

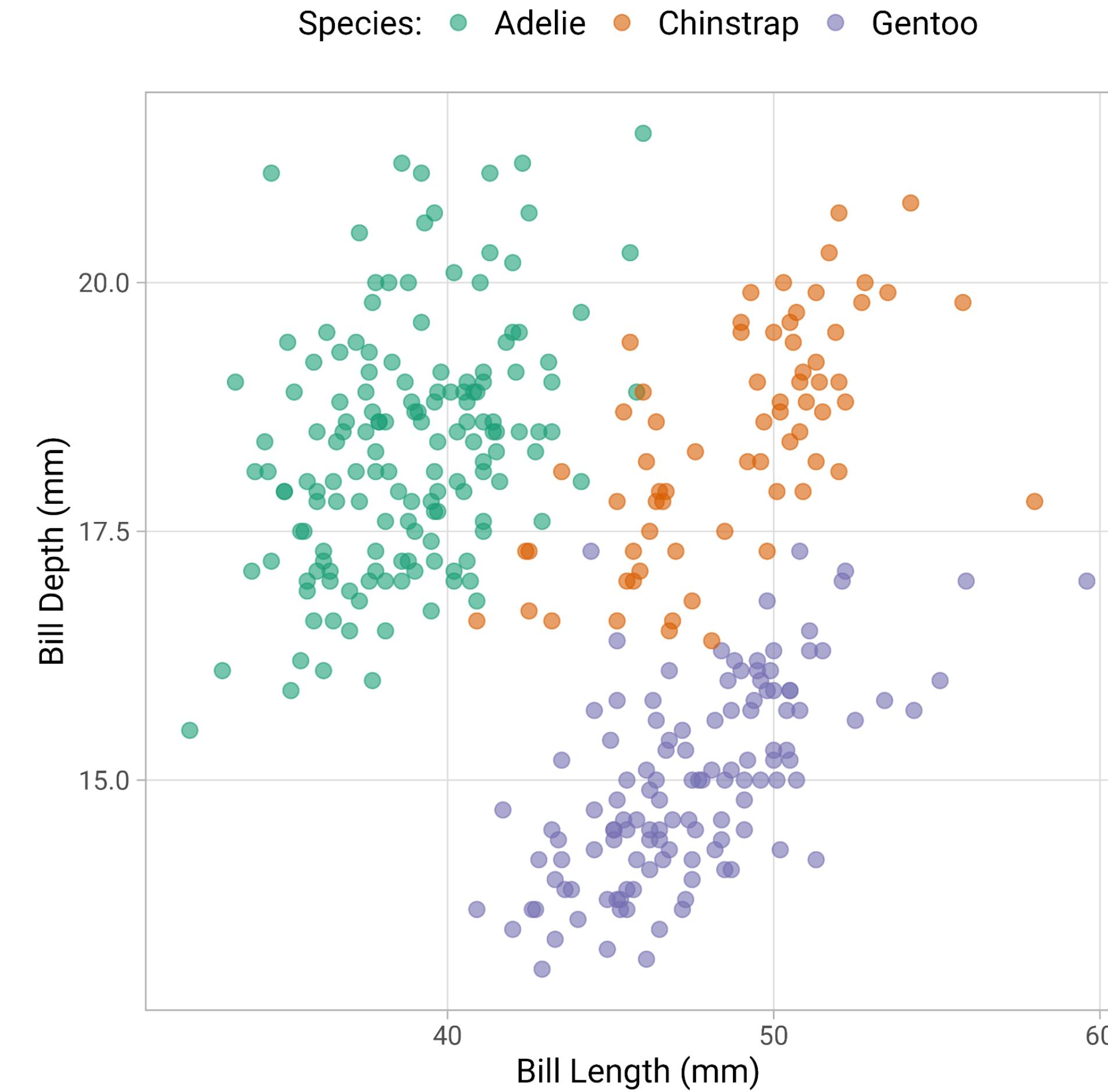
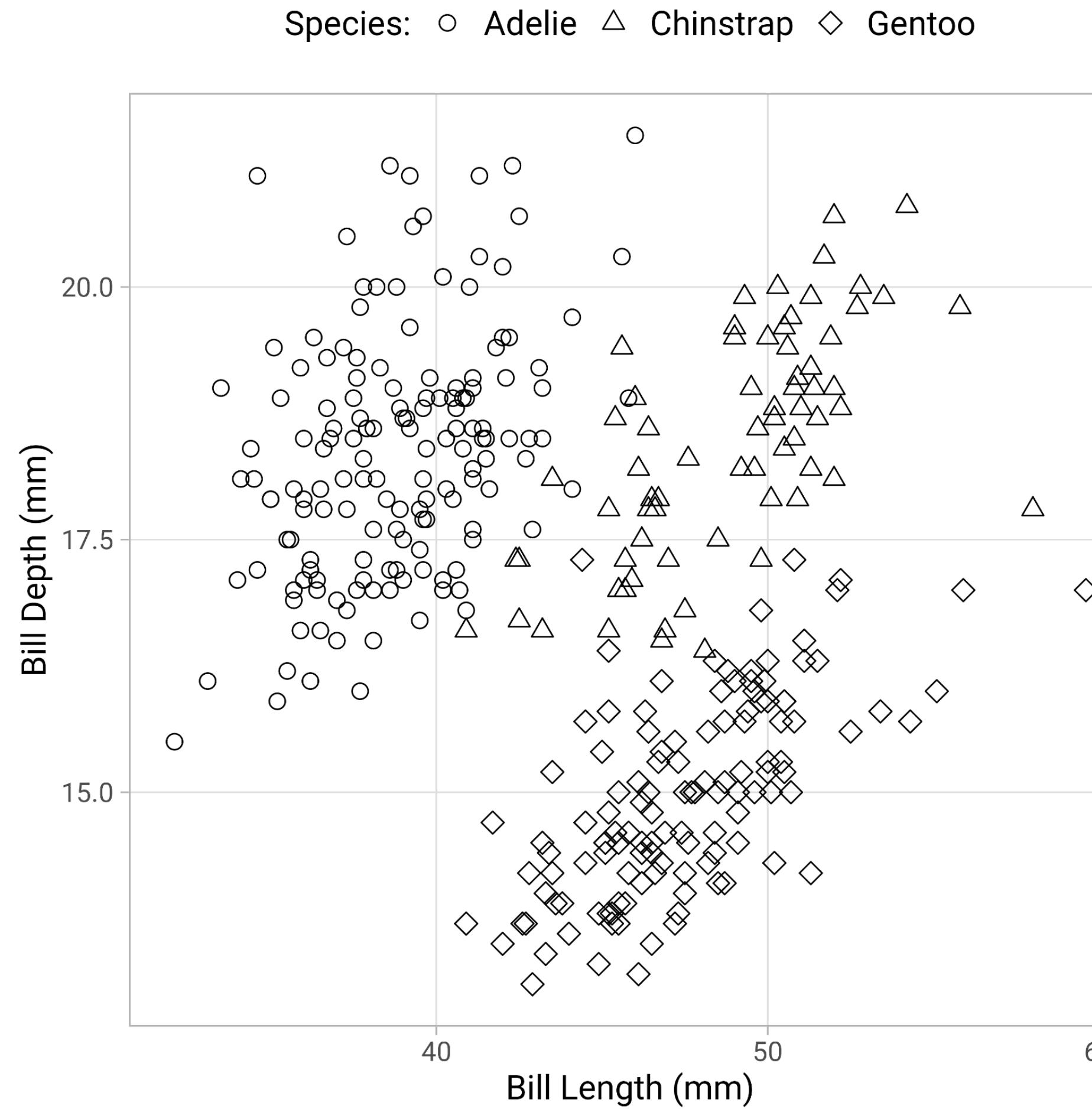
# Colorful Graphics

**How to use colors correctly and wisely**

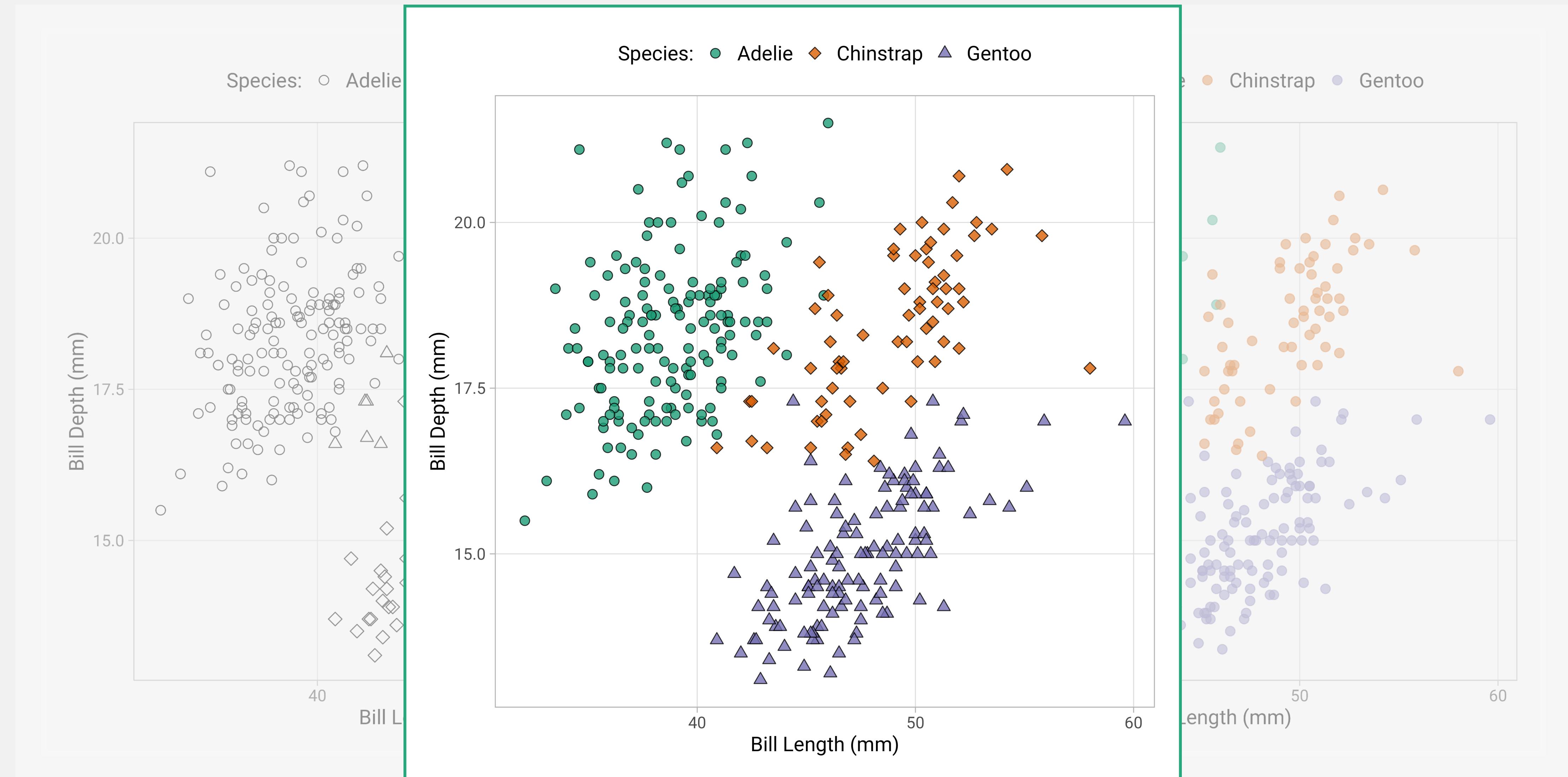
Cédric Scherer // rstudio::conf // July 2022



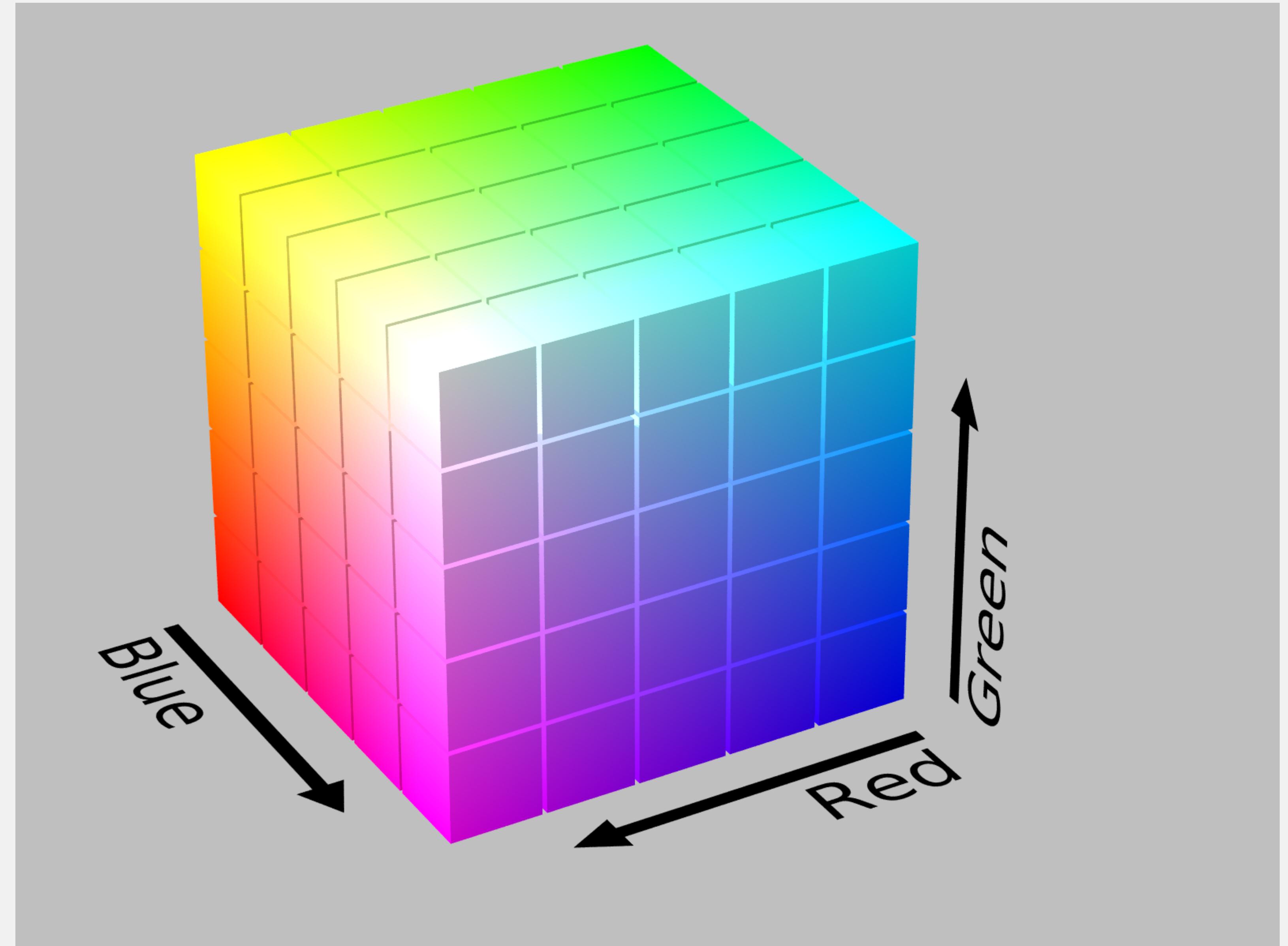
# Channels to Encode Information



# Use of Double Encoding

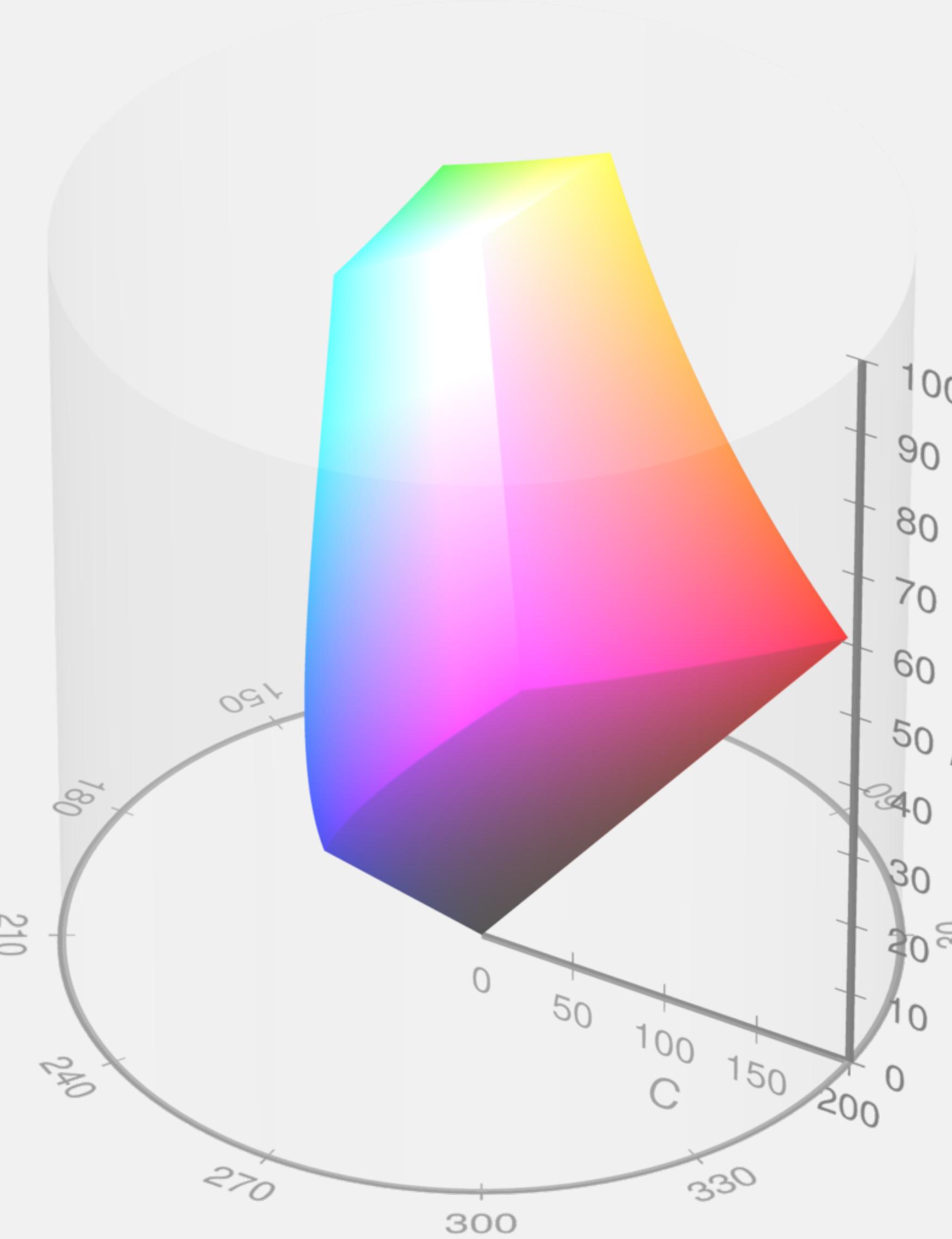


# The RGB Color Space



*Michael Horvath*

# The HCL Color Space



*Michael Horvath & Christoph Lipka*

Cédric Scherer // rstudio::conf // July 2022

## Hue

color family



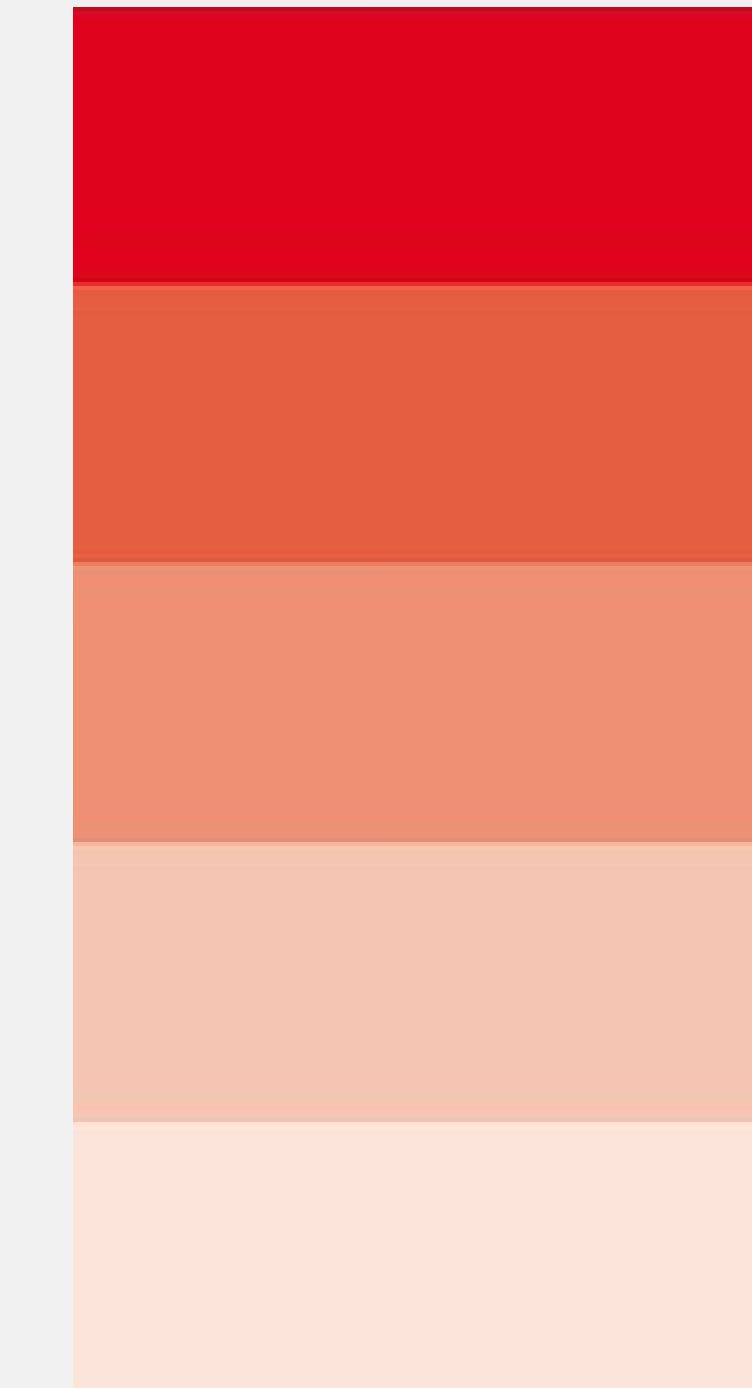
## Chroma

colorfulness



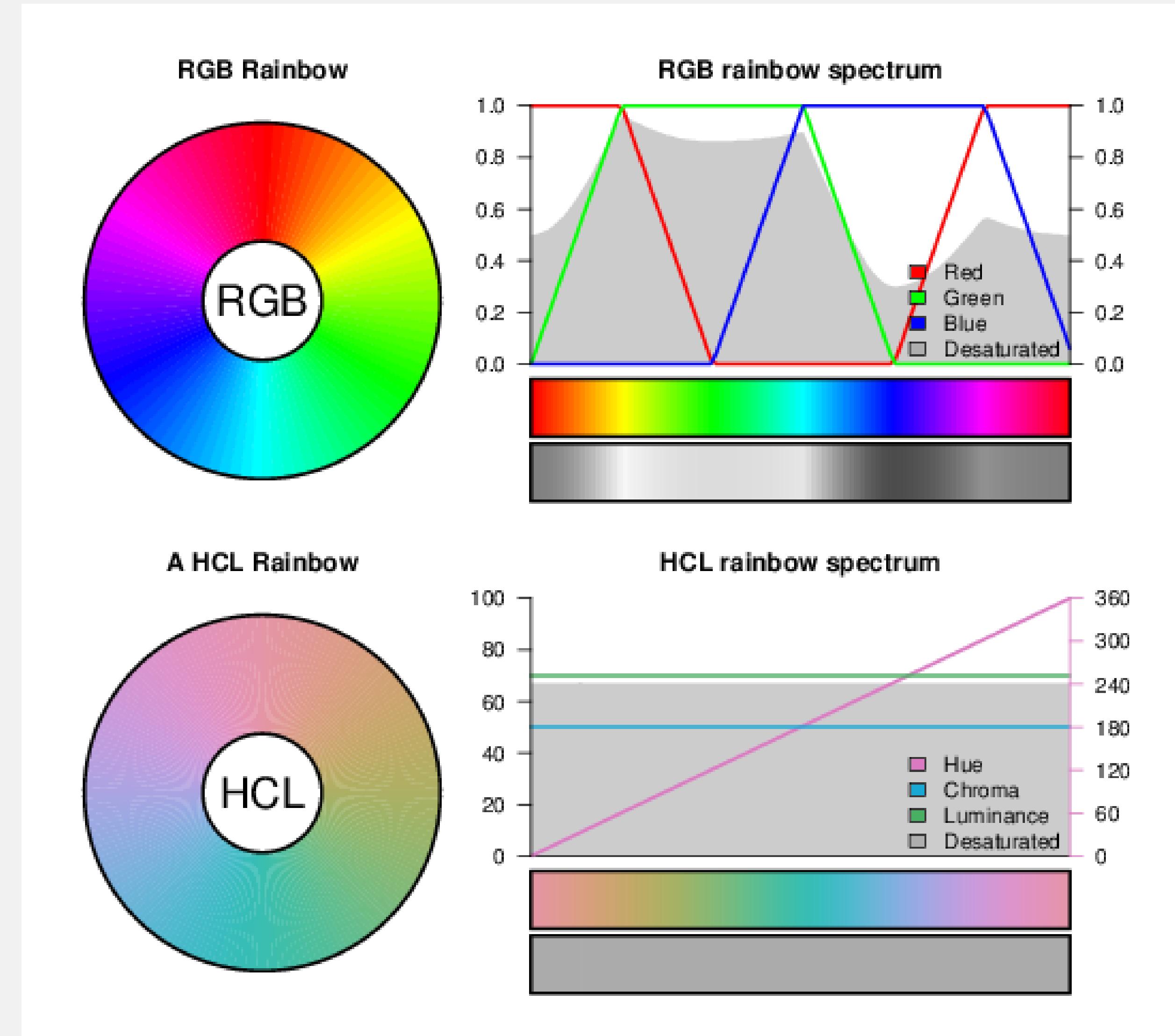
## Luminance

lightness / brightness



*Modified from [uxplanet.org](http://uxplanet.org)*

# RGB versus HCL



[hclwizard.org](http://hclwizard.org)

# Color Palette Choice

## Sequential



Use to encode  
***numerical information  
with order***

*use highest contrast for  
most important information*

*either single- or multi-hue*

*Modified from the [{colorspace} R package vignette](#)*

# Color Palette Choice

## Sequential

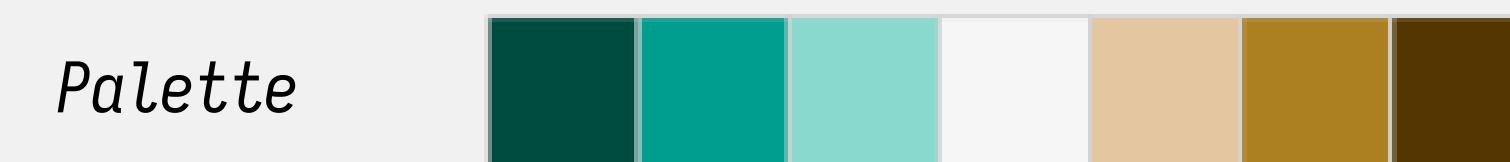


*Use to encode  
**numerical information  
with order***

*use highest contrast for  
most important information*

*either single- or multi-hue*

## Diverging



*Use to encode  
**numerical information  
with critical midpoint***

*ensure a meaningful midpoint value  
and use balanced extremes*

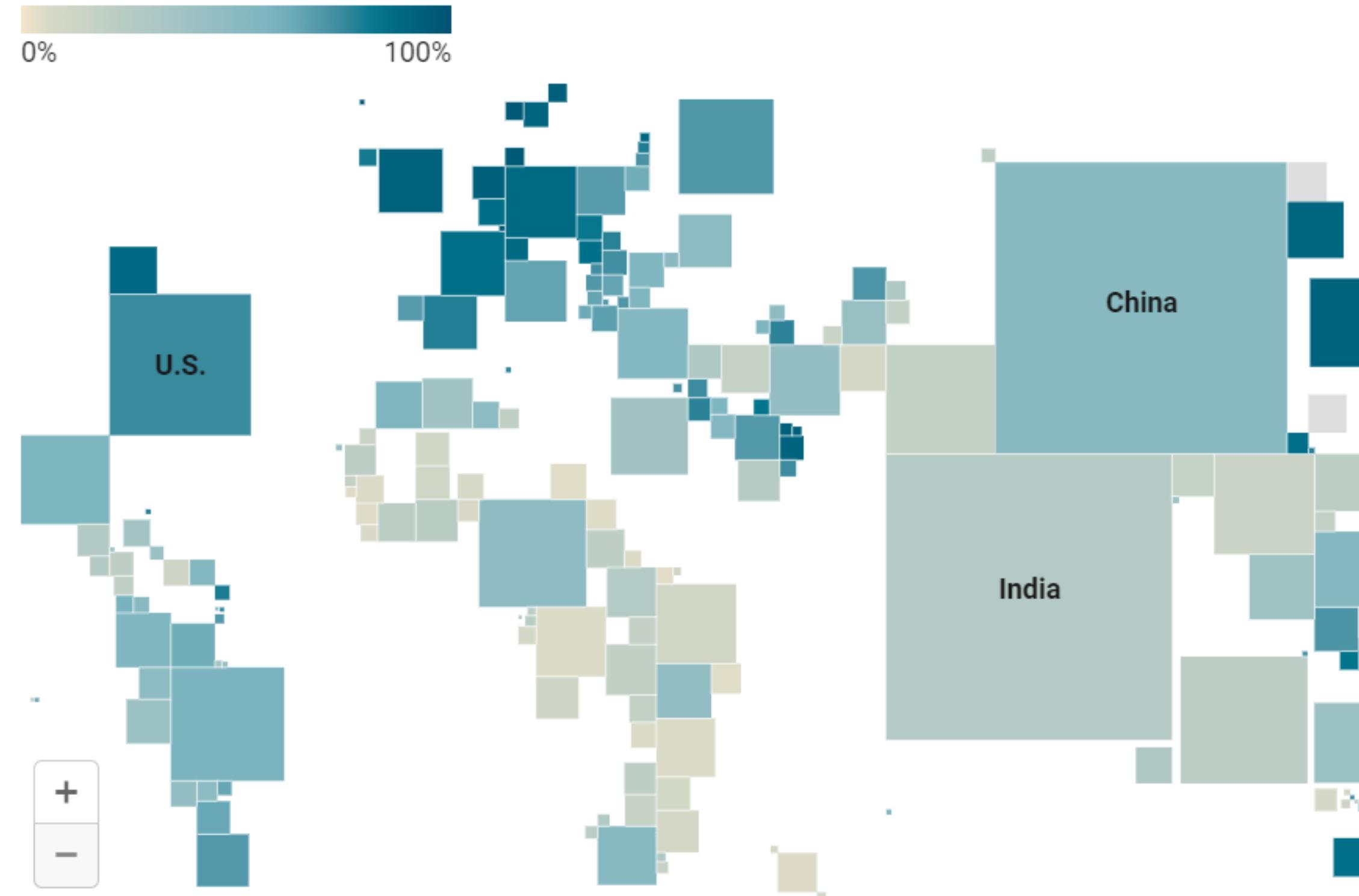
*combination of  
two sequential palettes*

*Modified from the [{colorspace} R package vignette](#)*

# Sequential versus Diverging Palettes

## The internet was mostly used by the Western World in 2015

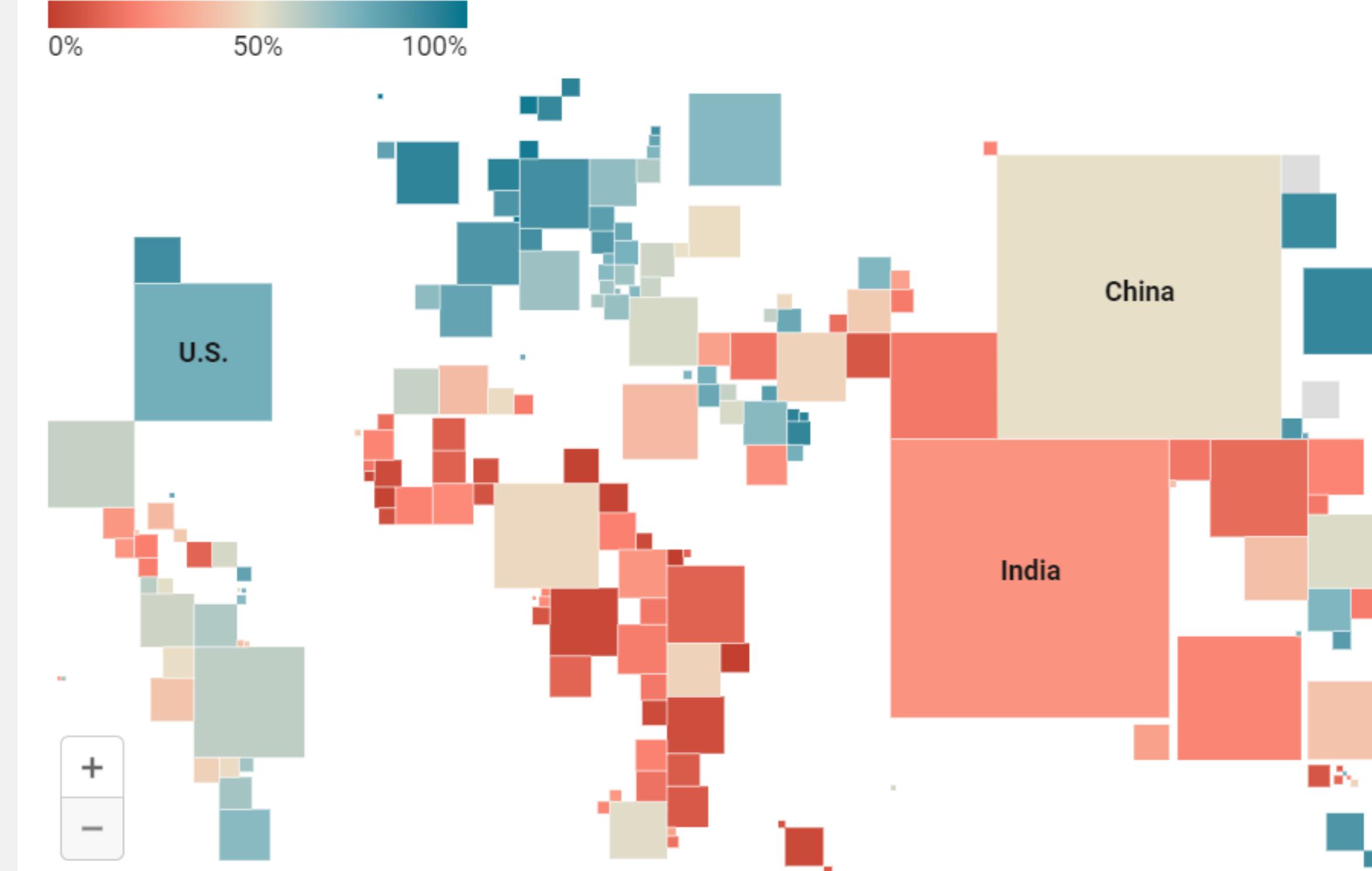
Share of individuals who have used the Internet in the last 3 months (via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.), in selected countries, 2015



Map: Lisa Charlotte Rost, Datawrapper • Source: Our World in Data • Get the data • Created with Datawrapper

## In most African and Asian countries, less than half of the population was using the internet in 2015.

Share of individuals who have used the Internet in the last 3 months (via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.), in selected countries, 2015

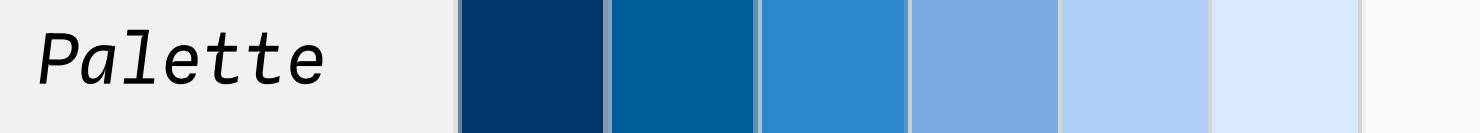


Map: Lisa Charlotte Rost, Datawrapper • Source: Our World in Data • Get the data • Created with Datawrapper

*"When to use sequential and when to use diverging color scales" by Lisa C. Muth / DataWrapper*

# Color Palette Choice

## Sequential

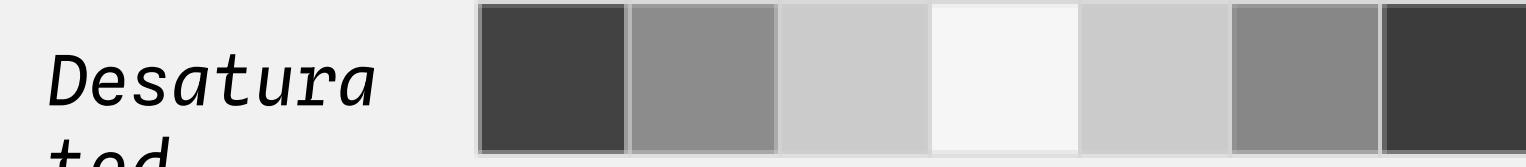
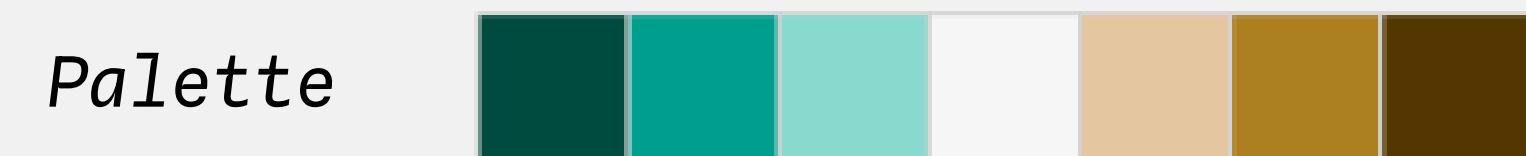


Use to encode  
**numerical information with order**

use highest contrast for most important information

either single- or multi-hue

## Diverging

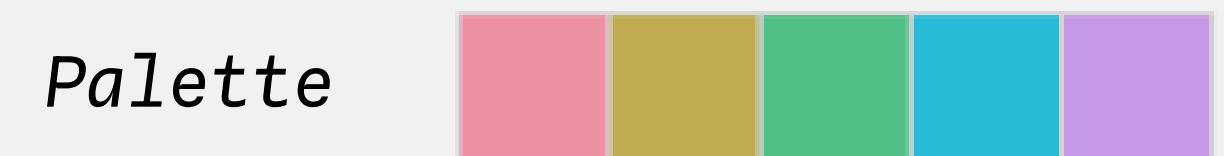


Use to encode  
**numerical information with critical midpoint**

ensure a meaningful midpoint value and use balanced extremes

combination of two sequential palettes

## Qualitative



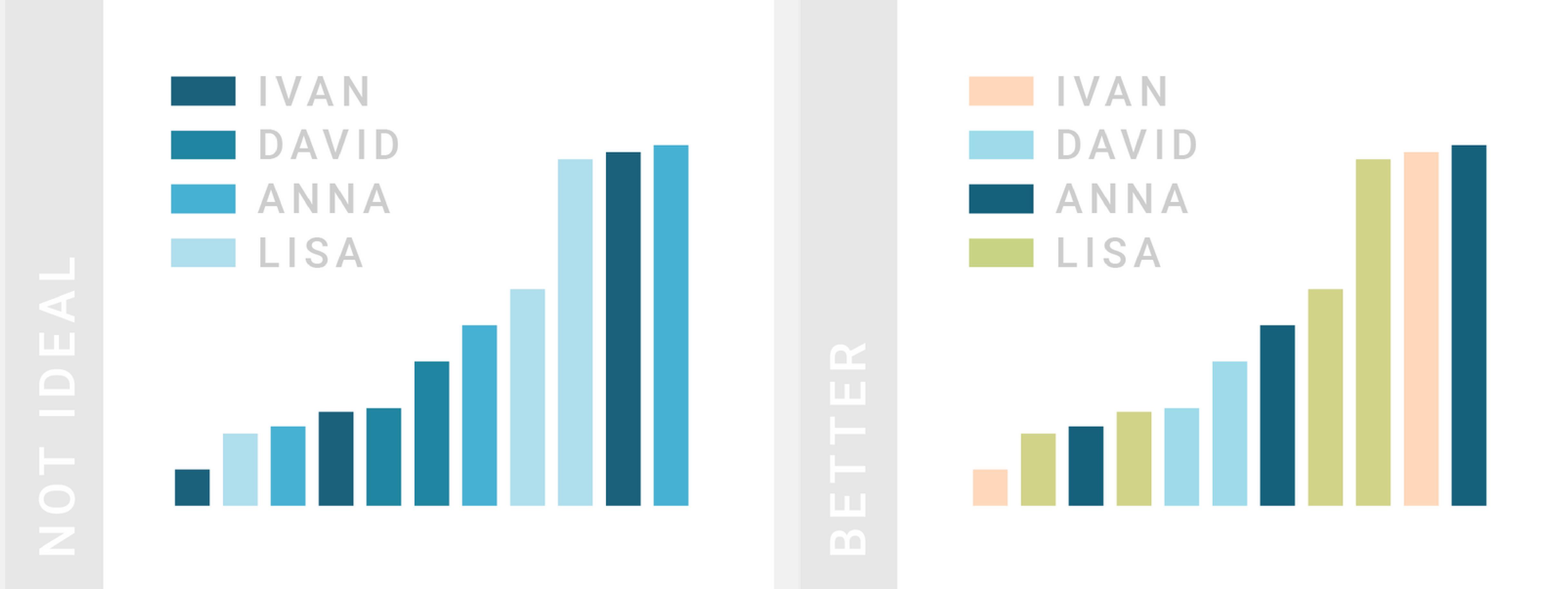
Use to encode  
**categorical information**

pick distinct colors with the same perceptual weight

limit categories to 6-8

Modified from the `{colorspace}` R package vignette

# Sequential versus Qualitative Palettes



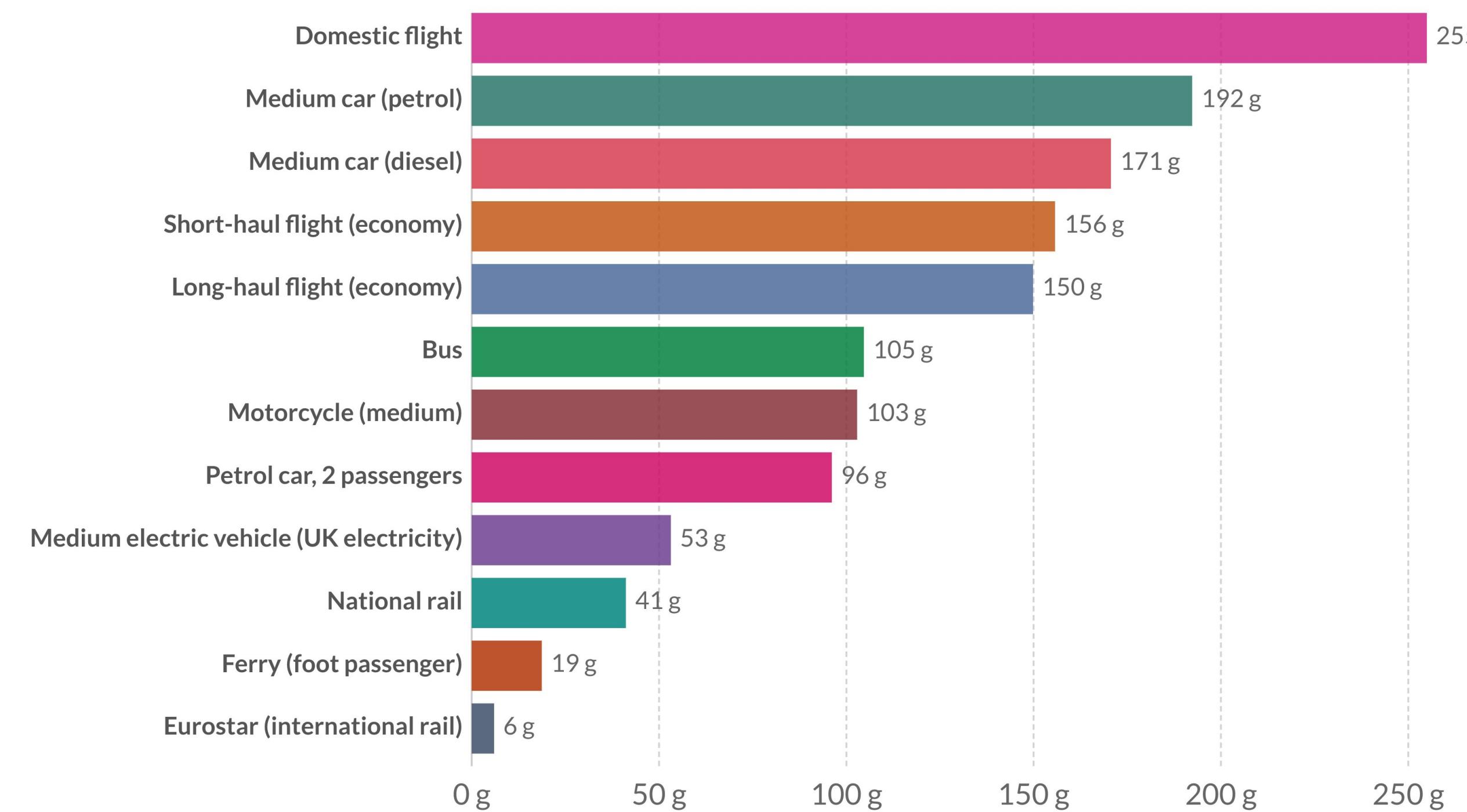
*"What to consider when choosing colors for data visualization"* by Lisa C. Muth / Datawrapper

# Use color wisely (and correctly)

## Carbon footprint of travel per kilometer, 2018

The carbon footprint of travel is measured in grams of carbon dioxide equivalents per passenger kilometer. This includes carbon dioxide, but also other greenhouse gases, and increased warming from aviation emissions at altitude.

Our World  
in Data



Source: UK Department for Business, Energy & Industrial Strategy. Greenhouse gas reporting: conversion factors 2019.  
Note: Data is based on official conversion factors used in UK reporting. These factors may vary slightly depending on the country.

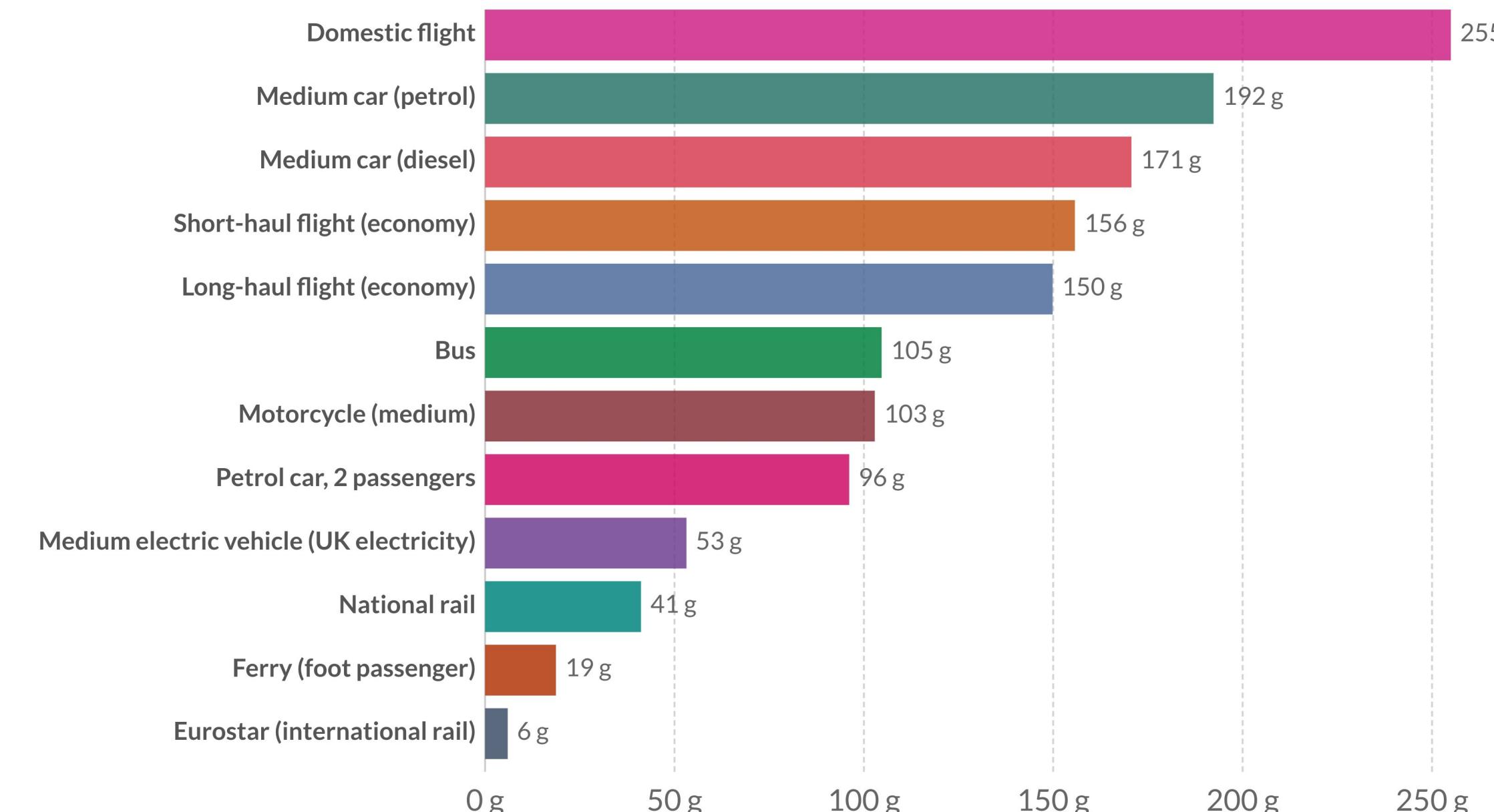
CC BY

*Original graphic with a random categorical palette*

# Use color wisely (and correctly)

Carbon footprint of travel per kilometer, 2018

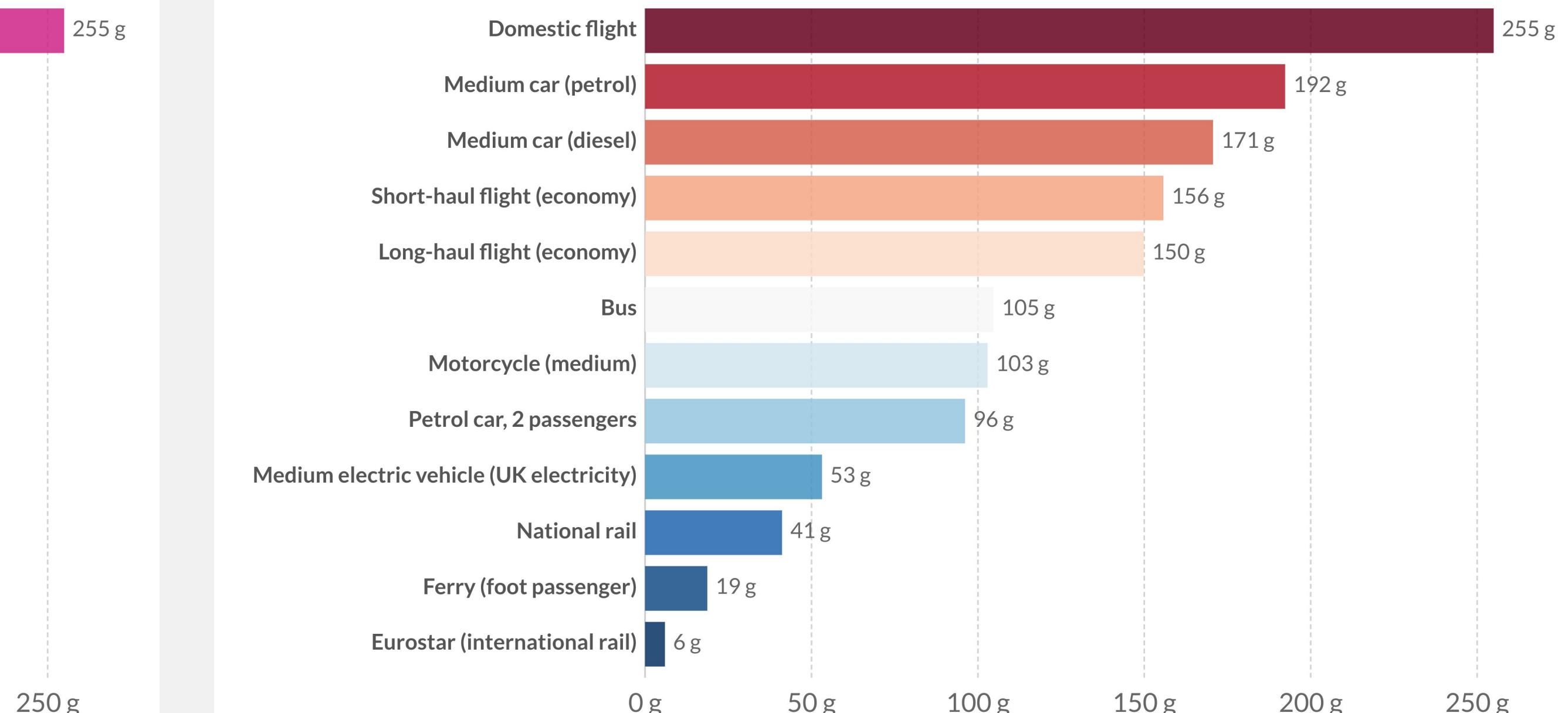
The carbon footprint of travel is measured in grams of carbon dioxide equivalents per passenger kilometer. This includes carbon dioxide, but also other greenhouse gases, and increased warming from aviation emissions at altitude.



Source: UK Department for Business, Energy & Industrial Strategy. Greenhouse gas reporting: conversion factors 2019.  
Note: Data is based on official conversion factors used in UK reporting. These factors may vary slightly depending on the country.

Carbon footprint of travel per kilometer, 2018

The carbon footprint of travel is measured in grams of carbon dioxide equivalents per passenger kilometer. This includes carbon dioxide, but also other greenhouse gases, and increased warming from aviation emissions at altitude.



Source: UK Department for Business, Energy & Industrial Strategy. Greenhouse gas reporting: conversion factors 2019.  
Note: Data is based on official conversion factors used in UK reporting. These factors may vary slightly depending on the country.

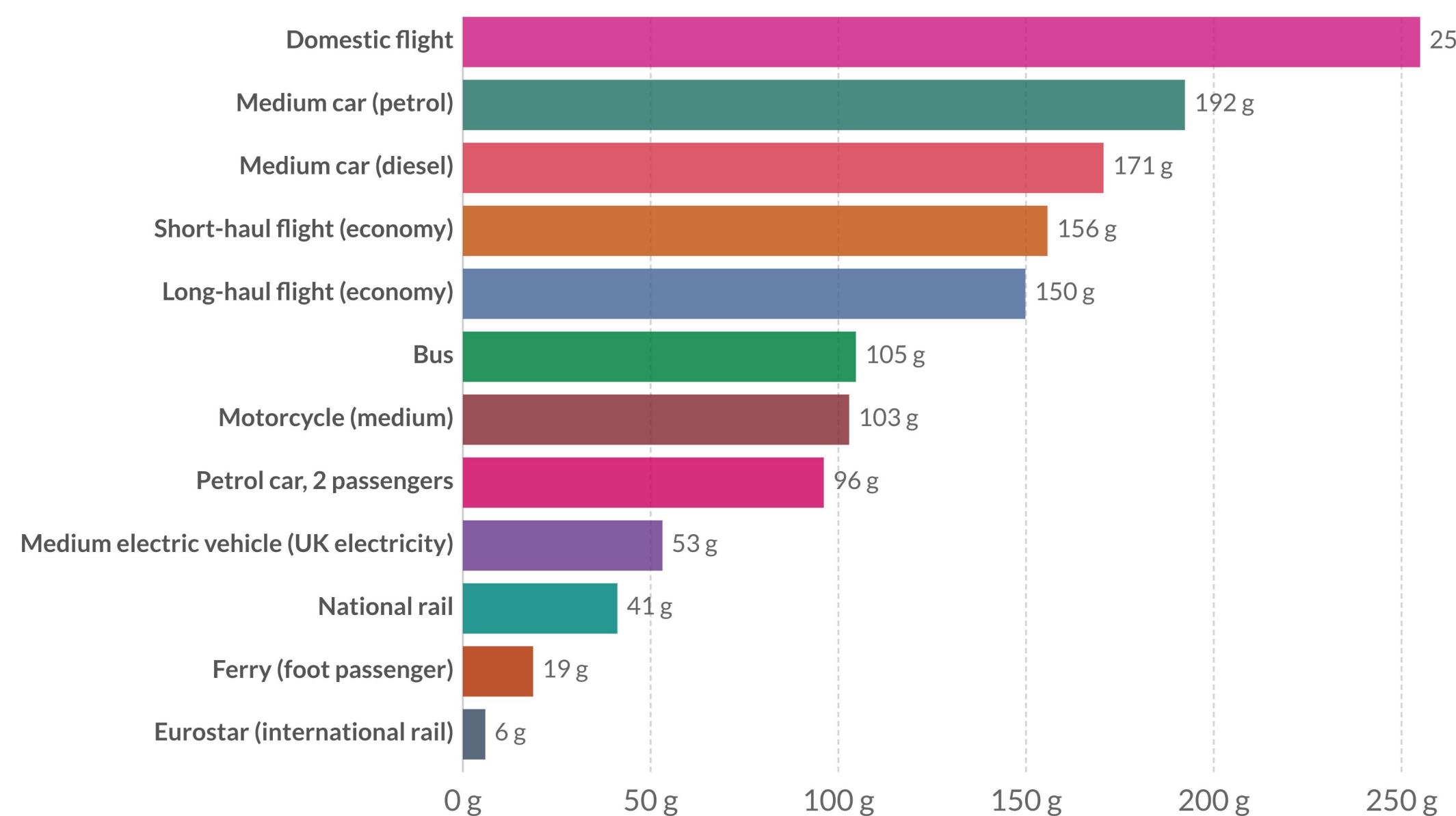
Original graphic with a random categorical palette

Reworked graphic using a diverging palette

# Use color wisely (and correctly)

## Carbon footprint of travel per kilometer, 2018

The carbon footprint of travel is measured in grams of carbon dioxide equivalents per passenger kilometer. This includes carbon dioxide, but also other greenhouse gases, and increased warming from aviation emissions at altitude.



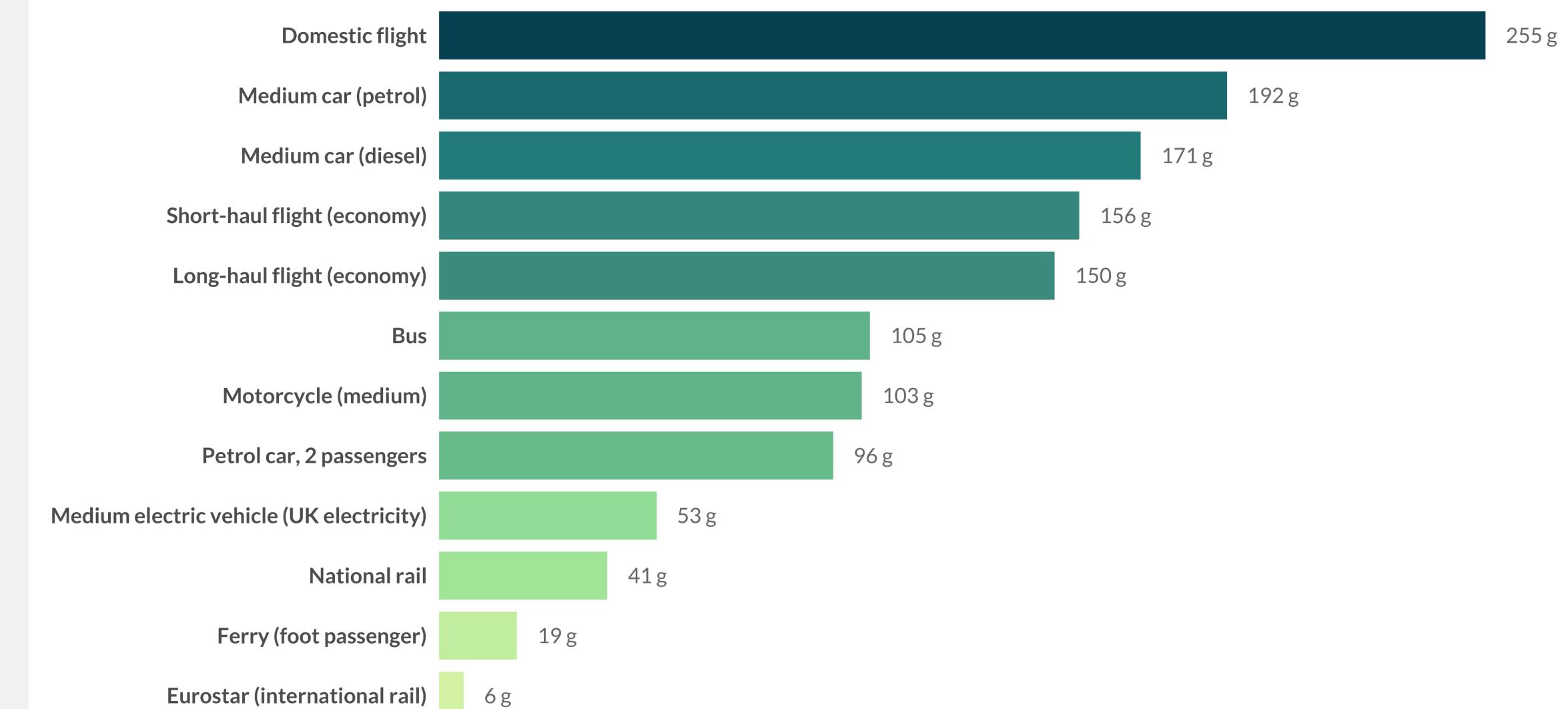
Source: UK Department for Business, Energy & Industrial Strategy. Greenhouse gas reporting: conversion factors 2019.

Note: Data is based on official conversion factors used in UK reporting. These factors may vary slightly depending on the country.

Original graphic with a random categorical palette

## Carbon footprint of travel per kilometer, 2018

The carbon footprint of travel is measured in grams of carbon dioxide equivalents per passenger kilometer. This includes carbon dioxide, but also other greenhouse gases, and increased warming from aviation emissions at altitude.



Source: UK Department for Business, Energy & Industrial Grenhouse gas reporting: conversion factors 2019.

Note: Data is based on official conversion factors used in UK reporting. These factors may vary slightly depending on the country.

Original visualization by Hannah Ritchie, OurWorldInData.org | Makeover by Cédric Scherer

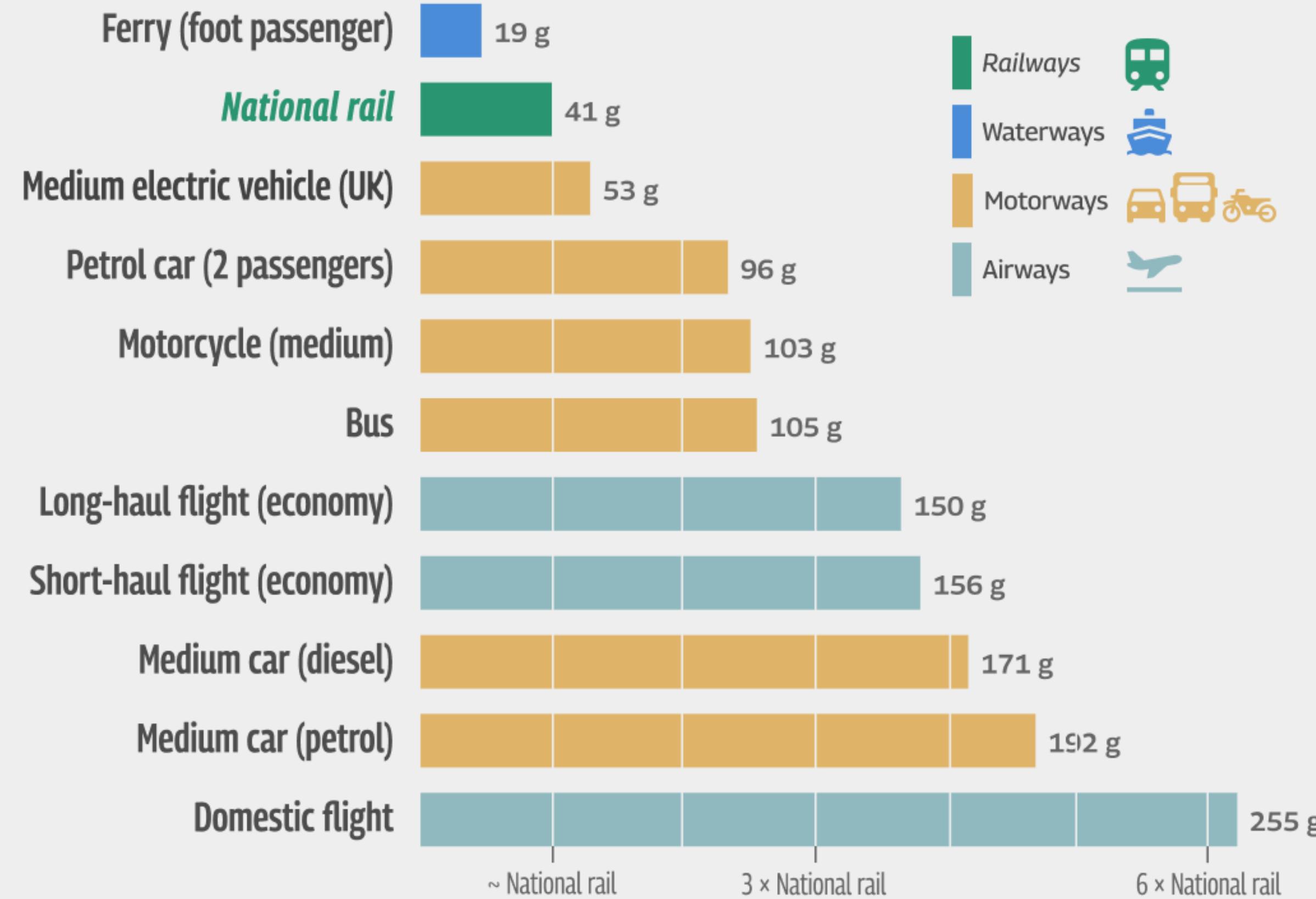
Makeover using a continuous palette

# Reduce your Carbon Footprint: *Take the Train*

It's too far to walk or go by bike? Trains are nearly always the winning option over other moderate-to-long distance transportation modes. Taking a train instead of a car for medium-length distances would cut your emissions by ~80% and by ~84% if the train ride replaces a domestic flight.

## *Eurostar (international rail)*

6 g of carbon dioxide equivalents per person and kilometer\*



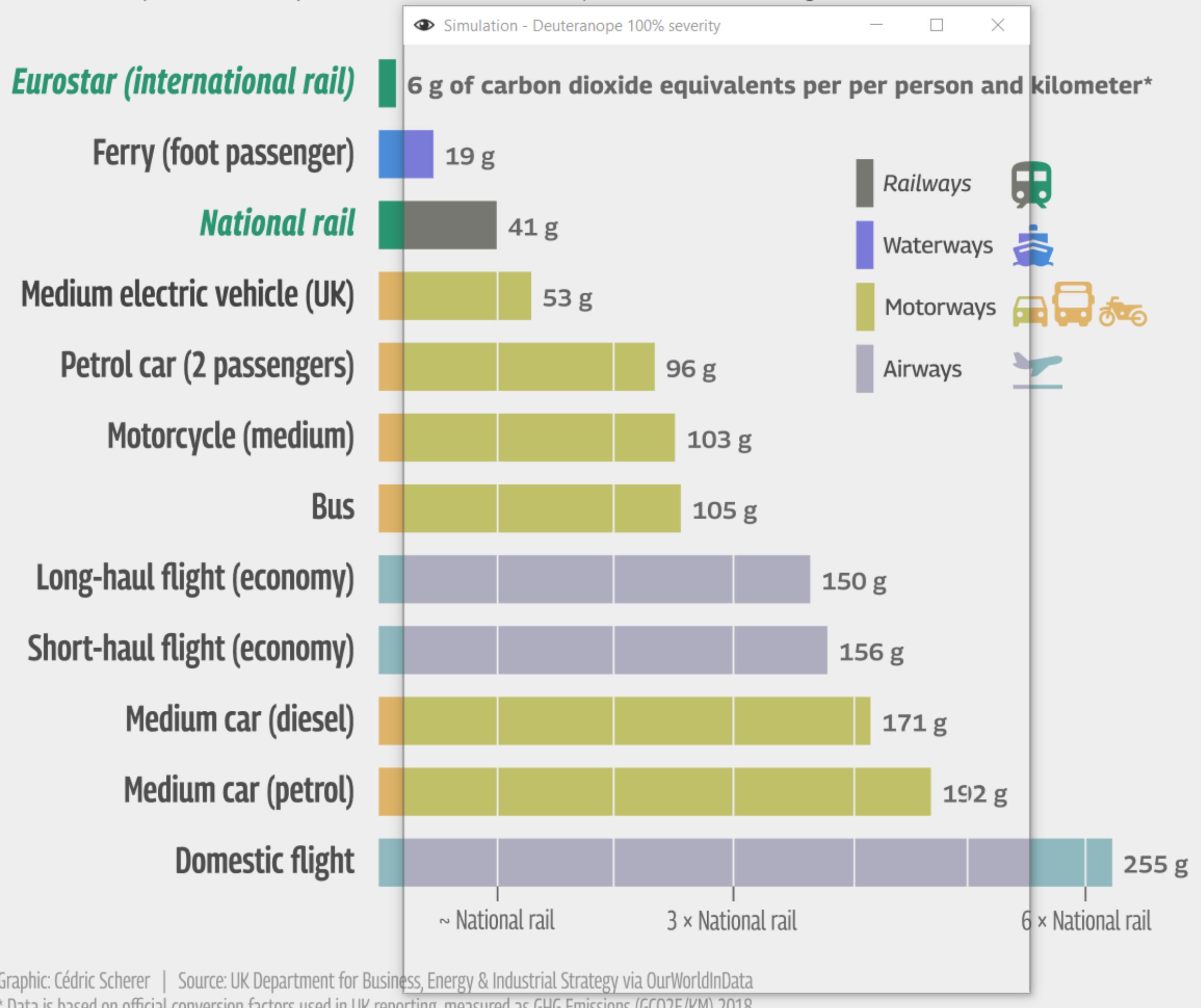
Graphic: Cédric Scherer | Source: UK Department for Business, Energy & Industrial Strategy via OurWorldInData

\* Data is based on official conversion factors used in UK reporting, measured as GHG Emissions (GCO2E/KM) 2018

Reworked graphic as contribution to the #30DayChartChallenge 2022

# Reduce your Carbon Footprint: *Take the Train*

It's too far to walk or go by bike? Trains are nearly always the winning option over other moderate-to-long distance transportation modes. Taking a train instead of a car for medium-length distances would cut your emissions by ~80% and by ~84% if the train ride replaces a domestic flight.

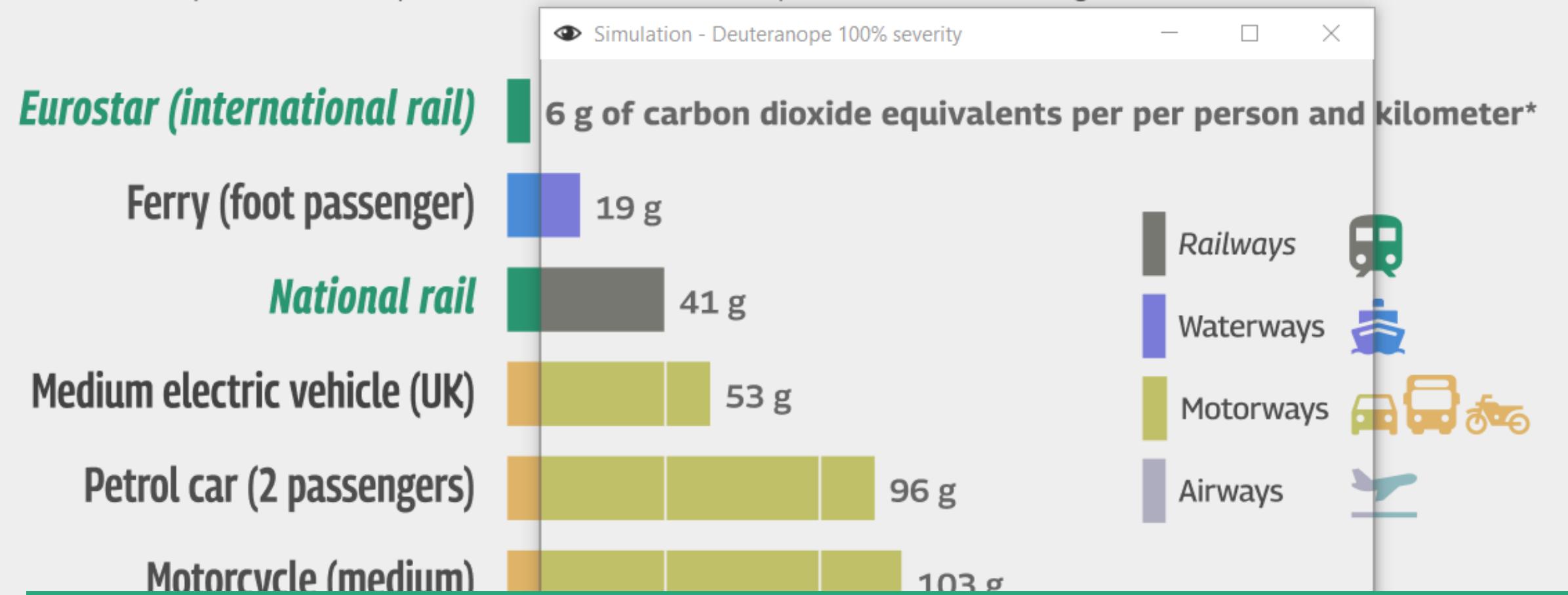


## Don't trust color palettes — test them!

Reworked graphic as contribution to the #30DayChartChallenge 2022

## Reduce your Carbon Footprint: *Take the Train*

It's too far to walk or go by bike? Trains are nearly always the winning option over other moderate-to-long distance transportation modes. Taking a train instead of a car for medium-length distances would cut your emissions by ~80% and by ~84% if the train ride replaces a domestic flight.



**Don't trust  
color palettes  
— test them!**

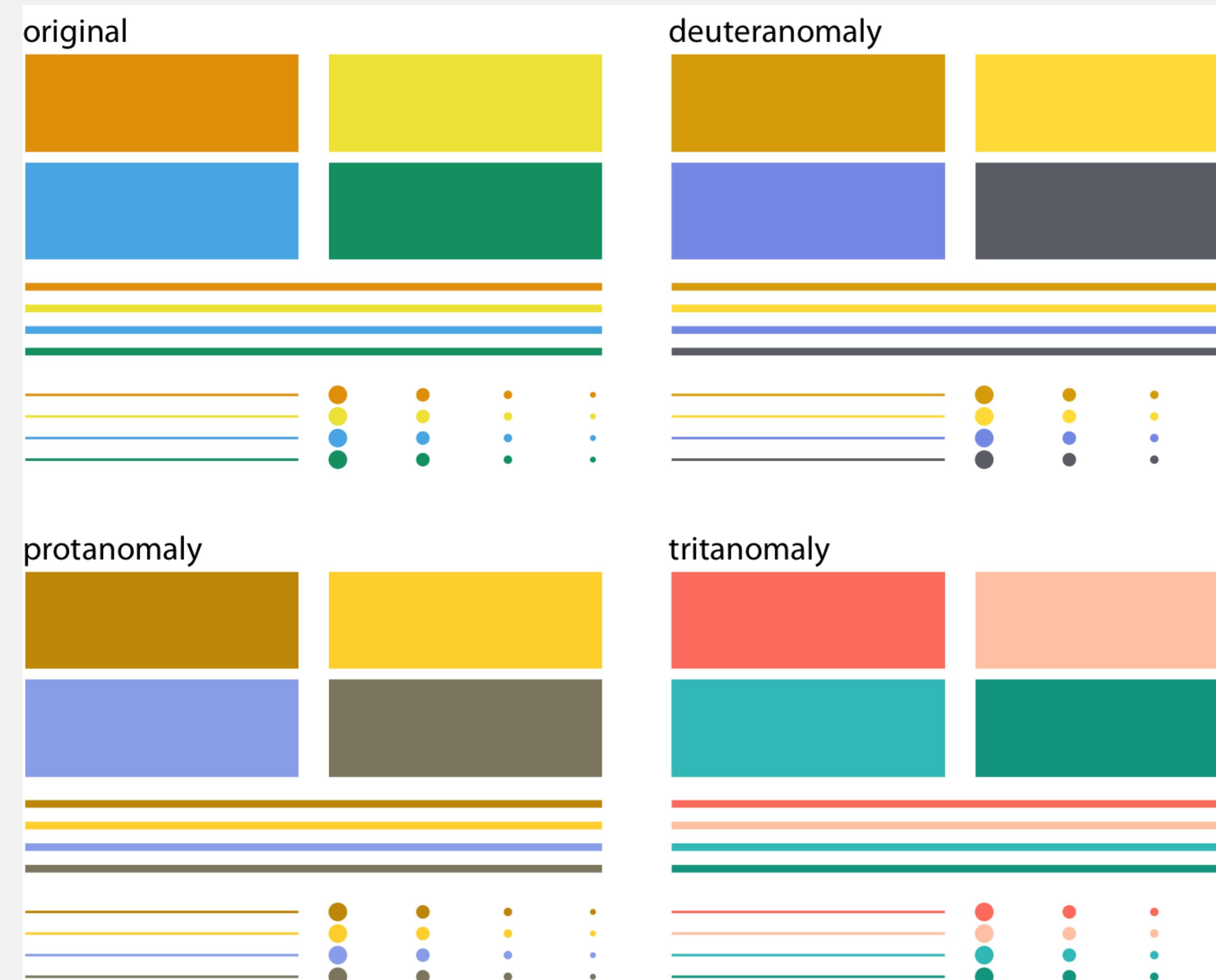
ColourSimulations  
SimDaltonims (Mac only)  
ColorFilter (for URLs)

Graphic: Cédric Scherer | Source: UK Department for Business, Energy & Industrial Strategy via OurWorldInData

\* Data is based on official conversion factors used in UK reporting, measured as GHG Emissions (GCO2E/KM) 2018

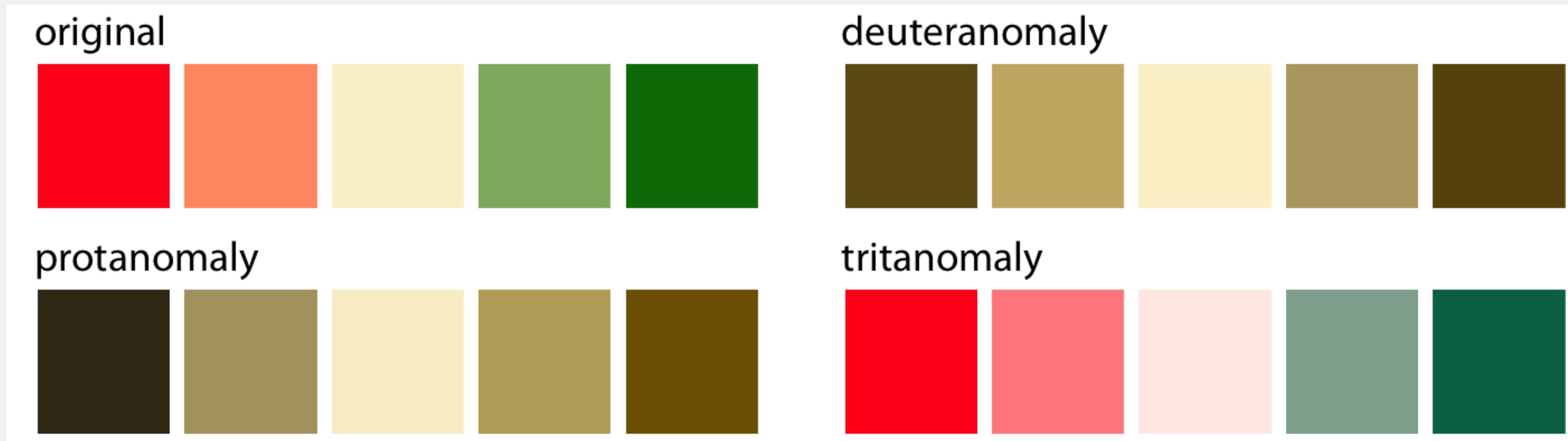
Reworked graphic as contribution to the #30DayChartChallenge 2022

# Ensure Readability for Color-Blind Persons



*“Fundamentals of Data Visualization” by Claus O. Wilke*

# Ensure Readability for Color-Blind Persons



*“Fundamentals of Data Visualization” by Claus O. Wilke*

Cédric Scherer // rstudio::conf // July 2022

# Ensure Readability for Color-Blind Persons



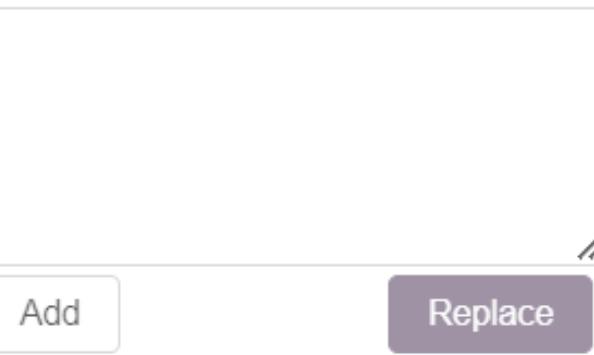
*“Fundamentals of Data Visualization” by Claus O. Wilke*

# VIZ PALETTE

By: Elijah Meeks  
& Susie Lu

## PICK

Use Chroma.js



Use Colorgorical

Use ColorBrewer

## EDIT

≡ 1 ● #2a9571 ↗

×

≡ 2 ● #8fb9bf ↗

×

≡ 3 ● #dfb468 ↗

×

≡ 4 ● #4b8cd8 ↗

×

Add

hex  rgb

hsl

## GET

String quotes  
 Object with metadata

```
[ "#2a9571",
  "#8fb9bf",
  "#dfb468",
  "#4b8cd8" ]
```

hex  rgb

hsl

# COLORS IN ACTION

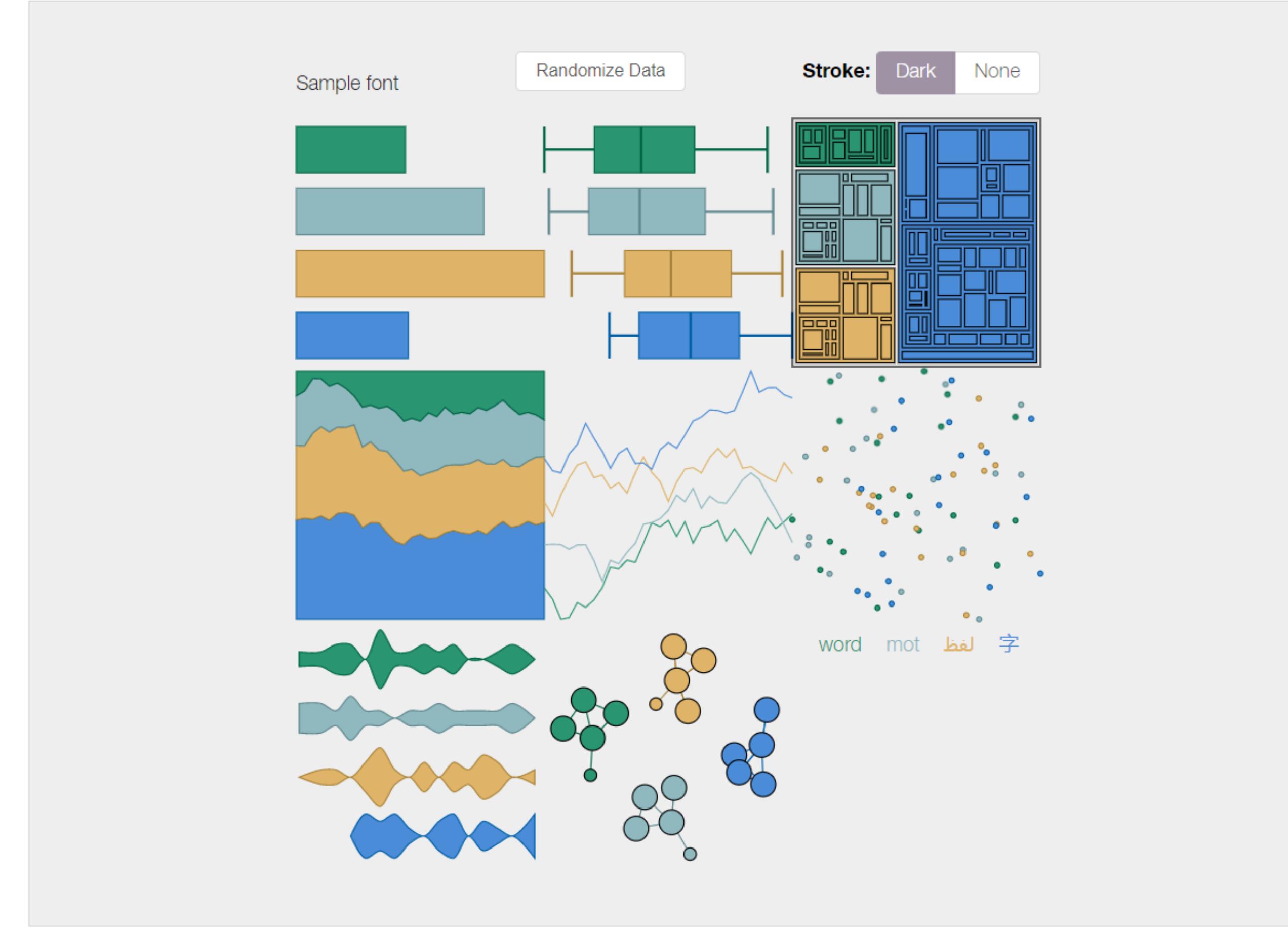
Background color: ● #eeeeee ↗

Font color: ● #212121 ↗

Charts made with [Semiotic](#)

### Color Population:

No Color Deficiency - 96% Deuteranomaly - 2.7% Protanomaly - 0.66% Protanopia - 0.59% Deuteranopia - 0.56% Greyscale



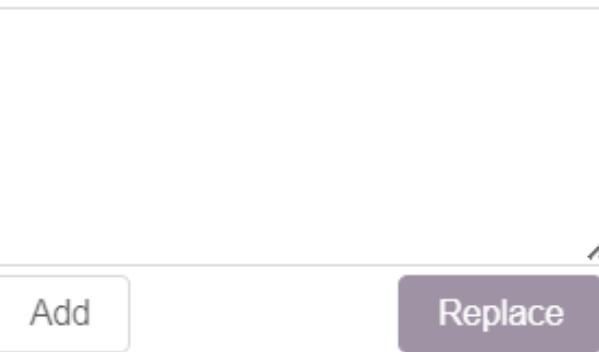
*Viz Palette displaying the “colors in action” without color deficiency*

# VIZ PALETTE

By: Elijah Meeks  
& Susie Lu

## PICK

Use Chroma.js



Use Colorgorical

Use ColorBrewer

## EDIT

- ≡ 1 ● #2a9571 [🔗](#) x
- ≡ 2 ● #8fb9bf [🔗](#) x
- ≡ 3 ● #dfb468 [🔗](#) x
- ≡ 4 ● #4b8cd8 [🔗](#) x

hex  rgb

hsl

## GET

String quotes  
 Object with metadata

```
[ "#2a9571",
  "#8fb9bf",
  "#dfb468",
  "#4b8cd8" ]
```

hex  rgb

hsl

# COLORS IN ACTION

Background color: #eeeeee [🔗](#)

Font color: ● #212121 [🔗](#)

Charts made with [Semiotic](#)

### Color Population:

No Color Deficiency - 96% Deuteranomaly - 2.7% Protanomaly - 0.66% Protanopia - 0.59% Deuteranopia - 0.56% Greyscale



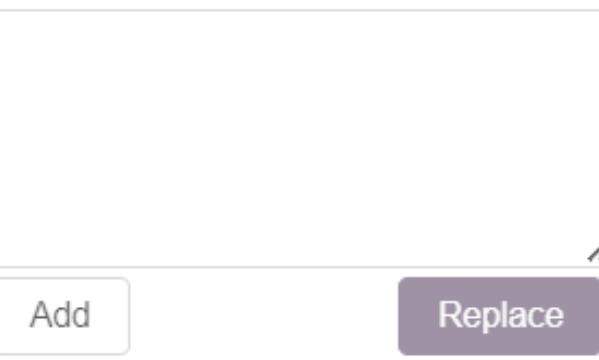
*Viz Palette* displaying the “colors in action” with deuteranopia

# VIZ PALETTE

By: Elijah Meeks  
& Susie Lu

## PICK

Use Chroma.js



Use Colorgorical

Use ColorBrewer

## EDIT

4 Colors

- ≡ 1 ● #2a9571 ↗ ×
- ≡ 2 ● #8fb9bf ↗ ×
- ≡ 3 ● #dfb468 ↗ ×
- ≡ 4 ● #4b8cd8 ↗ ×

hex  rgb

hsl

## GET

hex  rgb

hsl

String quotes  
 Object with metadata

```
[ "#2a9571",
  "#8fb9bf",
  "#dfb468",
  "#4b8cd8" ]
```

Background color:   ↗

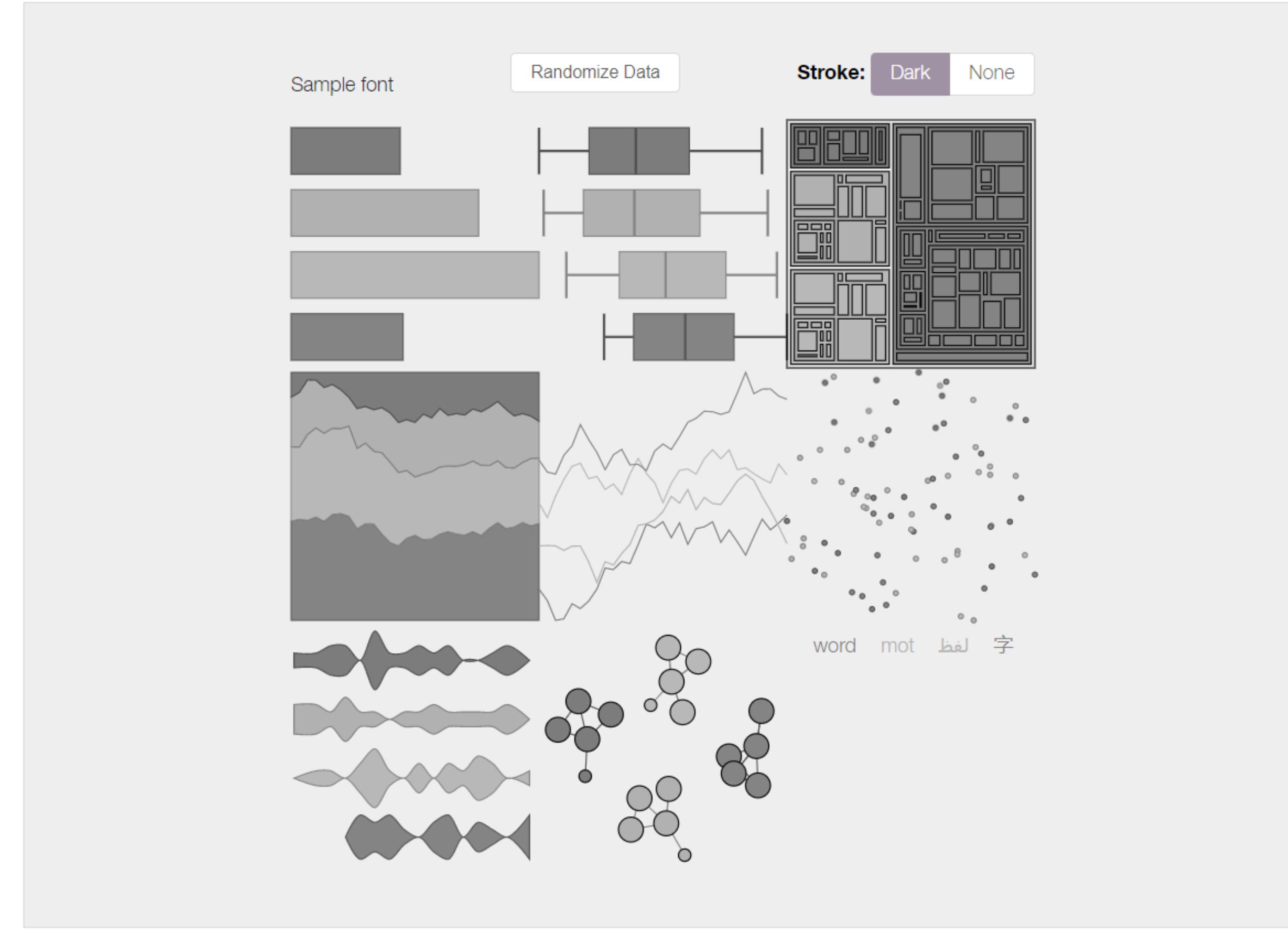
Font color: ● ↗

Charts made with [Semiotic](#)

# COLORS IN ACTION

## Color Population:

No Color Deficiency - 96% Deuteranomaly - 2.7% Protanomaly - 0.66% Protanopia - 0.59% Deuteranopia - 0.56% Greyscale



*Viz Palette displaying the “colors in action” with a greyscale*

# VIZ PALETTE

By: Elijah Meeks  
& Susie Lu

## PICK

Use Chroma.js

Use Colorgorical

Use ColorBrewer

## EDIT

- ≡ 1 ● #2a9571 [🔗](#)
- ≡ 2 ● #8fb9bf [🔗](#)
- ≡ 3 ● #dfb468 [🔗](#)
- ≡ 4 ● #4b8cd8 [🔗](#)

#hex  orgb

hsl

## GET

String quotes  
 Object with metadata

```
[ "#2a9571",
  "#8fb9bf",
  "#dfb468",
  "#4b8cd8" ]
```

hsl

# COLORS IN ACTION

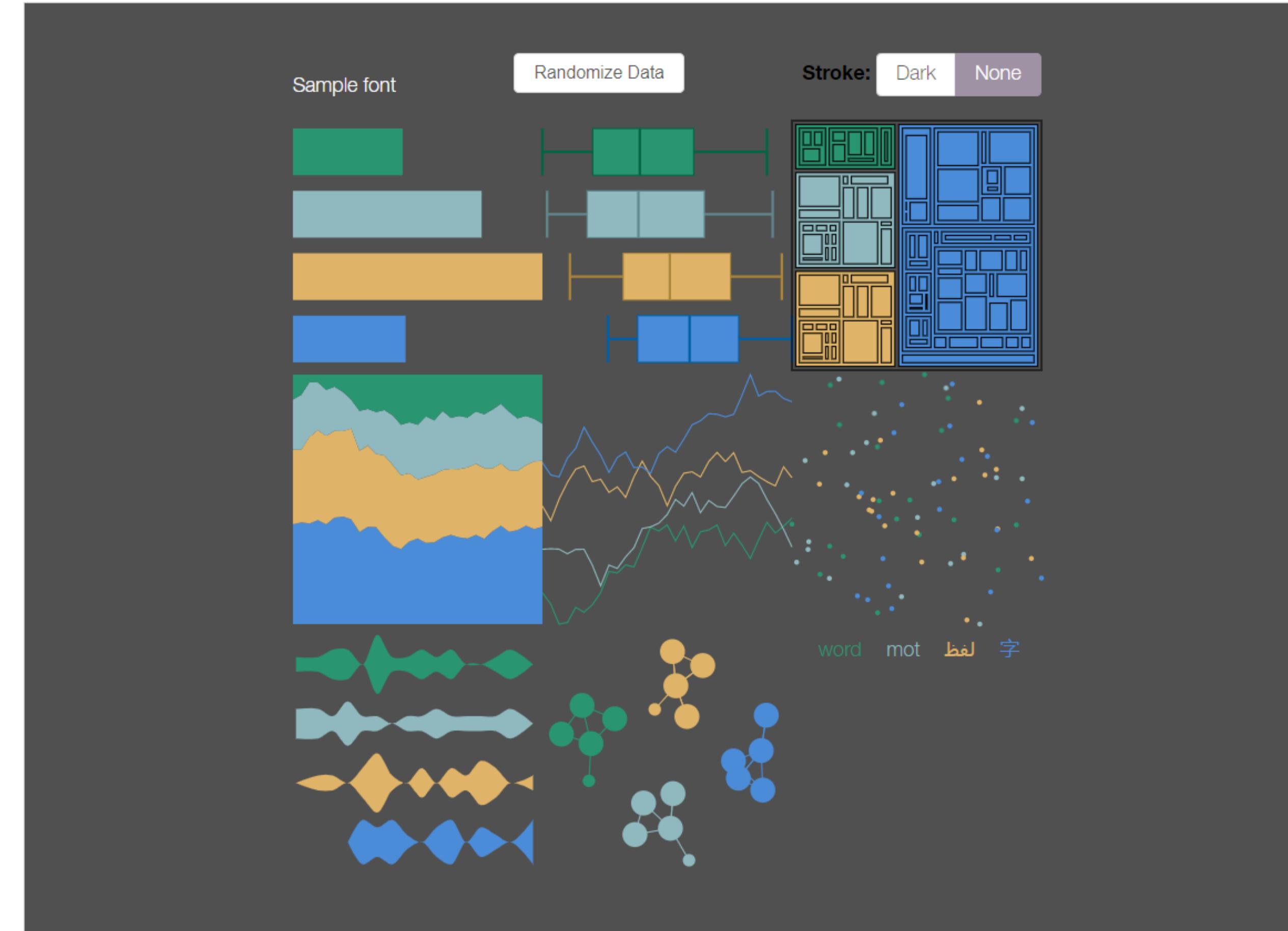
Background color: ● #505050 [🔗](#)

Font color: #fefefe [🔗](#)

Charts made with [Semiotic](#)

### Color Population:

No Color Deficiency - 96% Deuteranomaly - 2.7% Protanomaly - 0.66% Protanopia - 0.59% Deuteranopia - 0.56% Greyscale

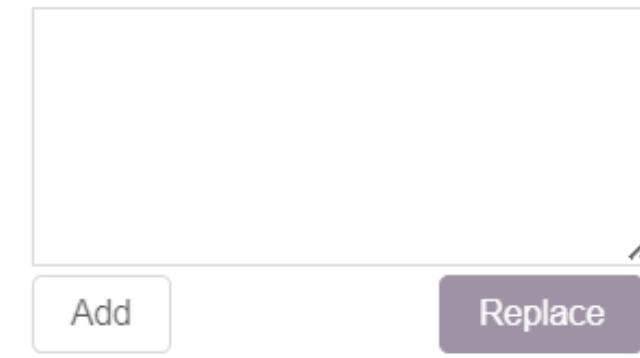


*Viz Palette displaying the same “colors in action” on a dark background*

# VIZ PALETTE

By: Elijah Meeks  
& Susie Lu

## PICK



Use Chroma.js

Add

Replace

Use Colorgorical

Use ColorBrewer

## EDIT

- ≡ 1 ● #2a9571 ↗ ×
- ≡ 2 ● #8fb9bf ↗ ×
- ≡ 3 ● #dfb468 ↗ ×
- ≡ 4 ● #4b8cd8 ↗ ×

hex  rgb

hsl

## GET

String quotes  
 Object with metadata

```
[ "#2a9571",
  "#8fb9bf",
  "#dfb468",
  "#4b8cd8" ]
```

hex  rgb

hsl

# COLORS IN ACTION

Background color: ● #eeeeee ↗

Font color: ● #212121 ↗

Charts made with [Semiotic](#)

### Color Population:

No Color Deficiency - 96% Deuteranomaly - 2.7% Protanomaly - 0.66% Protanopia - 0.59% Deuteranopia - 0.56% Greyscale

Sample font

Randomize Data

Stroke:  Dark  None



# COLOR REPORT

No color conflicts

#dfb468  
#2a9571

light orange  
teal  
light blue  
blue

No color name conflicts

*Viz Palette also checks if there is conflicts in colors and color names*

# APCA CONTRAST CALCULATOR

Click

TEXT COLOR

APCA CONTRAST

Lc 93.0

Click To Swap

#212121 • rgb(33,33,33)

BACKGROUND

eeeeeee

#eee • rgb(238,238,238)

All Font Sizes are in CSS px • Fonts Under 80px Shown With Colors at Actual Size & Weight

LEVEL

200 300 • Light 400 • Normal 500 600 700 • Bold

4

29px Sample

21px  
the lazy grey dog slept as the  
frisky fox frolicked freely in the  
field of grass without a care in  
the world, wondering if the dog  
would ever wake up so they could  
have another nap.

15px  
the lazy grey dog slept as the  
frisky fox frolicked freely in the  
field of grass without a care in  
the world, wondering if the dog  
would ever wake up so they could  
have another nap.

14.5px  
the lazy grey dog slept as the  
frisky fox frolicked freely in the  
field of grass without a care in  
the world, wondering if the dog  
would ever wake up so they could  
have another nap.

14px MIN  
the lazy grey dog slept as the  
frisky fox frolicked freely in the  
field of grass without a care in  
the world, wondering if the dog  
would ever wake up so they could  
have another nap.

14px MINIMUM SIZE  
the lazy grey dog slept as the  
frisky fox frolicked freely in the  
field of grass without a care in  
the world, wondering if the dog  
would ever wake up so they could  
have another nap.

The [Myndex APCA Contrast Calculator](#) displays modern contrast ratios for various combinations of text size and font weight

# APCA CONTRAST CALCULATOR

TEXT COLOR **4d4d4d** #4d4d4d • rgb(77,77,77)

APCA CONTRAST **Lc 79.0** Click To Swap

BACKGROUND **eeeeee** #eee • rgb(238,238,238)

All Font Sizes are in CSS px · Fonts Under 80px Shown With Colors at Actual Size & Weight

LEVEL 200 300 • Light 400 • Normal 500 600 700 • Bold

4 34px Samp 23.5px the lazy grey dog slept as frisky fox frolicked freely field of grass without a care in the world, wondering if they would ever wake up so they could ever

17.5px the lazy grey dog slept as frisky fox frolicked freely field of grass without a care in the world, wondering if they would ever wake up so they could ever

16.5px the lazy grey dog slept as frisky fox frolicked freely field of grass without a care in the world, wondering if they would ever wake up so they could ever

15px the lazy grey dog slept as frisky fox frolicked freely field of grass without a care in the world, wondering if they would ever wake up so they could ever

14px the lazy grey dog slept as the frisky fox frolicked freely in the field of grass without a care in the world, wondering if the dog would ever wake up so they could ever

The [Myndex APCA Contrast Calculator](#) displays modern contrast ratios for various combinations of text size and font weight

# APCA CONTRAST CALCULATOR

TEXT COLOR **979494**  
#979494 • rgb(151,148,148)

APCA CONTRAST **Lc 46.7**  
Click To Swap

BACKGROUND **eeeeee**  
#eee • rgb(238,238,238)

All Font Sizes are in CSS px · Fonts Under 80px Shown With Colors at Actual Size & Weight

LEVEL 200 300 • Light 400 • Normal 500 600 700 • Bold

4 67px 48px Sample T 34px Sample Text 27px Sample 23px the lazy dog slept frisky fox frolicked free field of grass without

19.5px the lazy grey dog slept frisky fox frolicked free field of grass without

The [Myndex APCA Contrast Calculator](#) displays modern contrast ratios for various combinations of text size and font weight

# APCA CONTRAST CALCULATOR

TEXT COLOR **8fb9bf** #8fb9bf • rgb(143,185,191)

APCA CONTRAST **Lc 31.7** Click To Swap

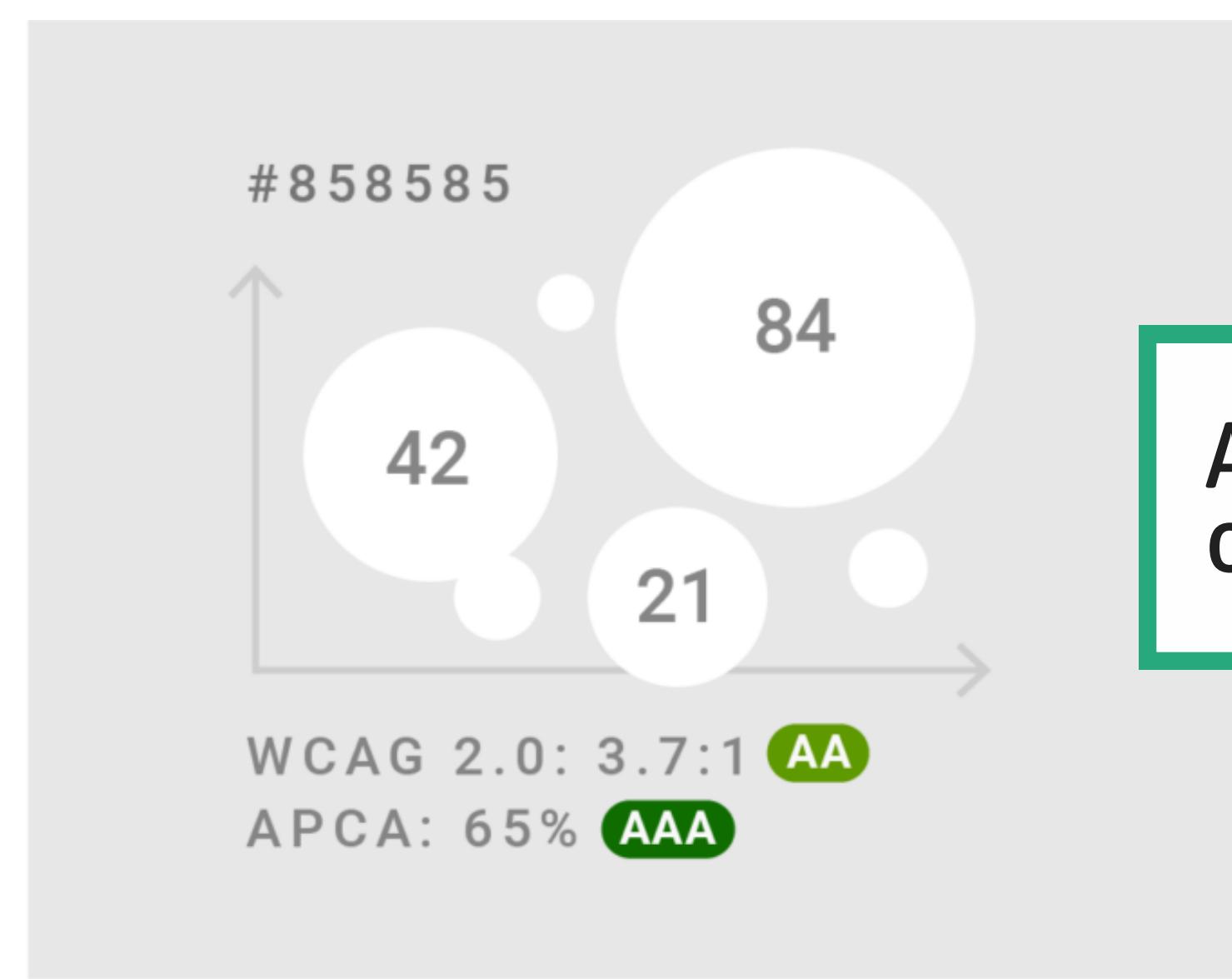
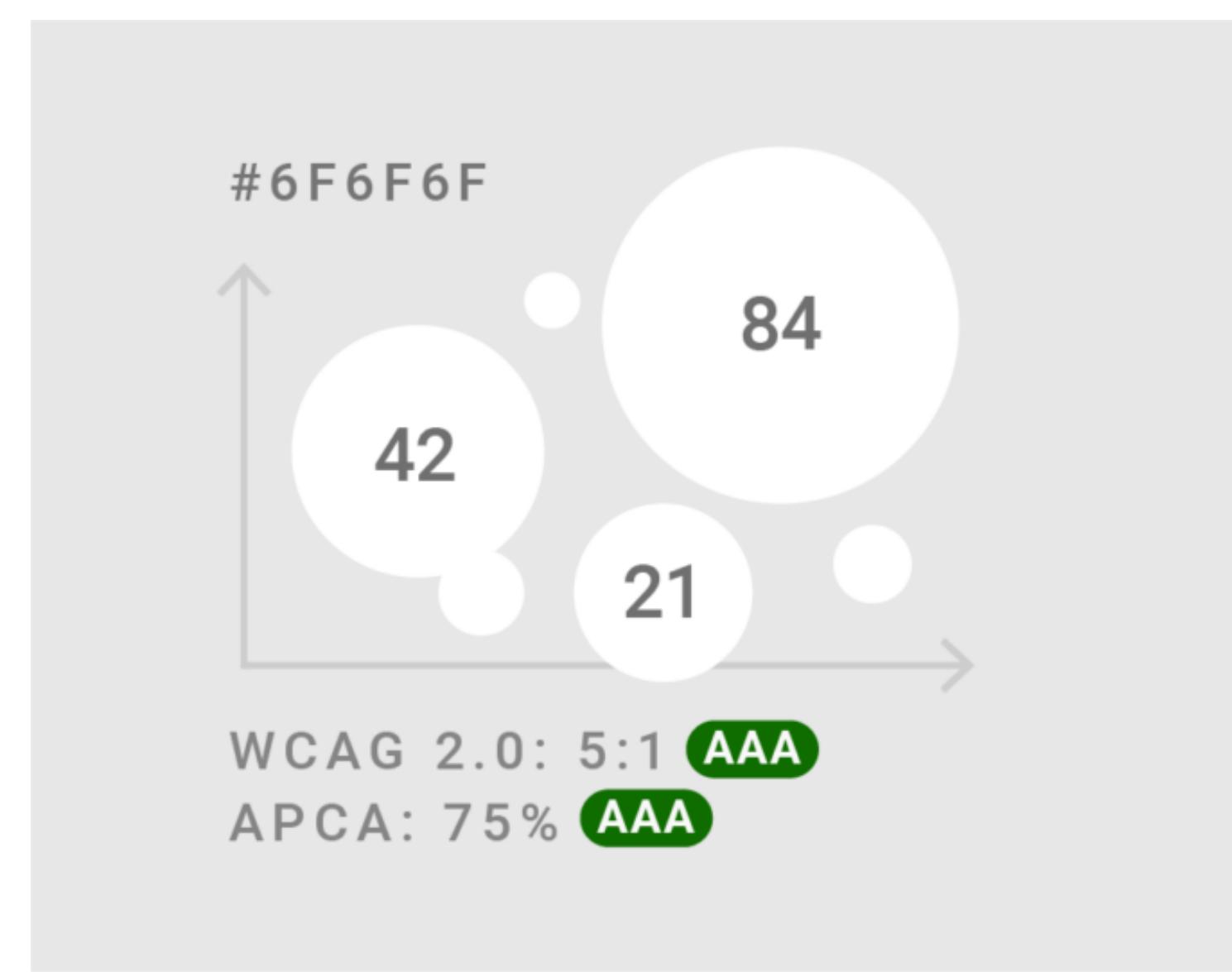
BACKGROUND **eeeeee** #eee • rgb(238,238,238)

All Font Sizes are in CSS px · Fonts Under 80px Shown With Colors at Actual Size & Weight

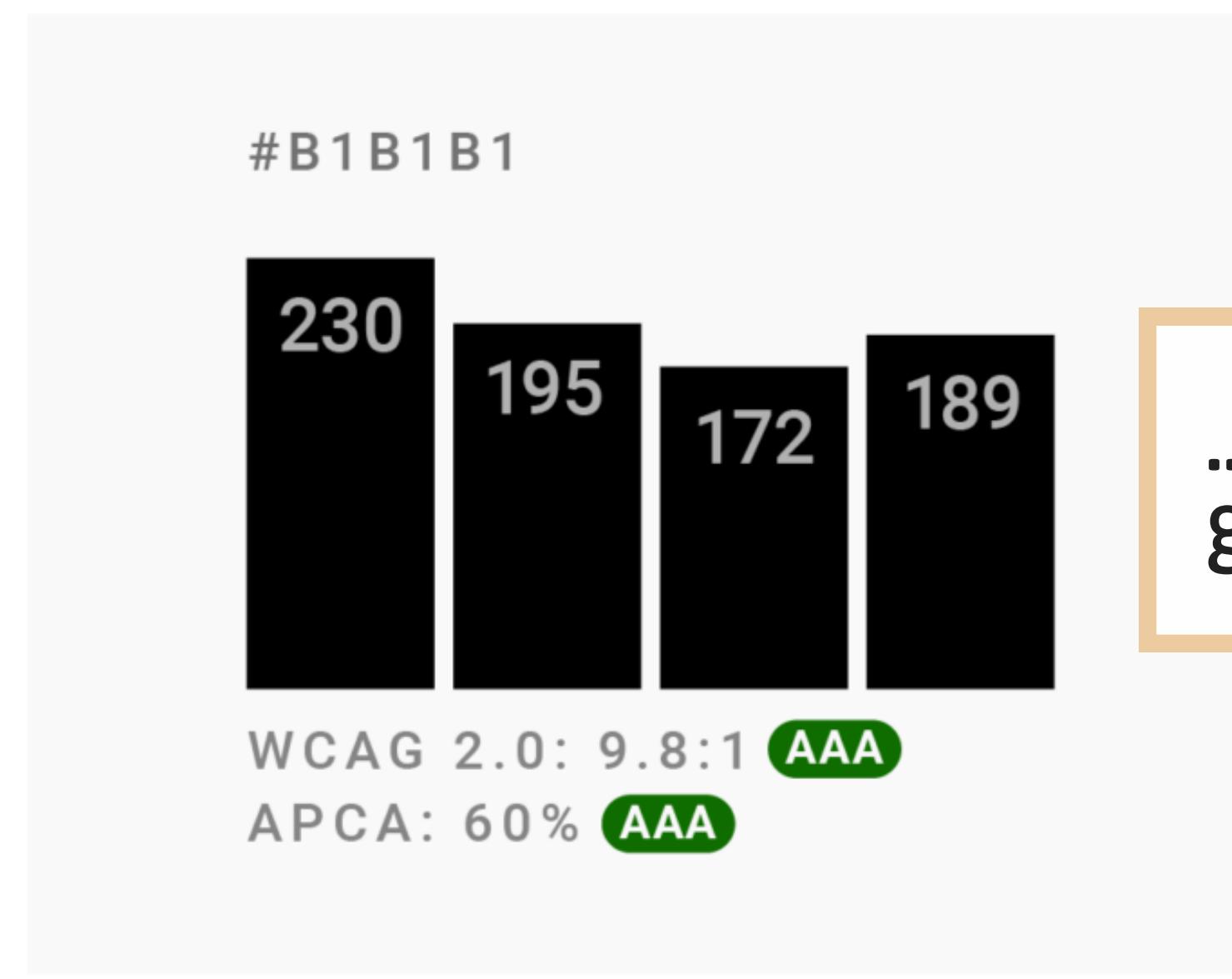
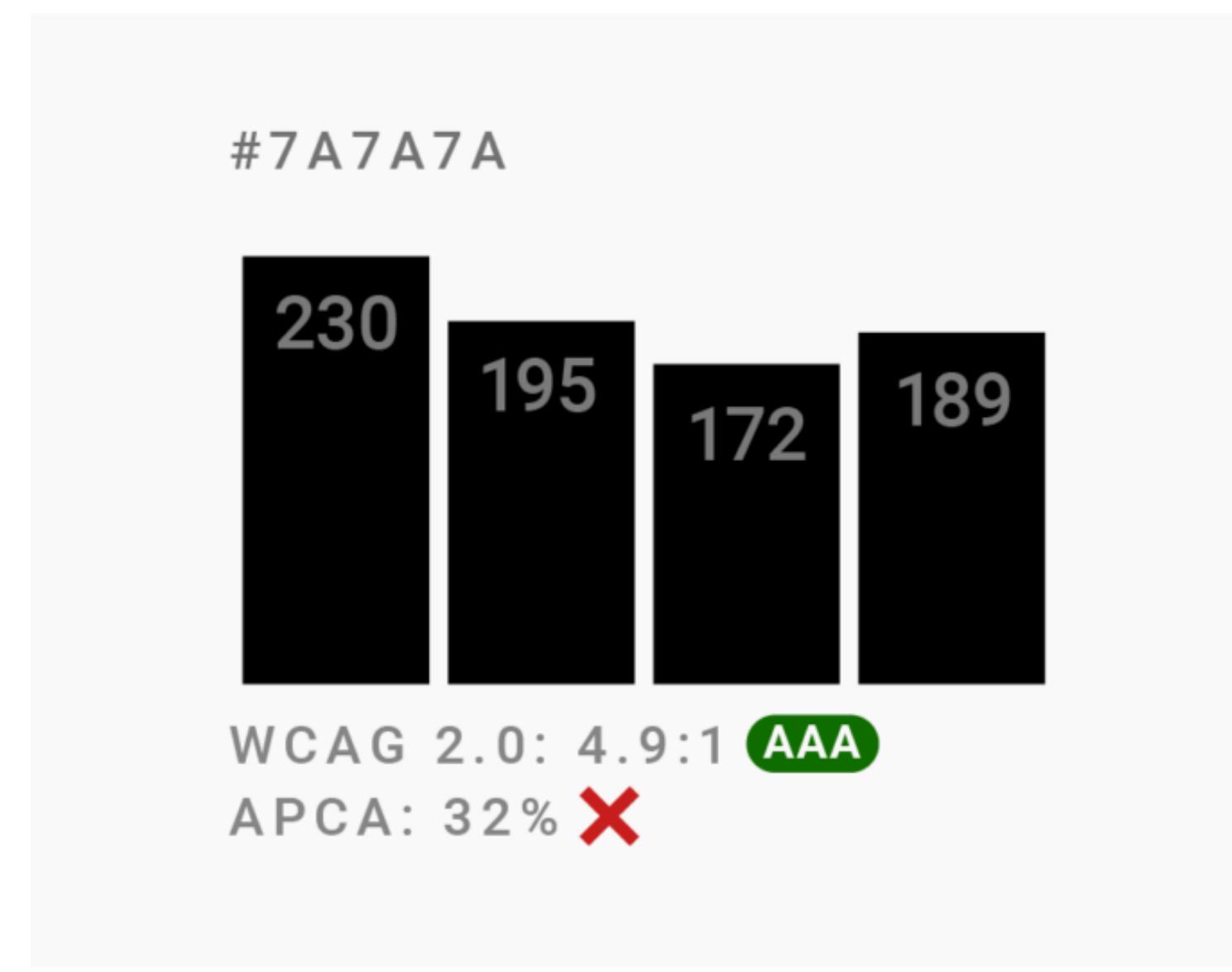
LEVEL 200 300 • Light 400 • Normal 500 600 700 • Bold

4 N 111 86px 61p 52p 43px Sample Te

The [Myndex APCA Contrast Calculator](#) displays modern contrast ratios for various combinations of text size and font weight



APCA allows for lighter grey on light backgrounds...



... but also requests lighter grey on dark backgrounds

*"It's time for a more sophisticated color contrast check for data visualizations"* by Lisa C. Muth /

DataWrapper

Cédric Scherer // rstudio::conf // July 2022

[Med Phys.](#) 2015 Jun; 42(6): 2942–2954. Published online 2015 May 20. doi: [10.1118/1.4921125](https://doi.org/10.1118/1.4921125)

PMCID: PMC5148121 | PMID: [26127048](https://pubmed.ncbi.nlm.nih.gov/26127048/)

## Effect of color visualization and display hardware on the visual assessment of pseudocolor medical images

Silvina Zabala-Travers, Mina Choi, Wei-Chung Cheng, and Aldo Badano<sup>a)</sup>

10 March 2017

## Interpretation of the rainbow color scale for quantitative medical imaging: perceptually linear color calibration (CSDF) versus DICOM GSDF

[Frédérique Chesterman](#), [Hannah Manssens](#), [Céline Morel](#), [Guillaume Serrell](#), [Bastian Piepers](#), [Tom Kimpe](#)

[Author Affiliations +](#)

[Proceedings Volume 10136, Medical Imaging 2017: Image Perception, Observer Performance, and Technology Assessment; 101360R \(2017\)](#) <https://doi.org/10.1117/12.2253885>

Event: [SPIE Medical Imaging](#), 2017, Orlando, Florida, United States

*IEEE Computer Graphics and Applications*

## Rainbow Color Map (Still) Considered Harmful

March/April 2007, pp. 14-17, vol. 27

DOI Bookmark: [10.1109/MCG.2007.46](https://doi.org/10.1109/MCG.2007.46)

Authors

David Borland, University of North Carolina at Chapel Hill

Russell M. Taylor II, University of North Carolina at Chapel Hill

Education and communication

Rainbow color map distorts and misleads research in hydrology – guidance for better visualizations and science communication

Michael Stoelze<sup>1</sup> and Lina Stein<sup>2</sup>

<sup>1</sup>Faculty of Environment and Natural Resources, University of Freiburg, Freiburg, Germany

<sup>2</sup>Department of Civil Engineering, University of Bristol, Bristol, UK

[Med Phys.](#) 2015 Jun; 42(6): 2942–2954. Published online 2015 May 20. doi: [10.1118/1.4921125](https://doi.org/10.1118/1.4921125)

PMCID: PMC5148121 | PMID: [26127048](#)

Effect of color visualization and display hardware on the visual assessment of pseudocolor medical images

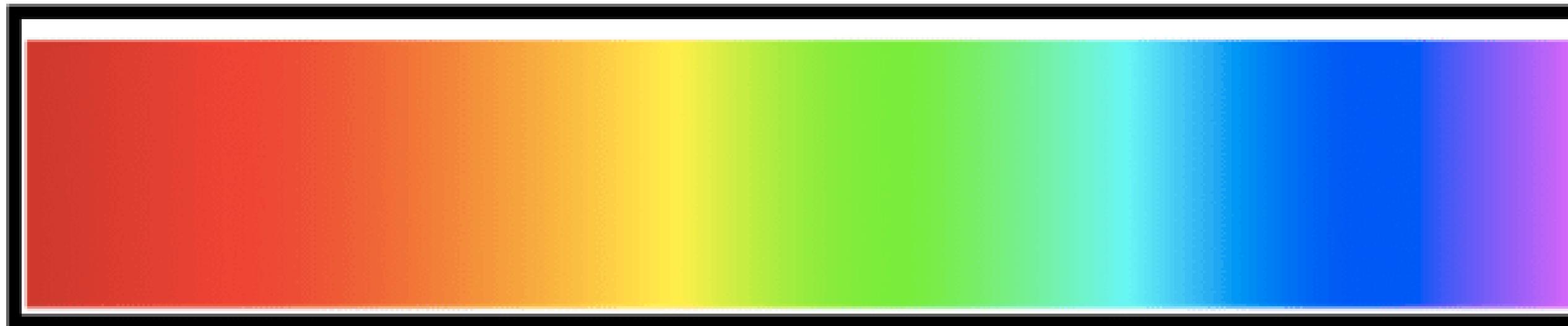
[Silvina Zabala-Travers](#), [Mina Choi](#), [Wei-Chung Cheng](#), and [Aldo Badano<sup>a\)</sup>](#)

**“The ad hoc manner in which color is handled and the lack of standard approaches have been associated with suboptimal and inconsistent diagnostic decisions with a negative impact on patient treatment and prognosis.”**

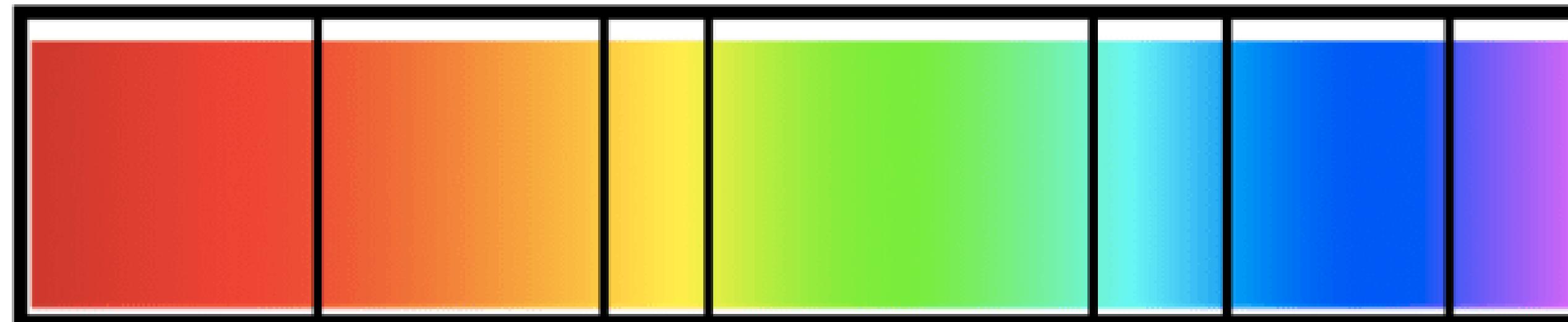
*Zabala-Travers, Choi, Cheng & Badano 2015 Med Phys.*

# Non-Uniform Distances between Hues in the Newton Rainbow Colormap

Red      Orange      Yellow      Green      Blue      Indigo      Purple



Typical Rainbow Colormap

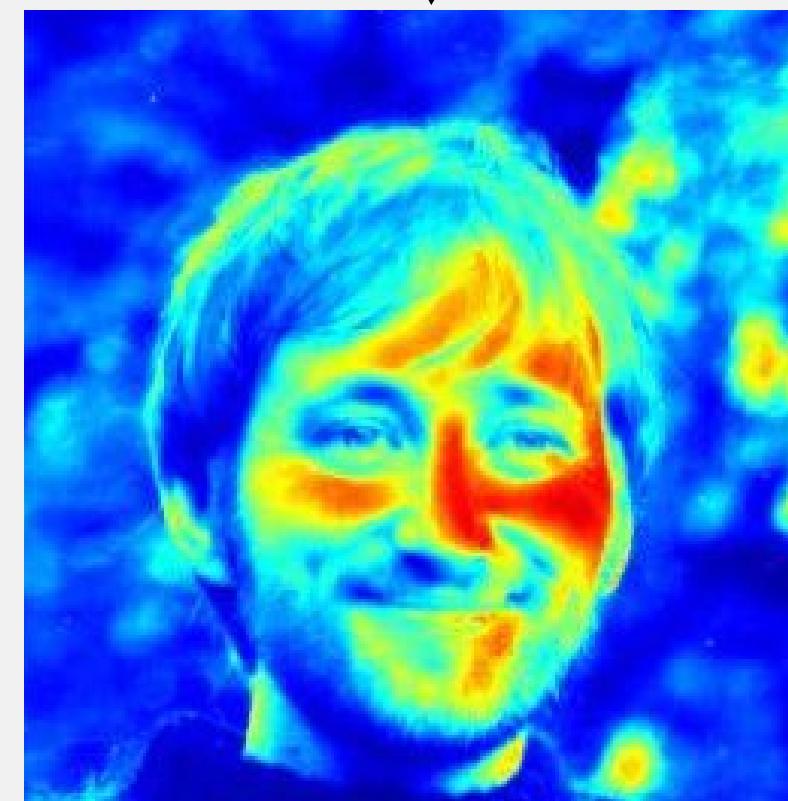


Non-Uniform Distances between Hues.

*Modified from [Fabio Cramer](#)*



**true-color Phil**



**rainbow Phil**

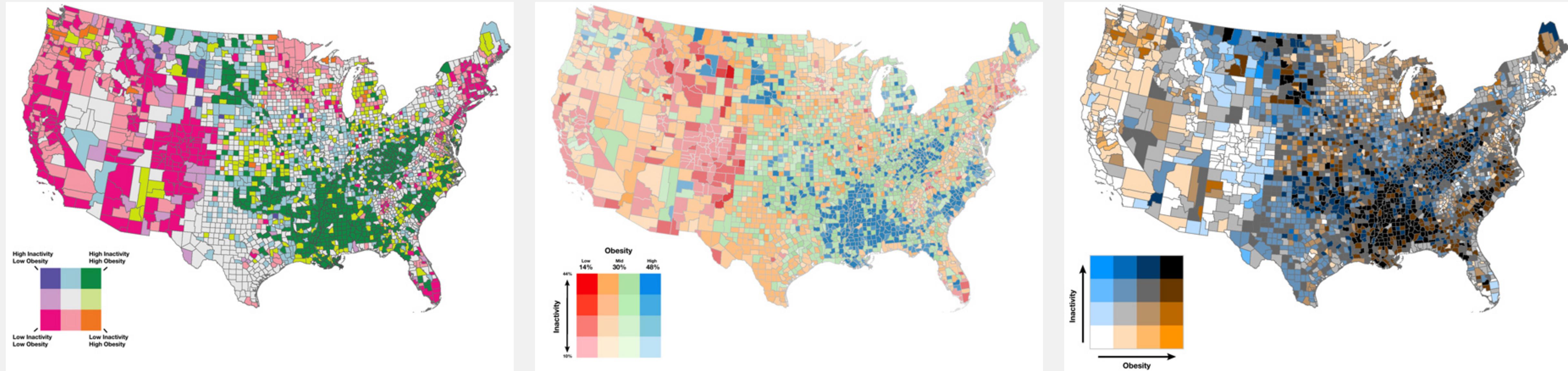


**batlow Phil**

*Modified from [Fabio Cramer](#)*

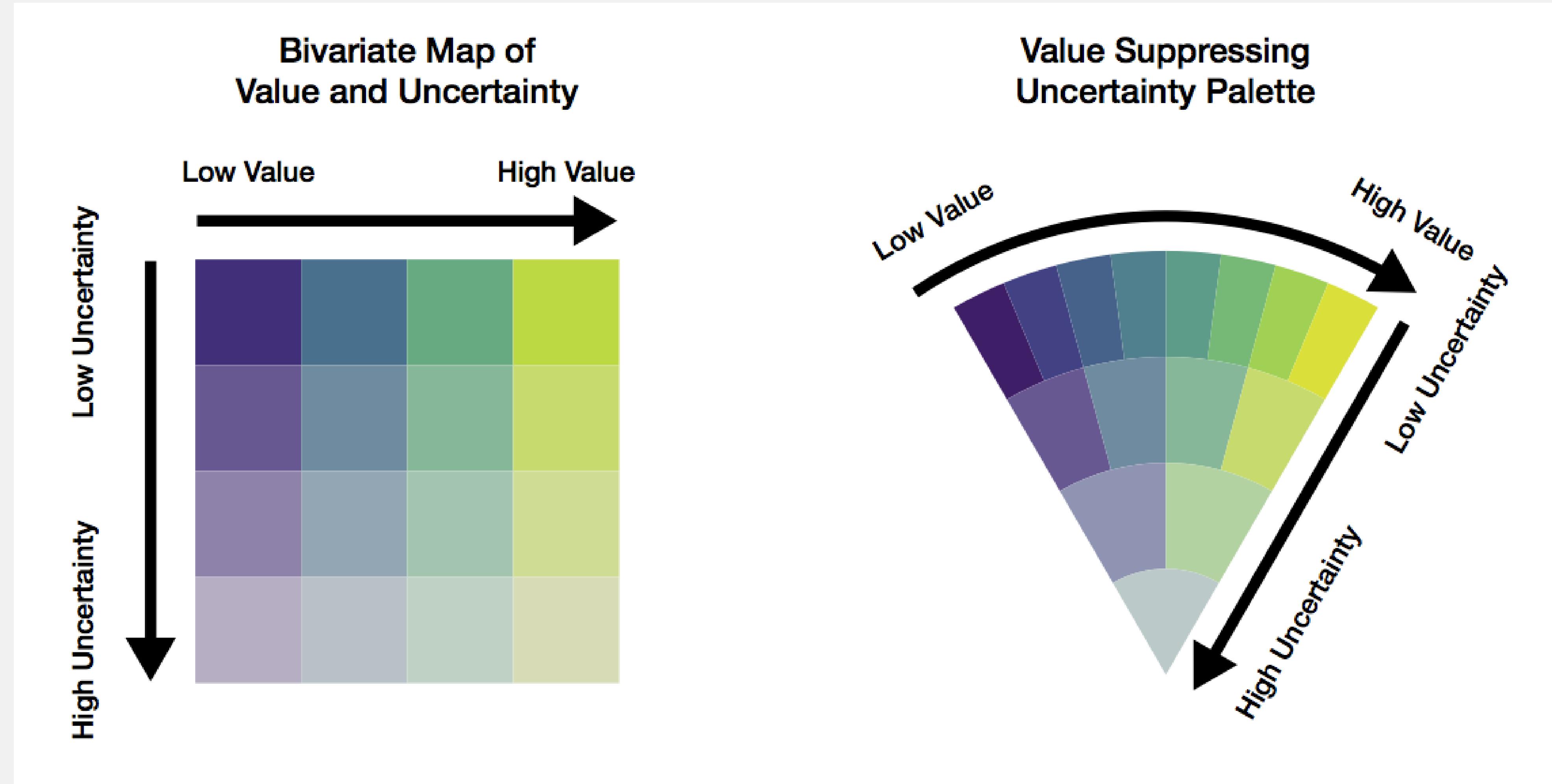
# Appendix

# Bivariate Color Palettes



Strode et al. (2020) ["Operationalizing Trumbo's Principles of Bivariate Choropleth Map Design"](#)

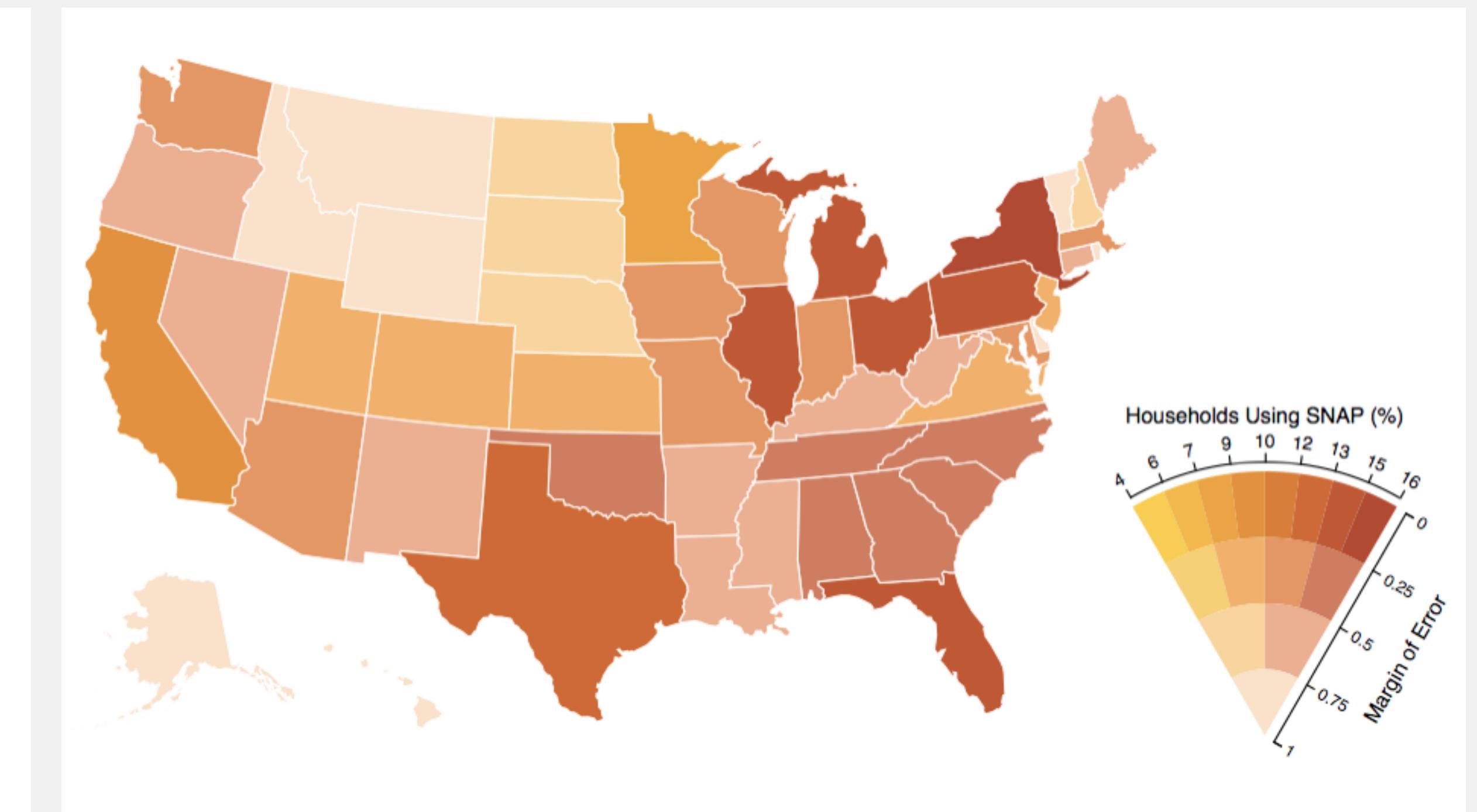
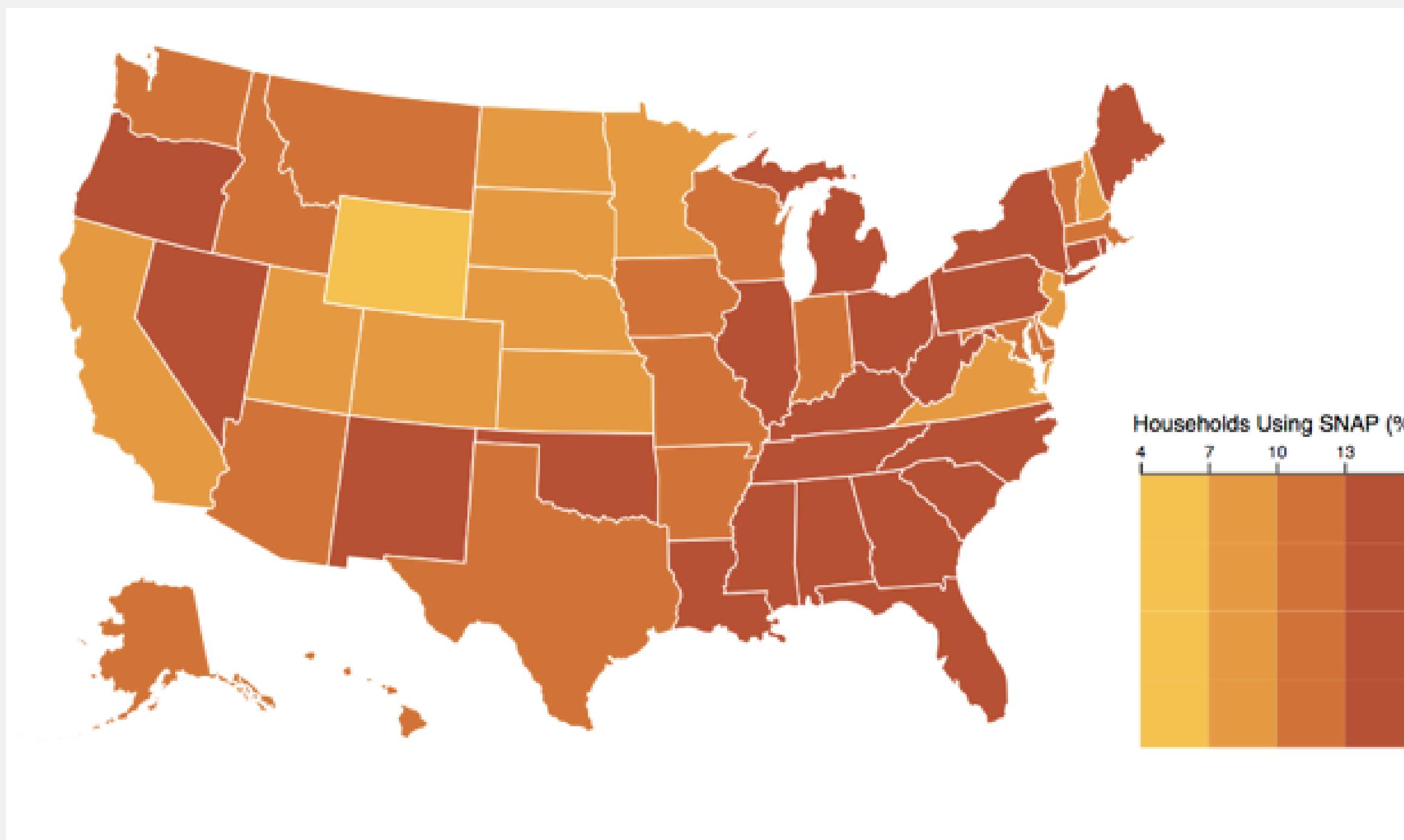
# Value-Suppressing Uncertainty Palettes



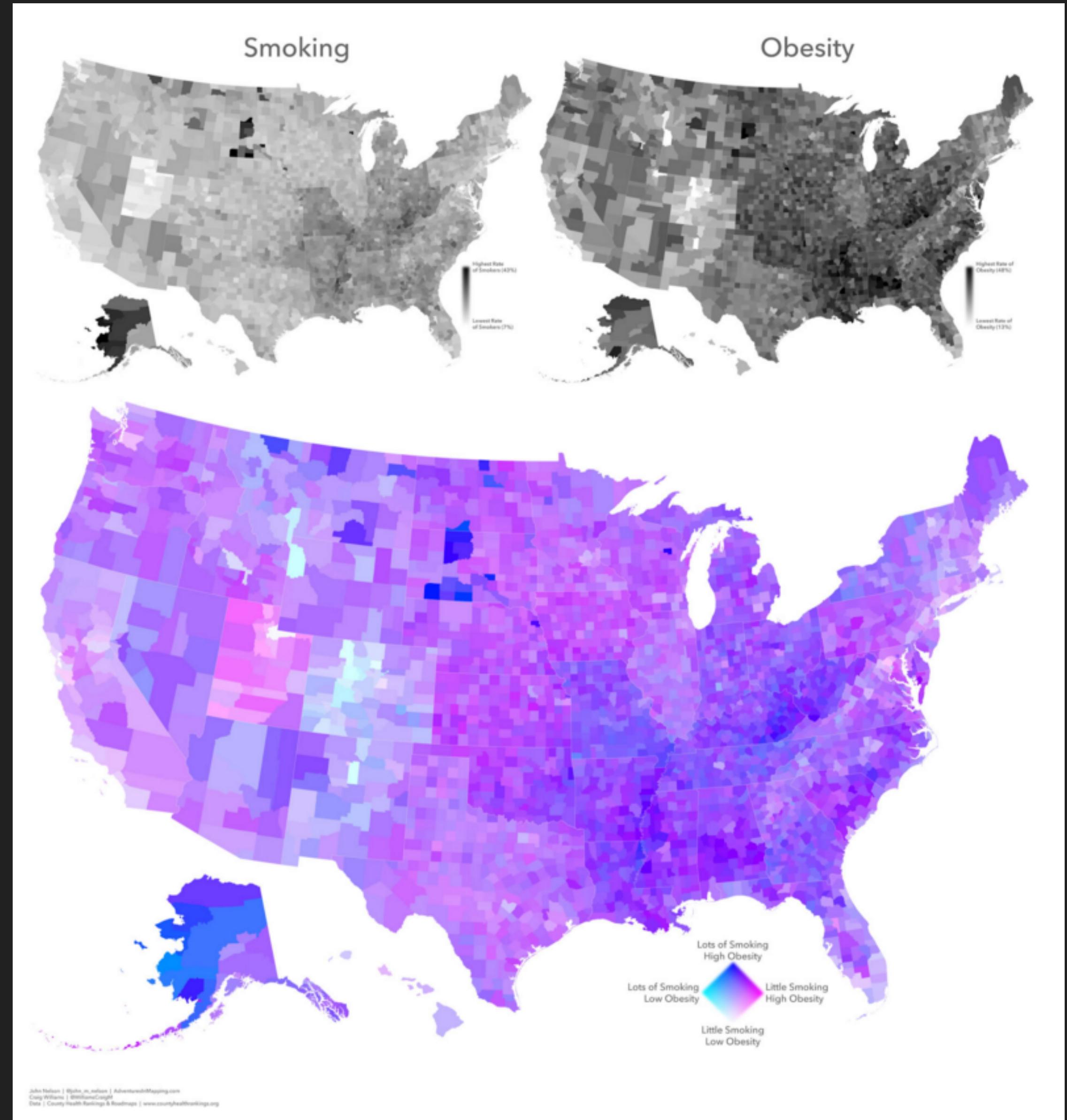
Correll, Moritz & Heer (2018) “[Value-Suppressing Uncertainty Palettes](#)”

Cédric Scherer // rstudio::conf // July 2022

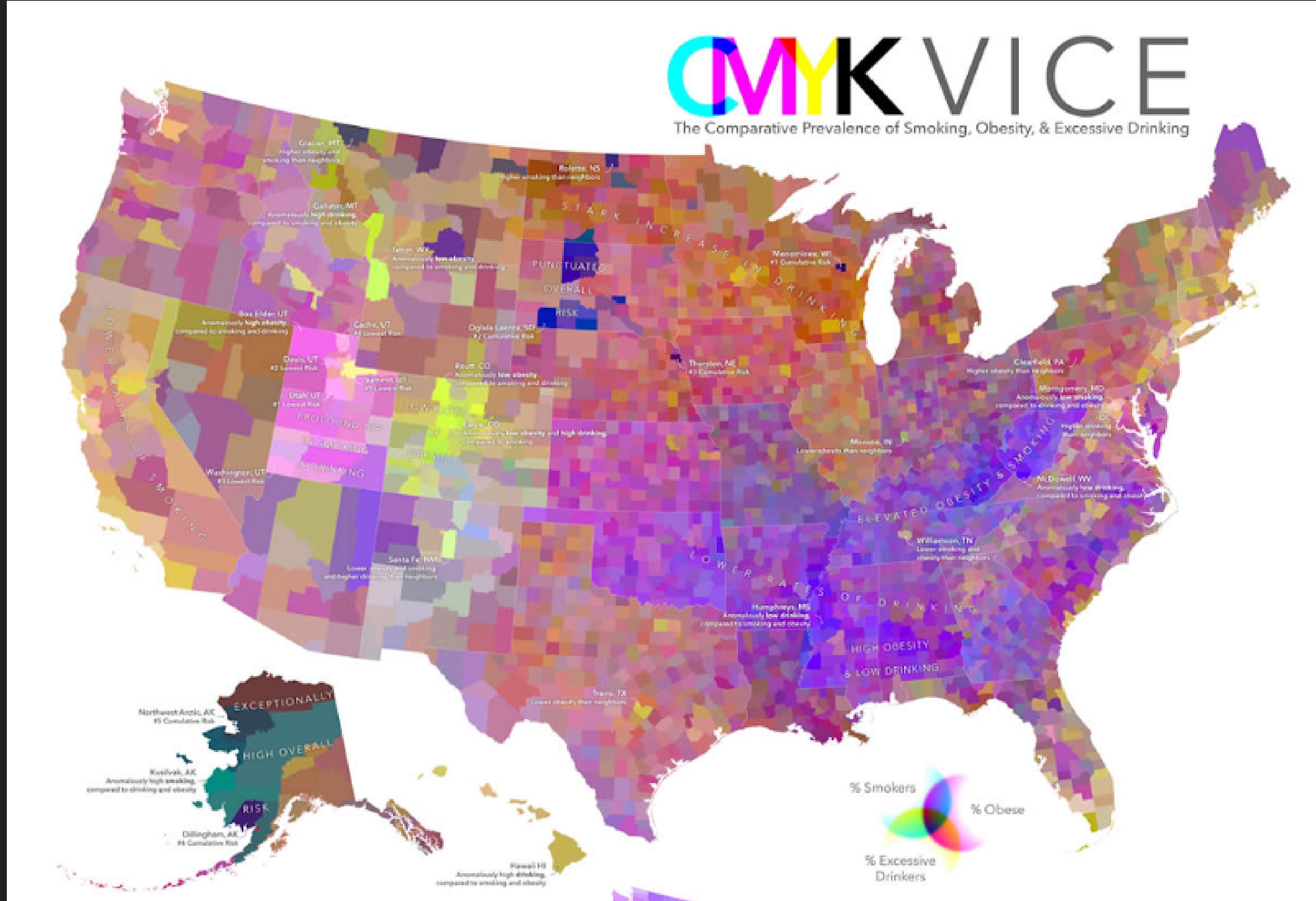
# Bivariate Color Palettes versus Value-Suppressing Uncertainty Palettes



Correll, Moritz & Heer (2018) ["Value-Suppressing Uncertainty Palettes "](#)



***“CMYK Vice Map” by John Nelson & Craig Williams***



**“CMYK Vice Map” by John Nelson & Craig Williams**