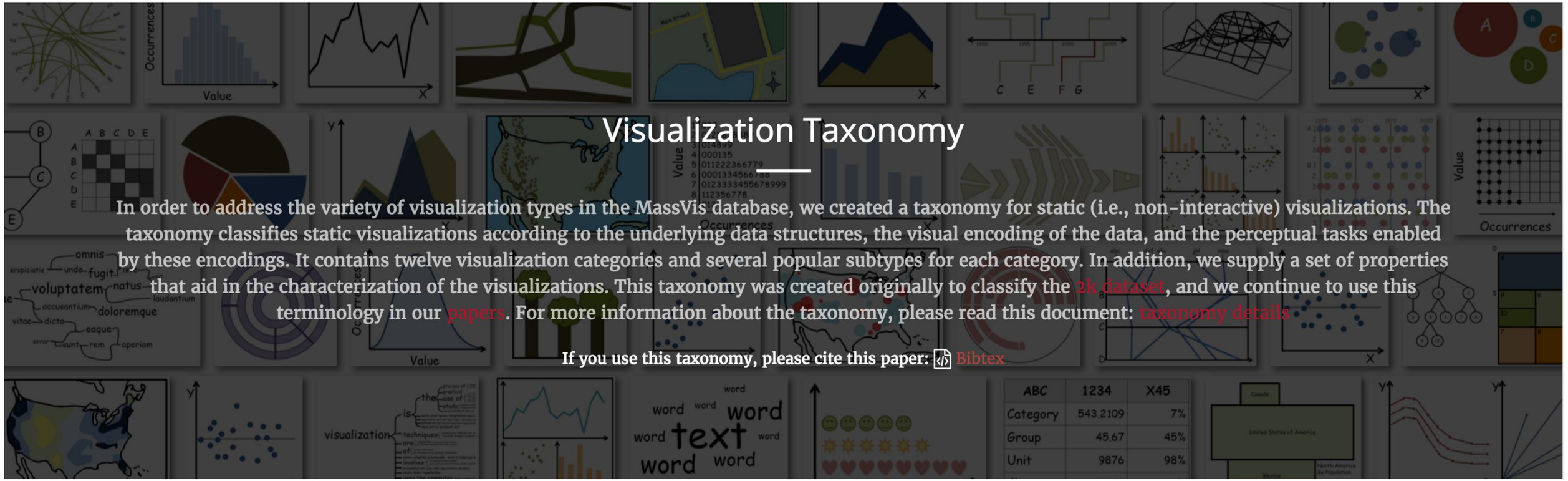


Interview Advice

- Have a designated note-taker and designated leader
- Be prepared. (Have some questions prepared in advance.)
- Start slow, safe, and personal.
- Coax, don’t hammer.
- Make some questions open ended.
- Ask what you don’t know.
- Let the interviewees wander a bit–but be careful.
- Listen, really listen.
- For software, look for “work arounds” and hacks.
- Make sure to write down your thoughts and impressions immediately after the interview.
- You are the visualization expert – don’t ask them what vis they want, don’t think too early about what vis to build.

Shel Israel, 2012

Visualization Ideas



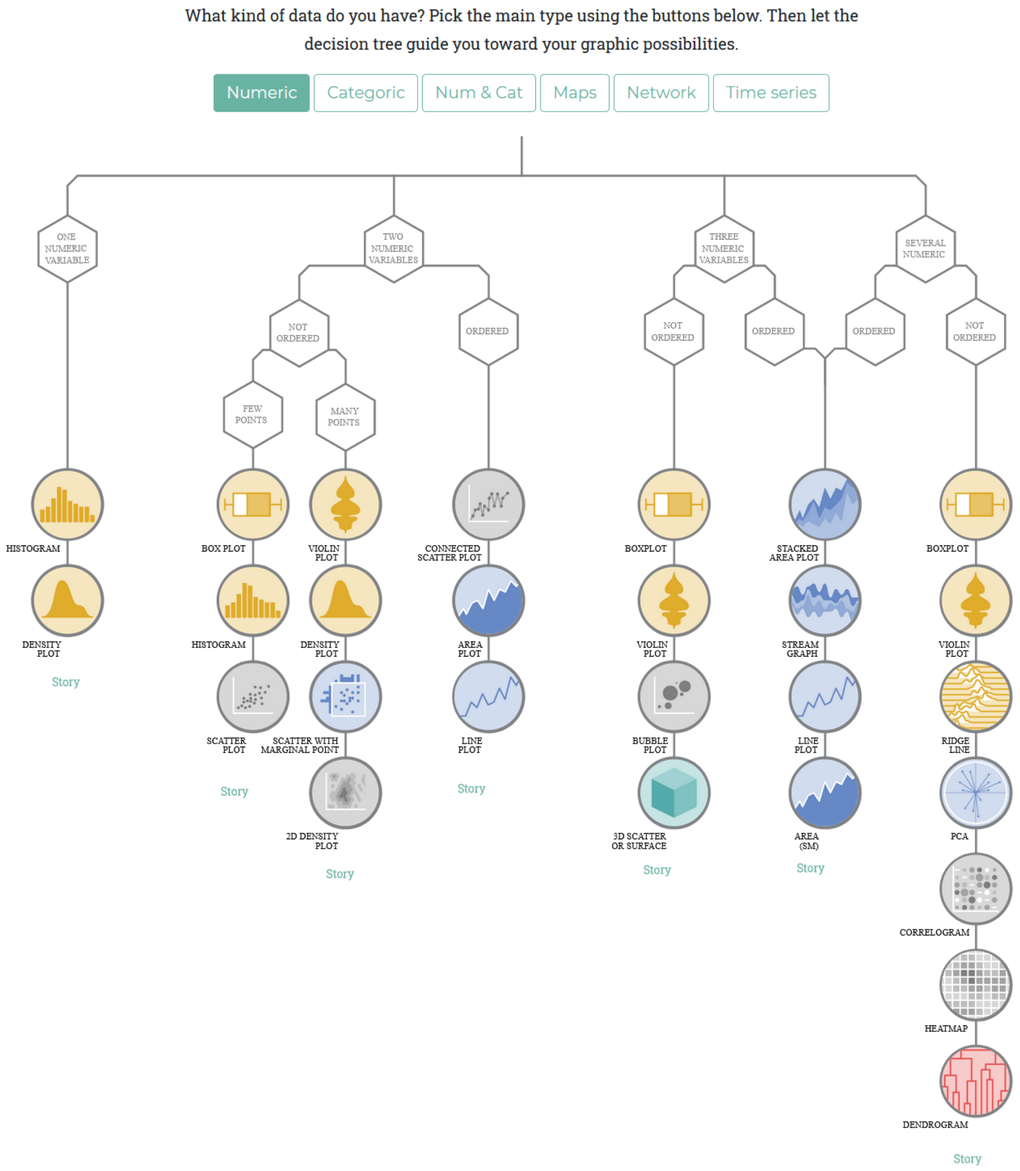
http://massvis.mit.edu/

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

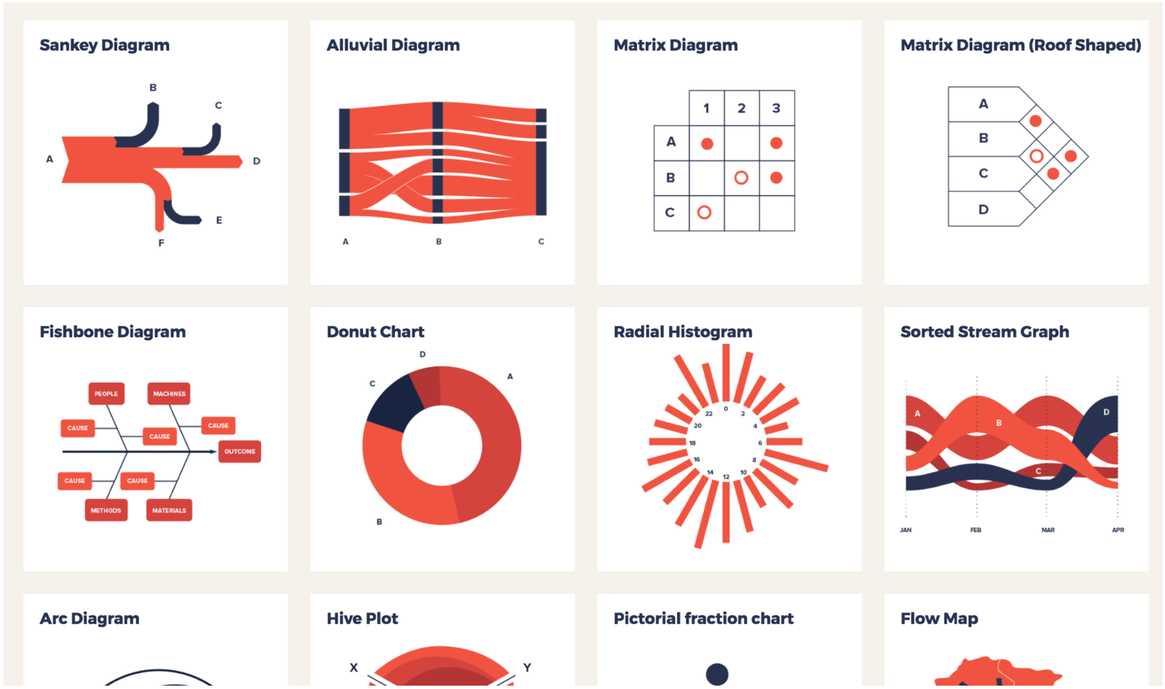
https://www.data-to-viz.com/



More visualization “catalogs”

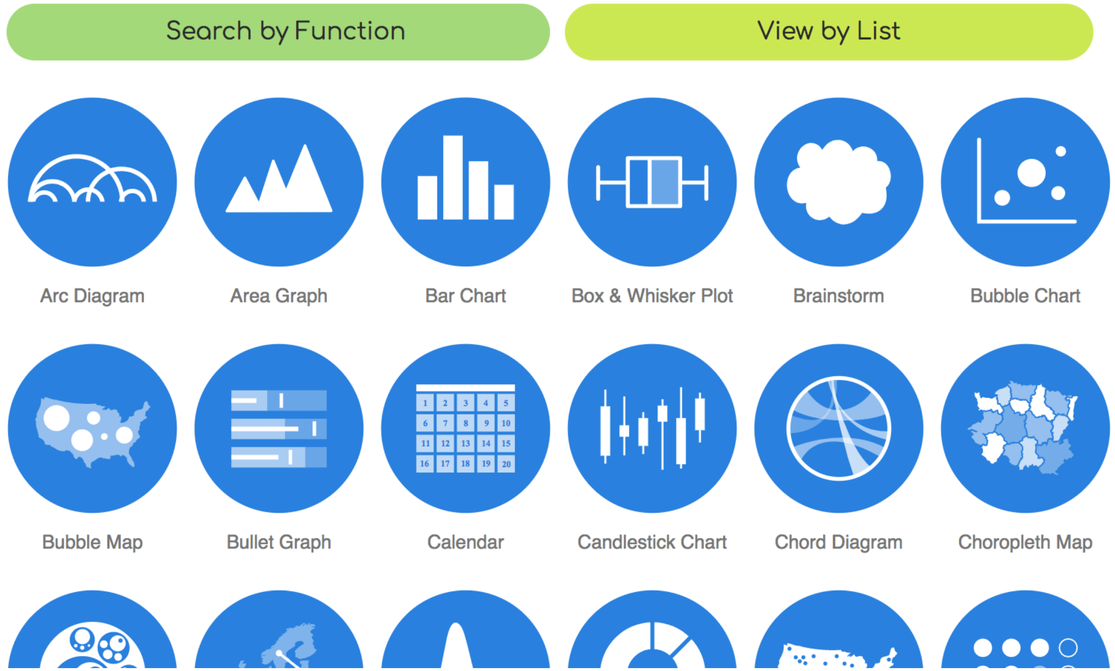
DataVizProject

http://datavizproject.com/



The Data Visualization Catalogue

http://www.datavizcatalogue.com/

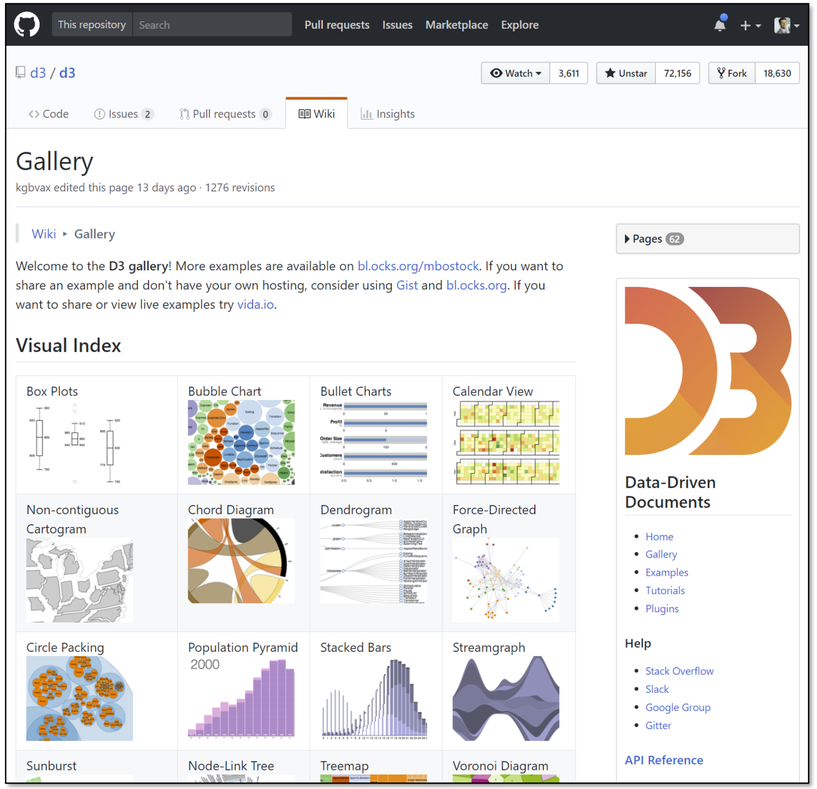


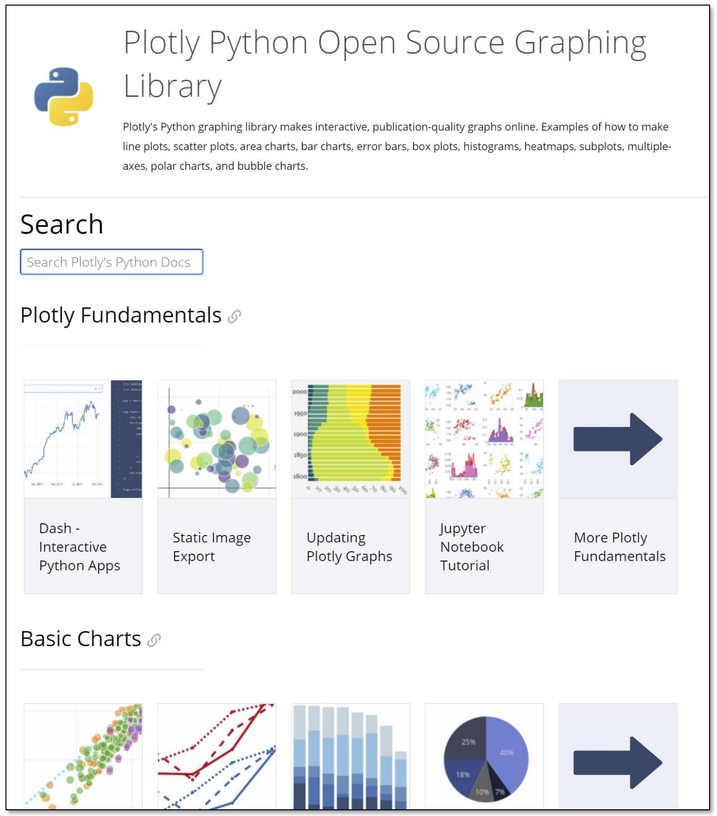
More visualization ideas

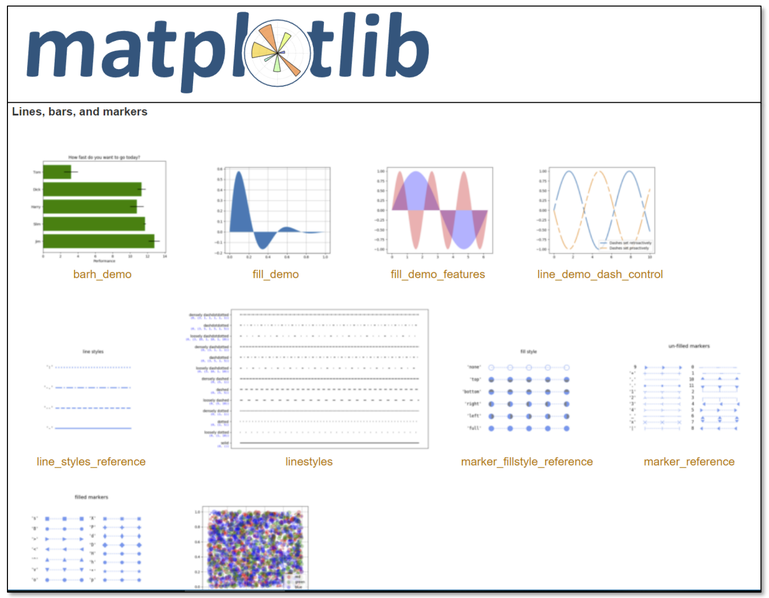
https://matplotlib.org/gallery.html

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

https://plot.ly/python/







COLOR

Visual Perception and Cognition

Pre-Attentive Processing

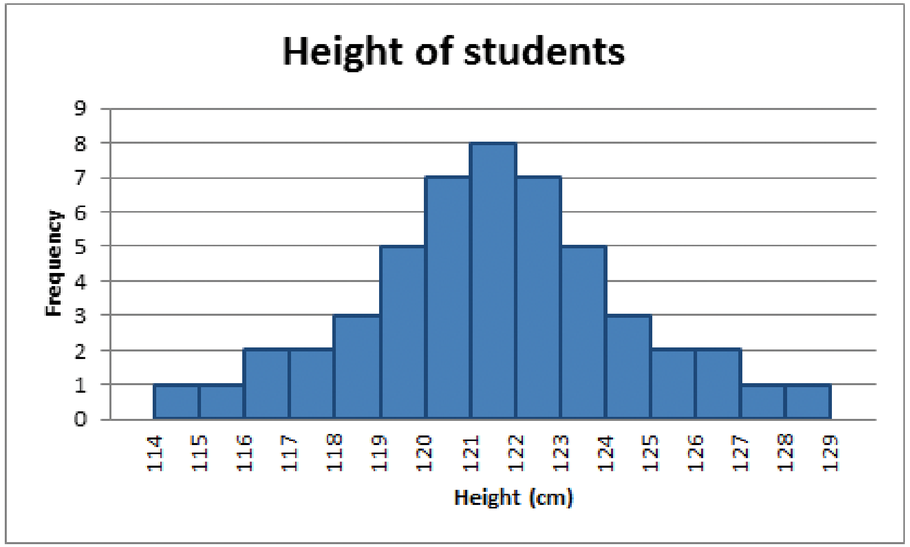
- Automatic
- Lasts < 1 second

Working Memory / Short-Term Memory

- Conscious
- Limited (information retained for seconds)

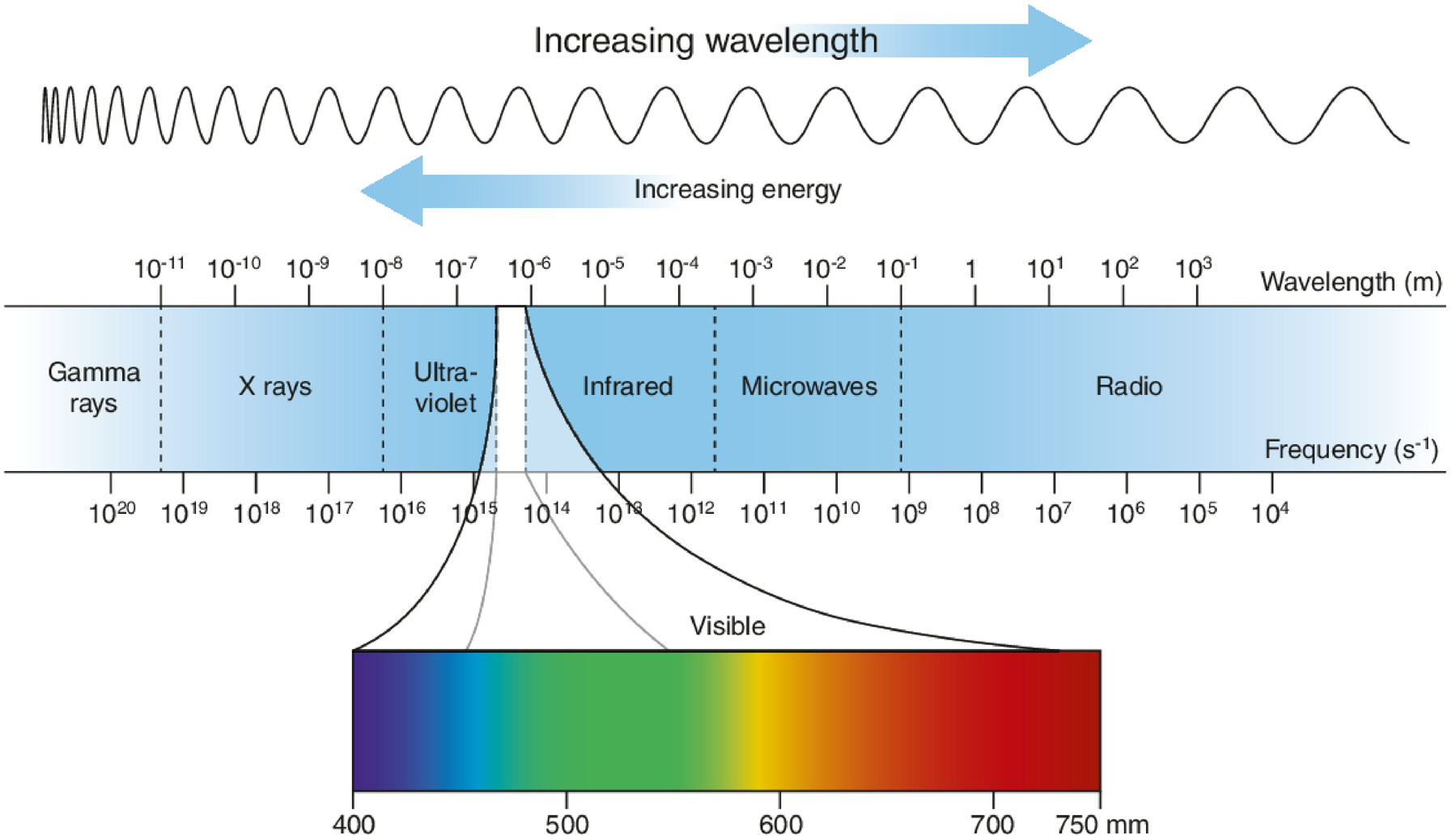
Long-Term Memory

- Storage of repeated working memory tasks
- Can be consciously retrieved



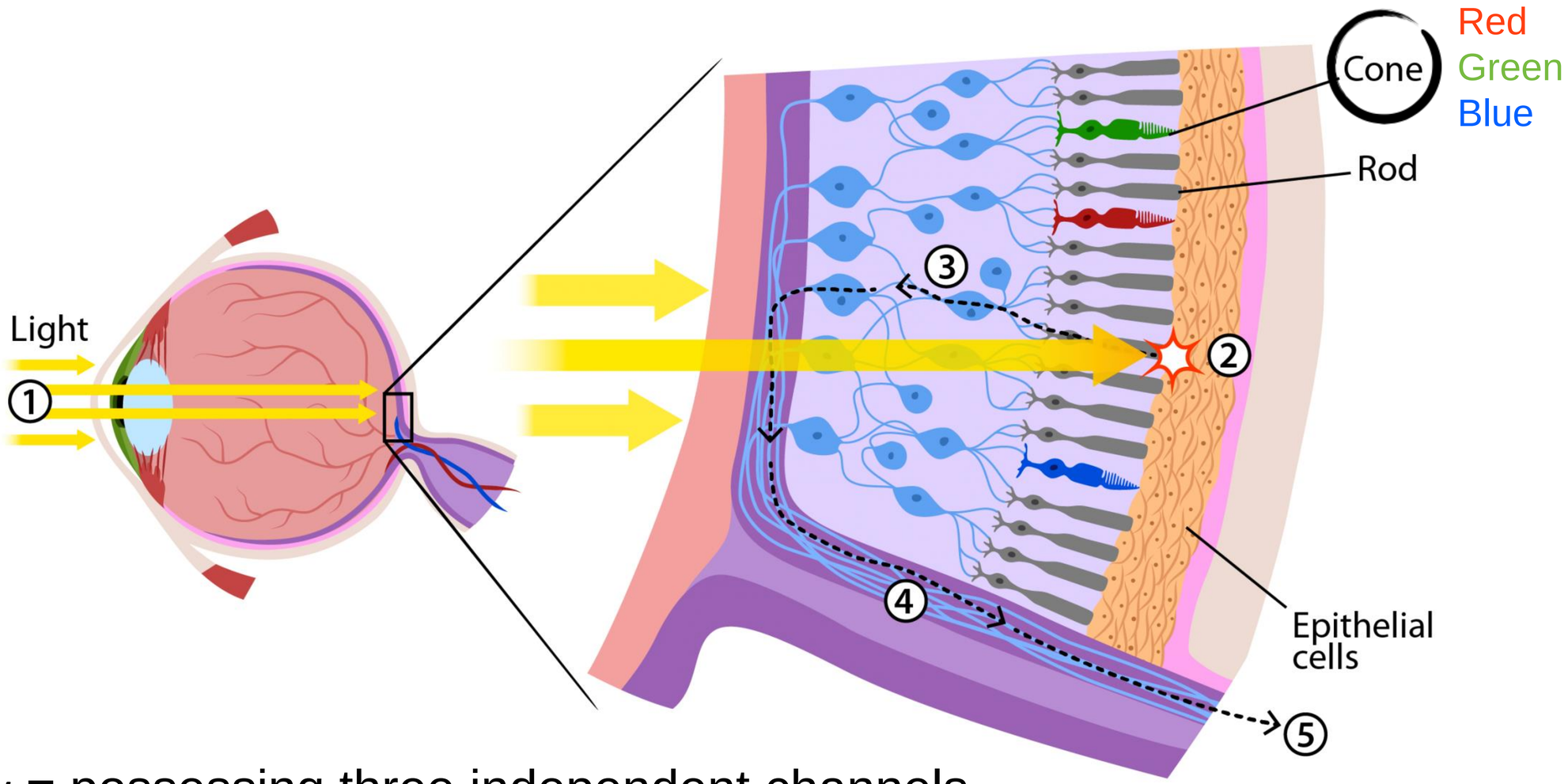
Boundless

Color = Wavelength



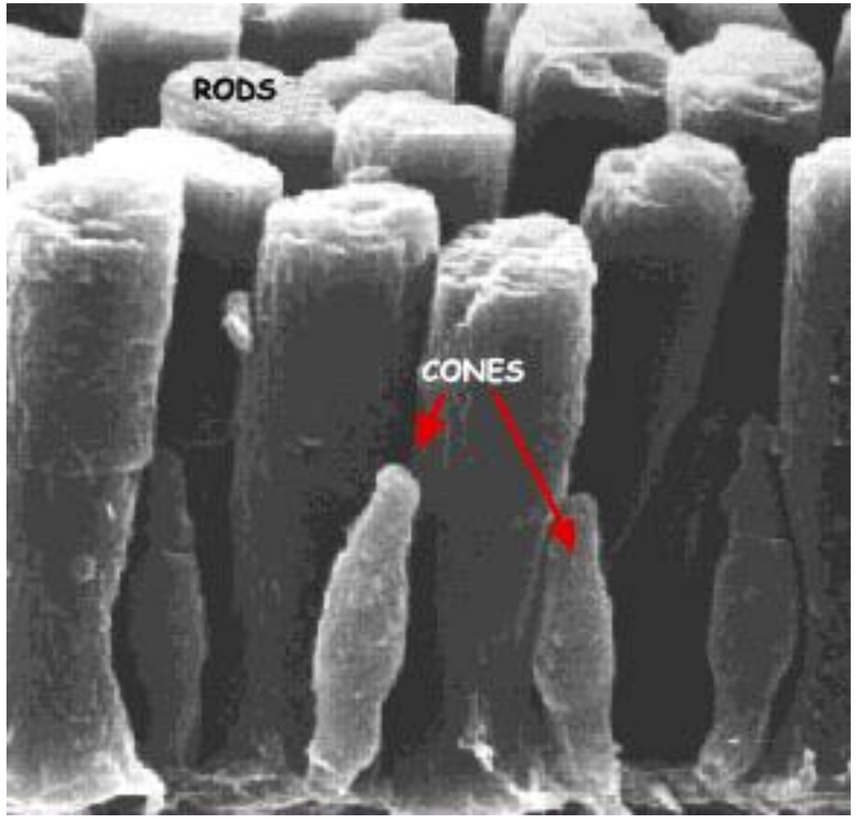
Paschos & Bentley, 2019

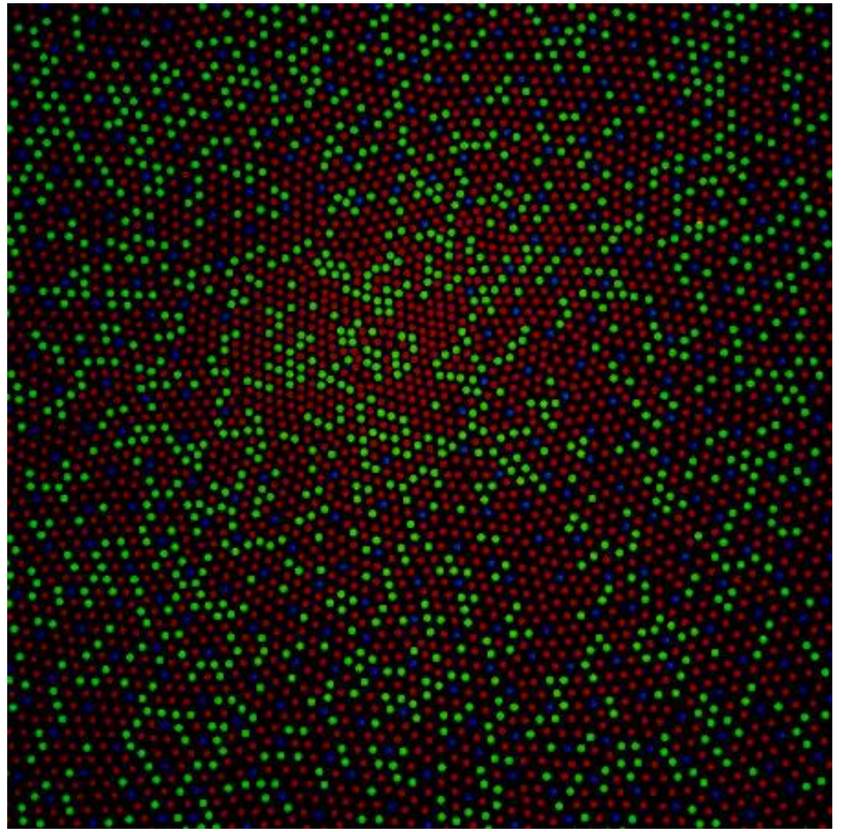
Wavelength → Signals



trichromacy = possessing three independent channels for conveying color information

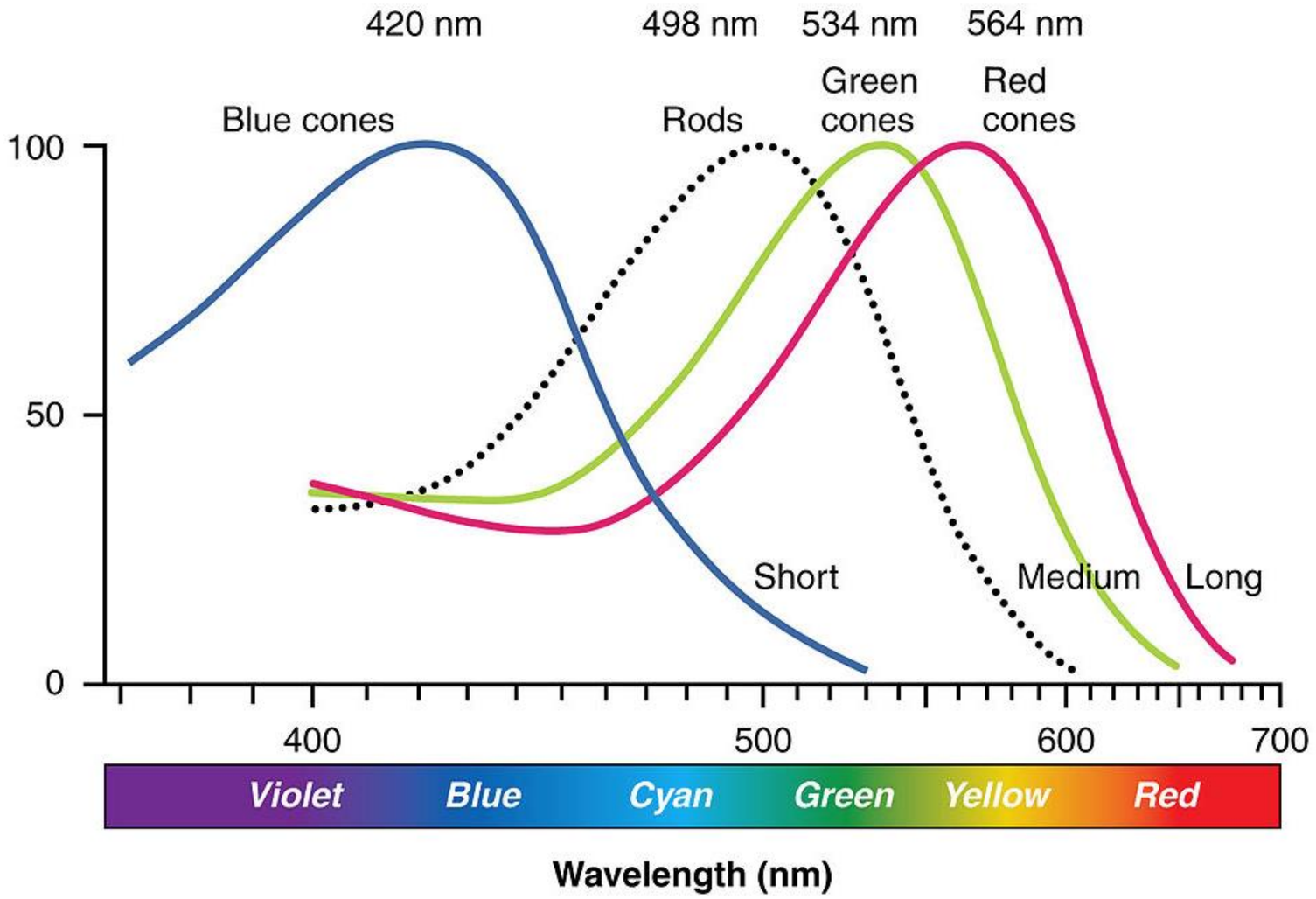
Rods & Cones





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

VARIABLE ACTIVATION



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:

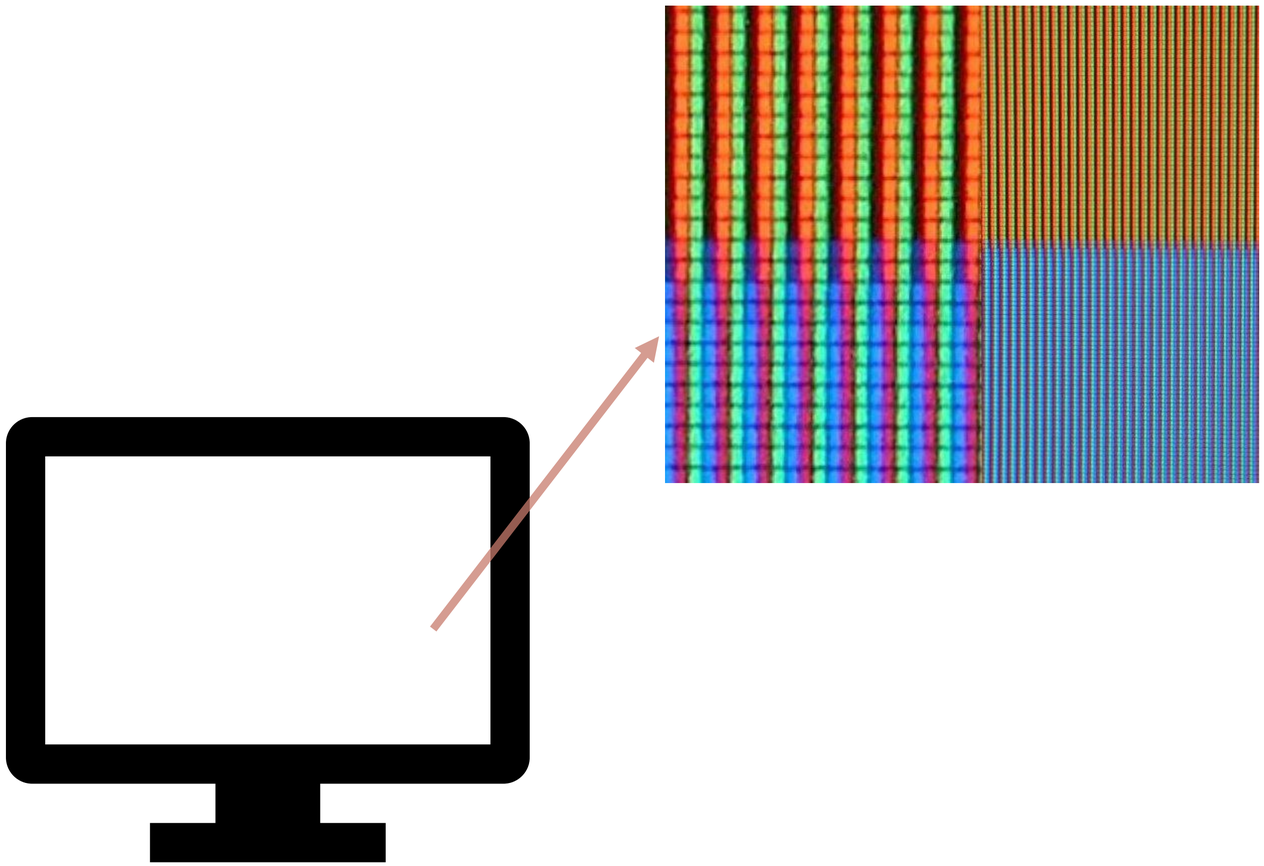
64% red-sensitive

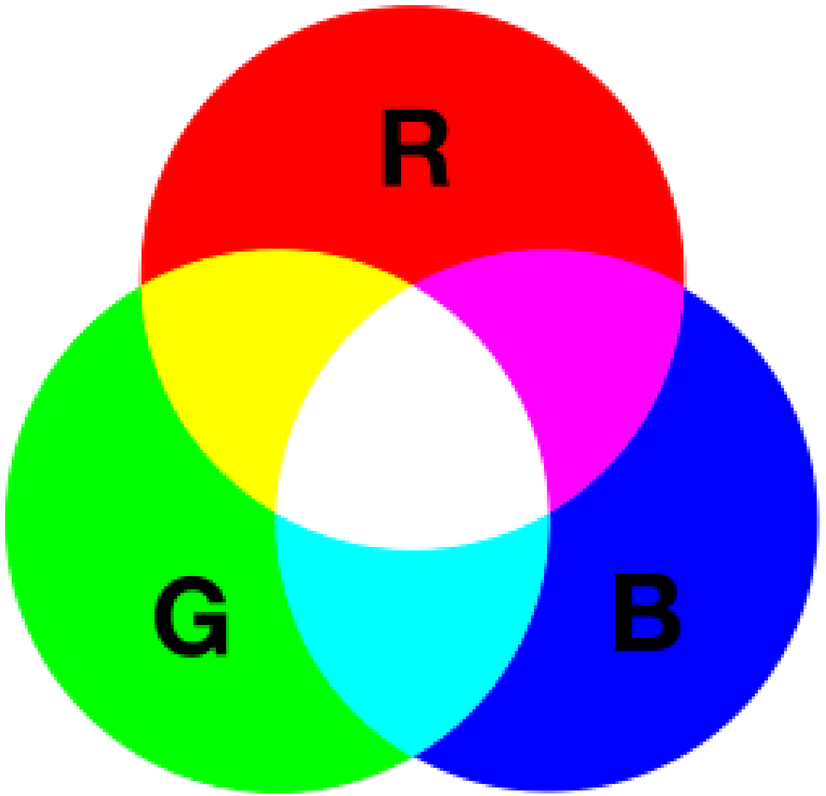
32% green-sensitive

2% blue-sensitive.

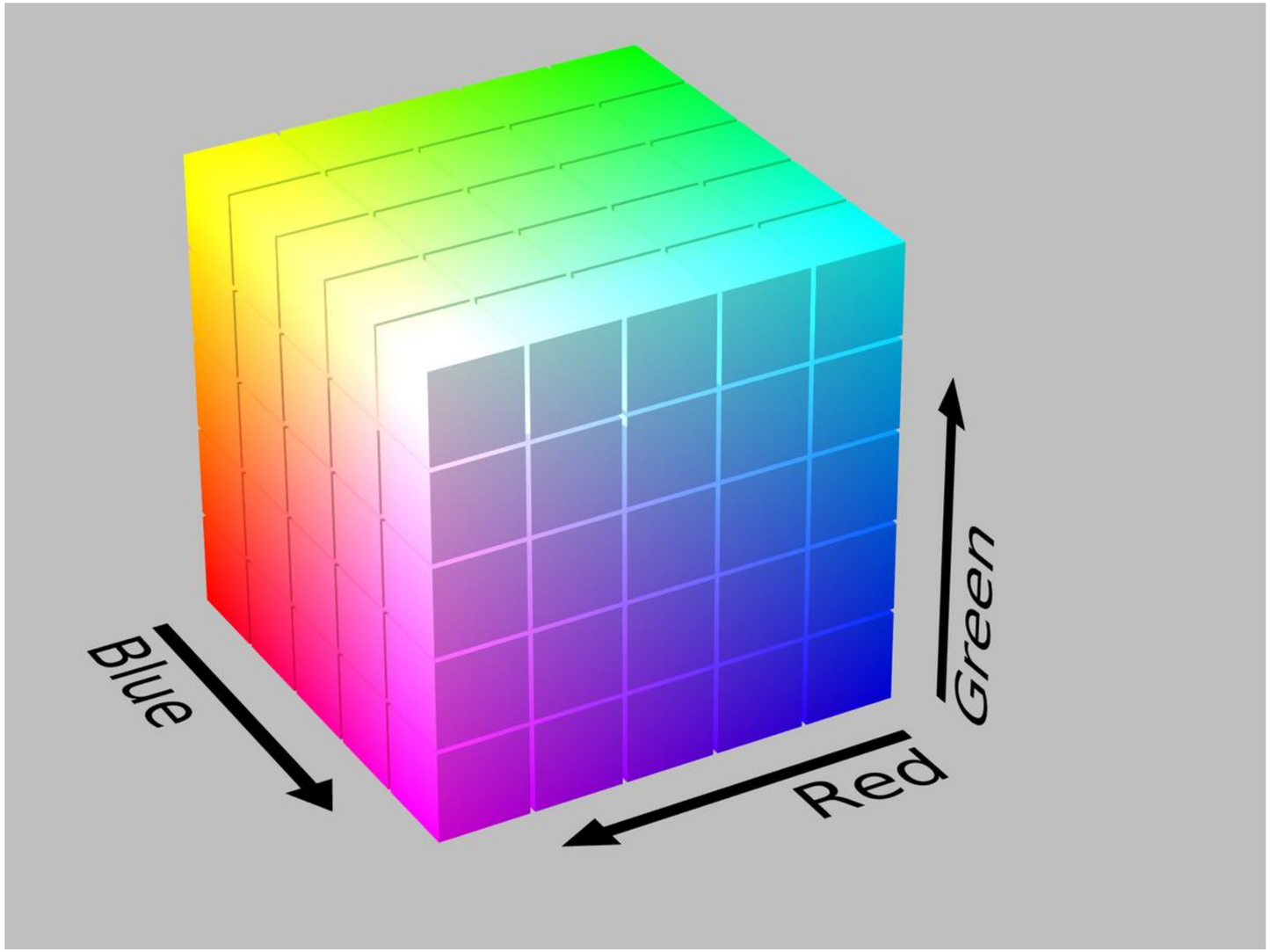
Witcombe, 2014

Modeling Color with RGB



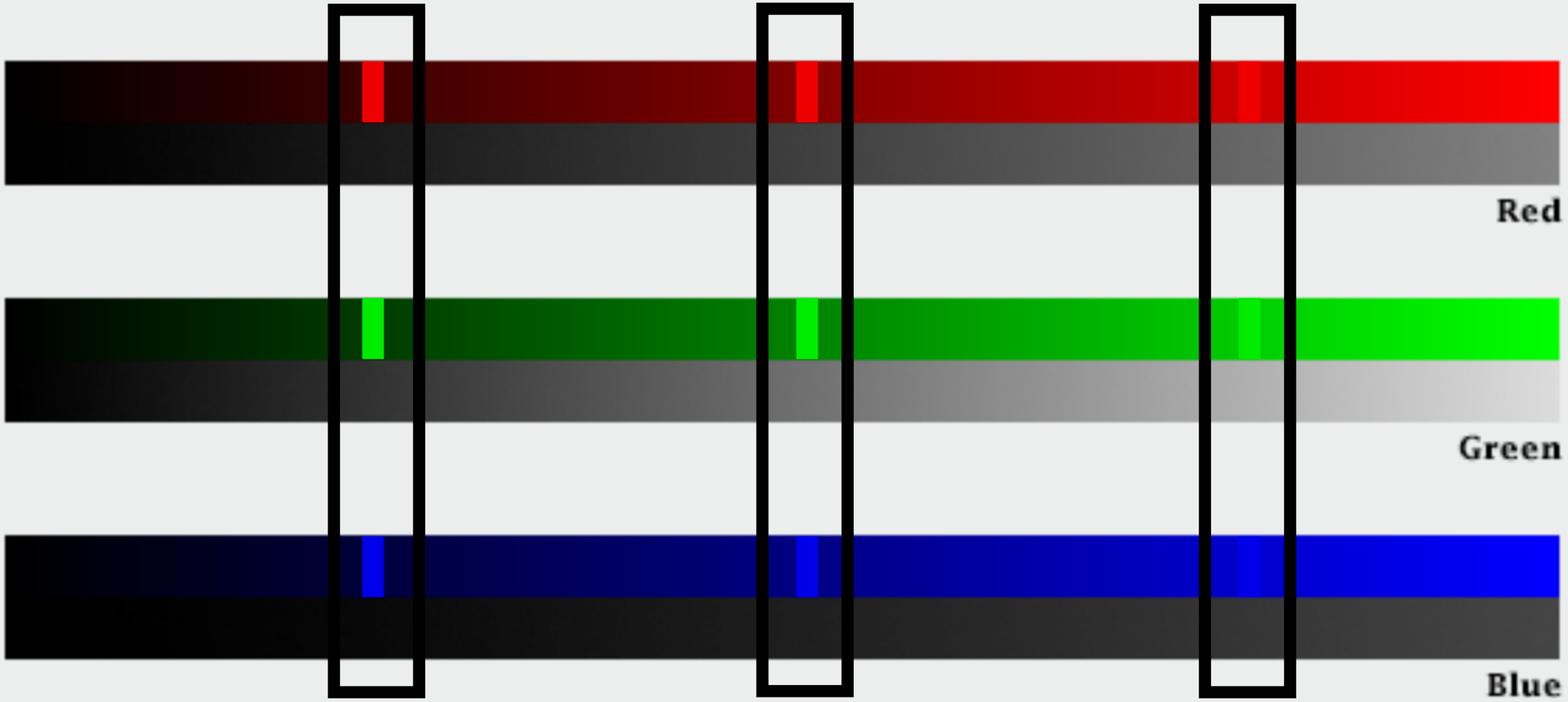


Modeling Color with RGB



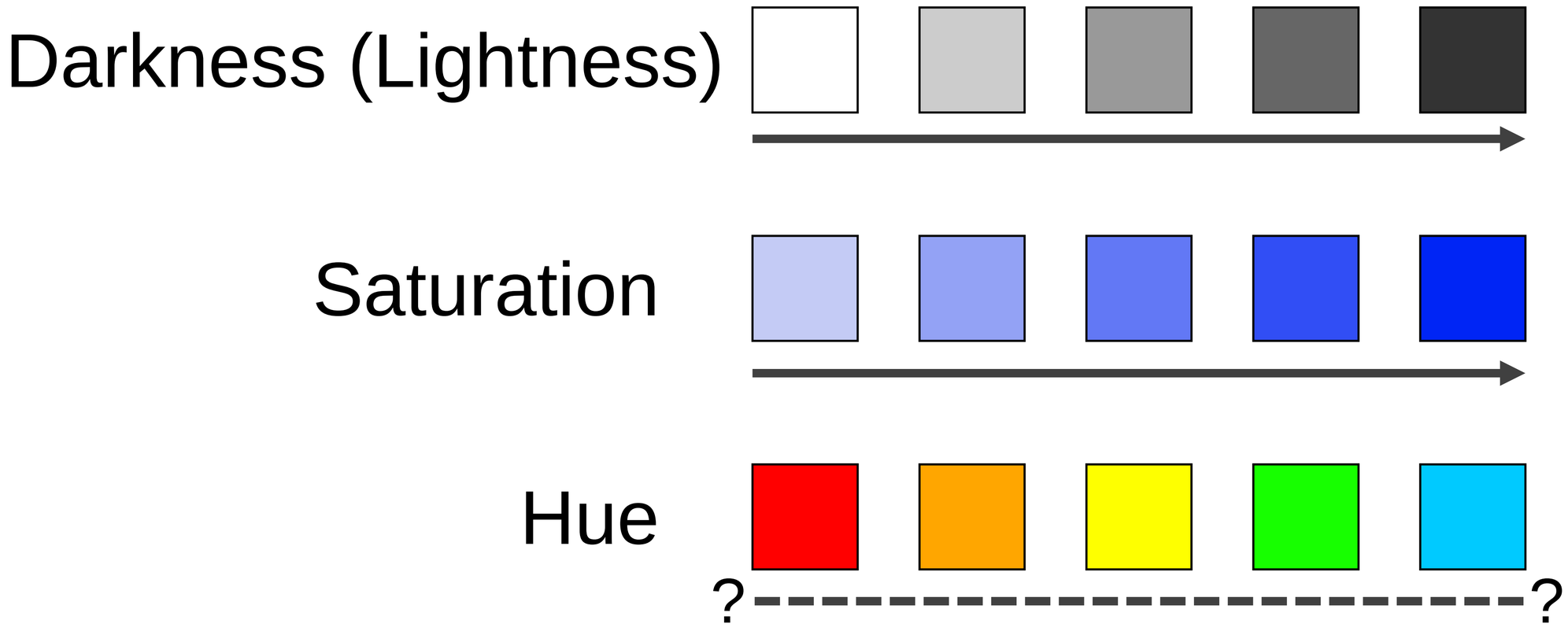
Wikimedia

Modeling Color with RGB: Problematic

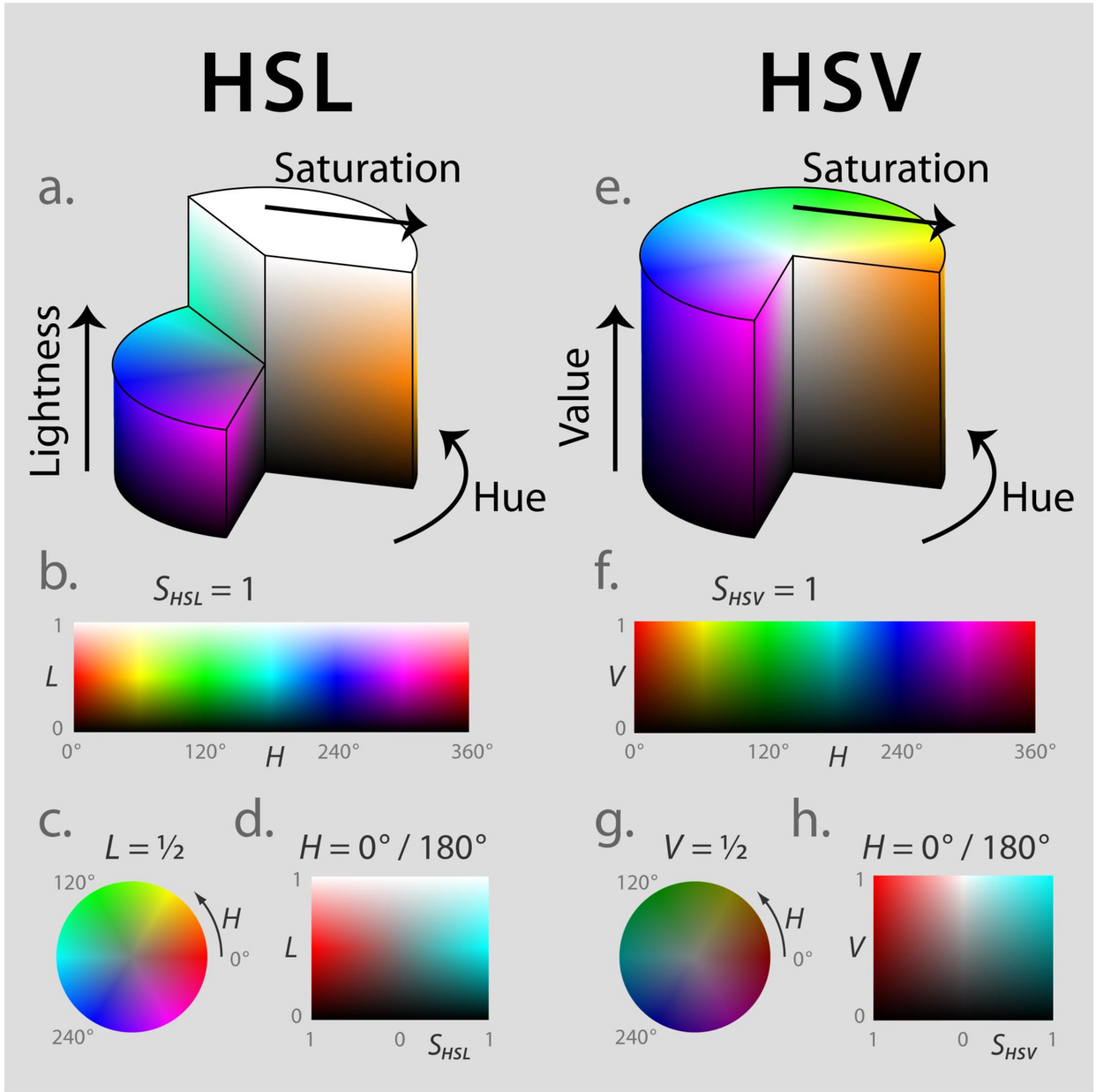


Simmon, 2014

Color Vocabulary and Perceptual Ordering



Modeling Color with HSL or HSV



Still Imperfect

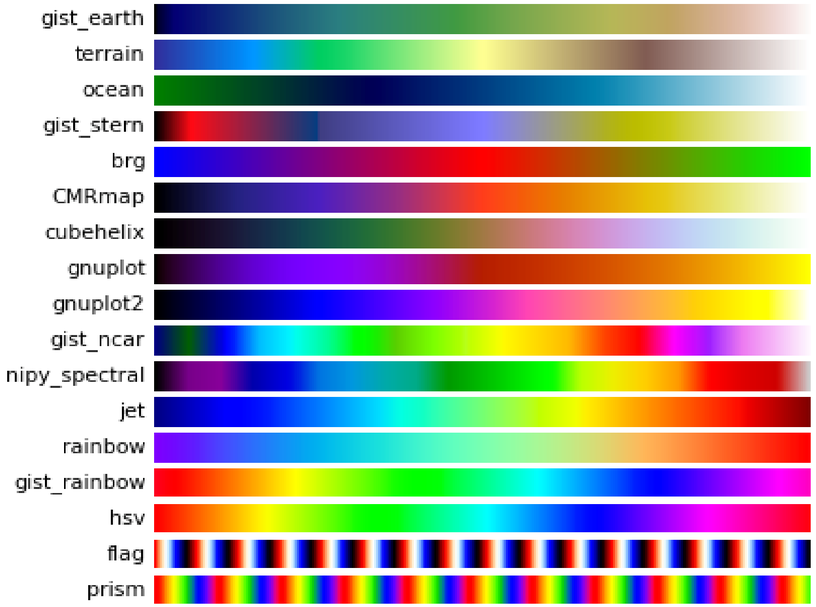
Wikimedia

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

-Edward Tufte

Color Maps

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



Bostock, 2018

matplotlib

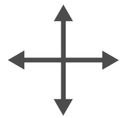
Color

- 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

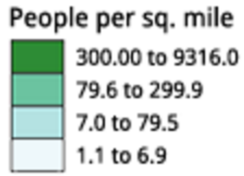
Three Main Types:

Categorical

Does not imply magnitude differences (categorical/nominal data)

Distinct hues with similar emphasis

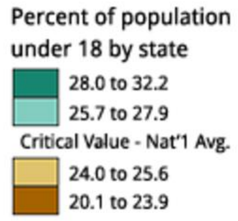
Sequential



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

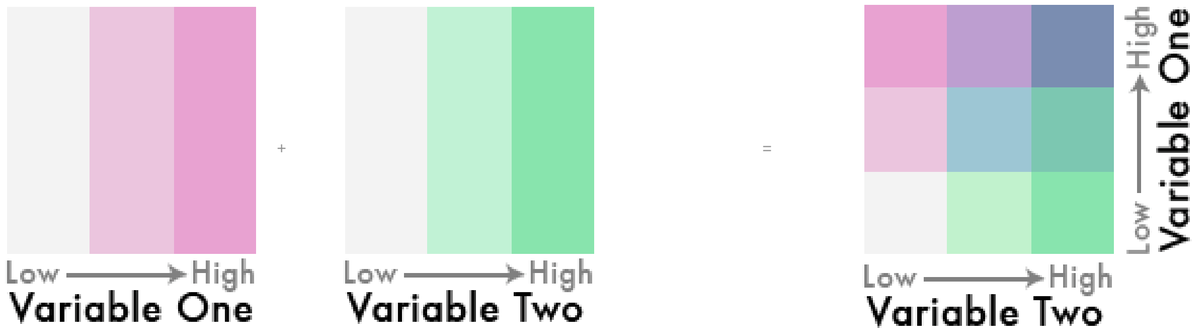
ALSO...

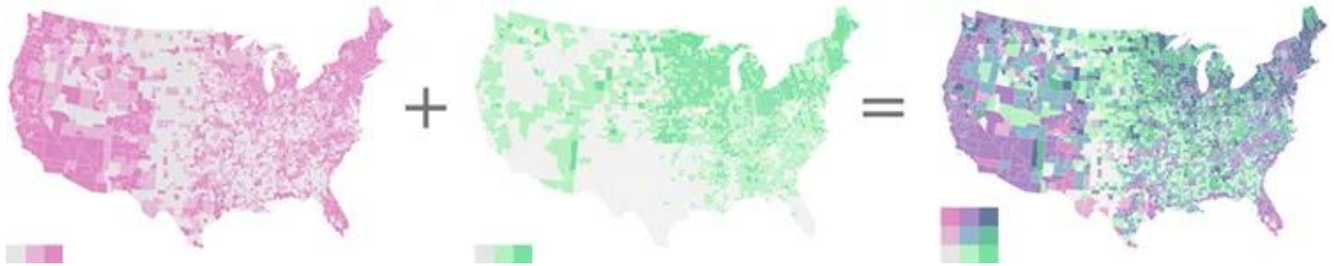
Bivariate

Displays two variables

Combination of two sequential color schemes

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

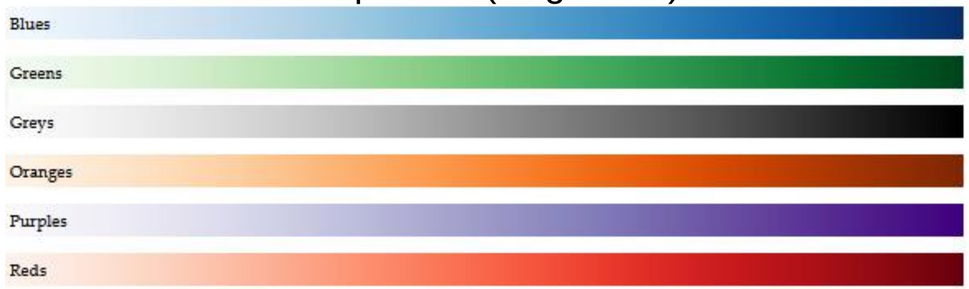




Stevens, 2015

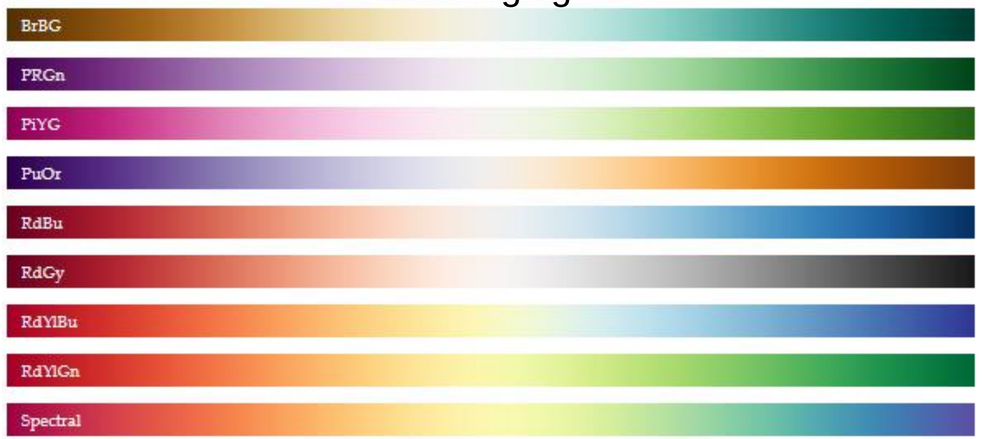
Types of Color Maps

Sequential (single hue)



Sequential (multiple hue)

Diverging

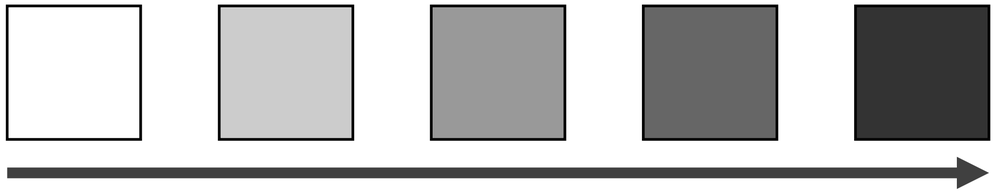


Categorical

Cyclical

Bostock, 2018

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

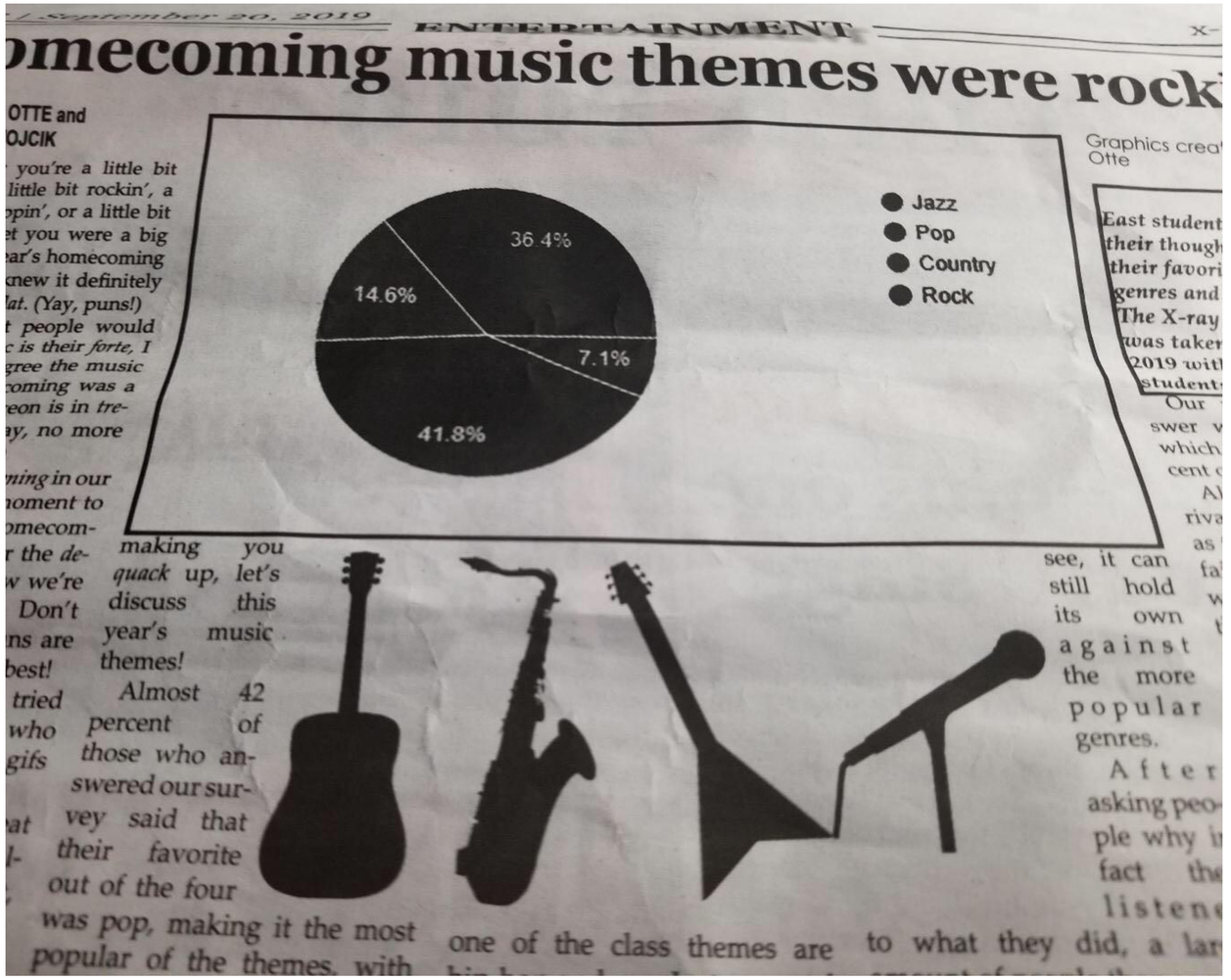
Stone, 2010


Petaluma
Tomales
1
Point Reyes-Petaluma Rd
Novato Blvd
101
121
37
Point Reyes Station
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
Novato Blvd
101
121
37
Point Reyes Station
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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omecom-
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w we're
Don't
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best!
tried
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gifs
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Graphics crea
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East student
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genres and
The X-ray
was taker
2019 with
student

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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

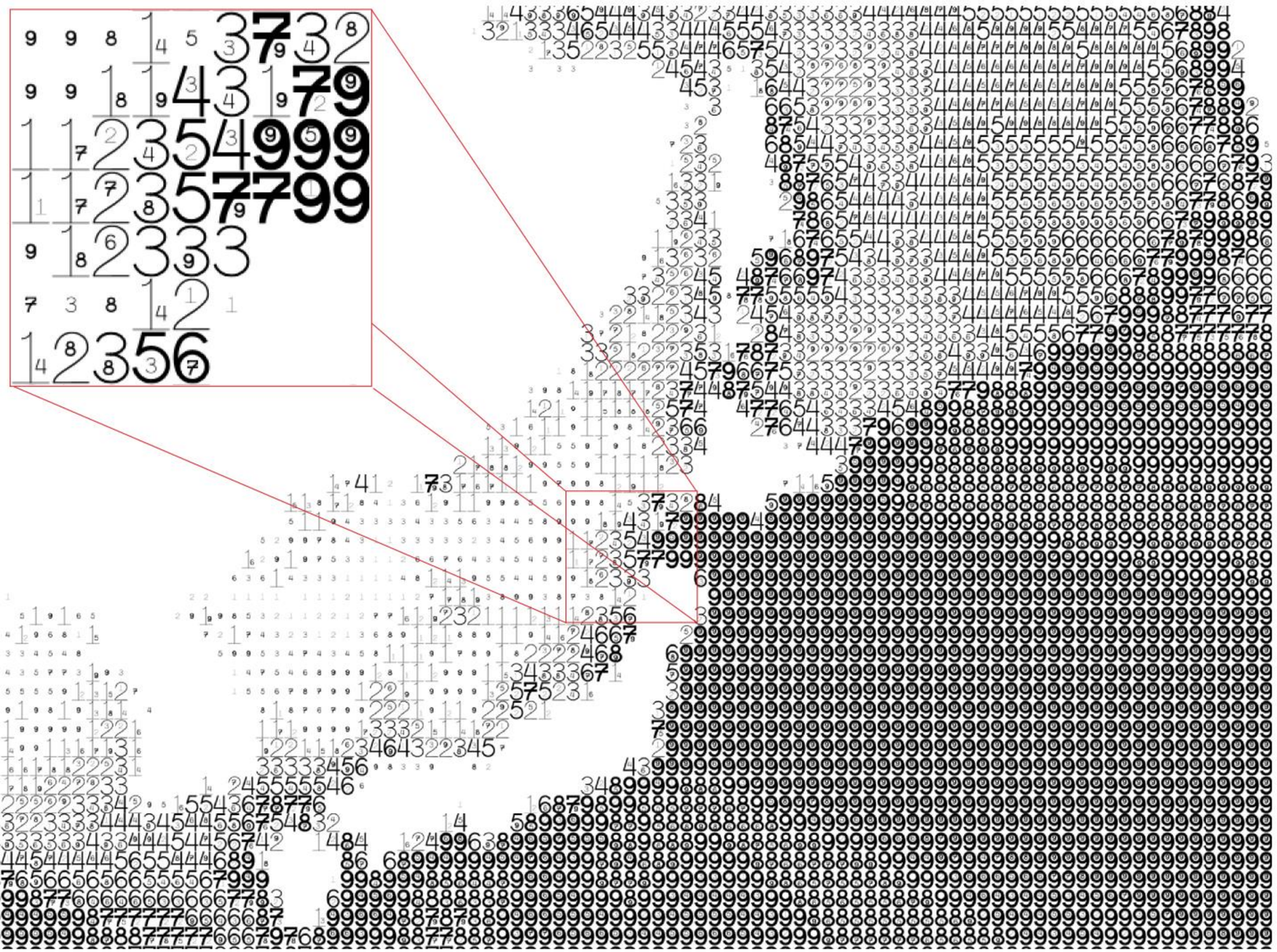
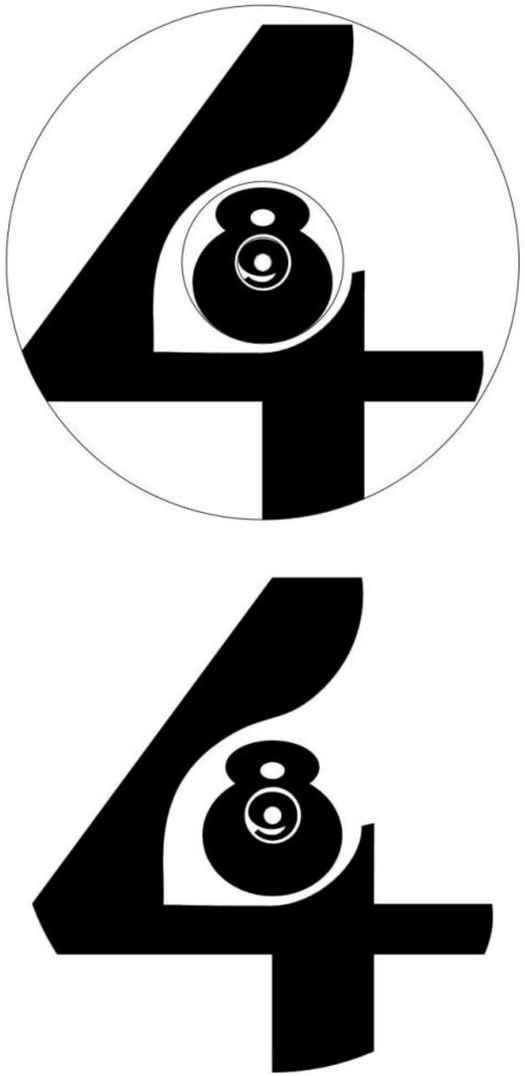


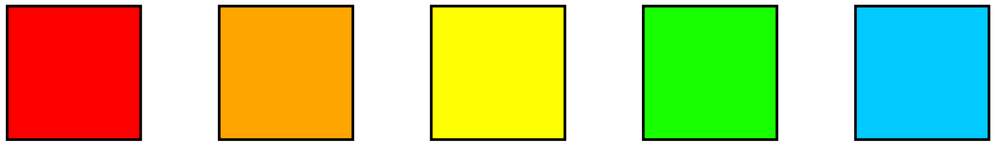
Figure 8: Maximum wave amplitudes for the Japan 2011 tsunami. Amplitudes were clipped at 99cm. Data adapted from NOAA; http://www.noaa.gov/.

FatFonts

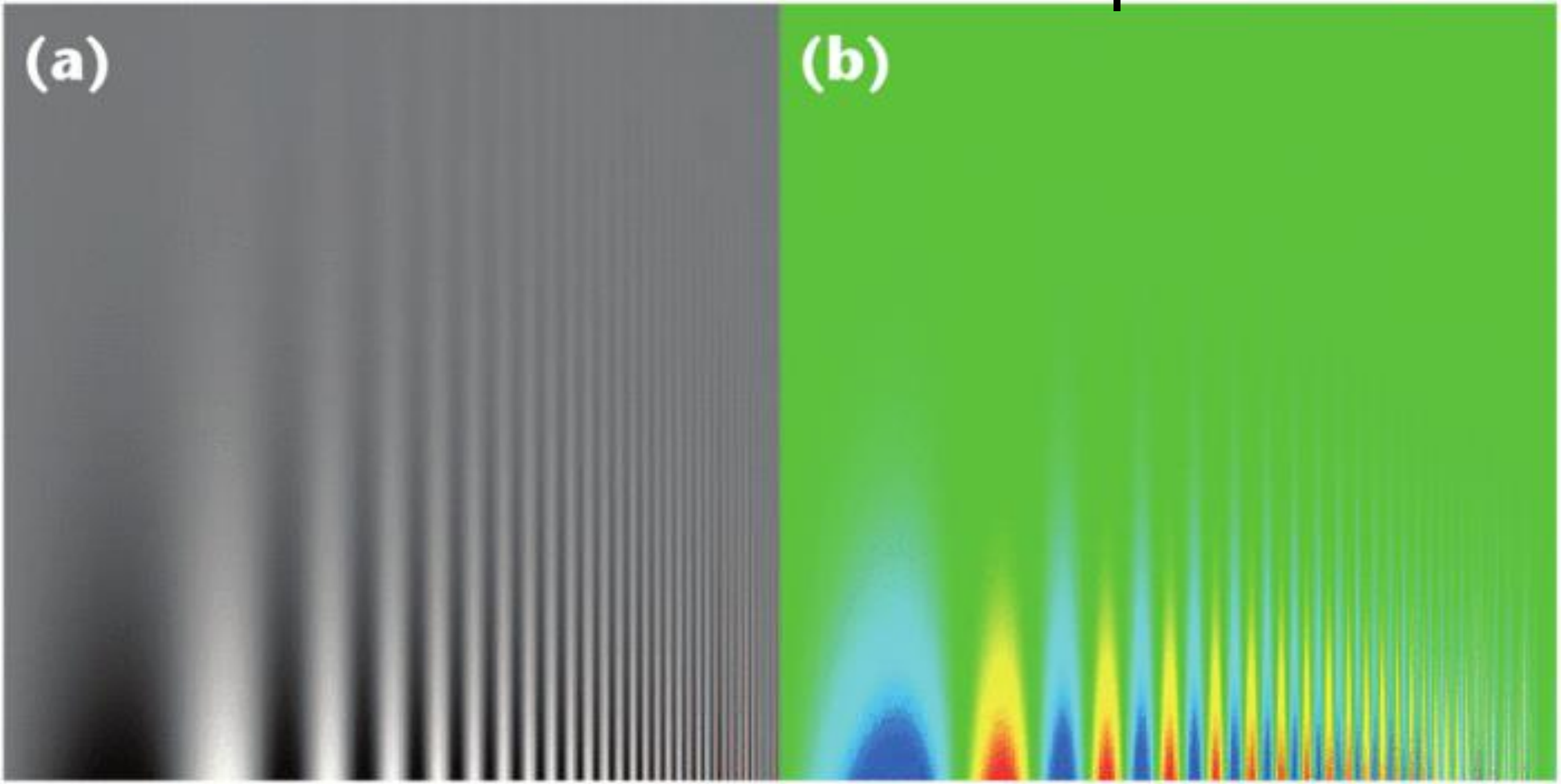


[Nacenta et al., 2012](#)

Rainbow Color Map (Hue)

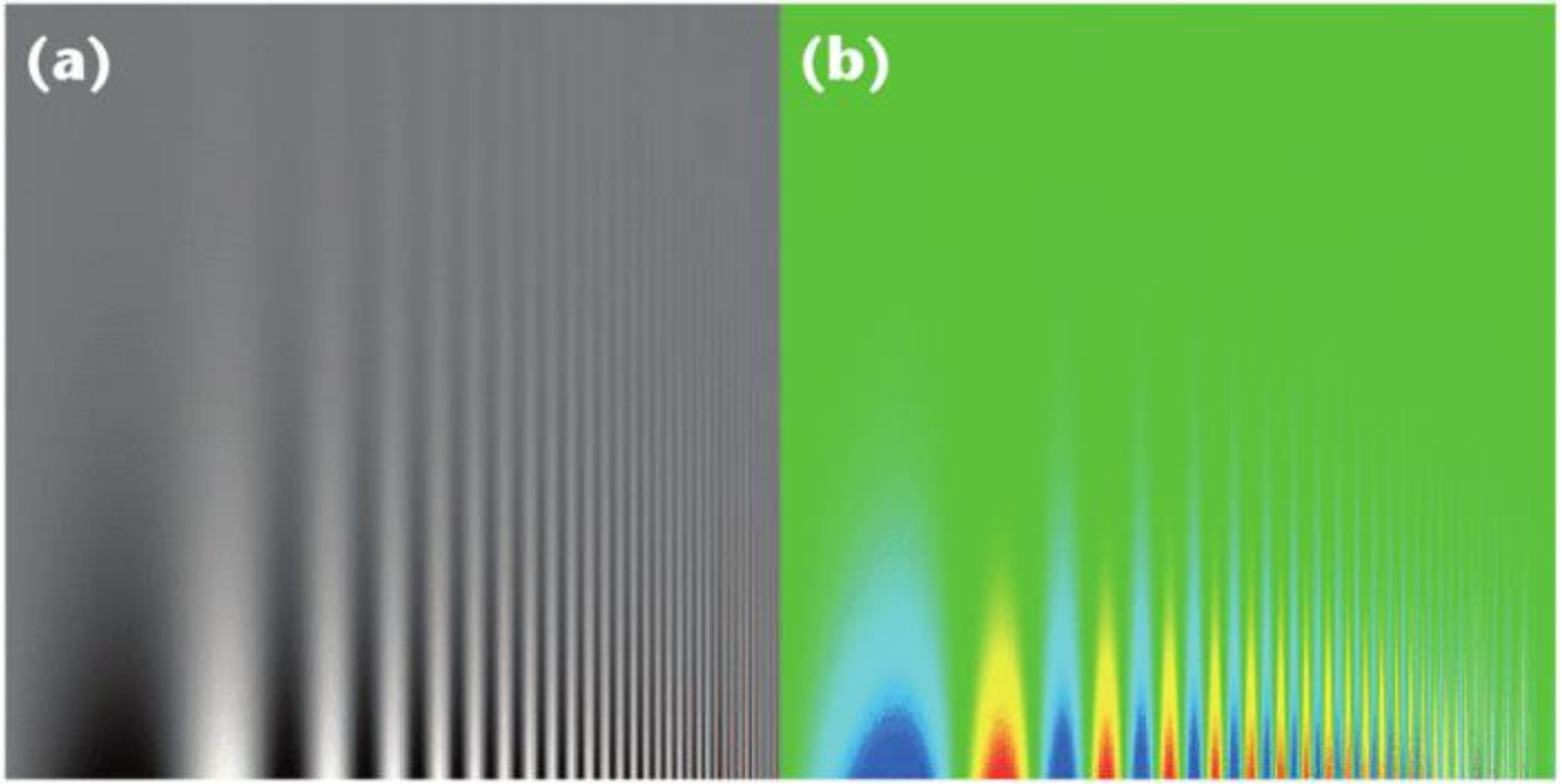


Rainbow Color Map



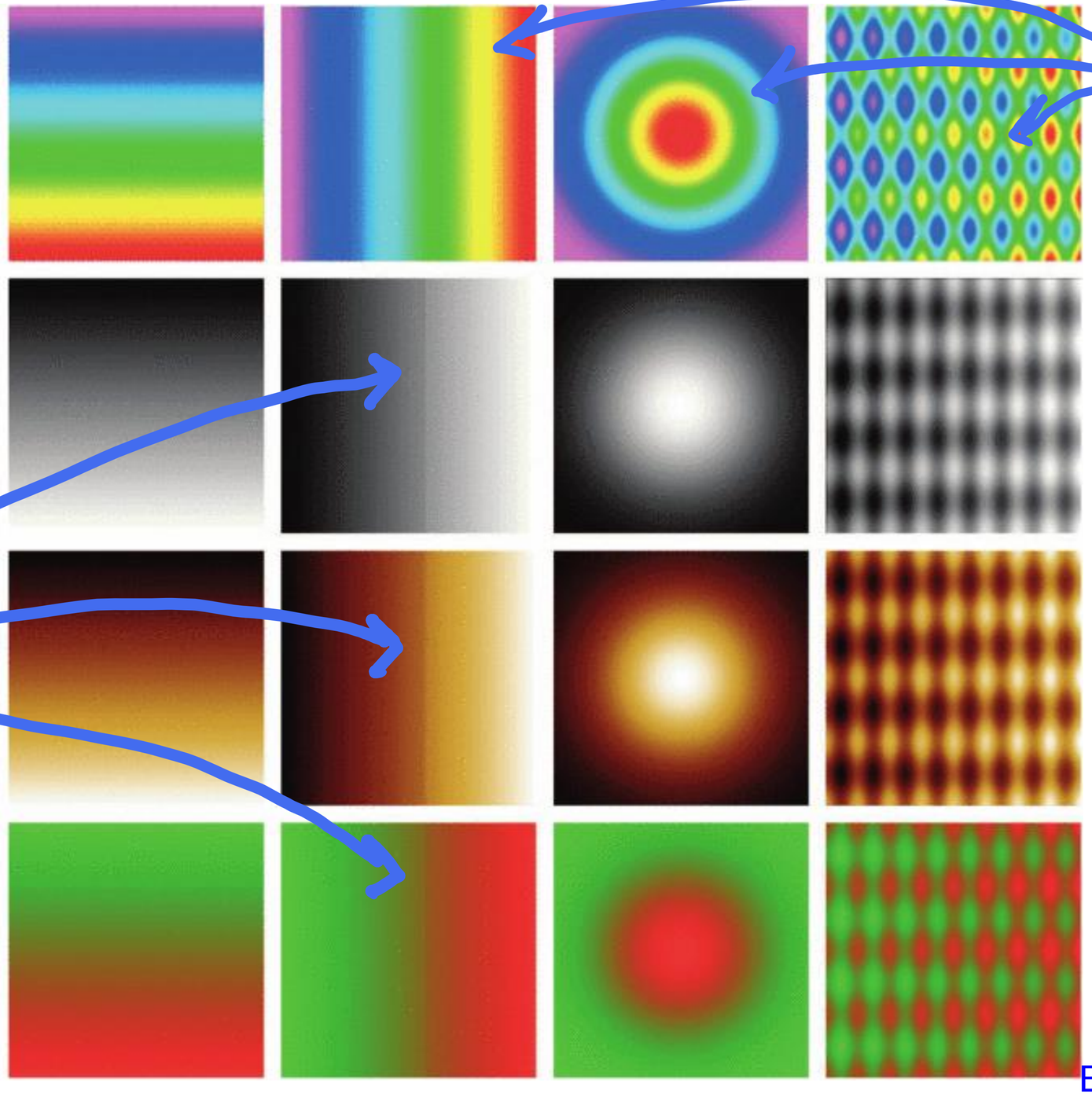
Borkin et al., 2011

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

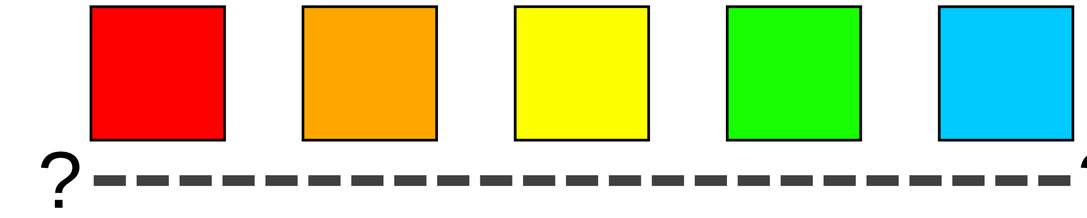


False

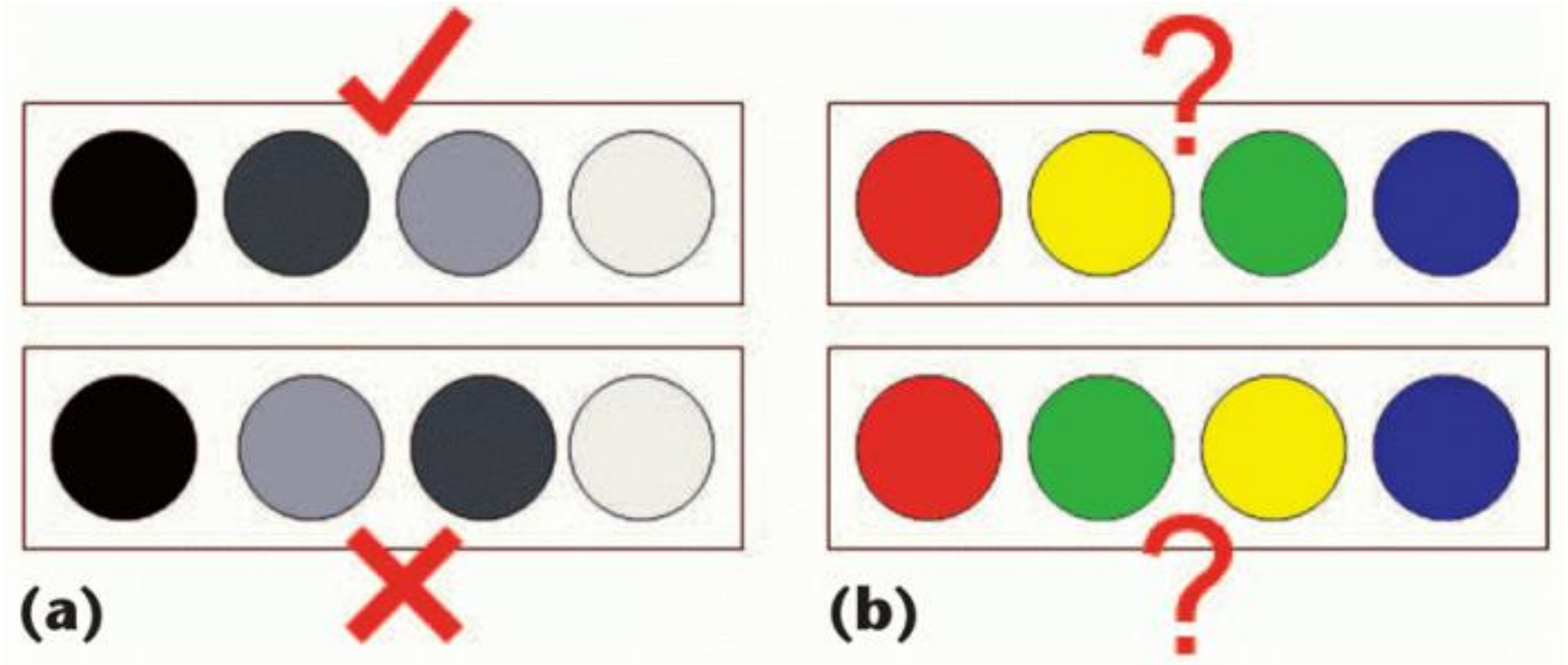
Real!

Borland & Russell, 2007

Rainbow Color Map (Hue)



No perceptual ordering (confusing)



Borland & Russell, 2007

Rainbow Color Map

Rainbow:

3D: 39%

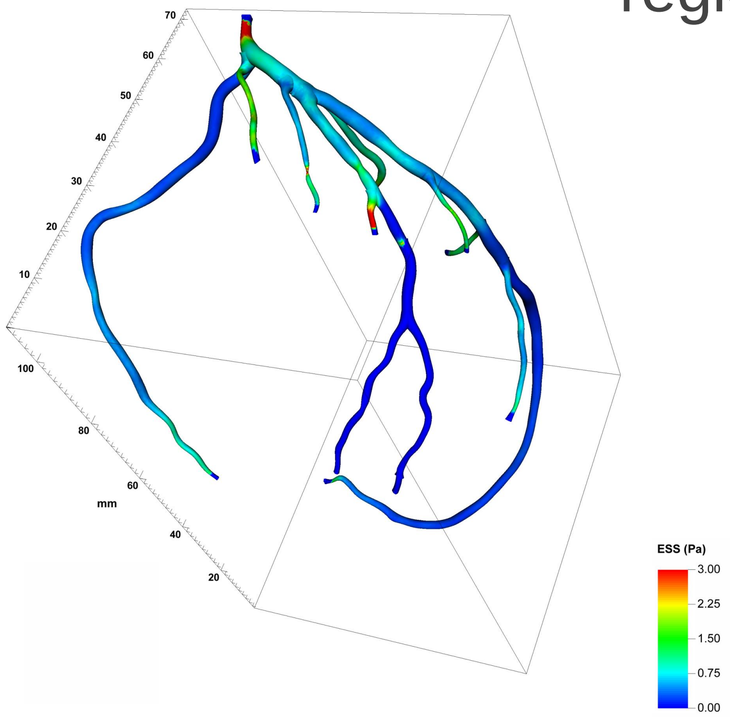
2D: 62%

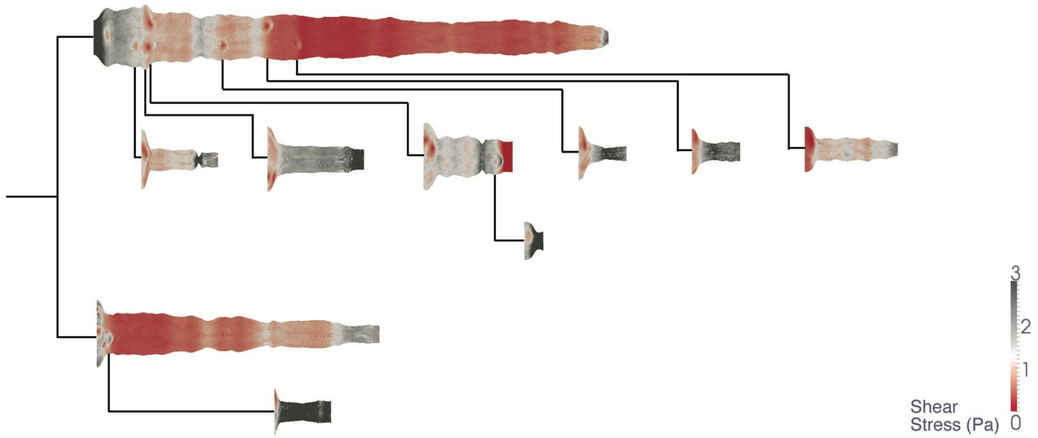
How many diseased regions found?

Diverging:

3D: 71% (*Δ +31%*)

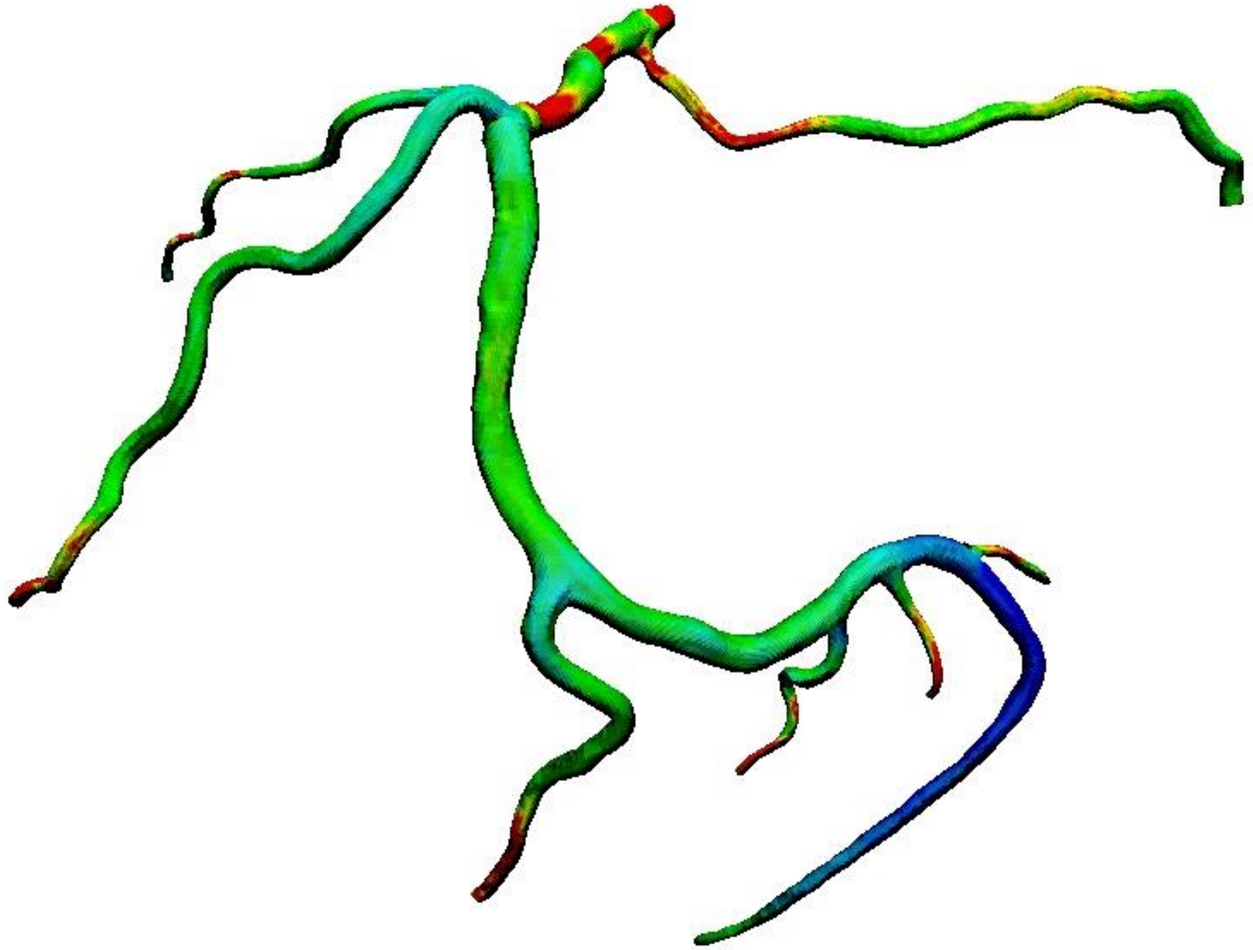
2D: 91% (*Δ +29%*)





Borkin et al., 2011

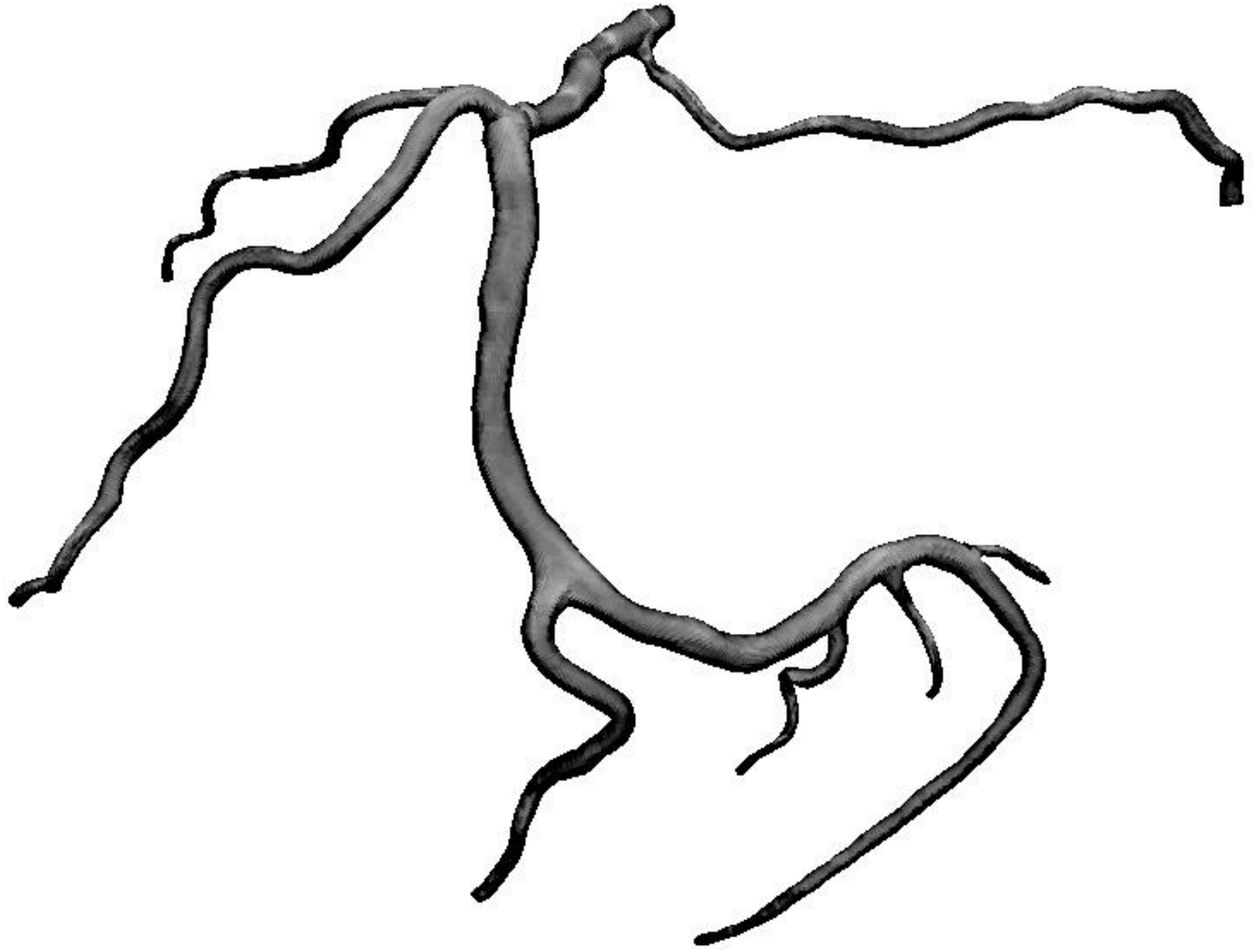
“Get it right in black and white.”



39% Diseased Regions Found

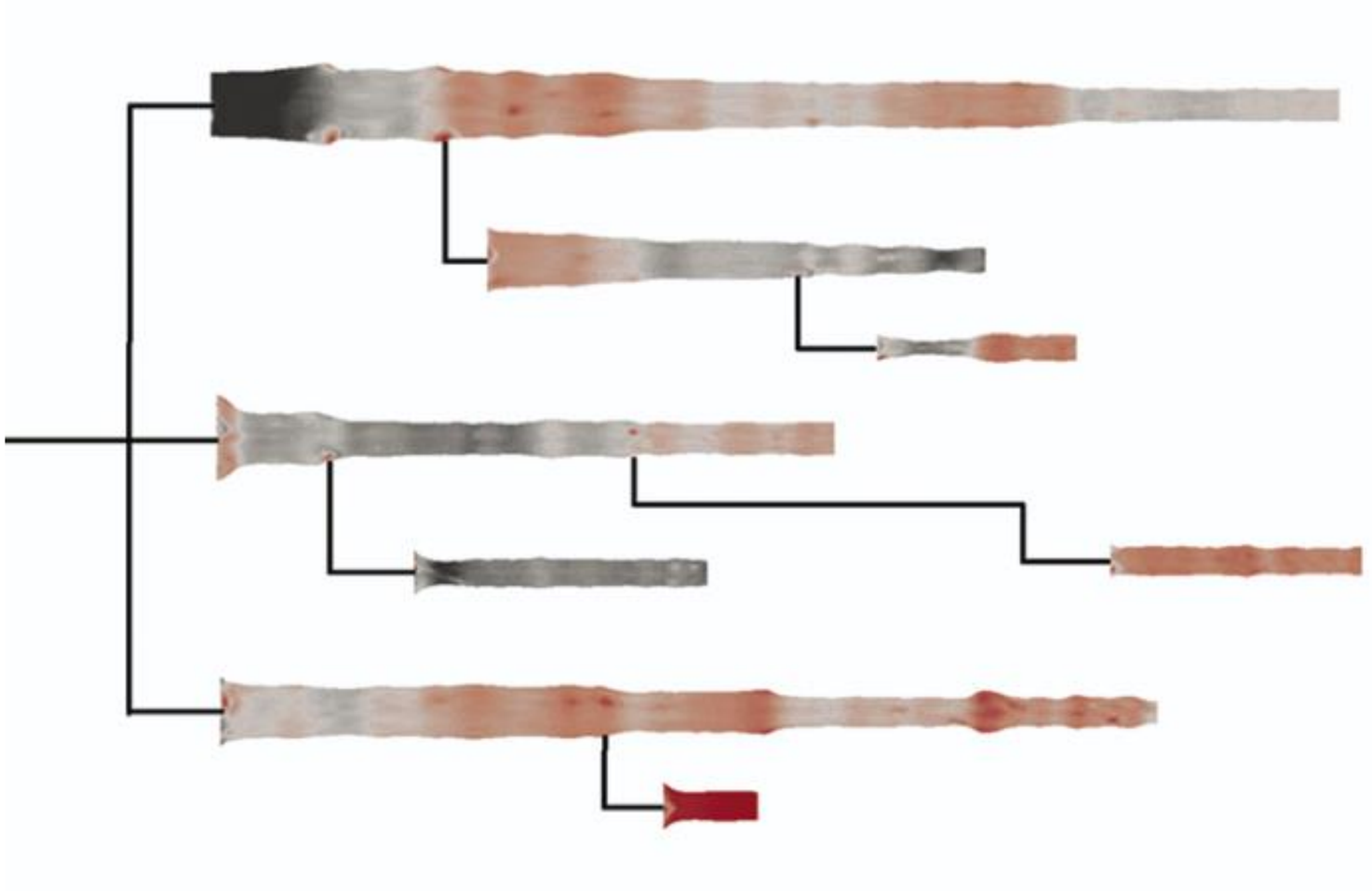
Borkin et al., 2011

“Get it right in black and white.”



Borkin et al., 2011

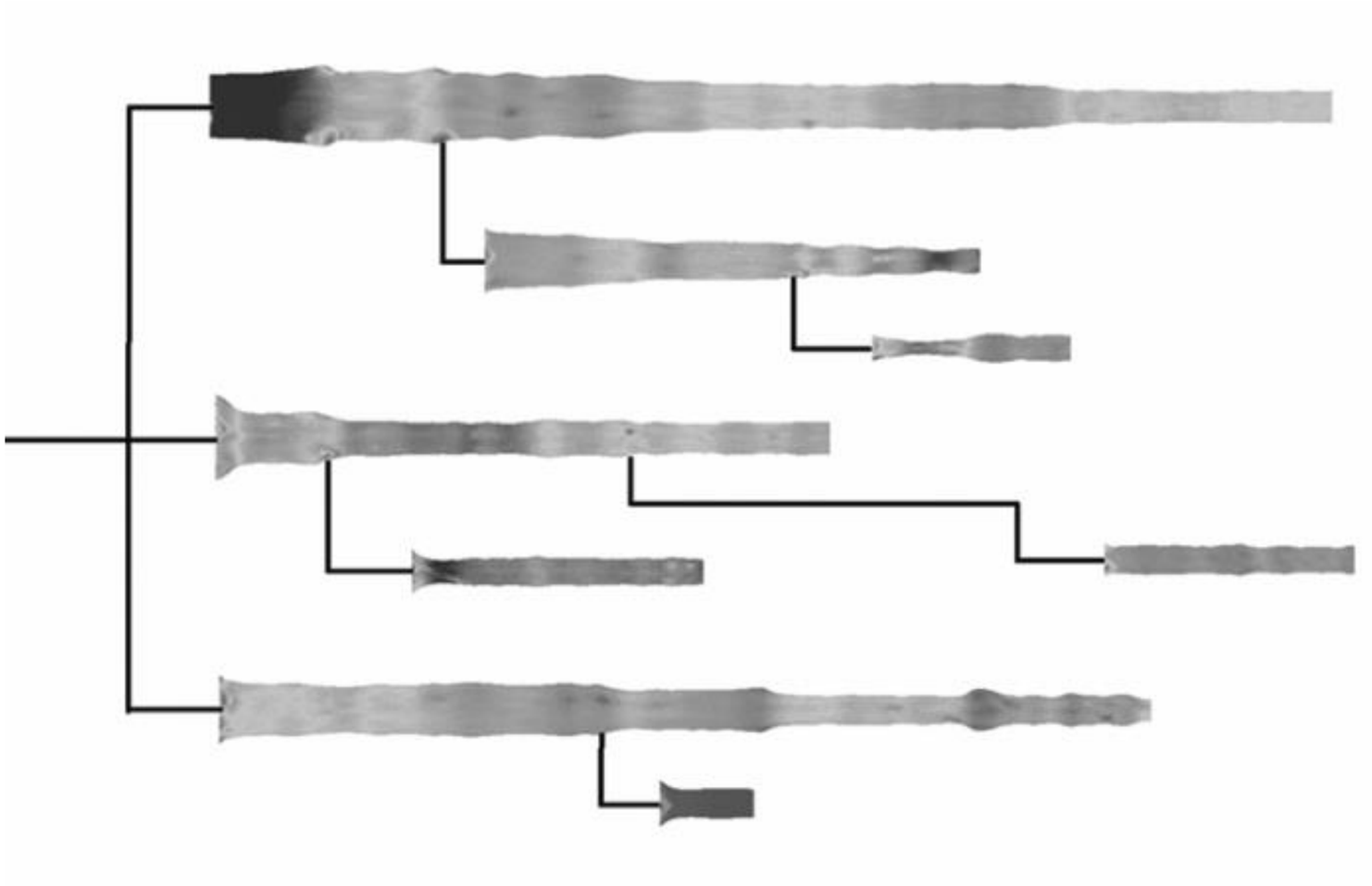
“Get it right in black and white.”



91% Diseased Regions Found

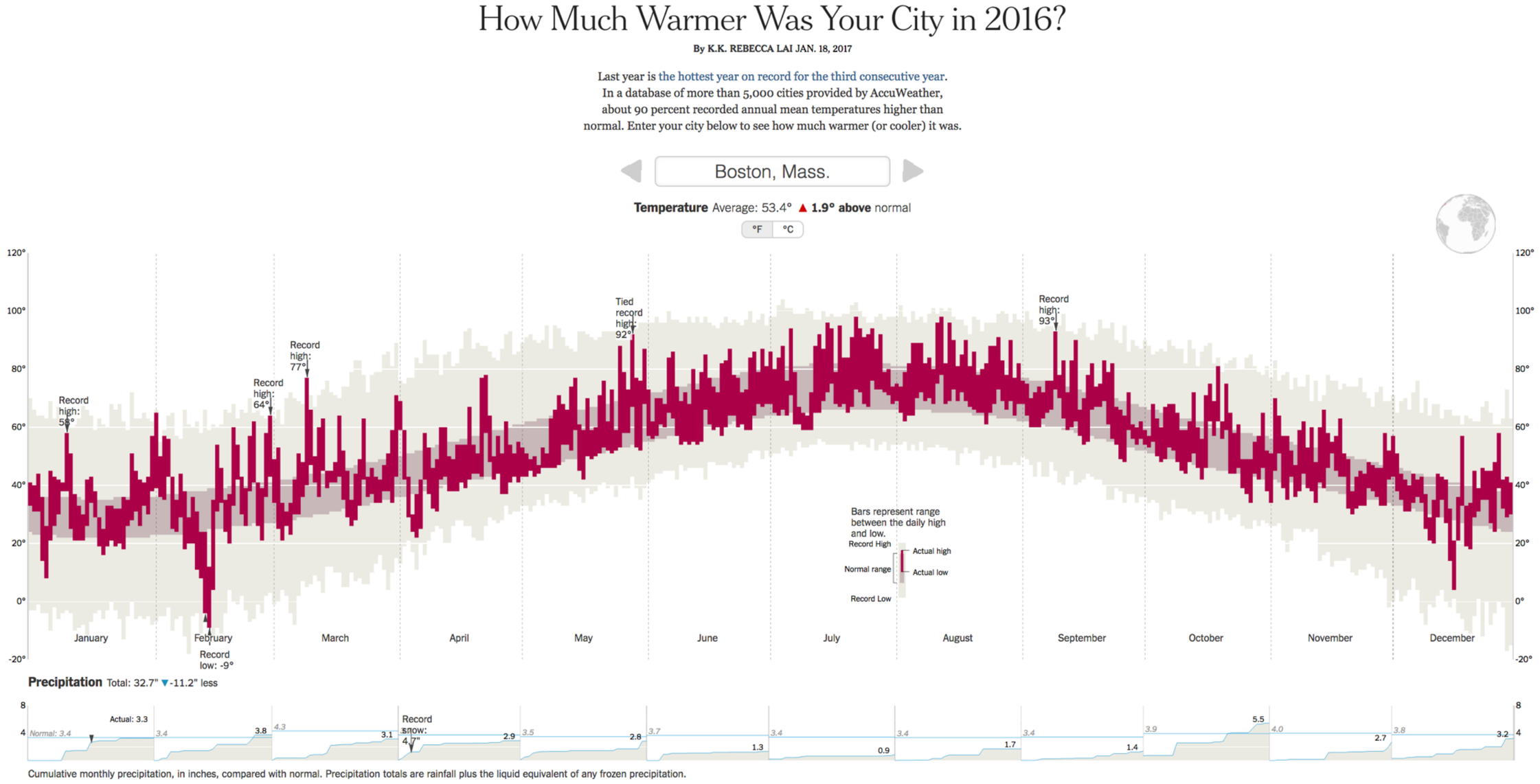
Borkin et al., 2011

“Get it right in black and white.”



Borkin et al., 2011

“Get it right in black and white.”

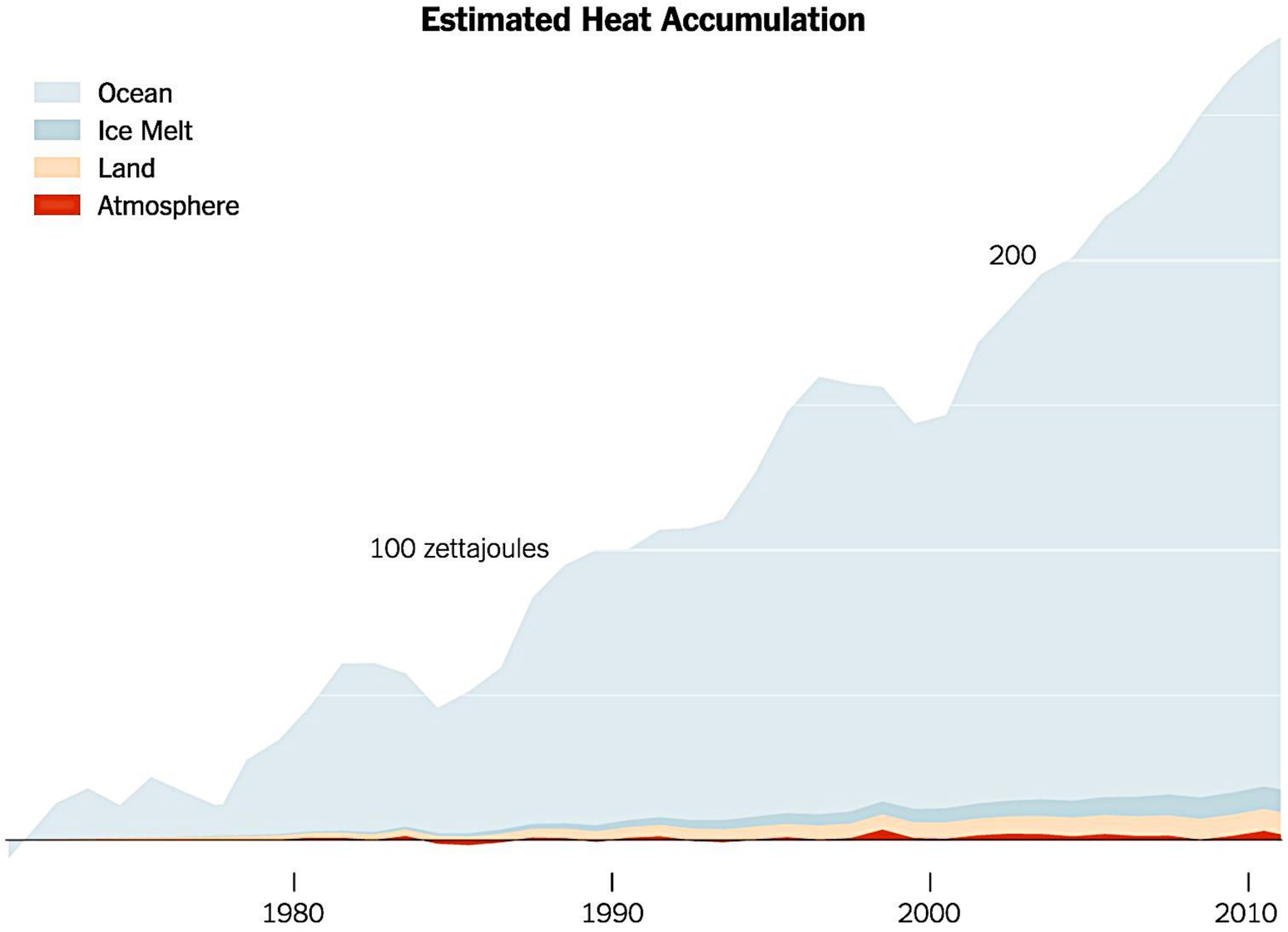


NY Times, 2017

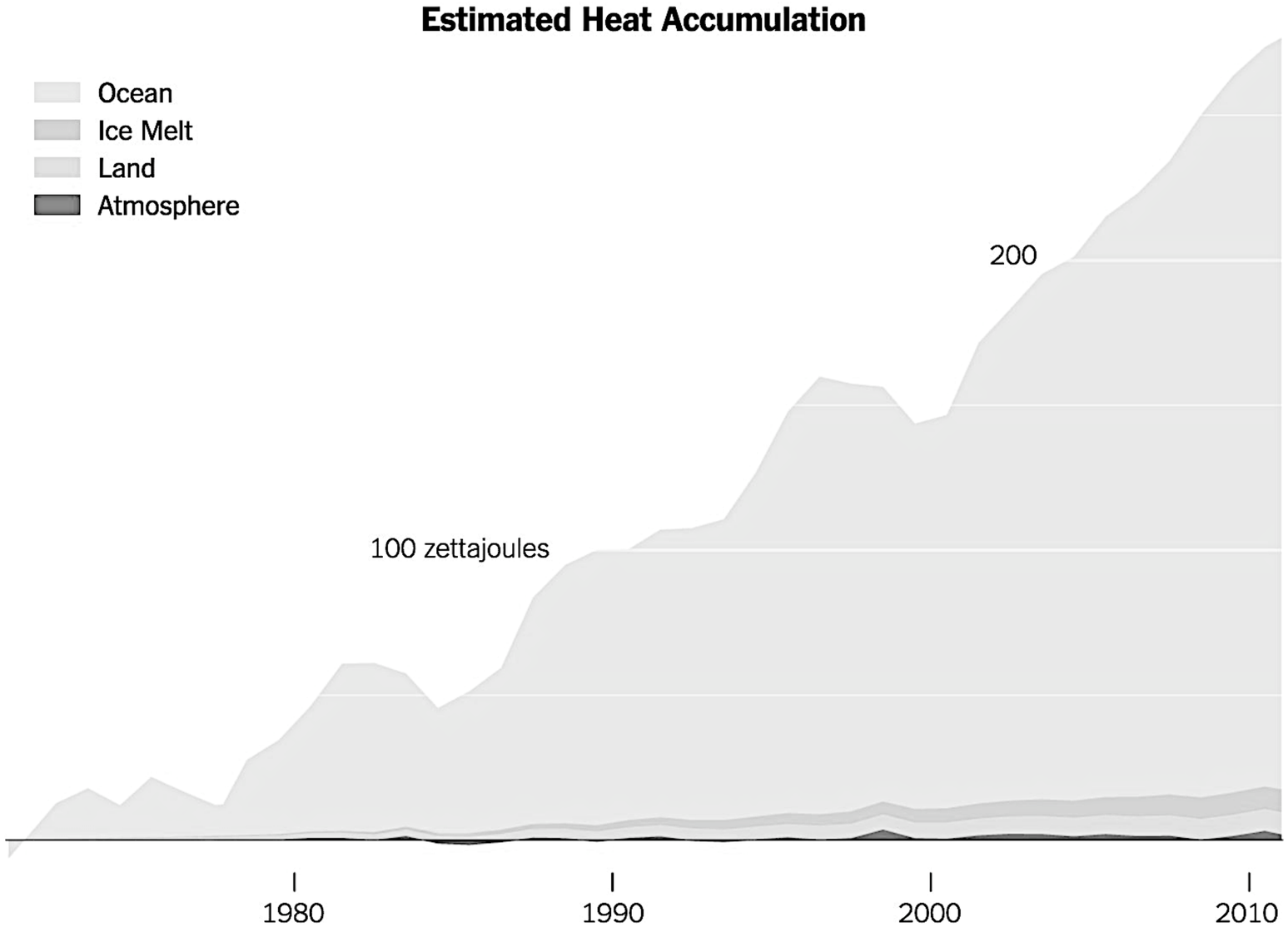
“Get it right in black and white.”

NY Times, 2017

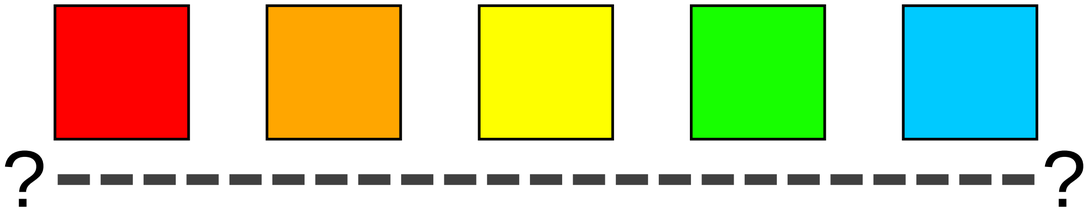
“Get it right in black and white.”



“Get it right in black and white.”



Rainbow Color Map (Hue)

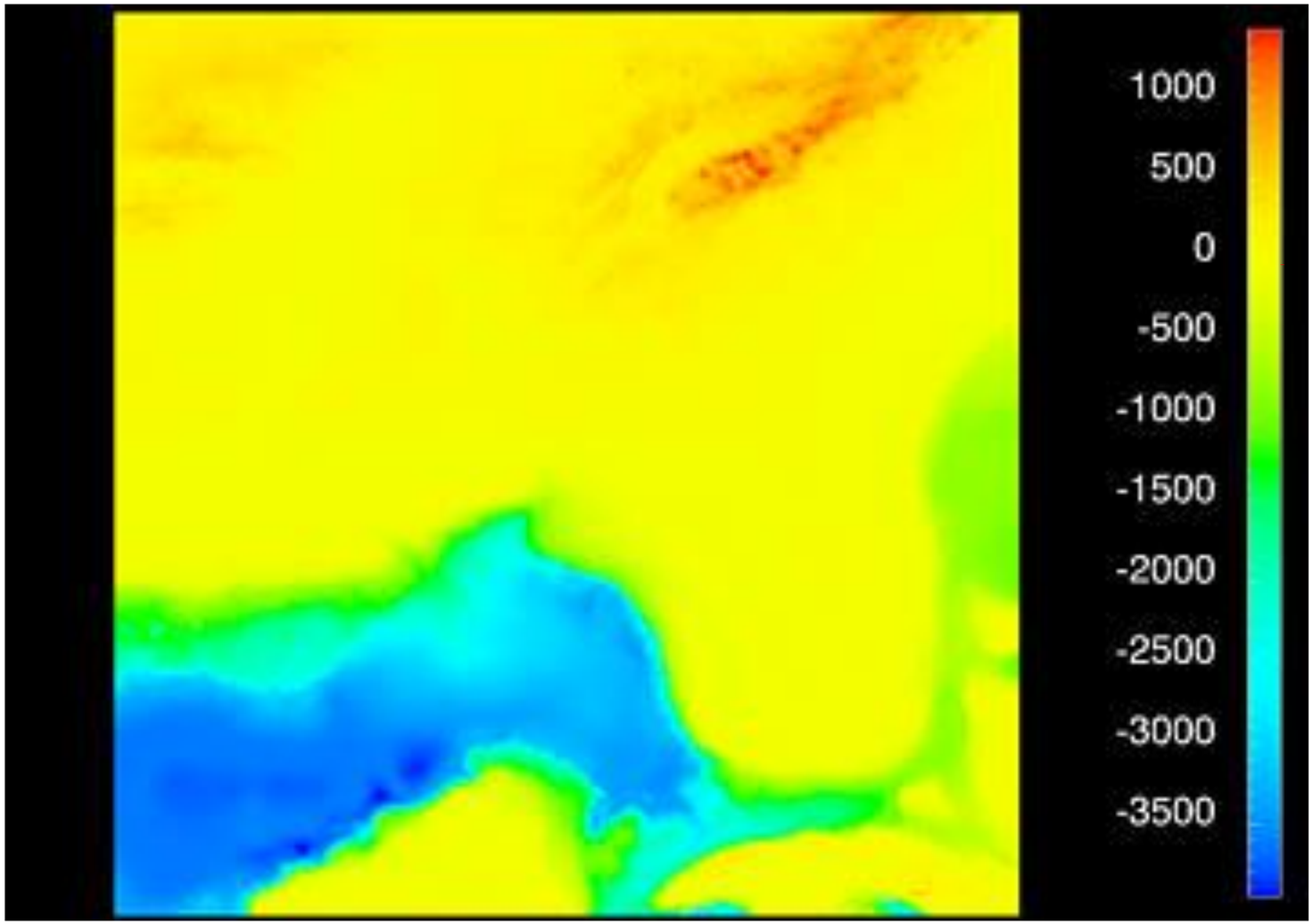


Why this color map is a poor choice for quantitative data…

- 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)

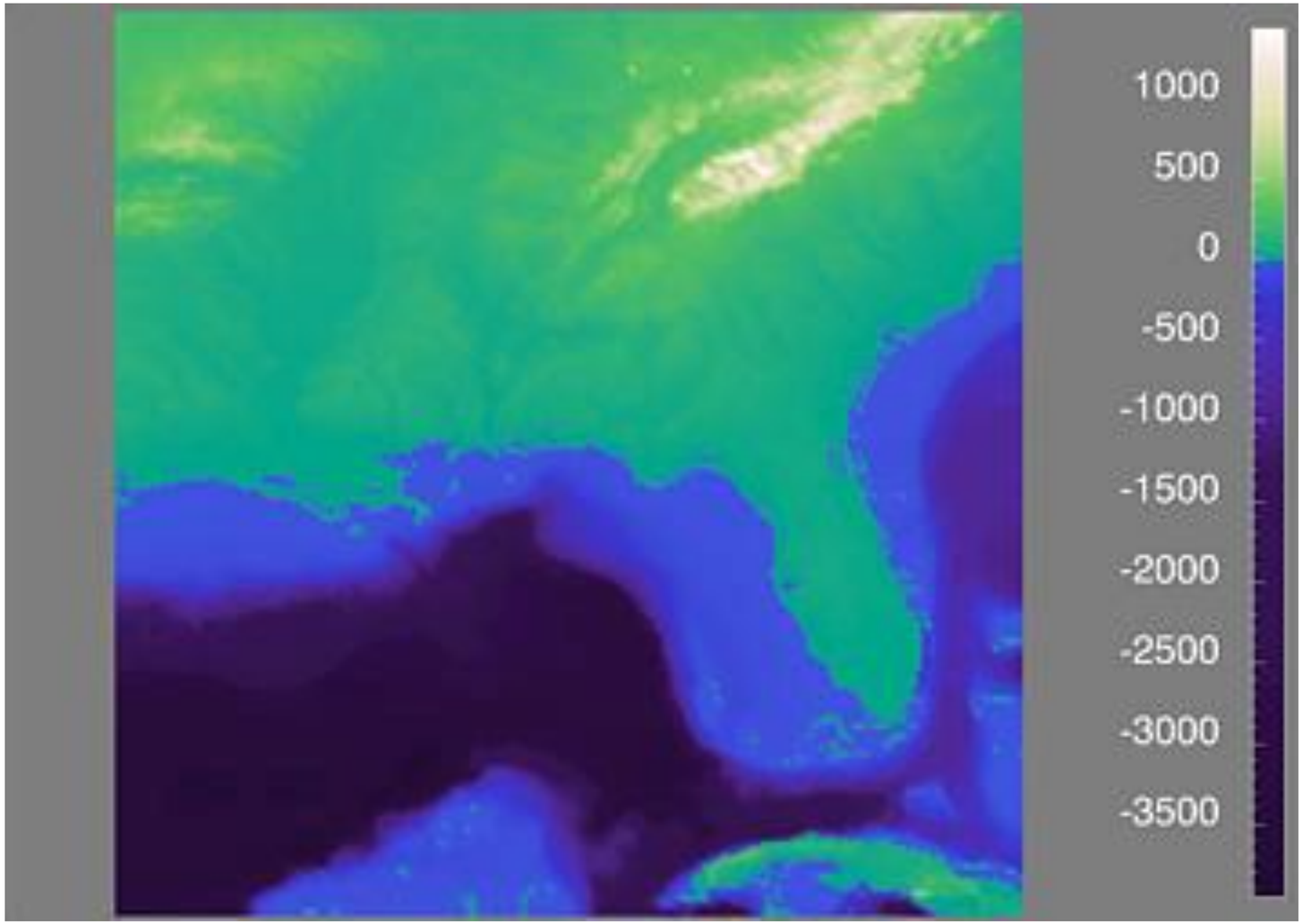
Borland & Russell, 2007

Color Maps



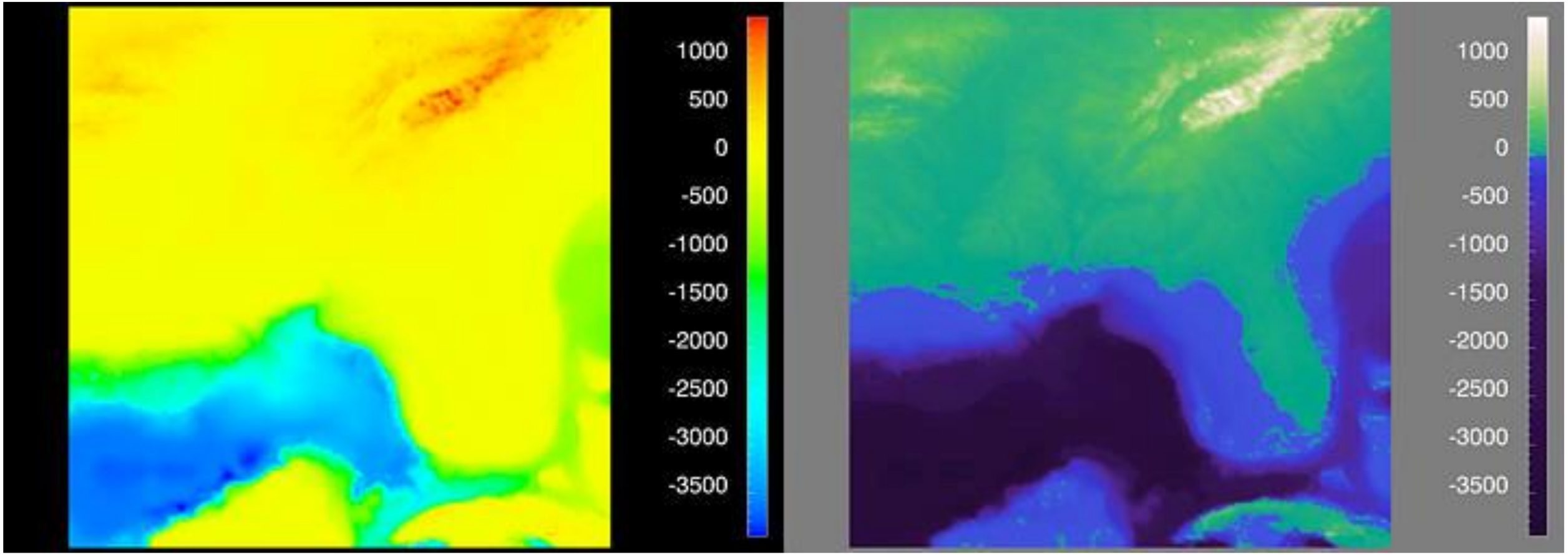
Rogowitz & Treinish, 1996

Color Maps



Rogowitz & Treinish, 1996

Color Maps



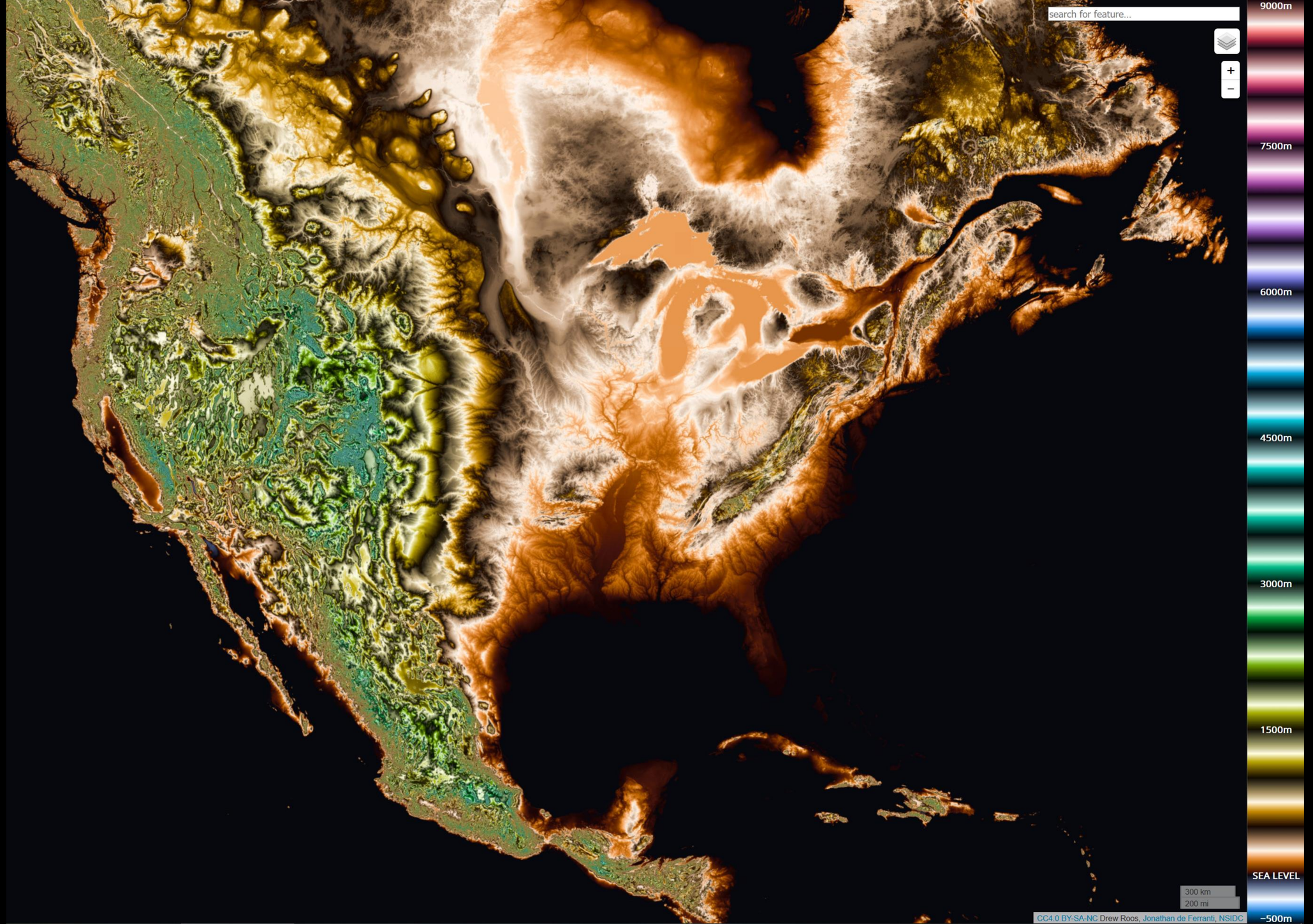
Sequential (possibly wrong)

Diverging

Sequential rainbow (wrong!)

Rogowitz & Treinish, 1996

Roos, 2015

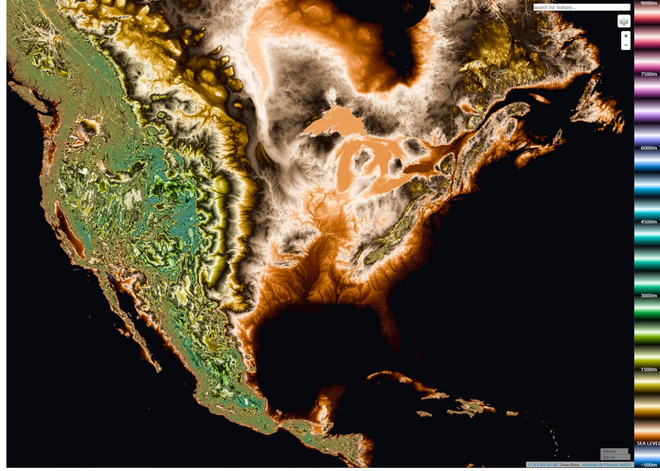

search for feature...
9000m
7500m
6000m
4500m
3000m
1500m
SEA LEVEL
−500m
300 km
200 mi
CC4.0 BY-SA-NC Drew Roos, Jonathan de Ferranti, NSIDC

Roos, 2015

IN-CLASS EXERCISE

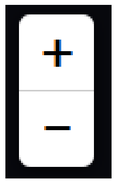
In-class exercise: Oilslick

10m



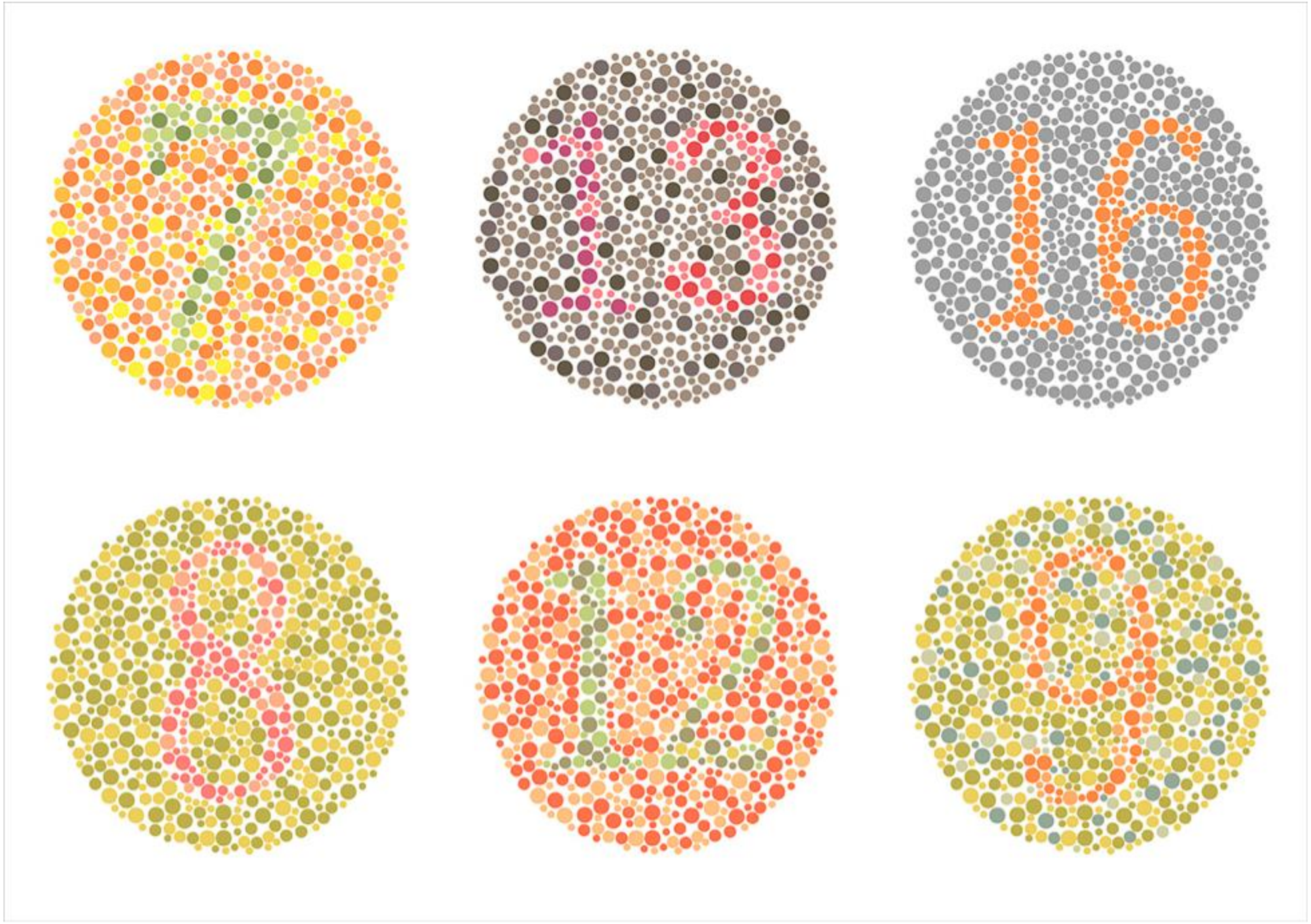
INSTRUCTIONS:

- 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.

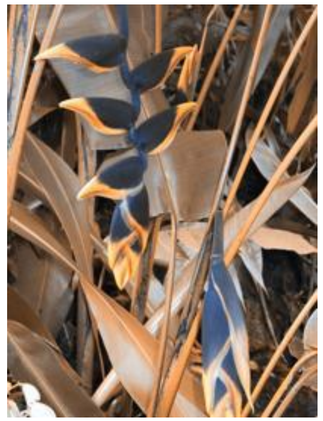


Those with deuteranope color blindness (red/green) will have difficulty seeing the numbers.

Color Deficiencies (Color Blindness)

Person with faulty cones (or faulty pathways):

Protanope = faulty red cones



Deuteranope = faulty green cones

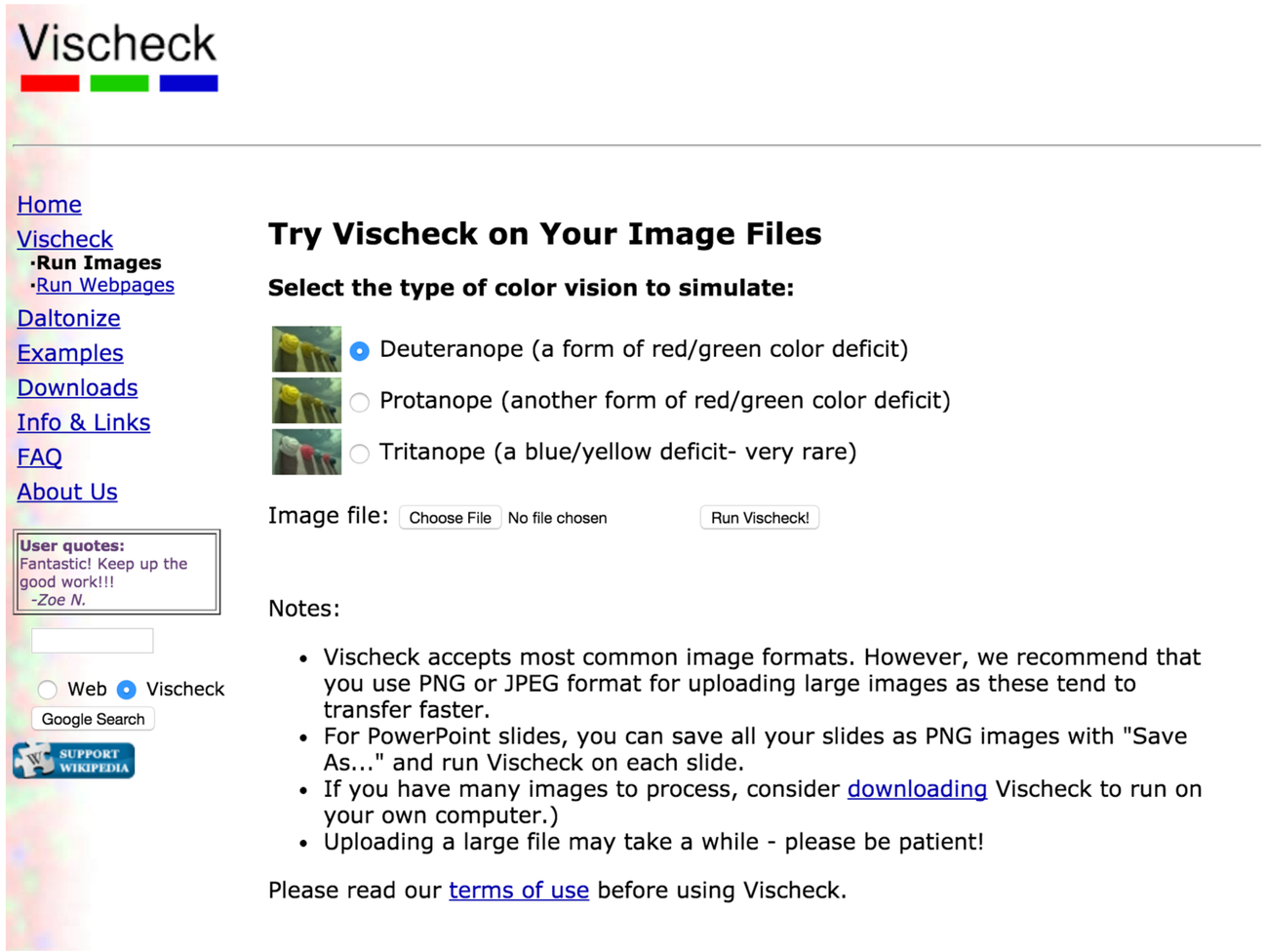
normal

Tritanope = faulty blue cones

Color Deficiencies (Color Blindness)

Based on Slides by Hanspeter Pfister, Maureen Stone

Check your images/colormaps for issues!



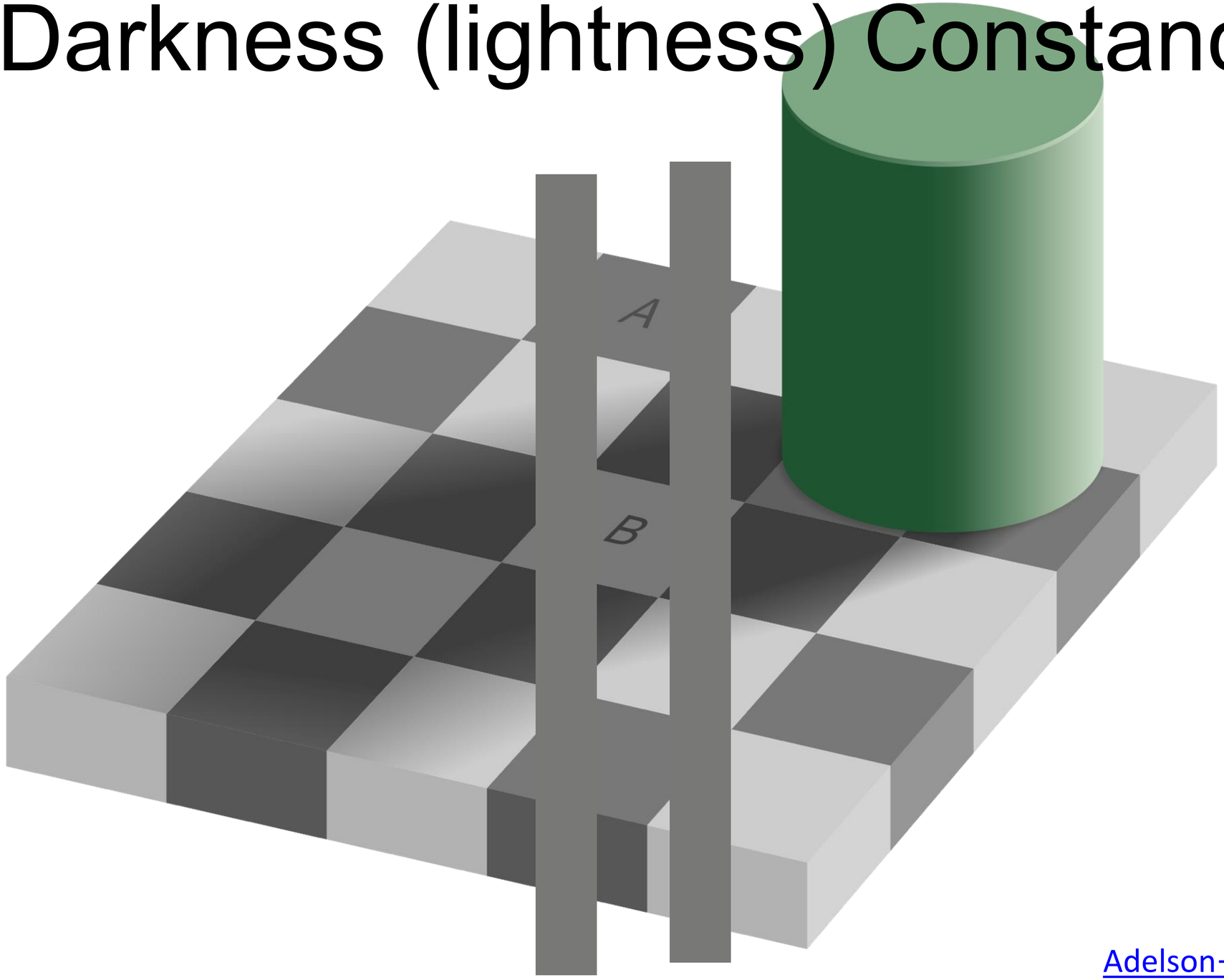
http://www.vischeck.com/vischeck/vischeckImage.php https://www.color-blindness.com/coblis-color-blindness-simulator/

Interactions between Colors and with Lighting

“Lightness Constancy”

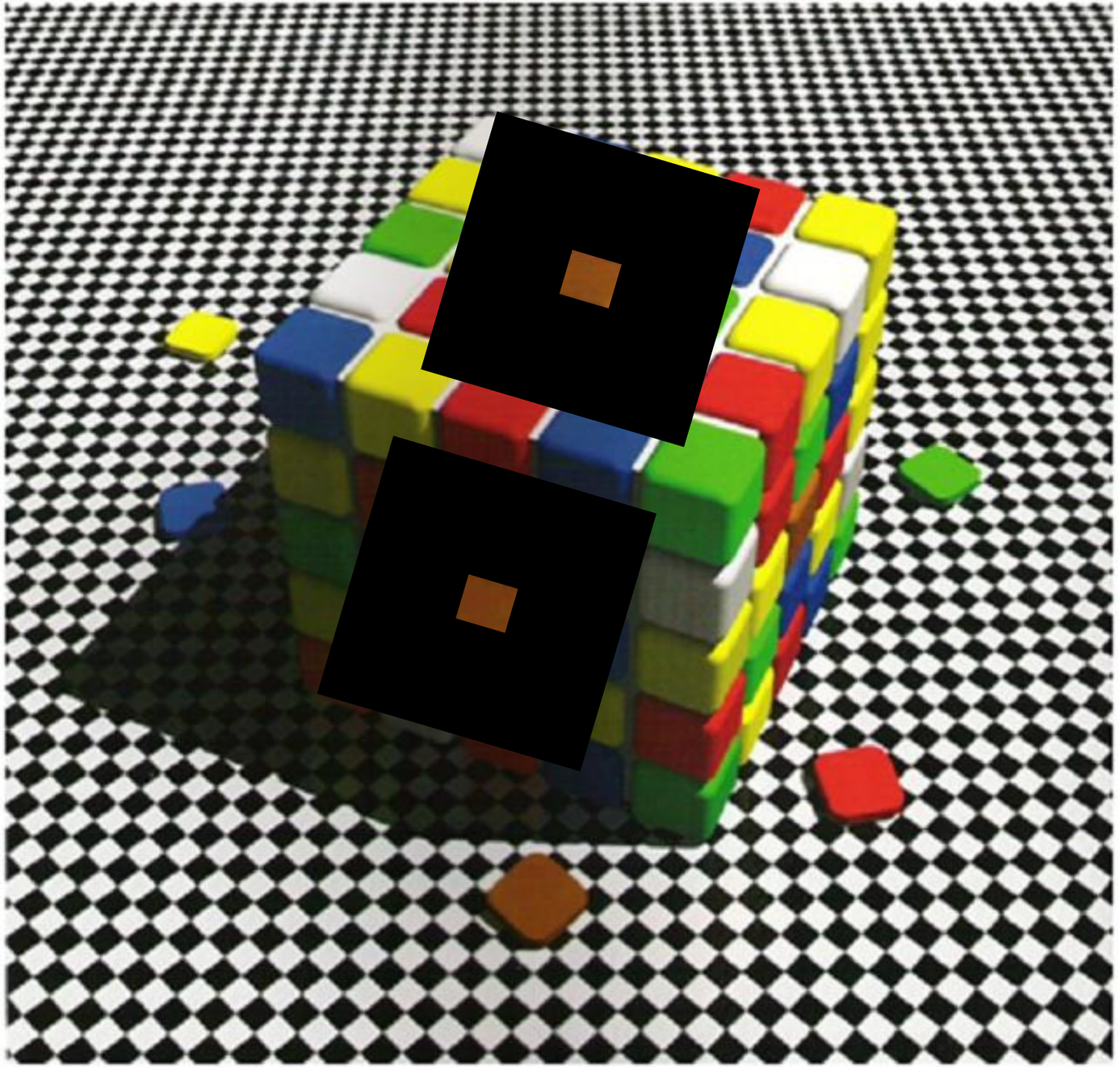
The perception that the apparent brightness of light and dark surfaces remains more or less the same under different luminance conditions is called **darkness (lightness) constancy**.

“Darkness (lightness) Constancy”



Adelson→Pingstone, 2015

“Color Constancy”



Lotto, 2009

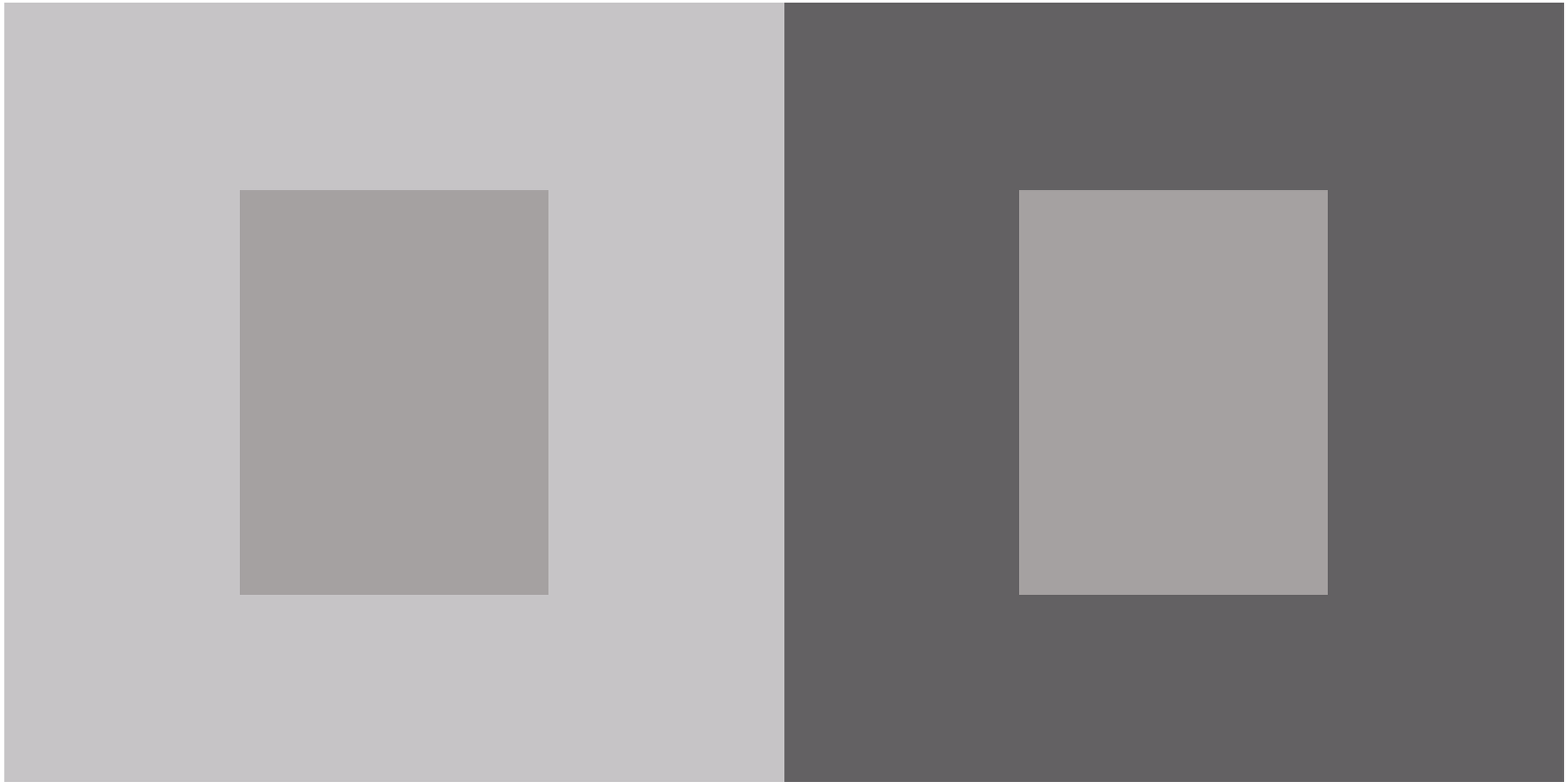
“Simultaneous Contrast”

“Simultaneous Contrast”

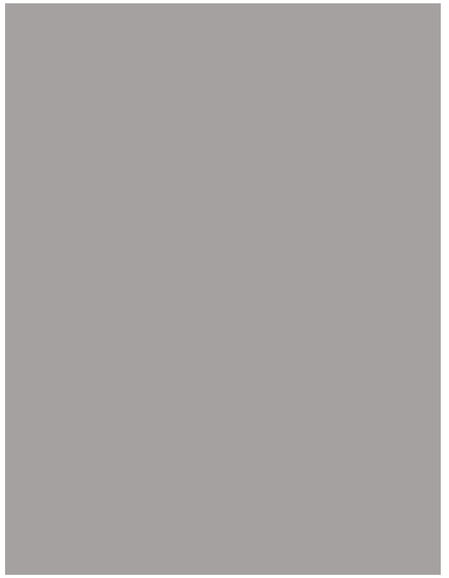
“Simultaneous Contrast”

Avoid gradients as backgrounds or bars!

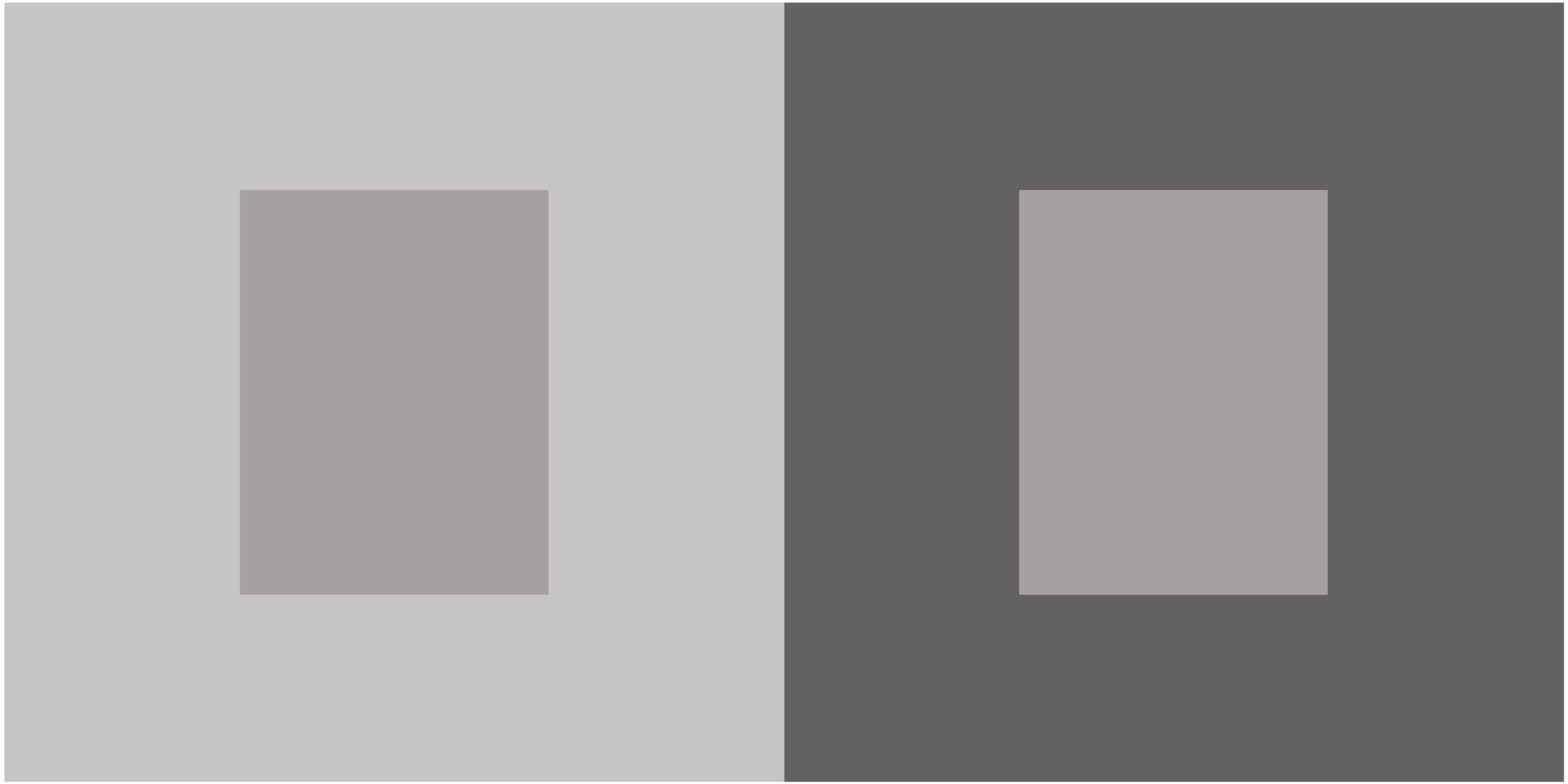
“Simultaneous Contrast”



“Simultaneous Contrast”

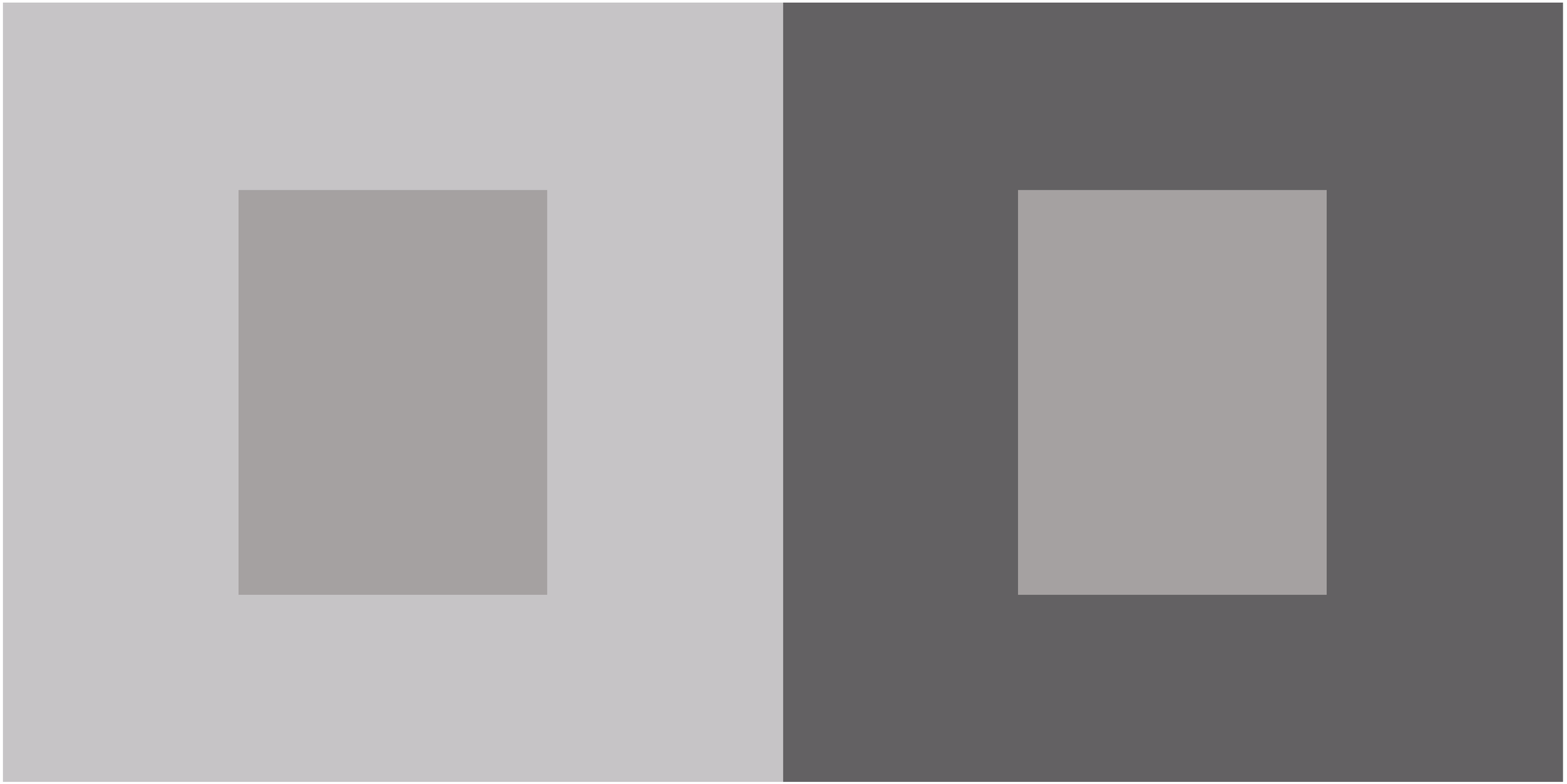


“Simultaneous Contrast”

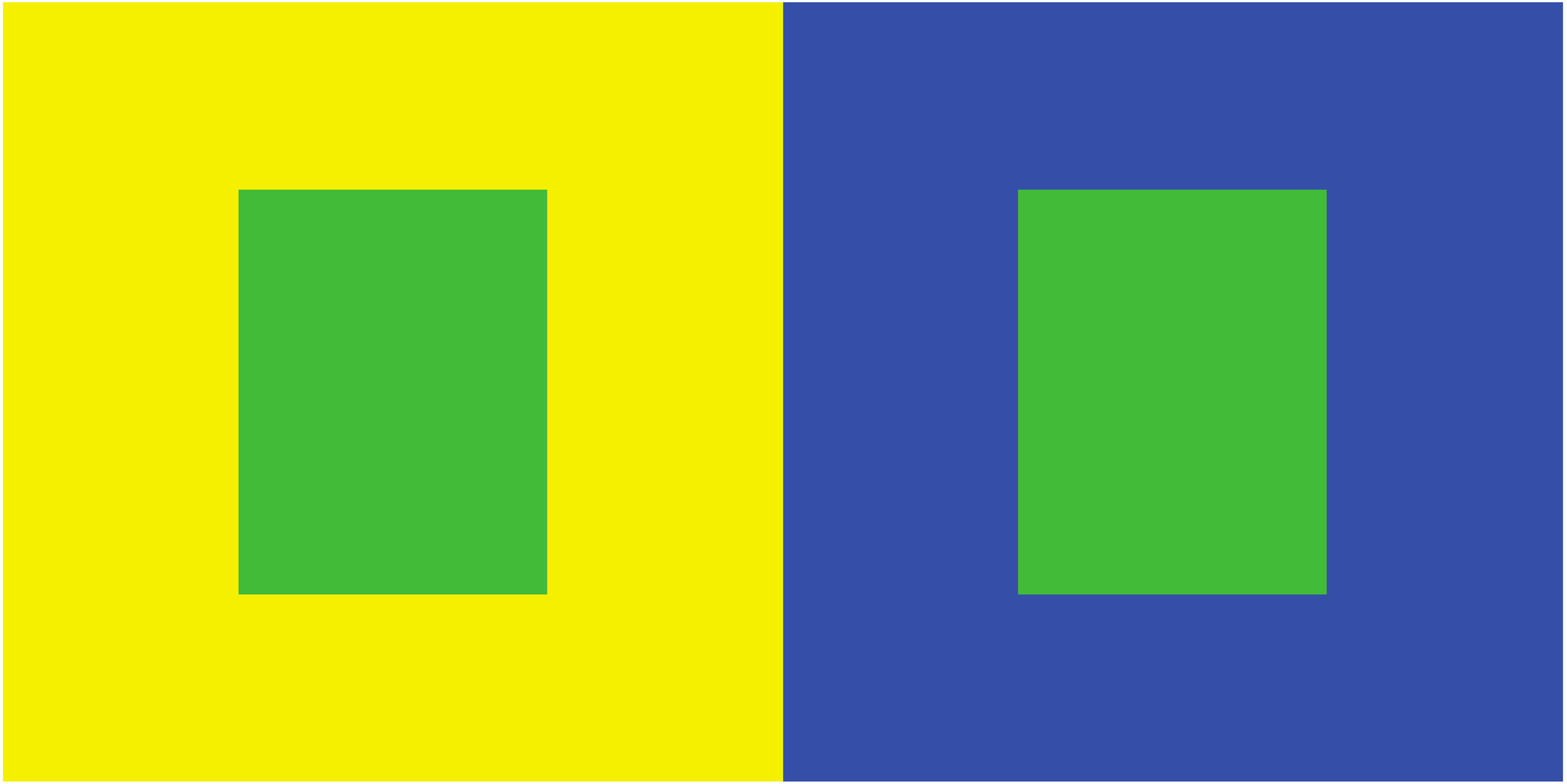


“Simultaneous Contrast”

“Simultaneous Contrast”

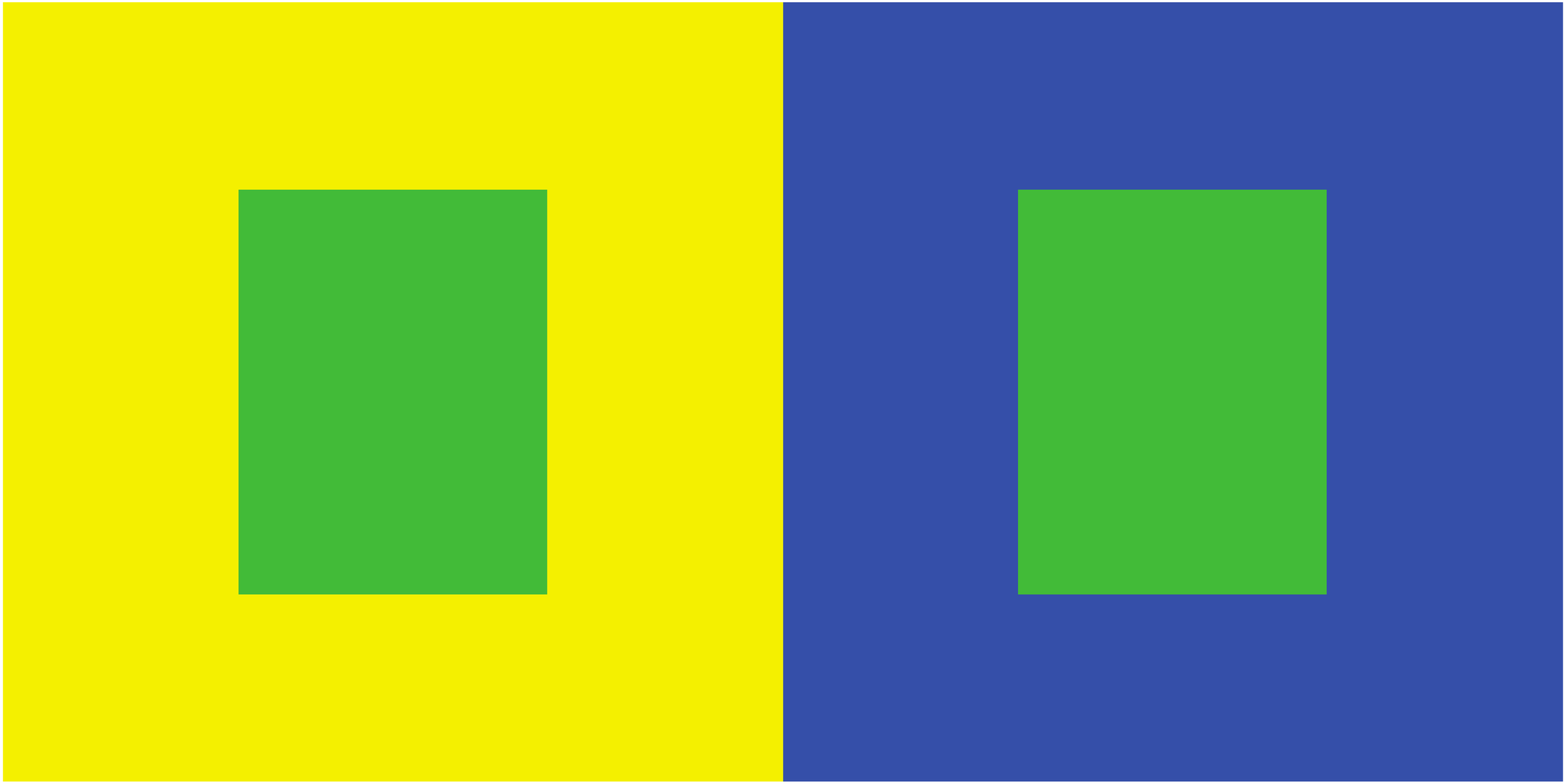


“Simultaneous Contrast”

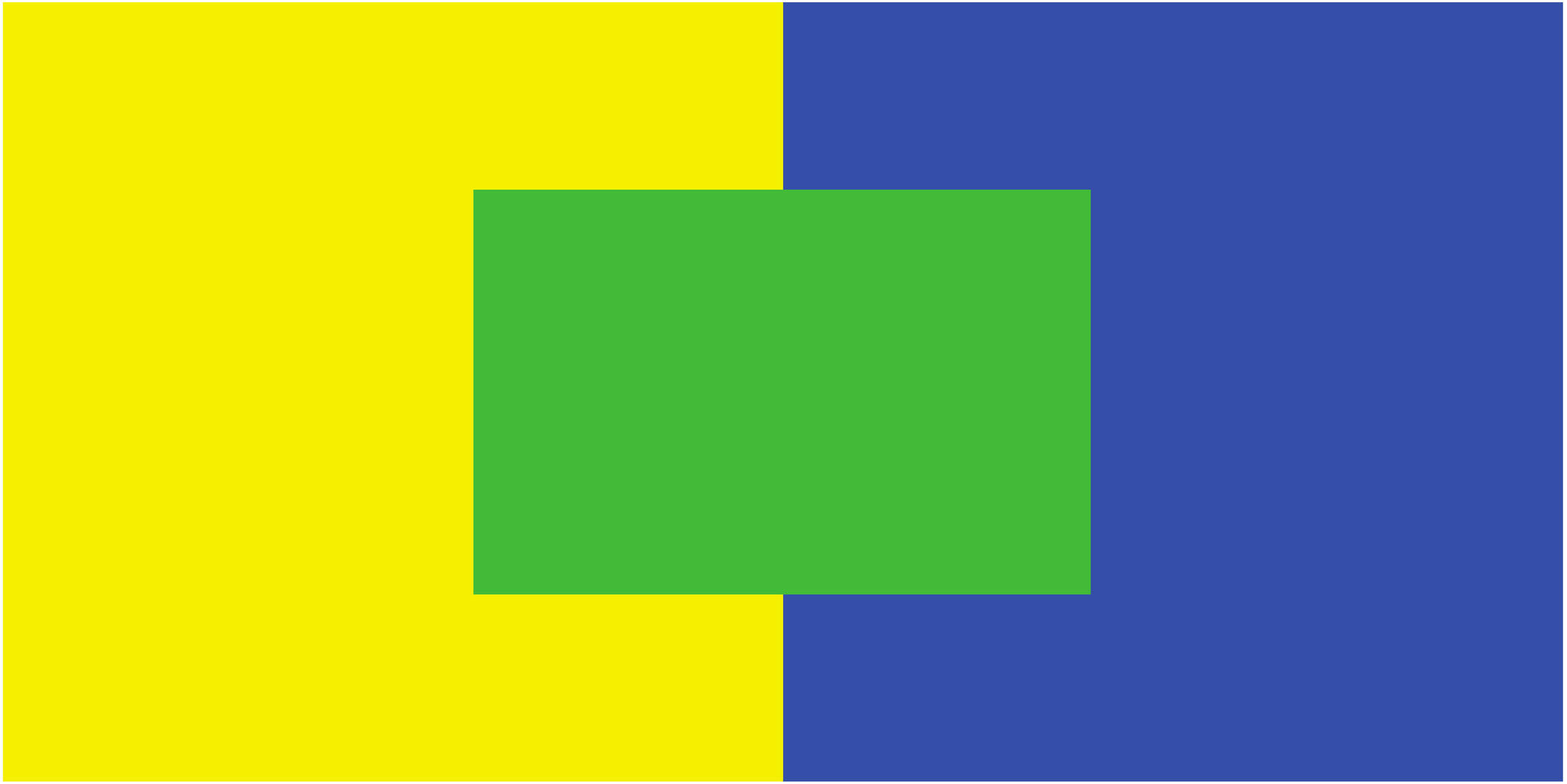


“Simultaneous Contrast”

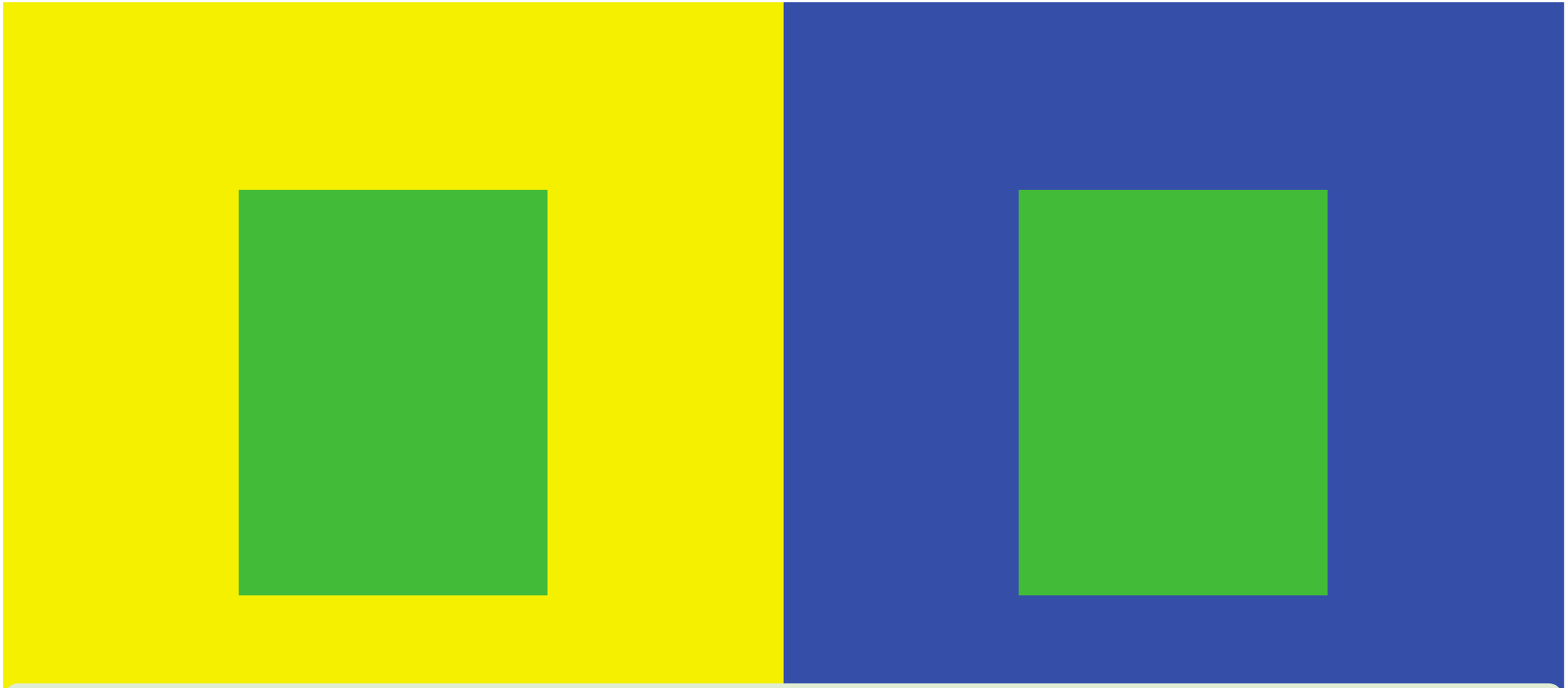
“Simultaneous Contrast”



“Simultaneous Contrast”



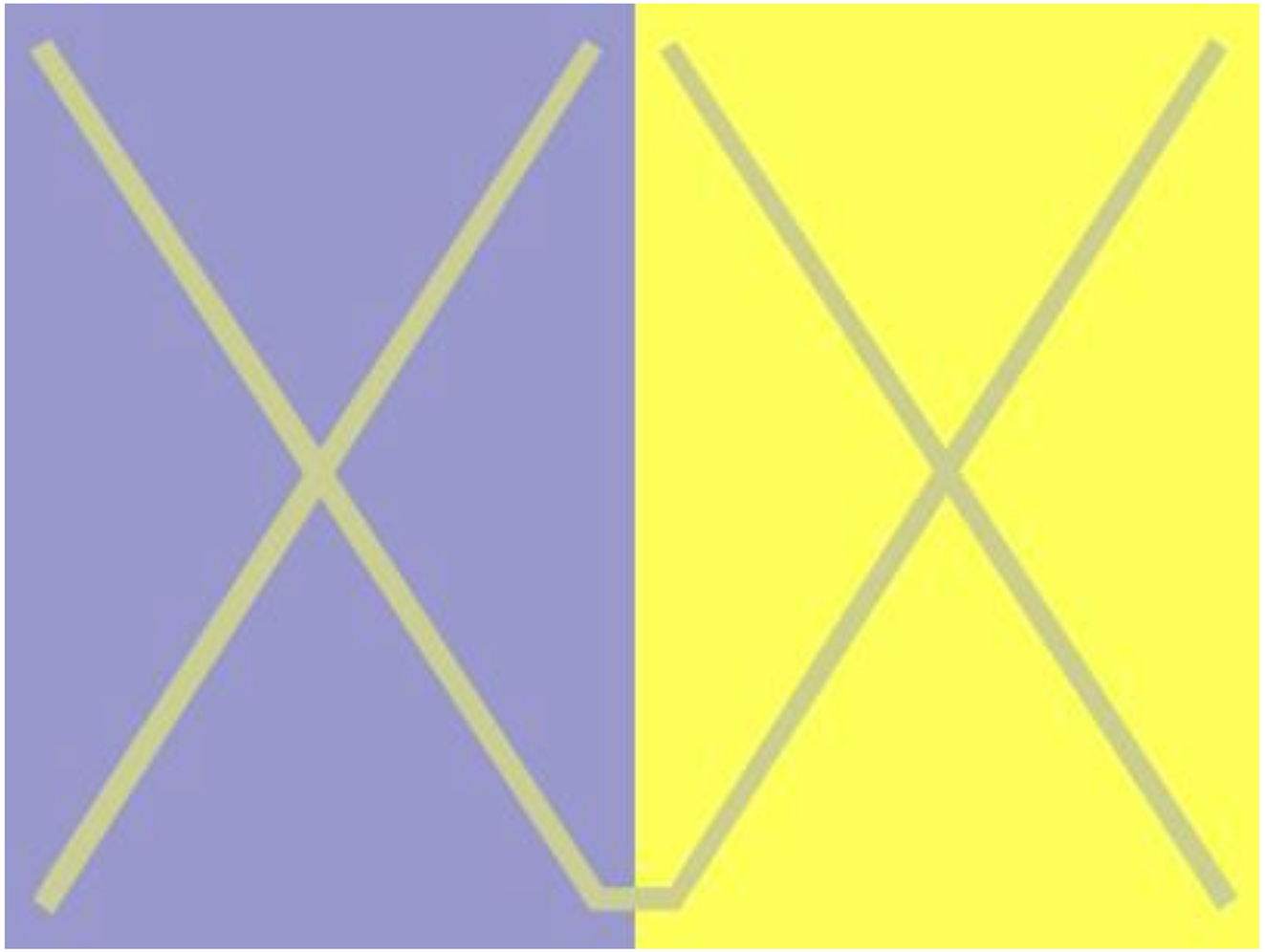
“Simultaneous Contrast”



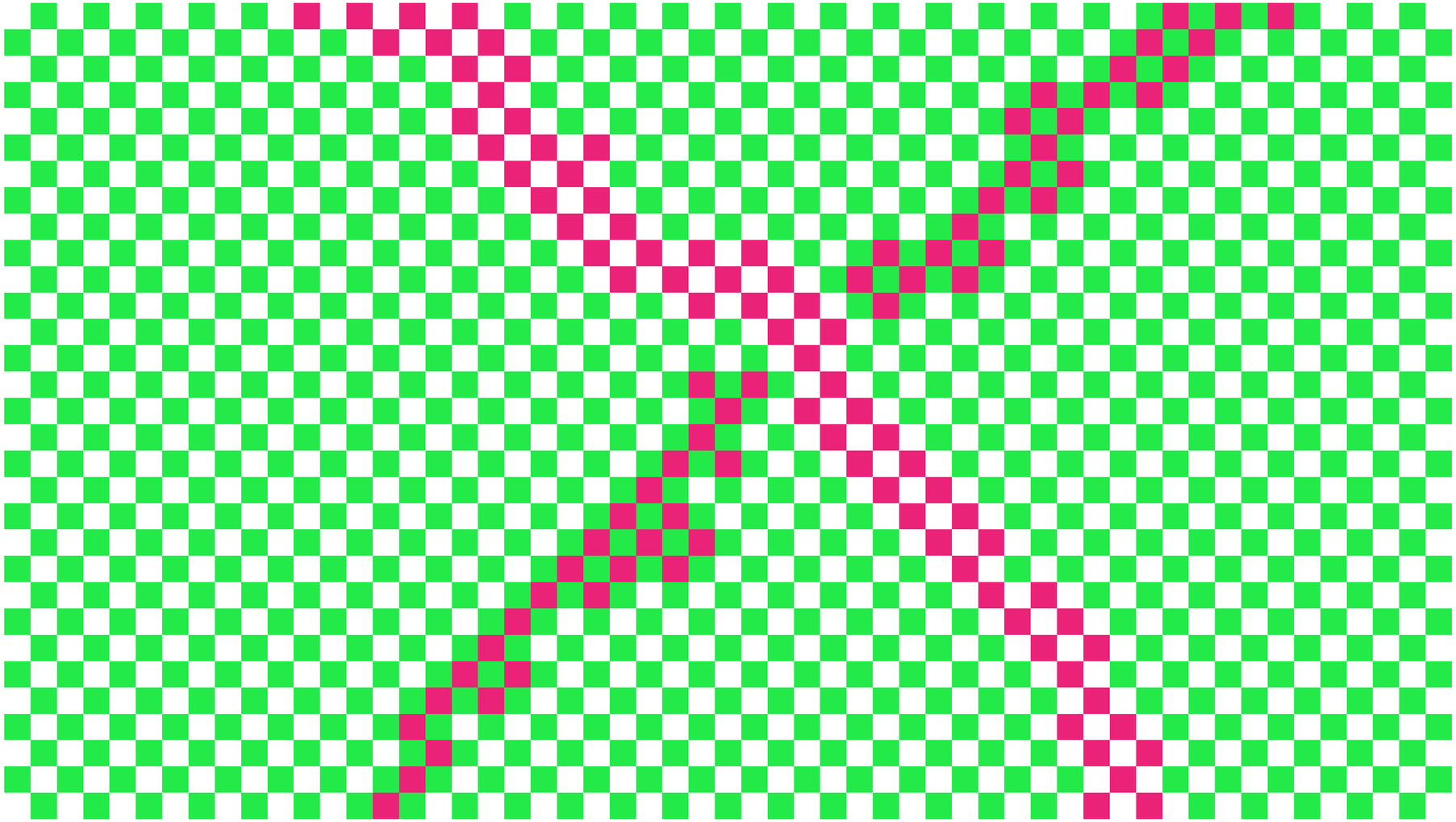
Be careful with bars and scatter plot points - the colors may appear differently with different background colors and neighboring colors!

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

“Simultaneous Contrast”

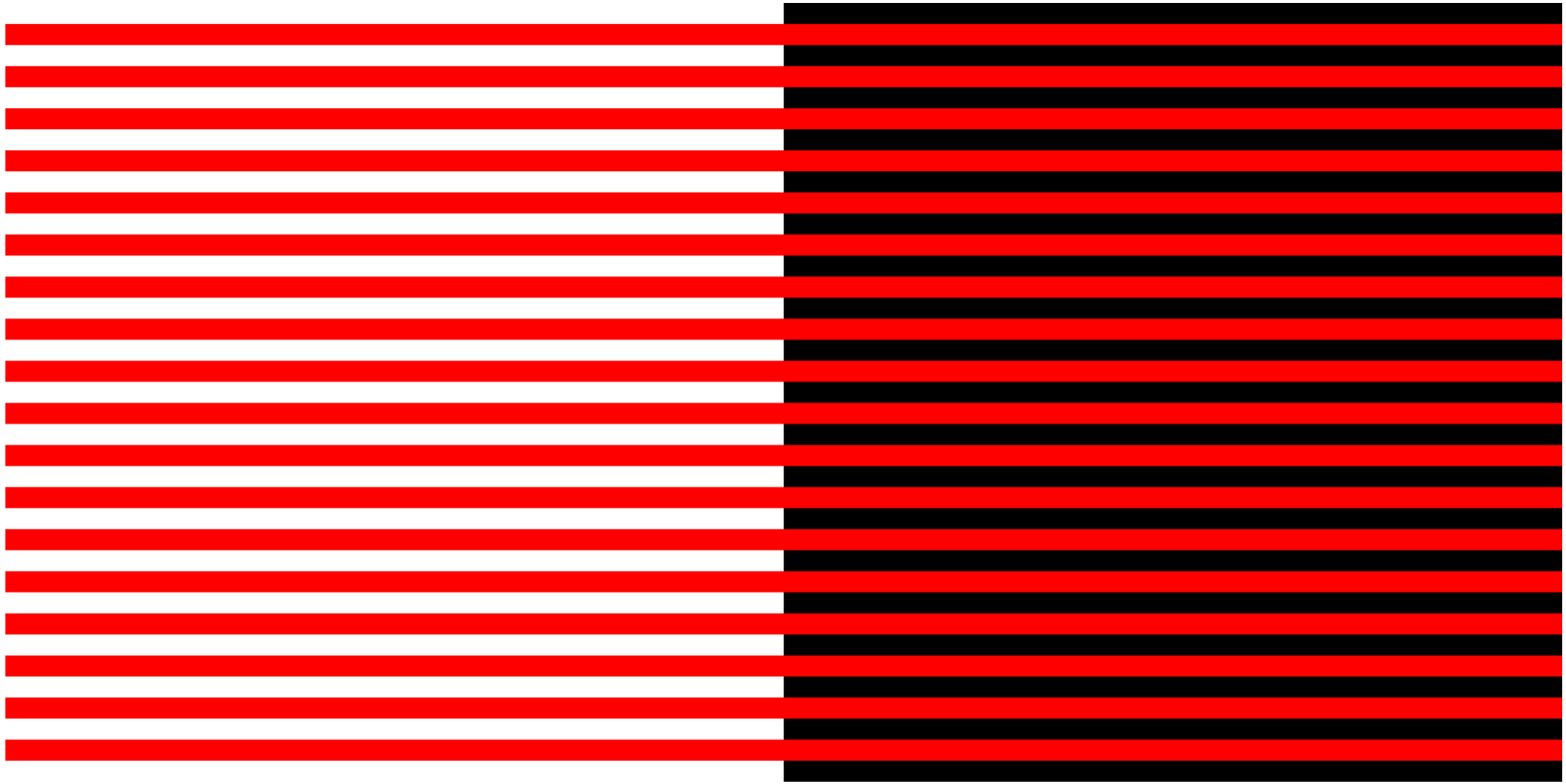


“Simultaneous Contrast”

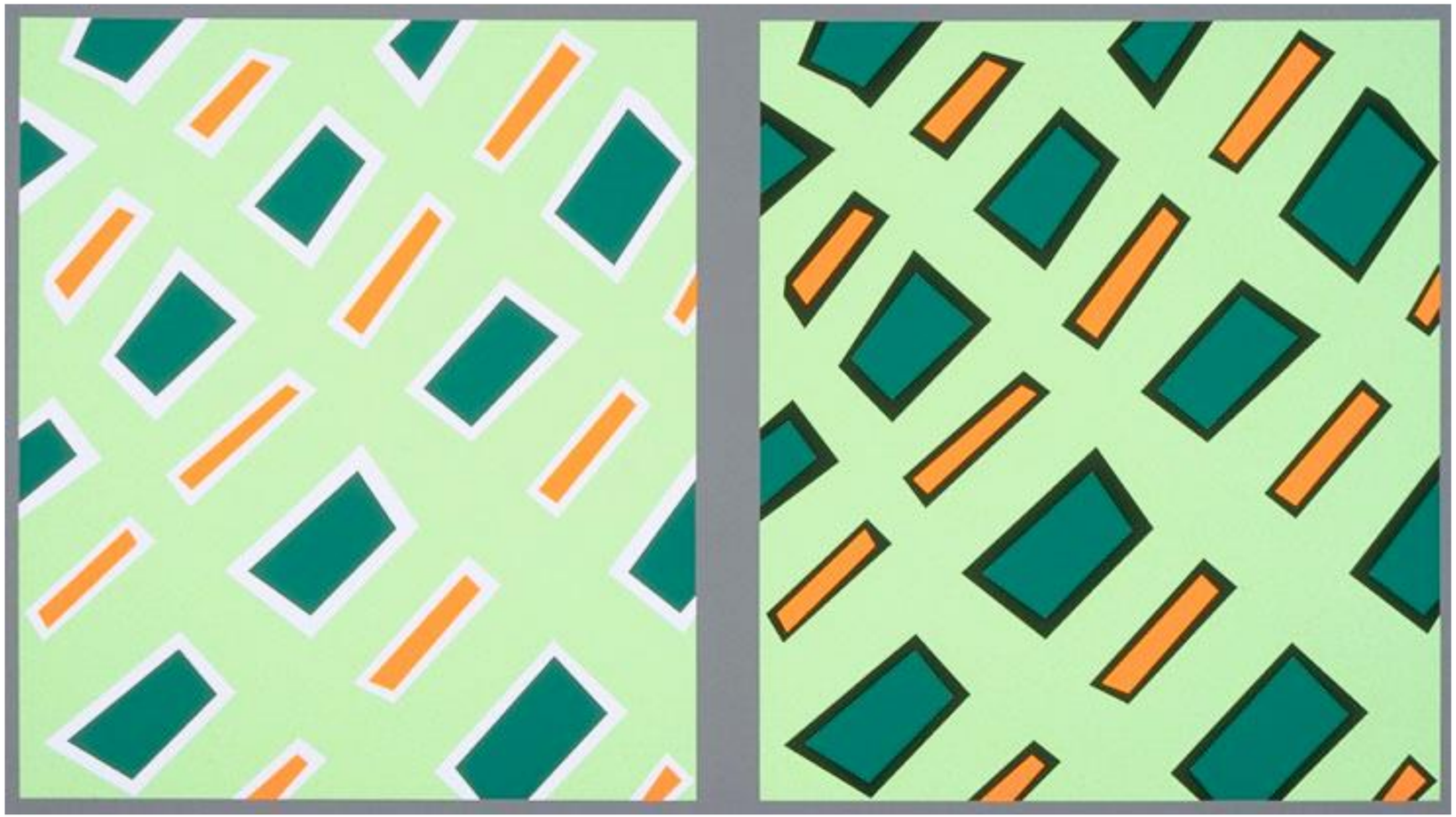


Griffin, 2015

“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)?

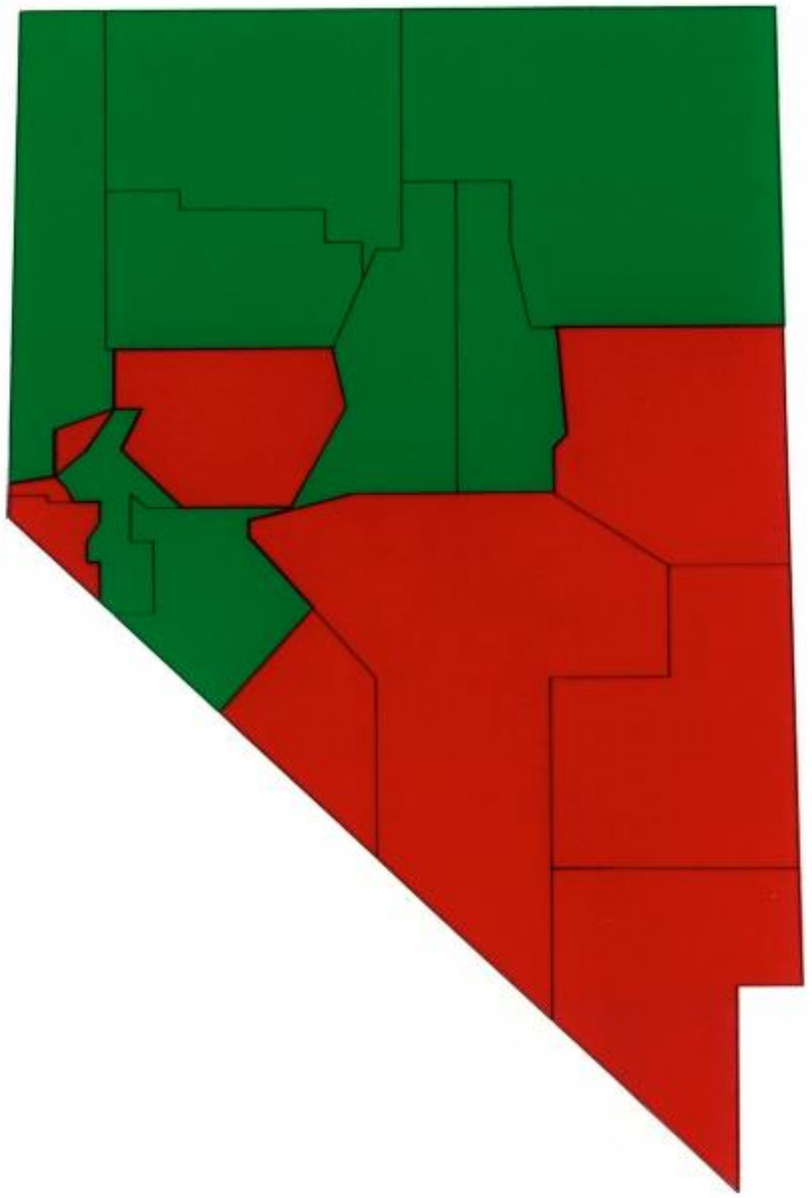


Figure 1. Stimulus From the High-Saturation Group

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)

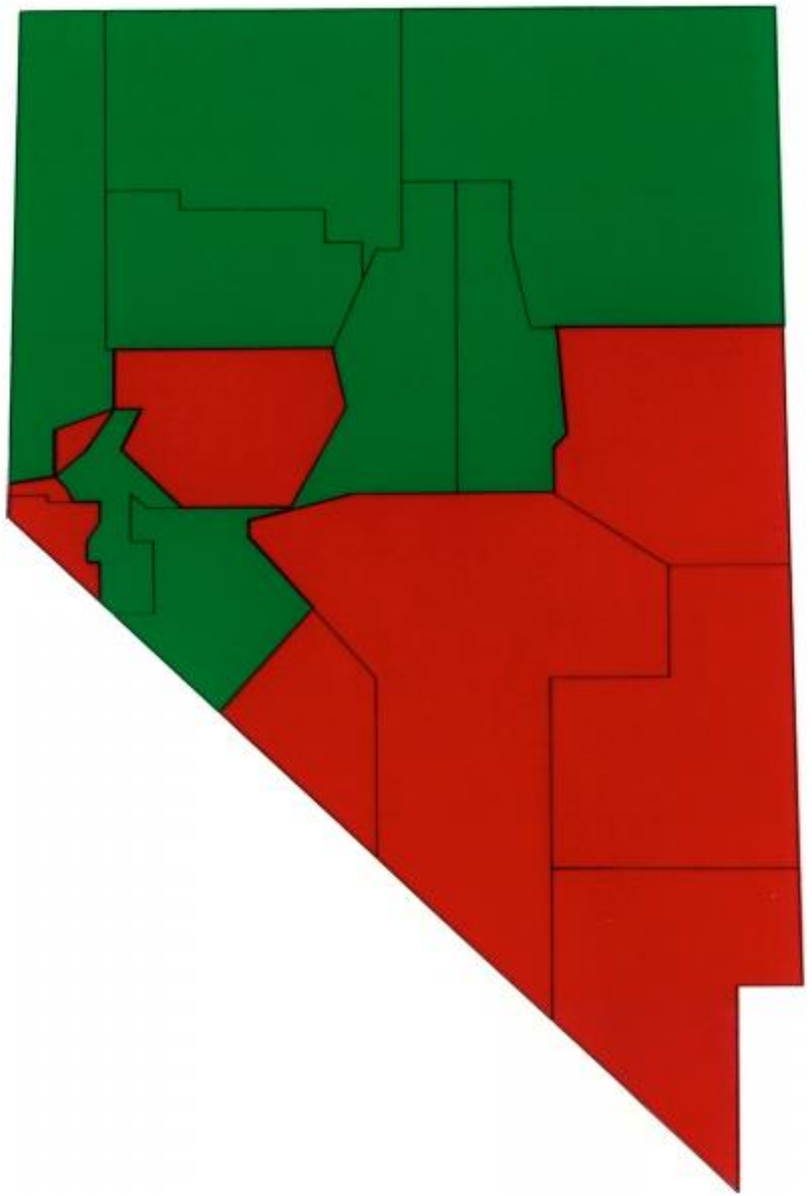


Figure 1. Stimulus From the High-Saturation Group

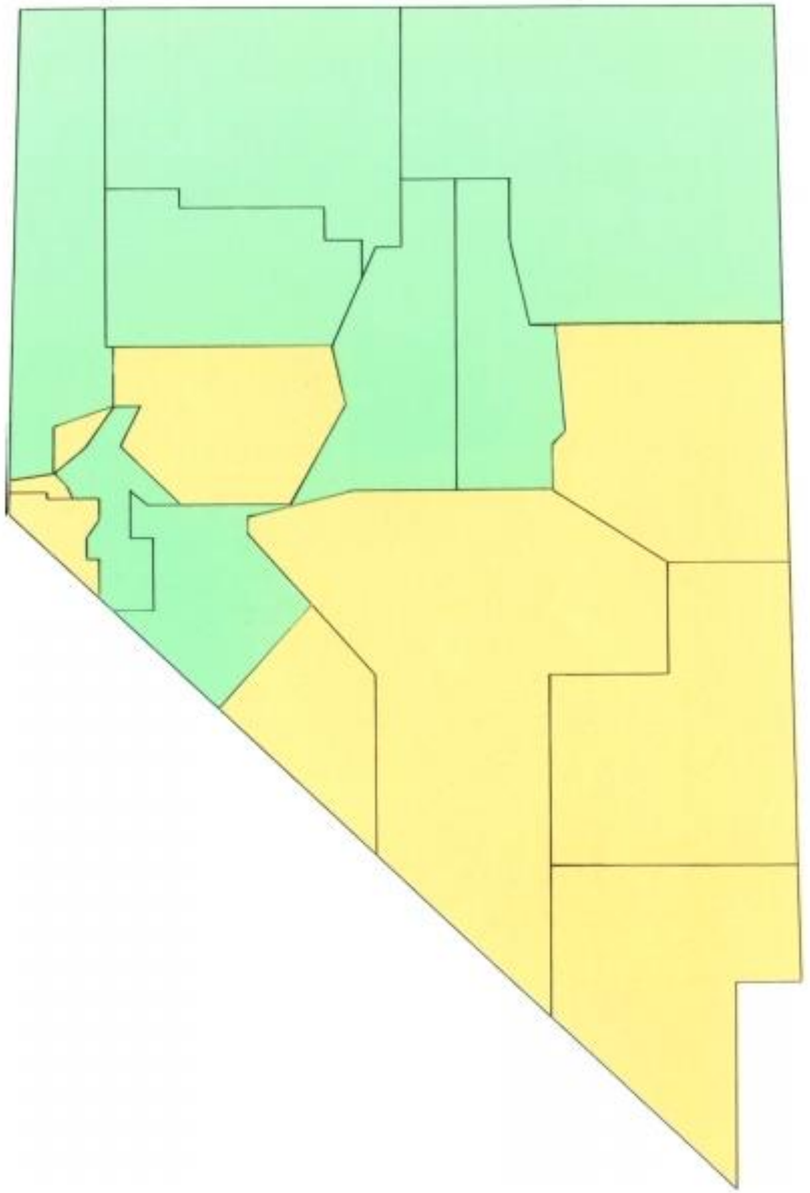
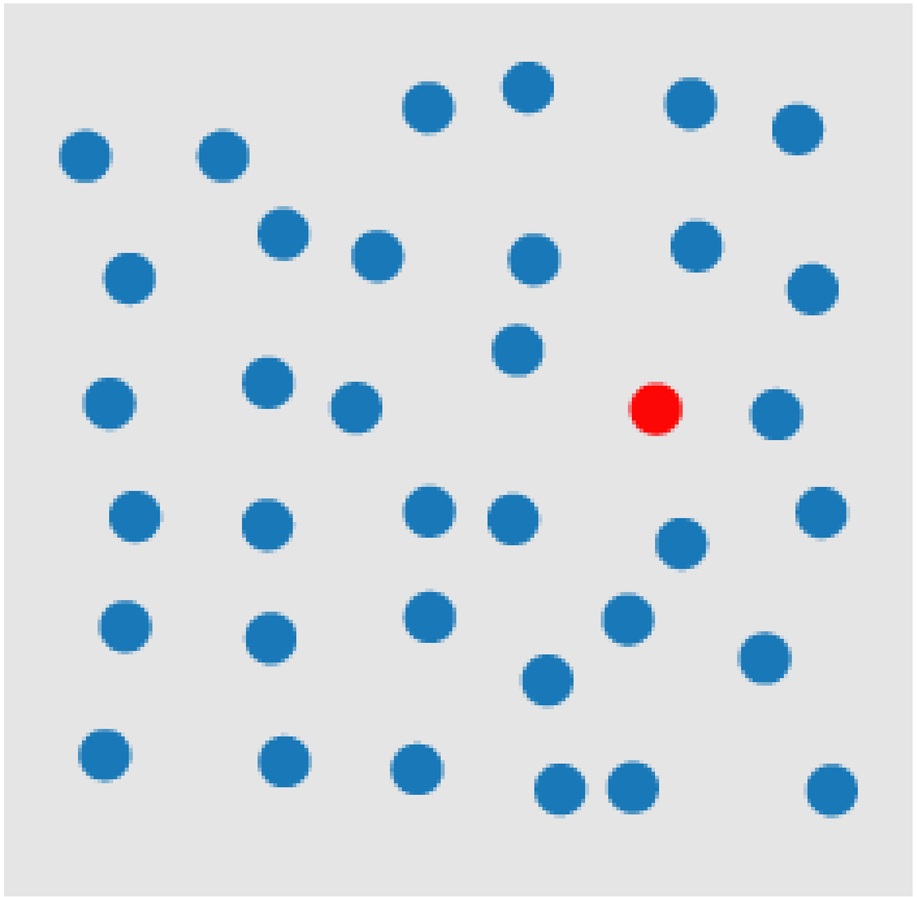
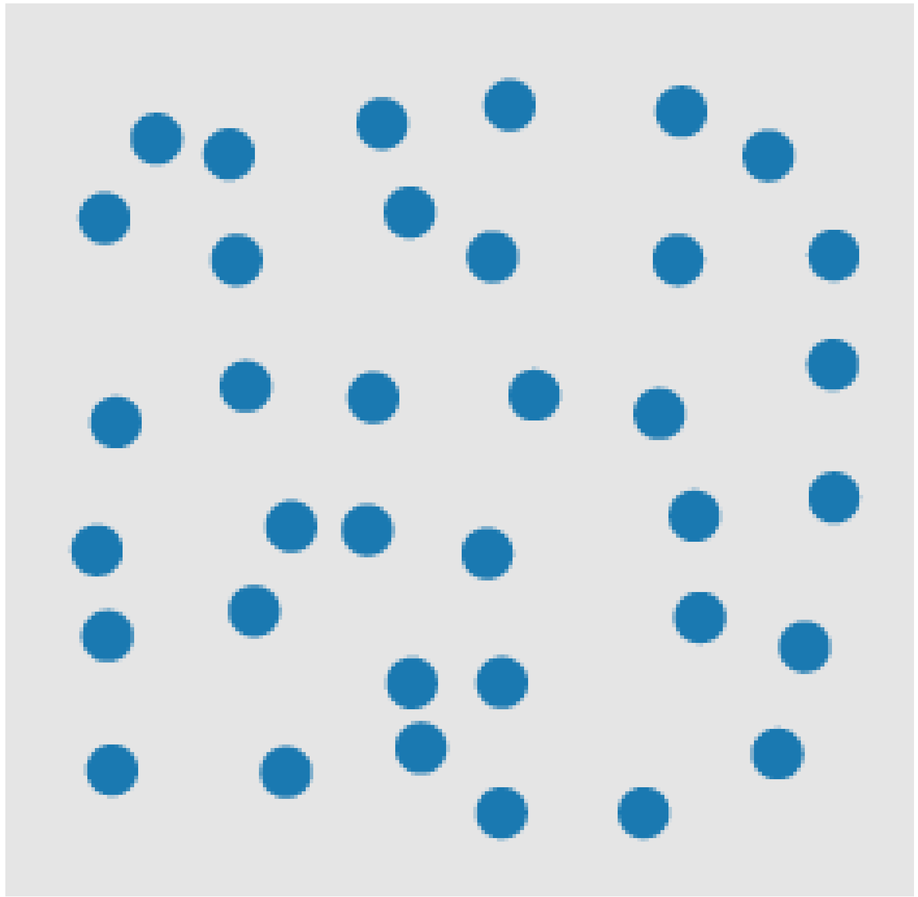


Figure 2. Stimulus From the Low-Saturation Group

Cleveland & McGill, 1983

POP-OUT EFFECTS





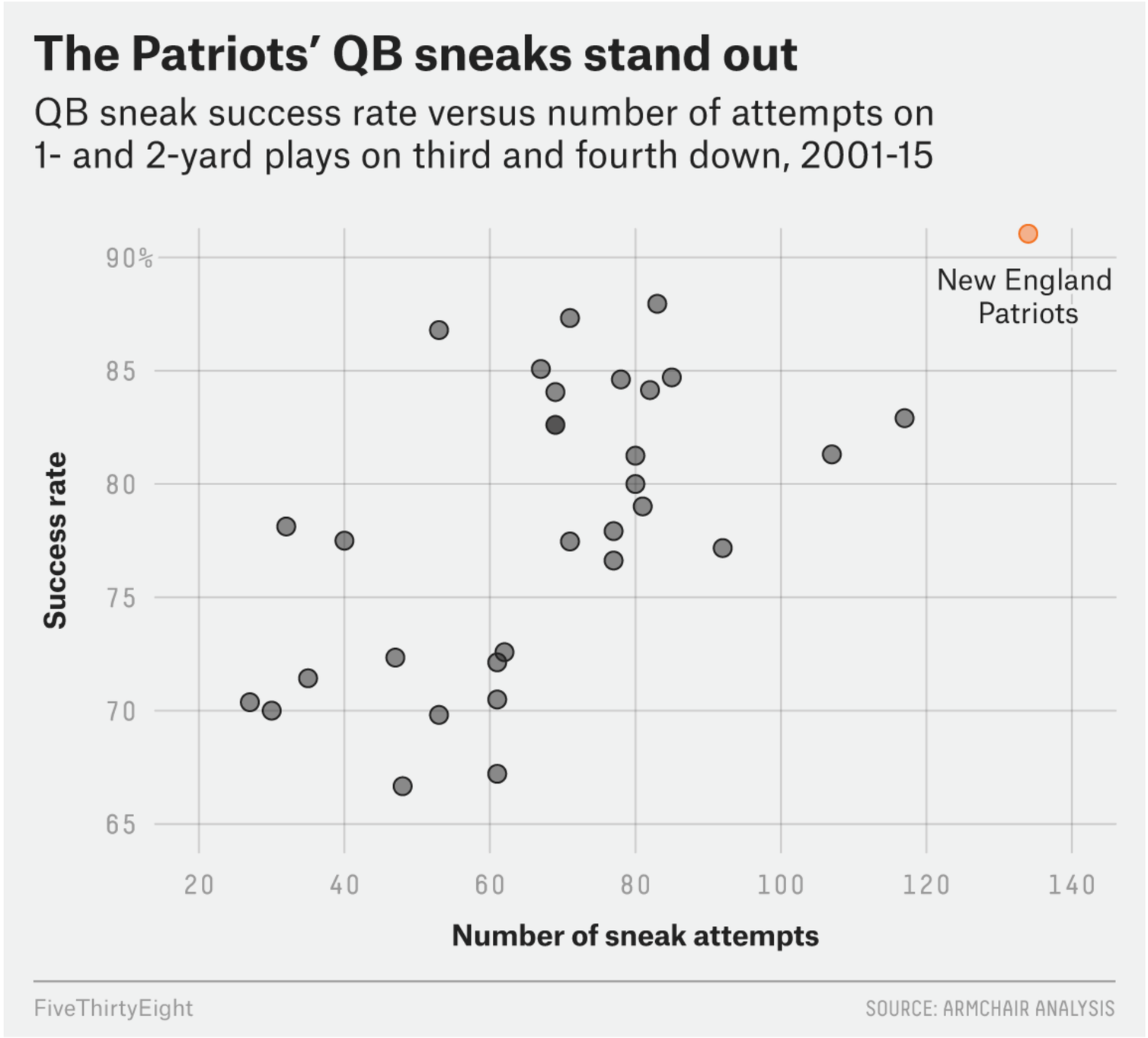
COLOR

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

For Next Time

neu-ds-4200-f23.github.io/schedule/

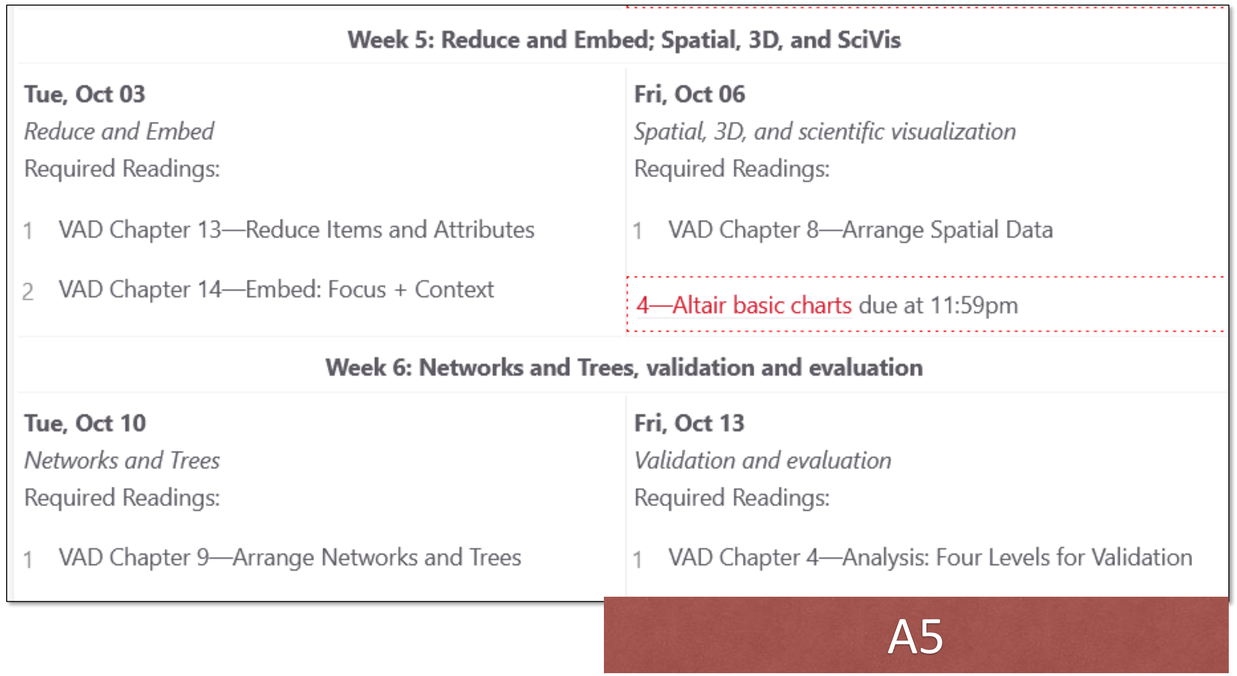
Look at the upcoming assignments and deadlines

- Textbook, Readings, & Reading Quizzes—Variable days
- In-Class Activities—If due, they are due 11:59pm the same day as class

Everyday Required Supplies:

- 5+ colors of pen or marker
- White paper
- Laptop and charger

Use Slack for general questions, email codydunne-and-tas@ccs.neu.edu for questions specific to you.



Week 5: Reduce and Embed; Spatial, 3D, and SciVis	
Tue, Oct 03 *Reduce and Embed* Required Readings: 1 VAD Chapter 13—Reduce Items and Attributes 2 VAD Chapter 14—Embed: Focus + Context	**Fri, Oct 06** *Spatial, 3D, and scientific visualization* Required Readings: 1 VAD Chapter 8—Arrange Spatial Data 4—Altair basic charts due at 11:59pm
Week 6: Networks and Trees, validation and evaluation	
Tue, Oct 10 *Networks and Trees* Required Readings: 1 VAD Chapter 9—Arrange Networks and Trees	**Fri, Oct 13** *Validation and evaluation* Required Readings: 1 VAD Chapter 4—Analysis: Four Levels for Validation