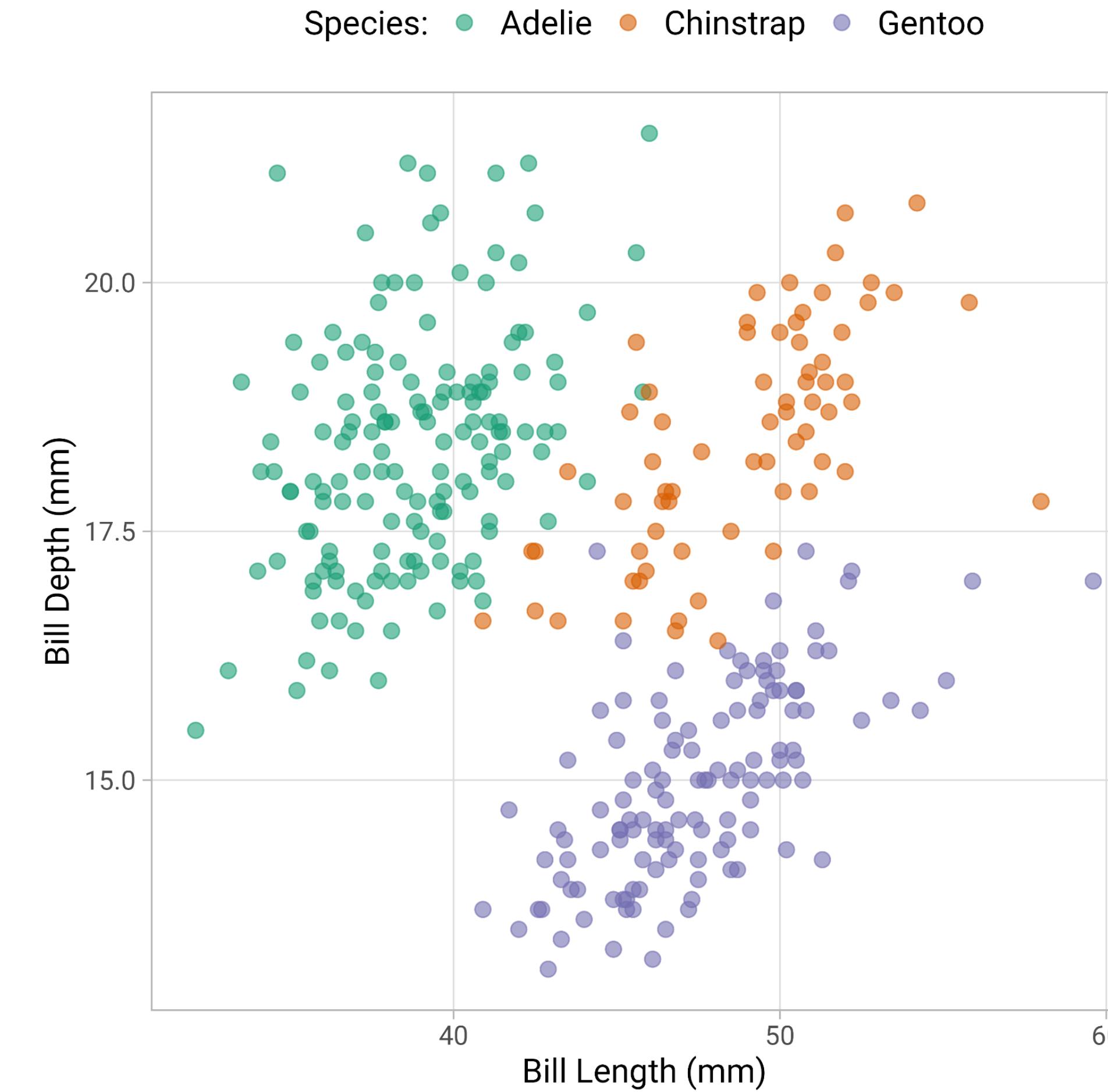
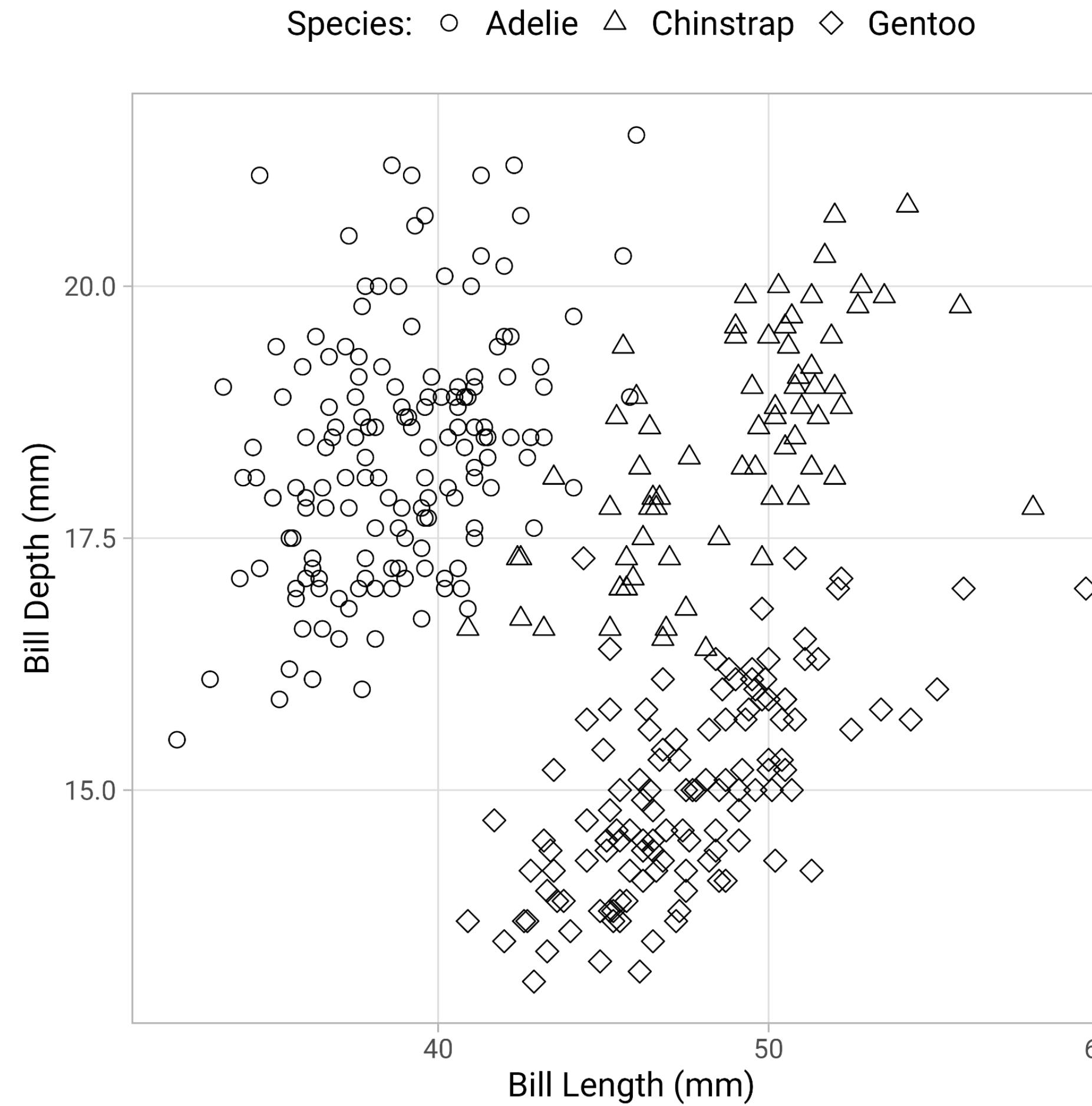


Colorful Graphics

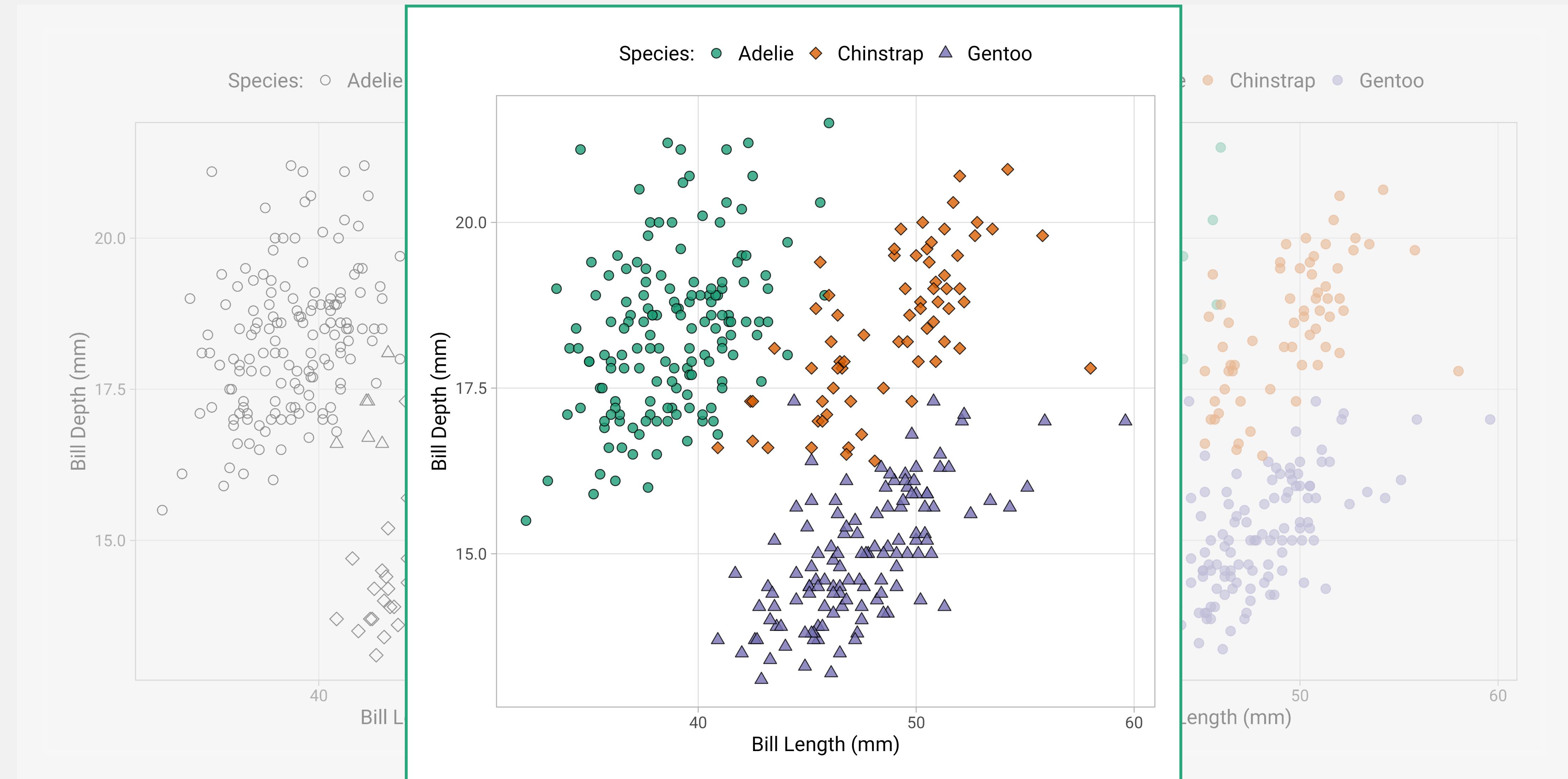
How to use colors correctly and wisely

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

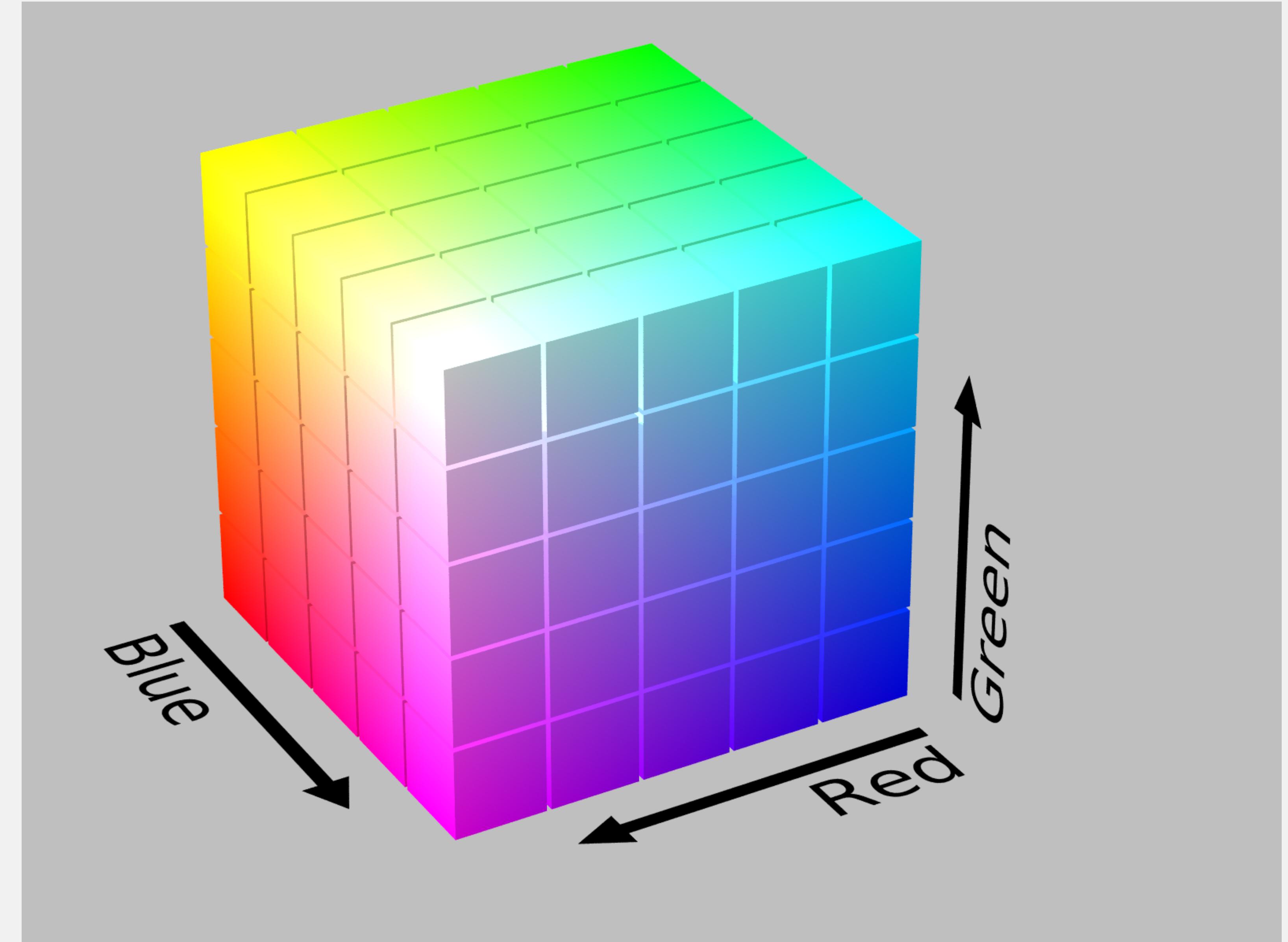
Channels to Encode Information



Use of Double Encoding



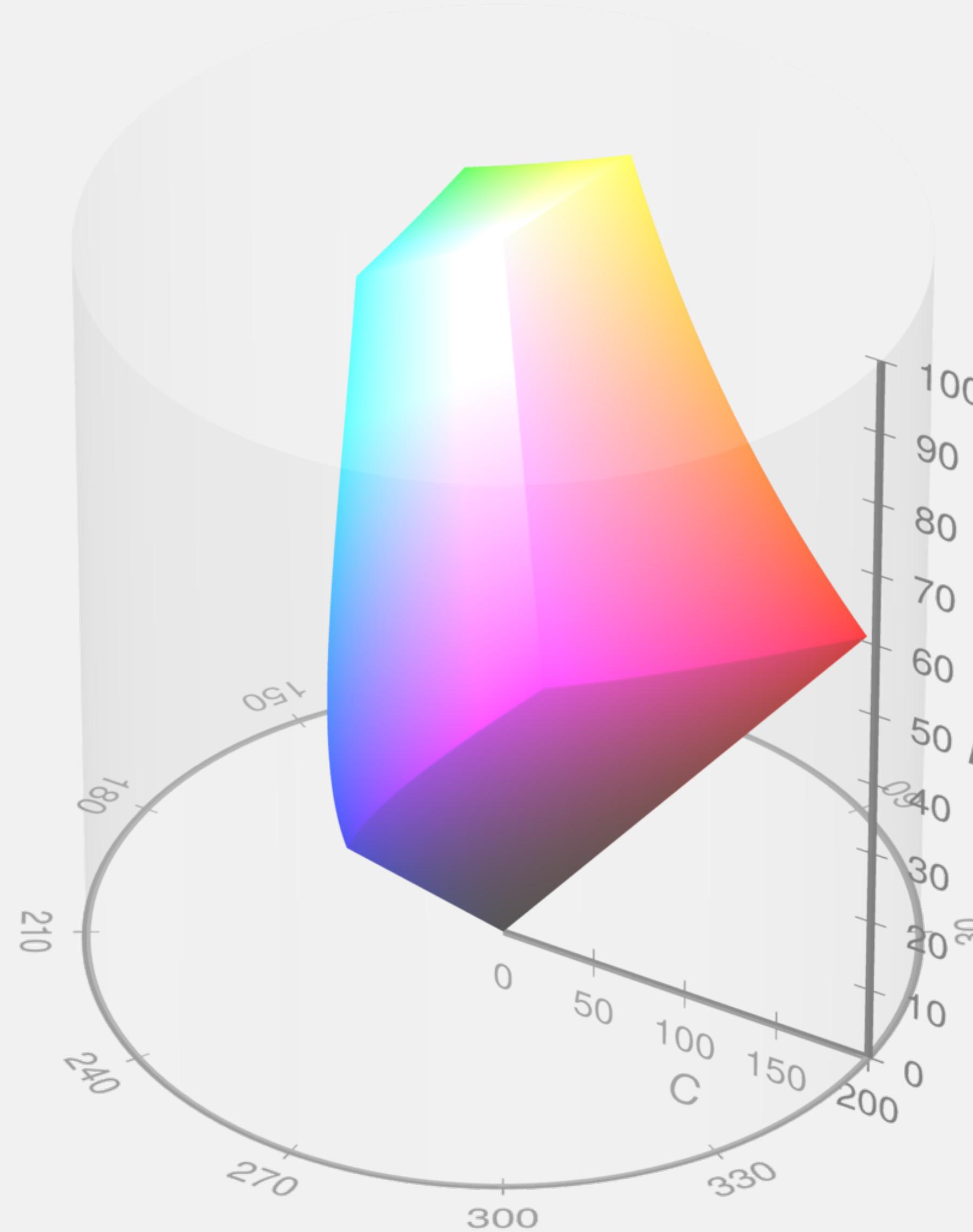
The RGB Color Space



Michael Horvath

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

The HCL Color Space



Michael Horvath & Christoph Lipka

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

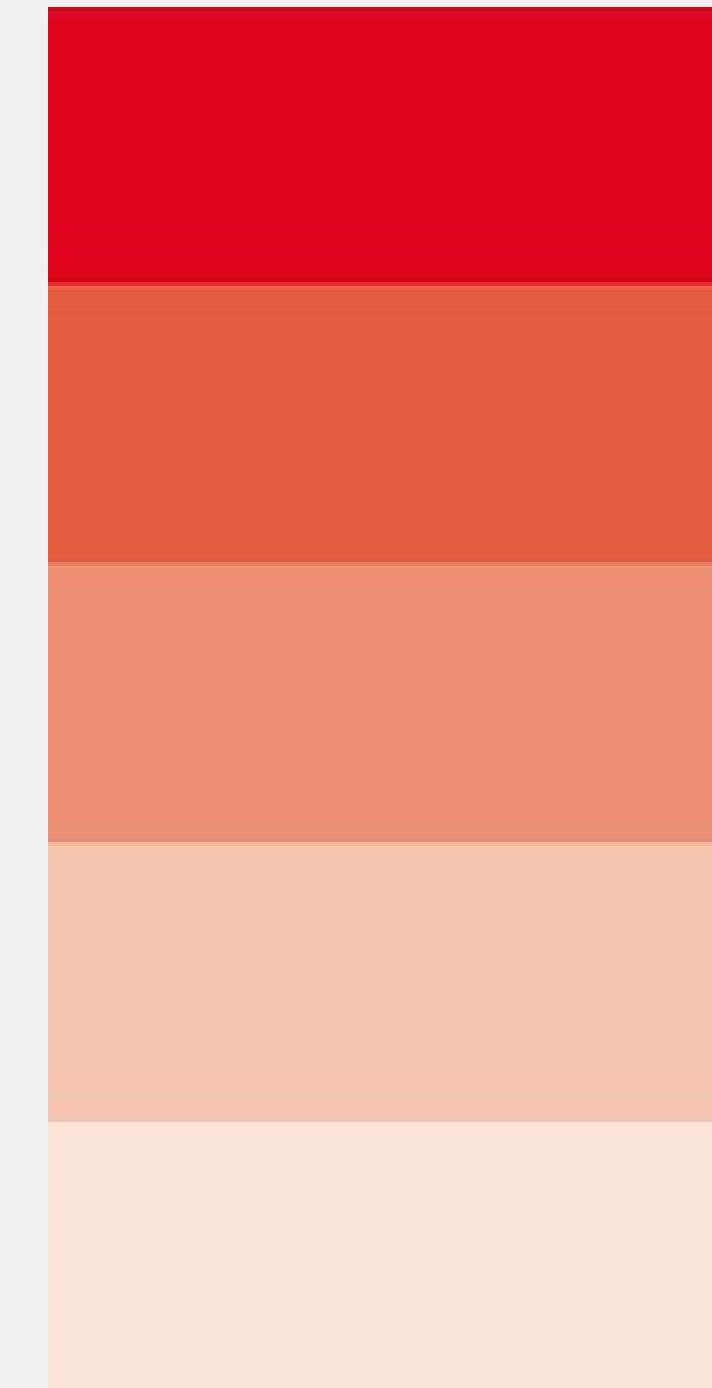
Hue
color family



Chroma
colorfulness

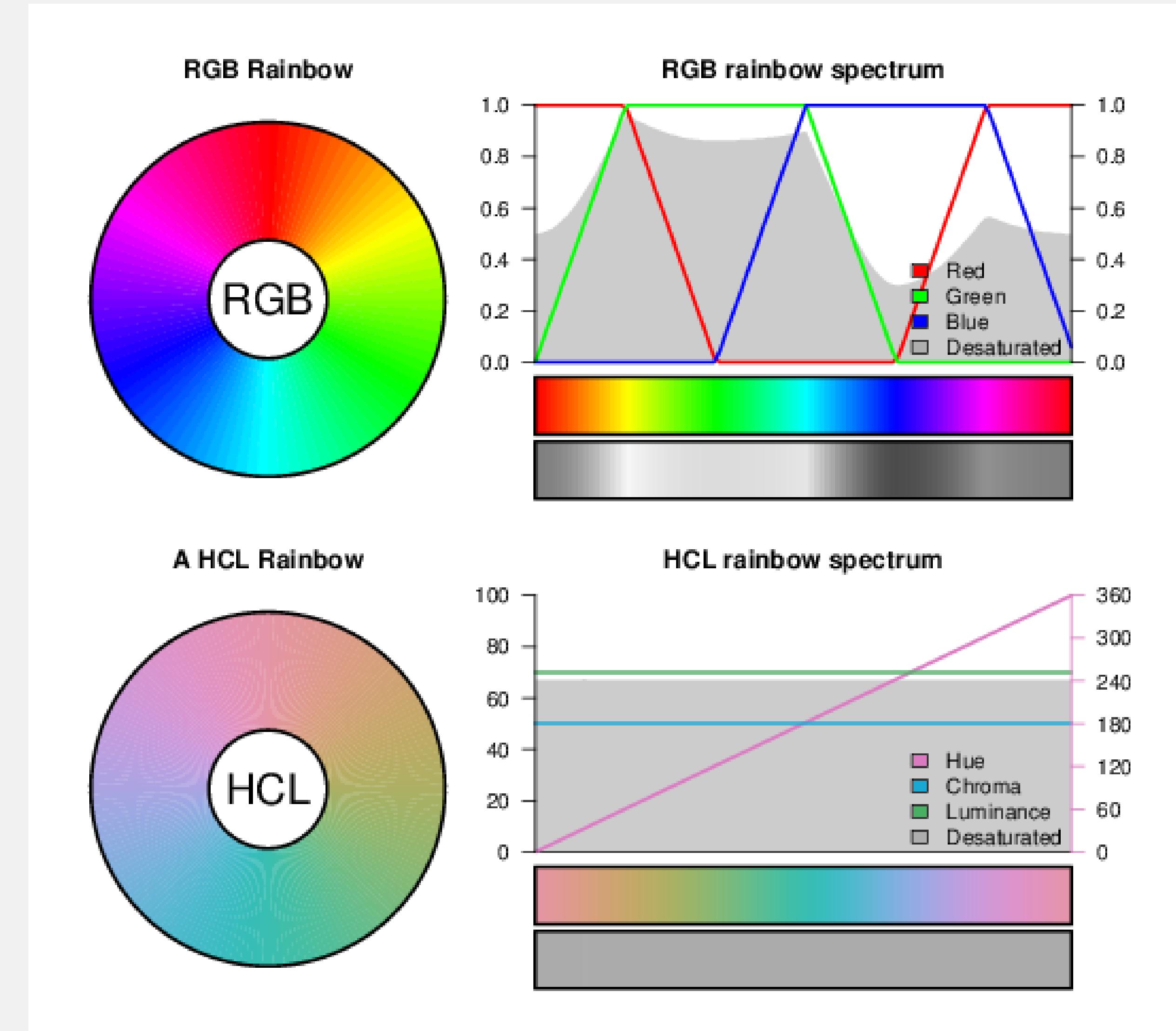


Luminance
lightness / brightness



Modified from uxplanet.org

RGB versus HCL

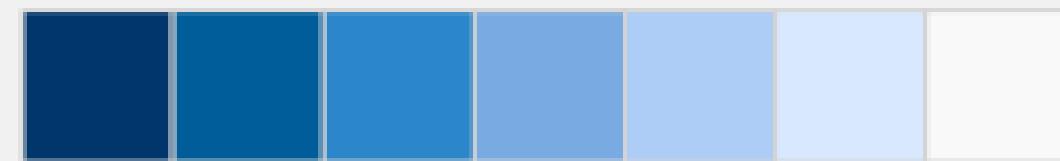


hclwizard.org

Color Palette Choice

Sequential

Palette



Desaturated



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

*use highest contrast for
most important information*

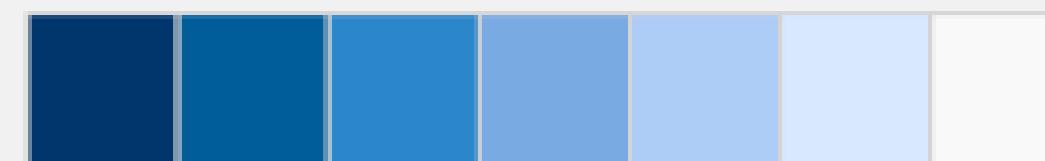
either single- or multi-hue

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

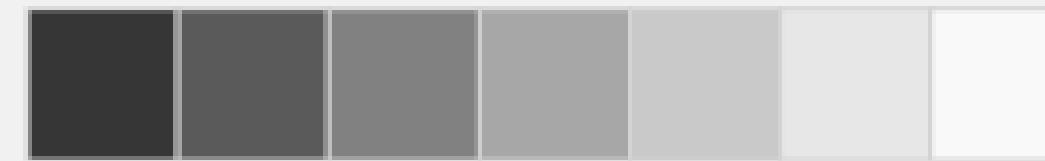
Color Palette Choice

Sequential

Palette



Desaturated



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

use highest contrast for
most important information

either single- or multi-hue

Diverging

Palette



Desaturated



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

ensure a meaningful midpoint value
and use balanced extremes

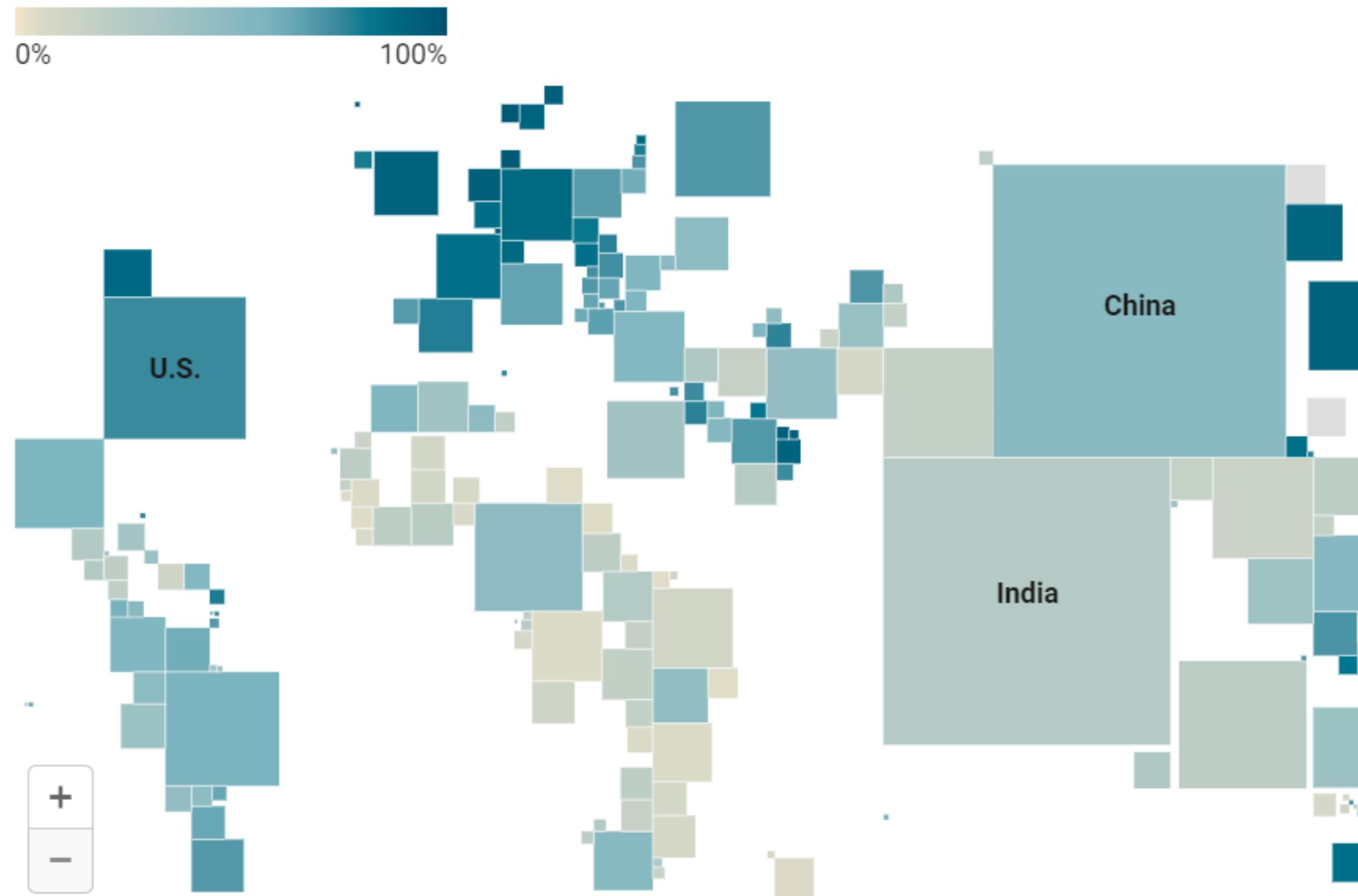
combination of
two sequential palettes

Modified from the `{colorspace}` R package vignette

Sequential versus Diverging Palettes

The internet was mostly used by the Western World in 2015

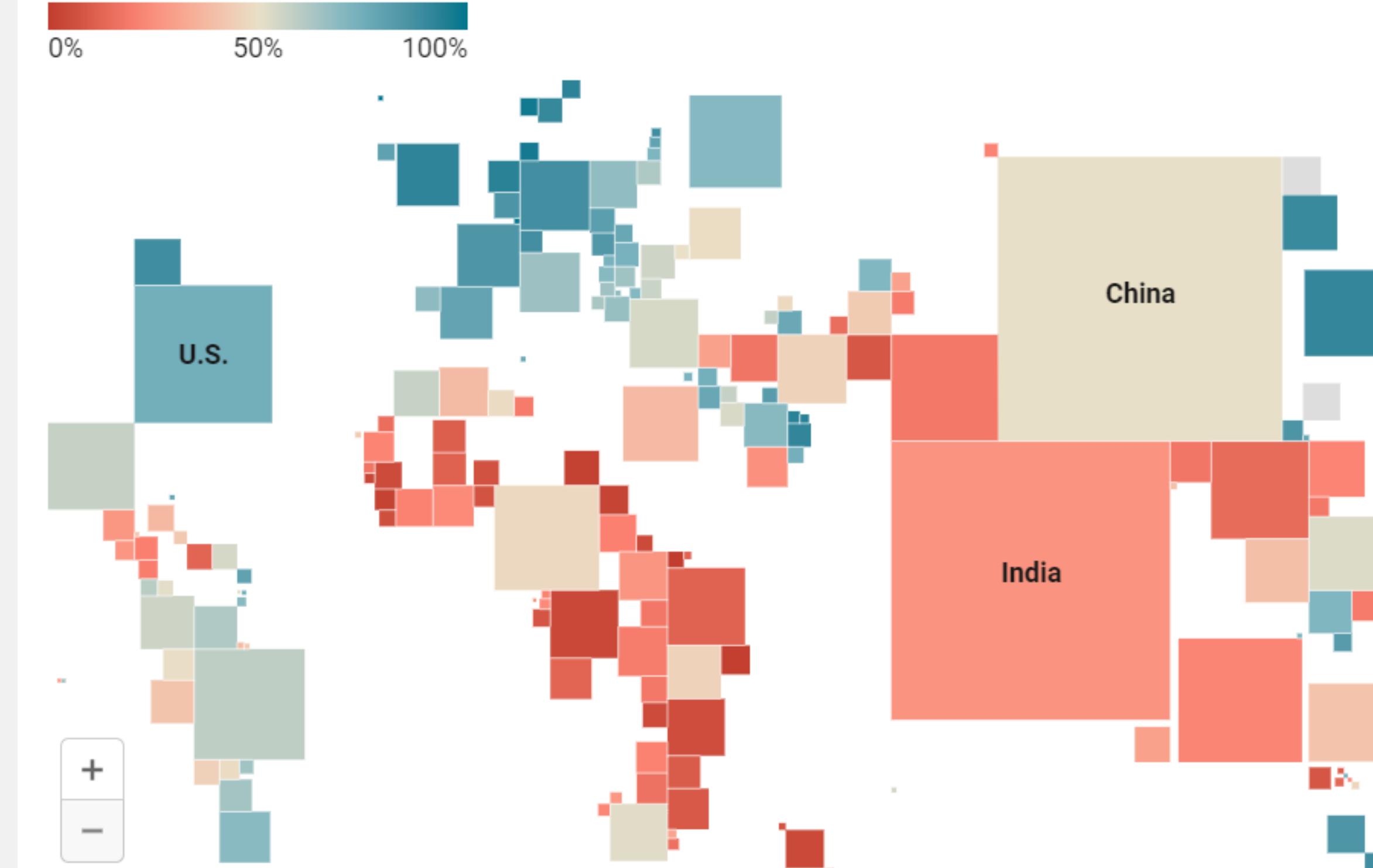
Share of individuals who have used the Internet in the last 3 months (via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.), in selected countries, 2015



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

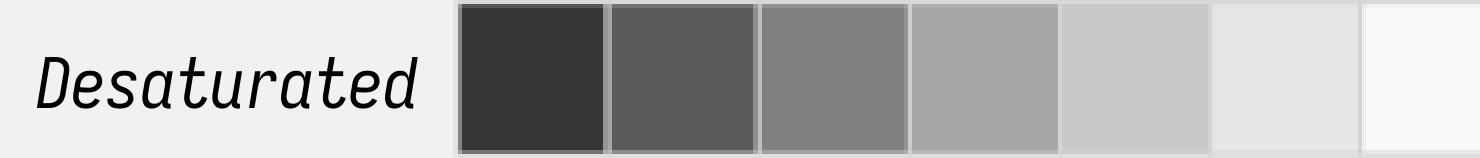
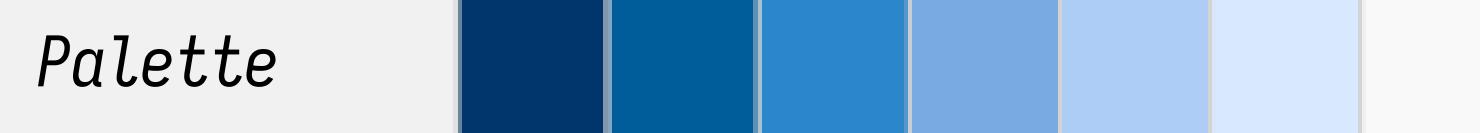


Map: Lisa Charlotte Rost, Datawrapper • Source: Our World in Data • Get the data • Created with Datawrapper

"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

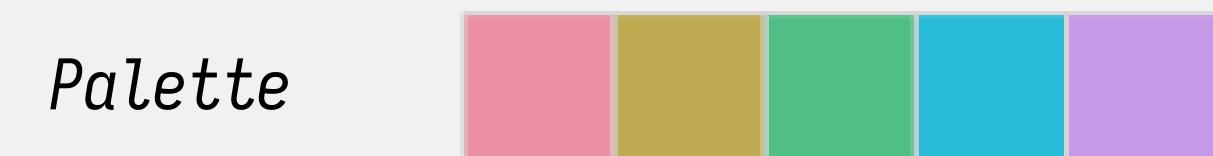


Use to encode
numerical information with critical midpoint

ensure a meaningful midpoint value
and use balanced extremes

combination of
two sequential palettes

Qualitative



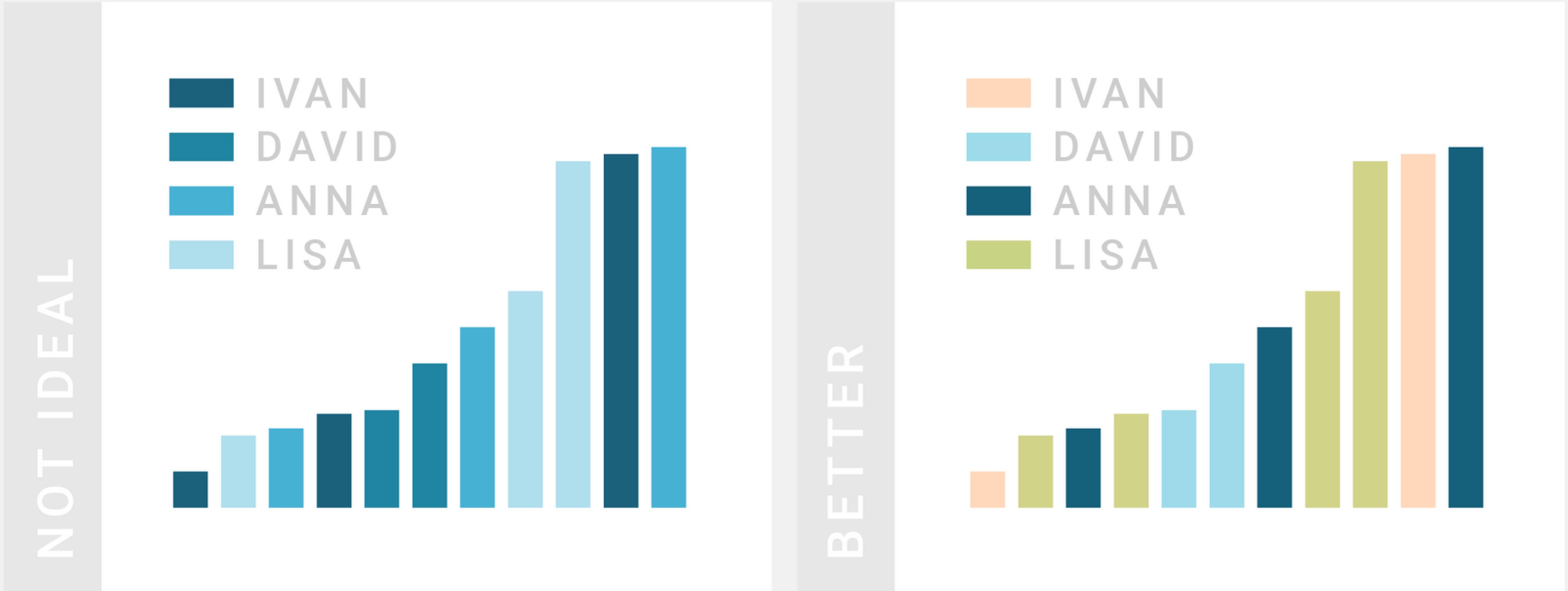
Use to encode
categorical information

pick distinct colors with
the same perceptual weight

limit categories to 6-8

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

Sequential versus Qualitative Palettes



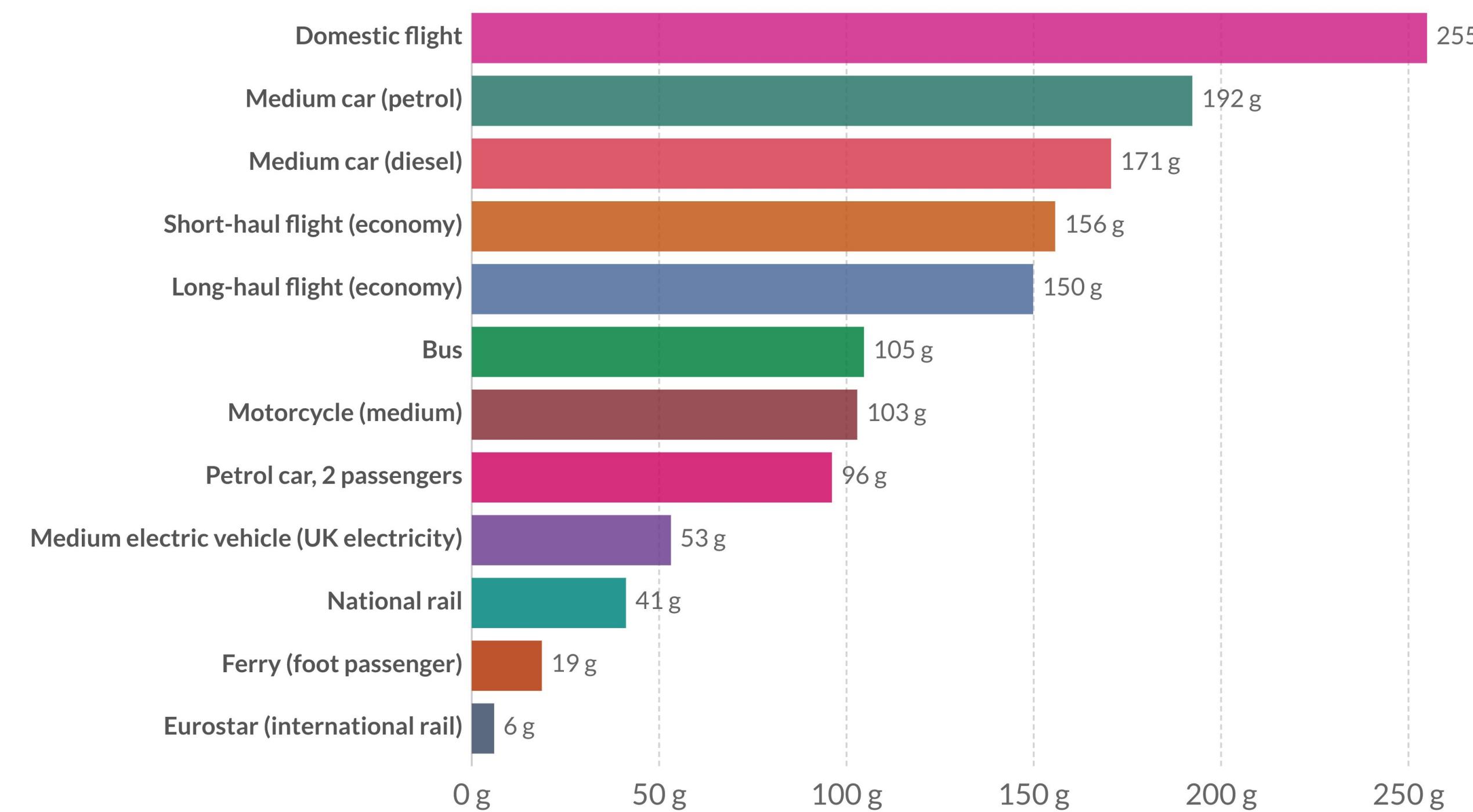
“What to consider when choosing colors for data visualization” by Lisa C. Muth / DataWrapper

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.

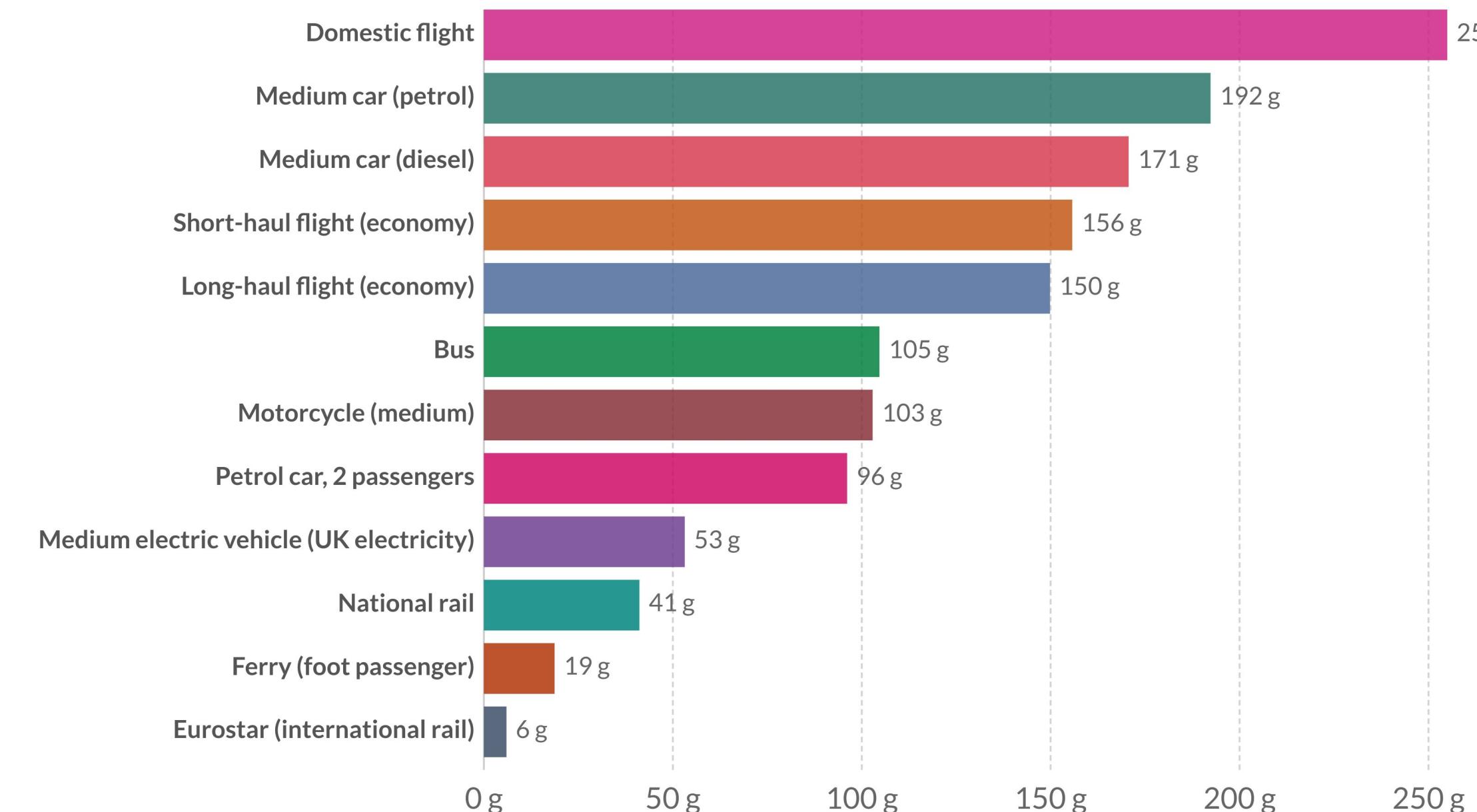
CC BY

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.



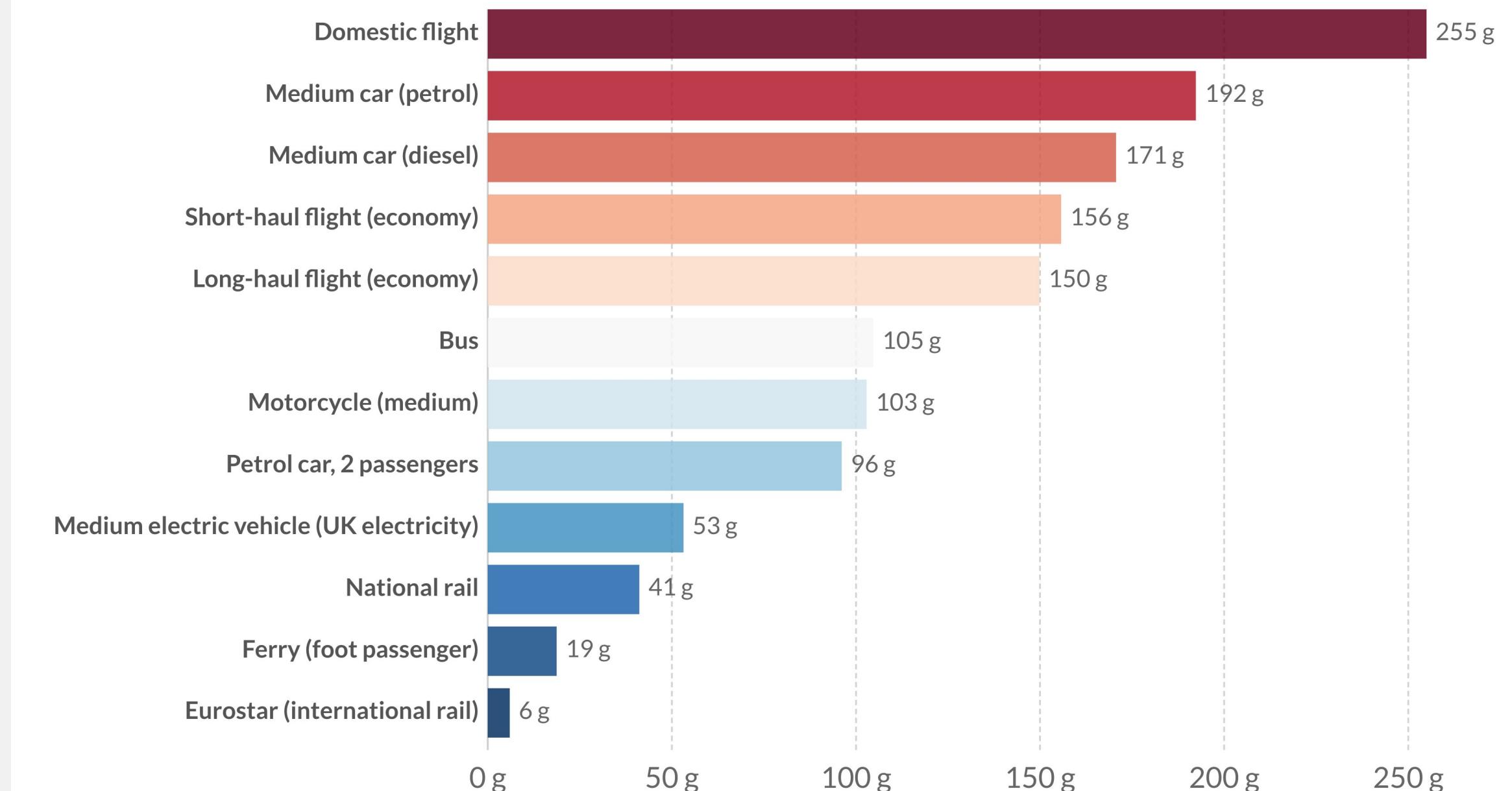
Source: UK Department for Business, Energy & Industrial Strategy. Greenhouse gas reporting: conversion factors 2019.
Note: Data is based on official conversion factors used in UK reporting. These factors may vary slightly depending on the country.

Our World
in Data

CC BY

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.

Our World
in Data

CC BY

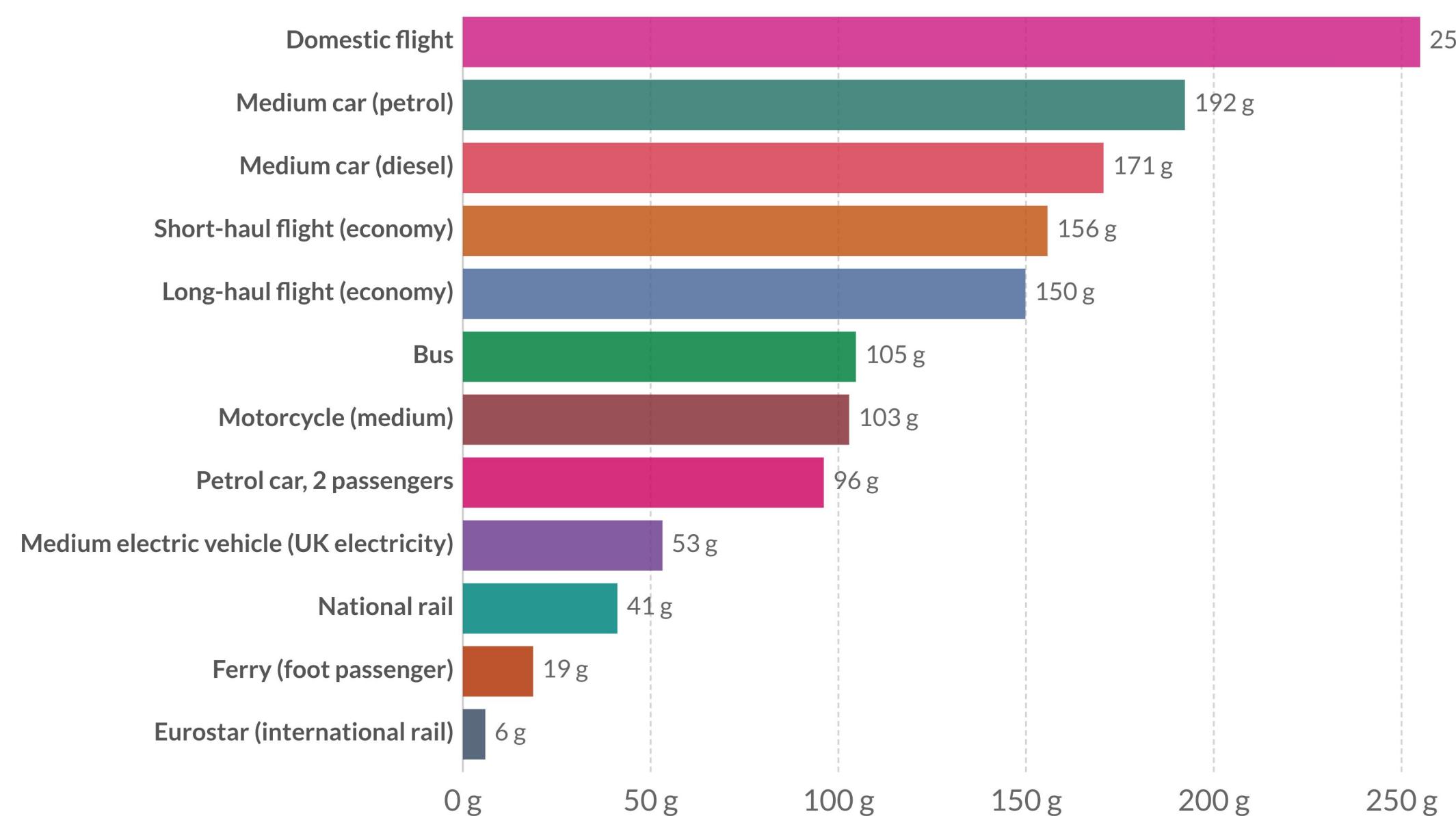
Original graphic with a random categorical palette

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.

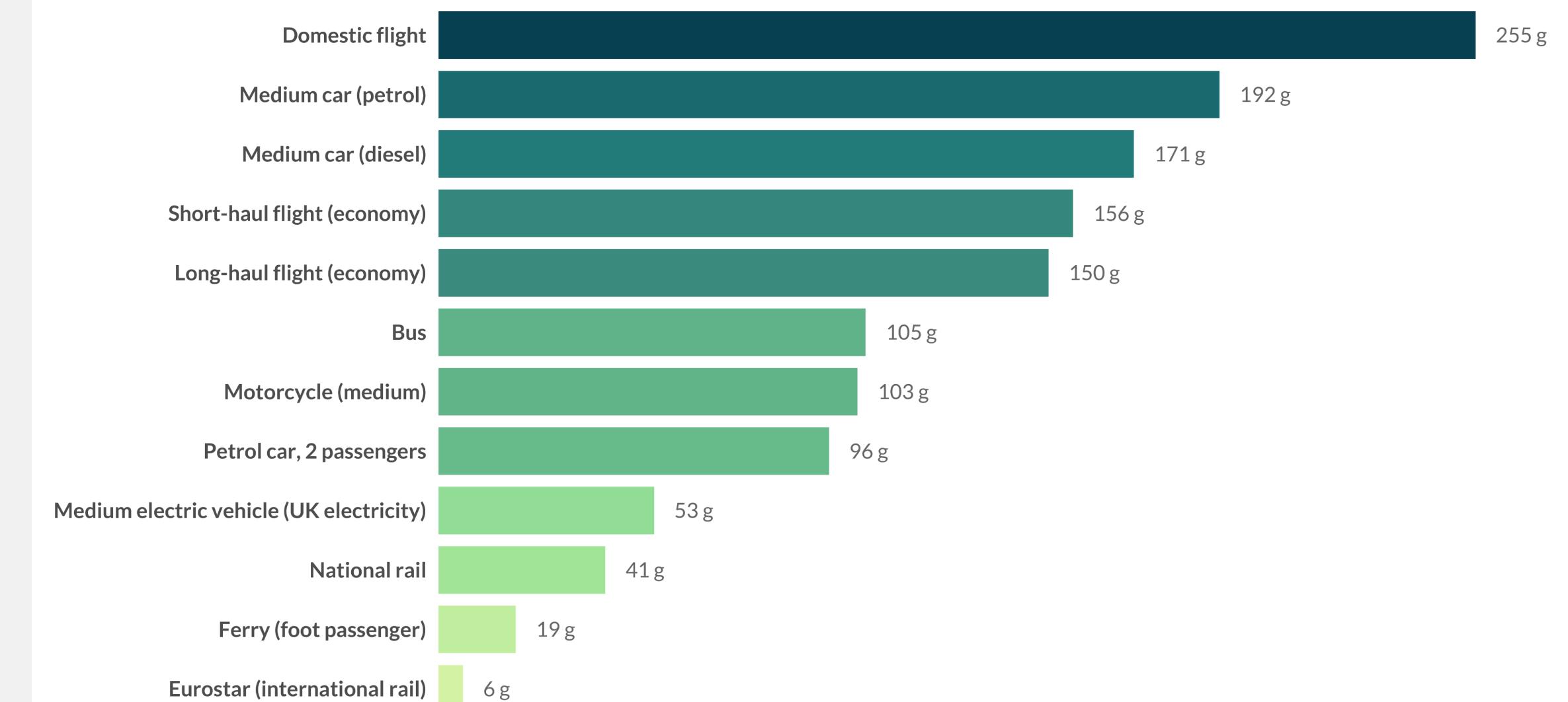
Note: Data is based on official conversion factors used in UK reporting. These factors may vary slightly depending on the country.

Our World
in Data

CC BY

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

Original graphic with a random categorical palette

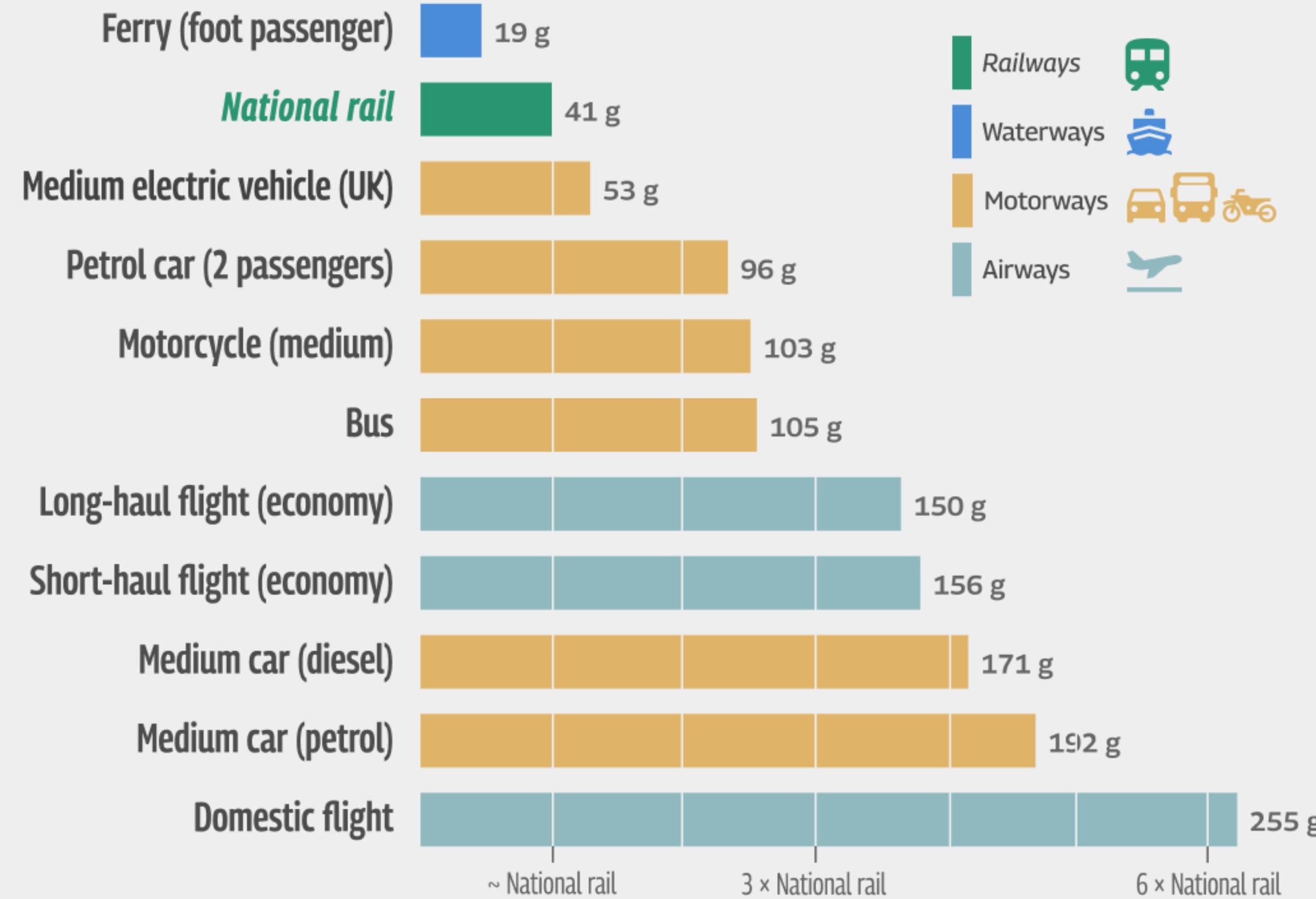
Makeover using a continuous palette

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*



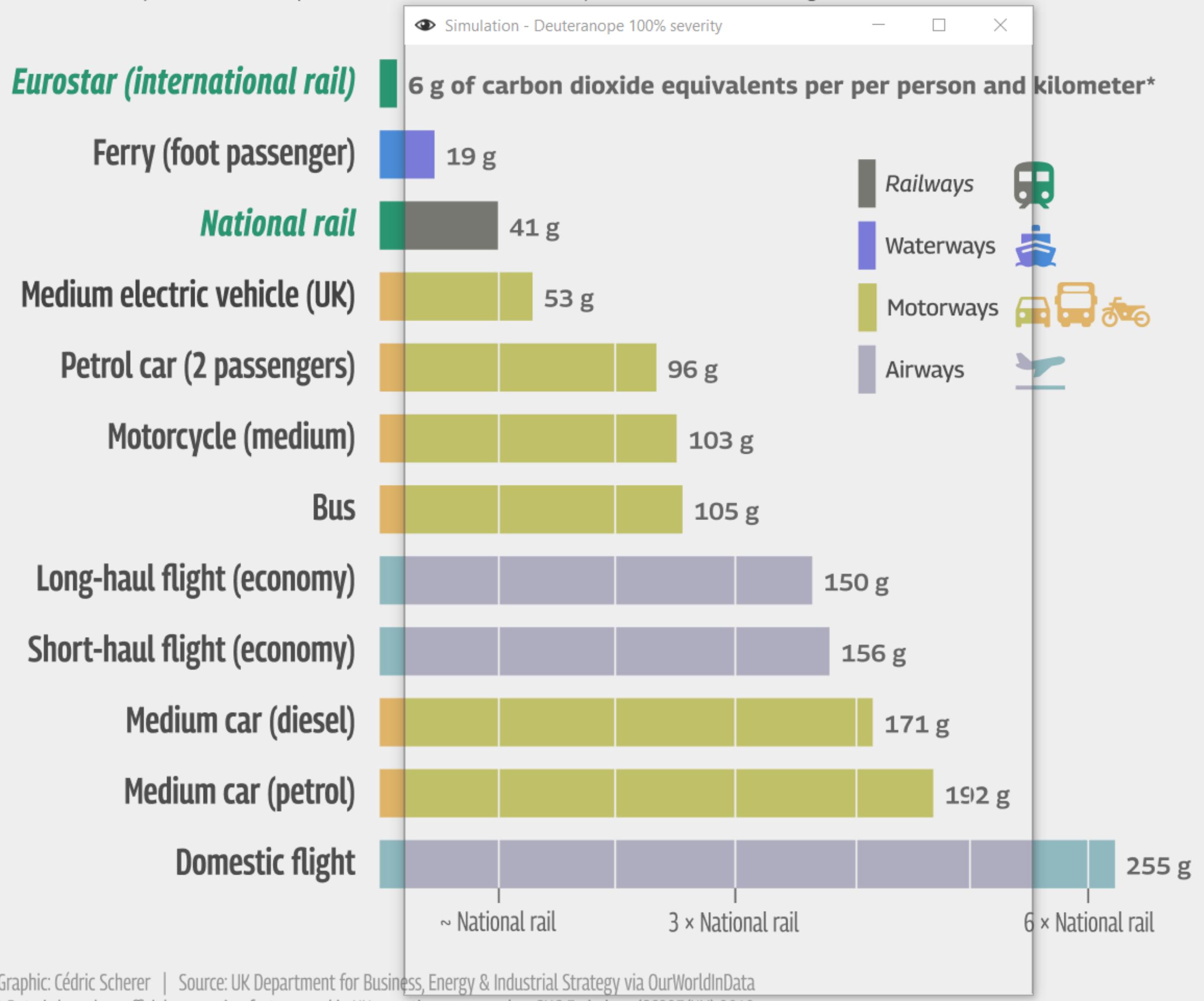
Graphic: Cédric Scherer | Source: UK Department for Business, Energy & Industrial Strategy via OurWorldInData

* 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.

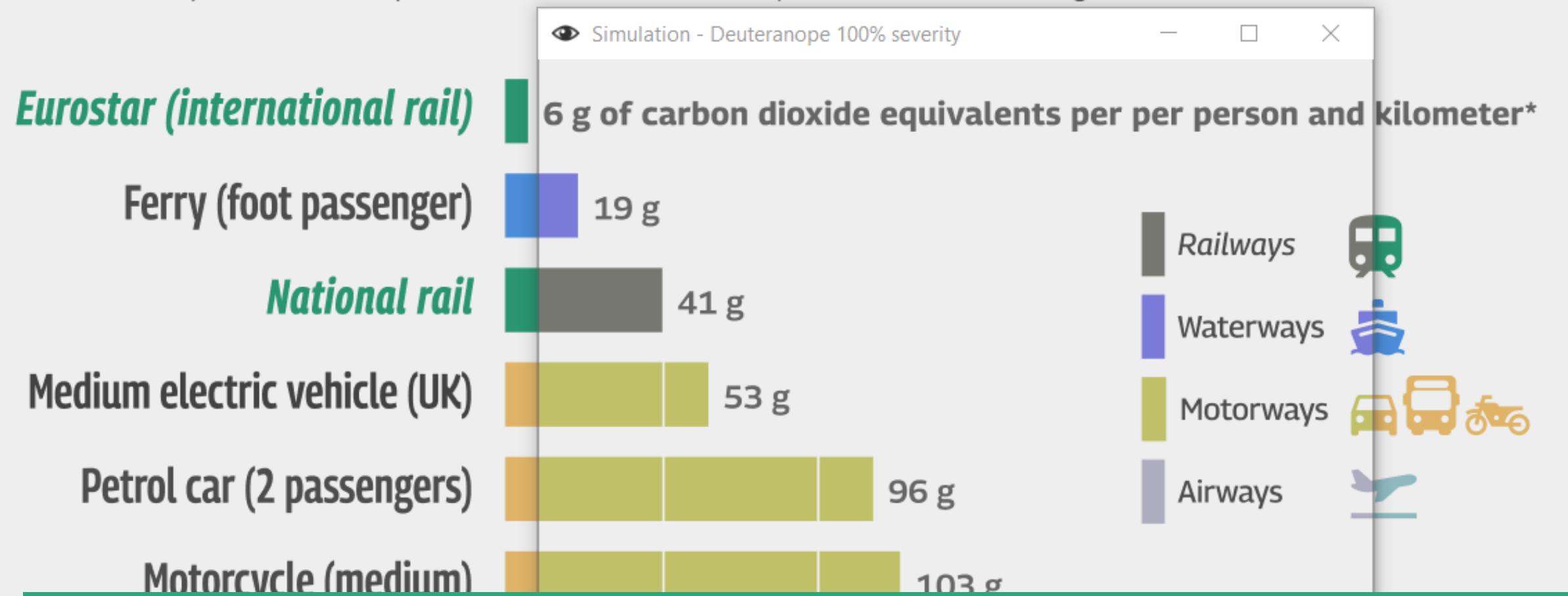


Don't trust color palettes — test them!

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!**

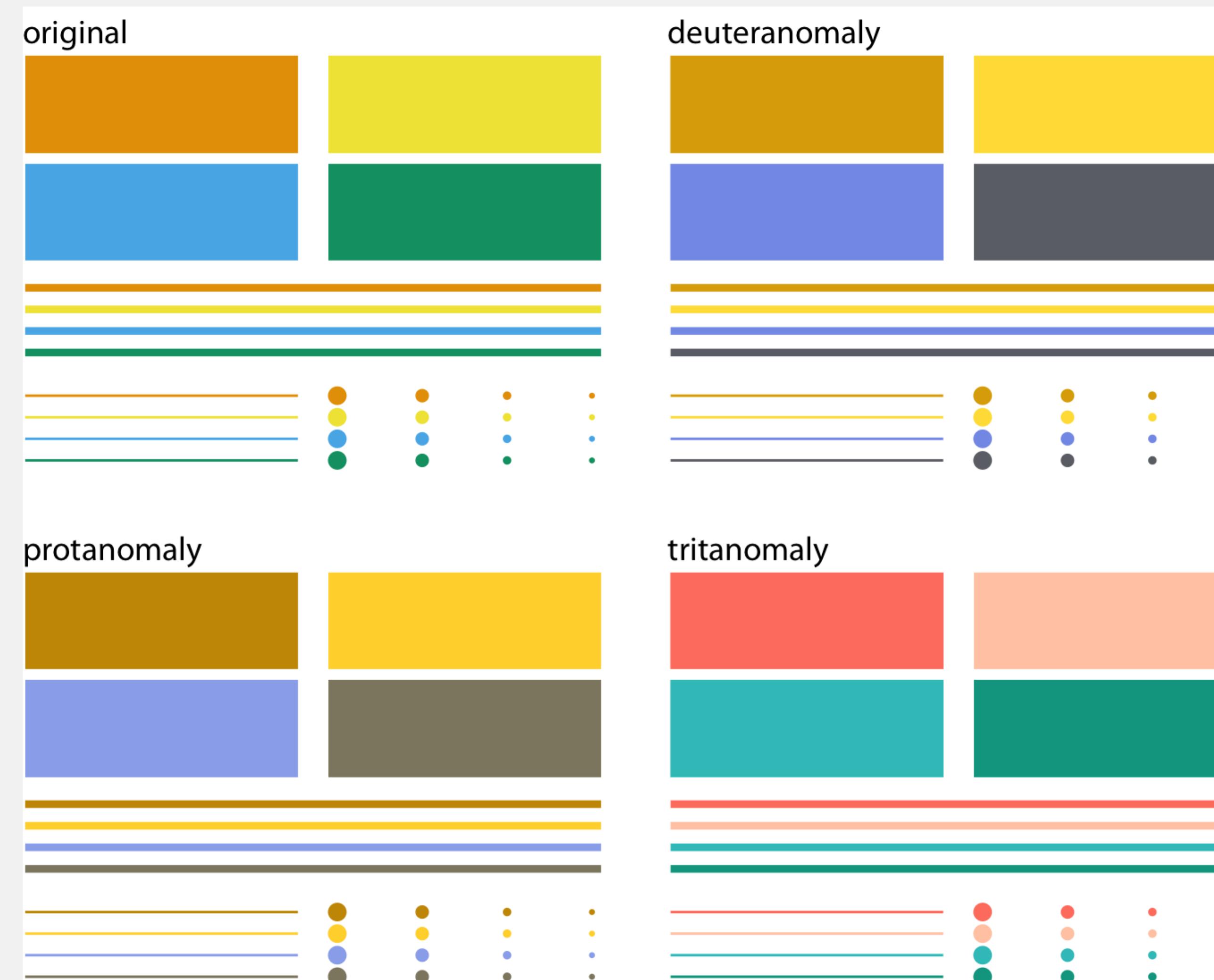
ColourSimulations
SimDaltonims (Mac only)
ColorFilter (for URLs)

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

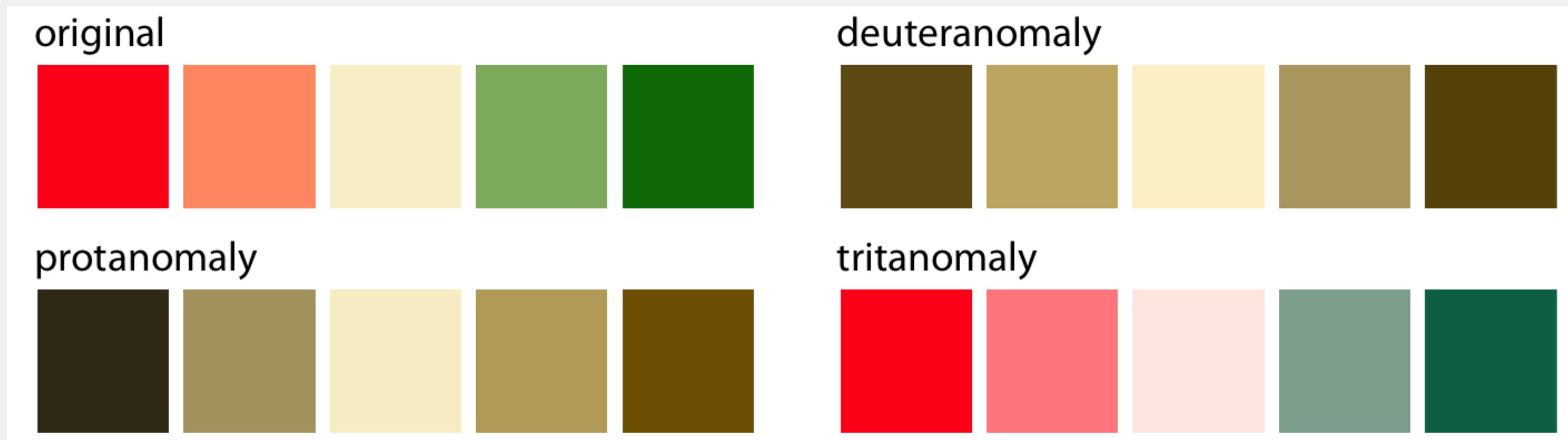
Reworked graphic as contribution to the #30DayChartChallenge 2022

Ensure Readability for Color-Blind Persons



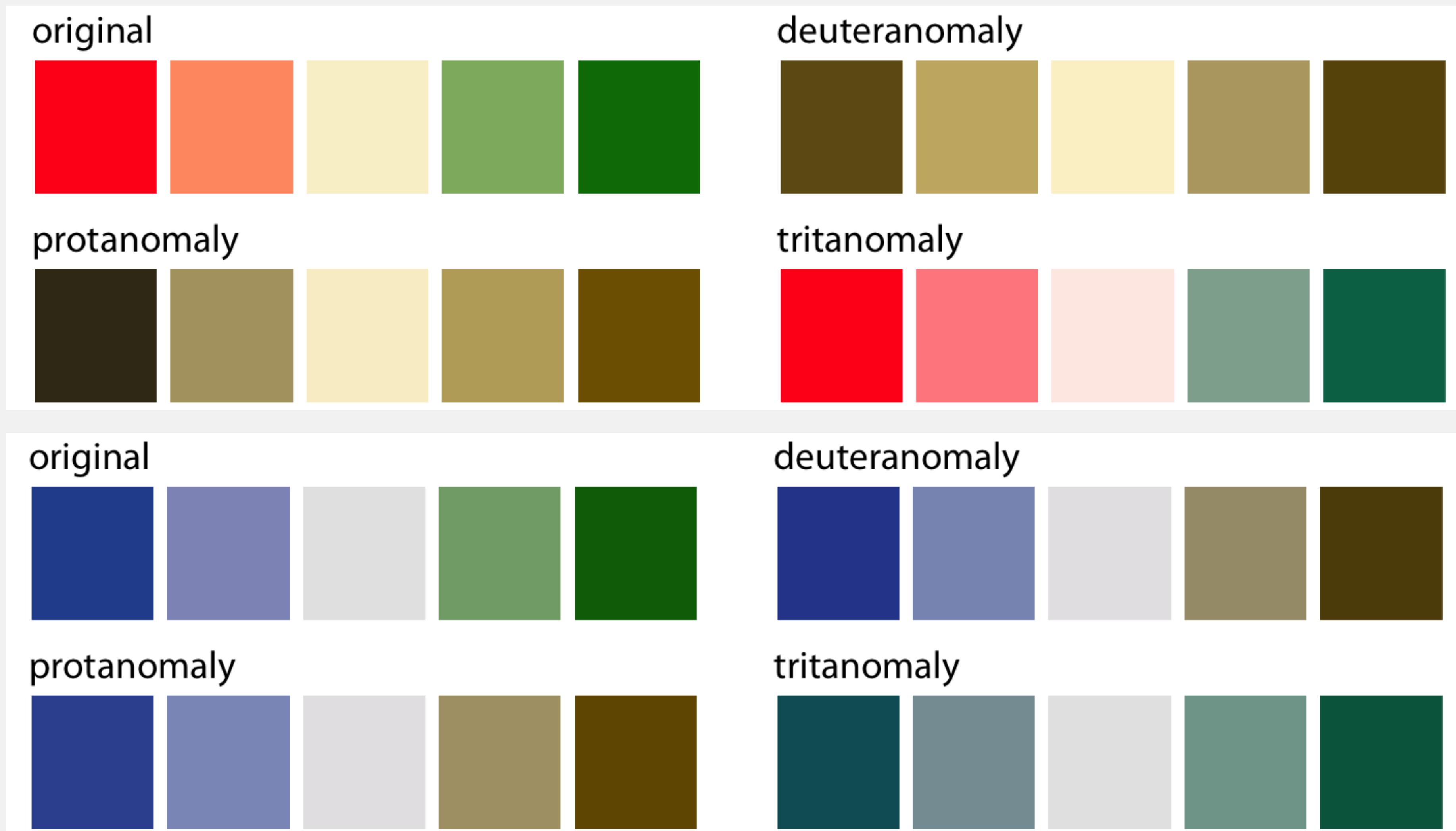
“Fundamentals of Data Visualization” by Claus O. Wilke

Ensure Readability for Color-Blind Persons



“Fundamentals of Data Visualization” by Claus O. Wilke

Ensure Readability for Color-Blind Persons



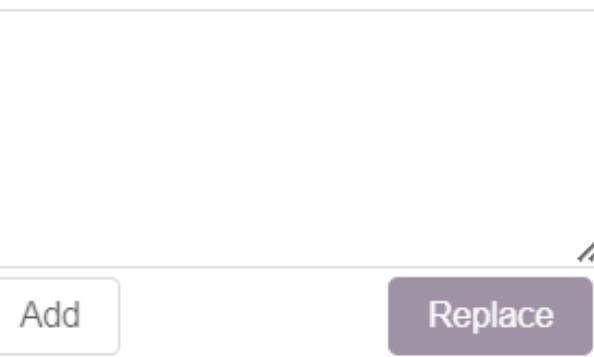
“Fundamentals of Data Visualization” by Claus O. Wilke

VIZ PALETTE

By: Elijah Meeks
& Susie Lu

PICK

Use Chroma.js



Use Colorgorical

Use ColorBrewer

EDIT

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: ↗

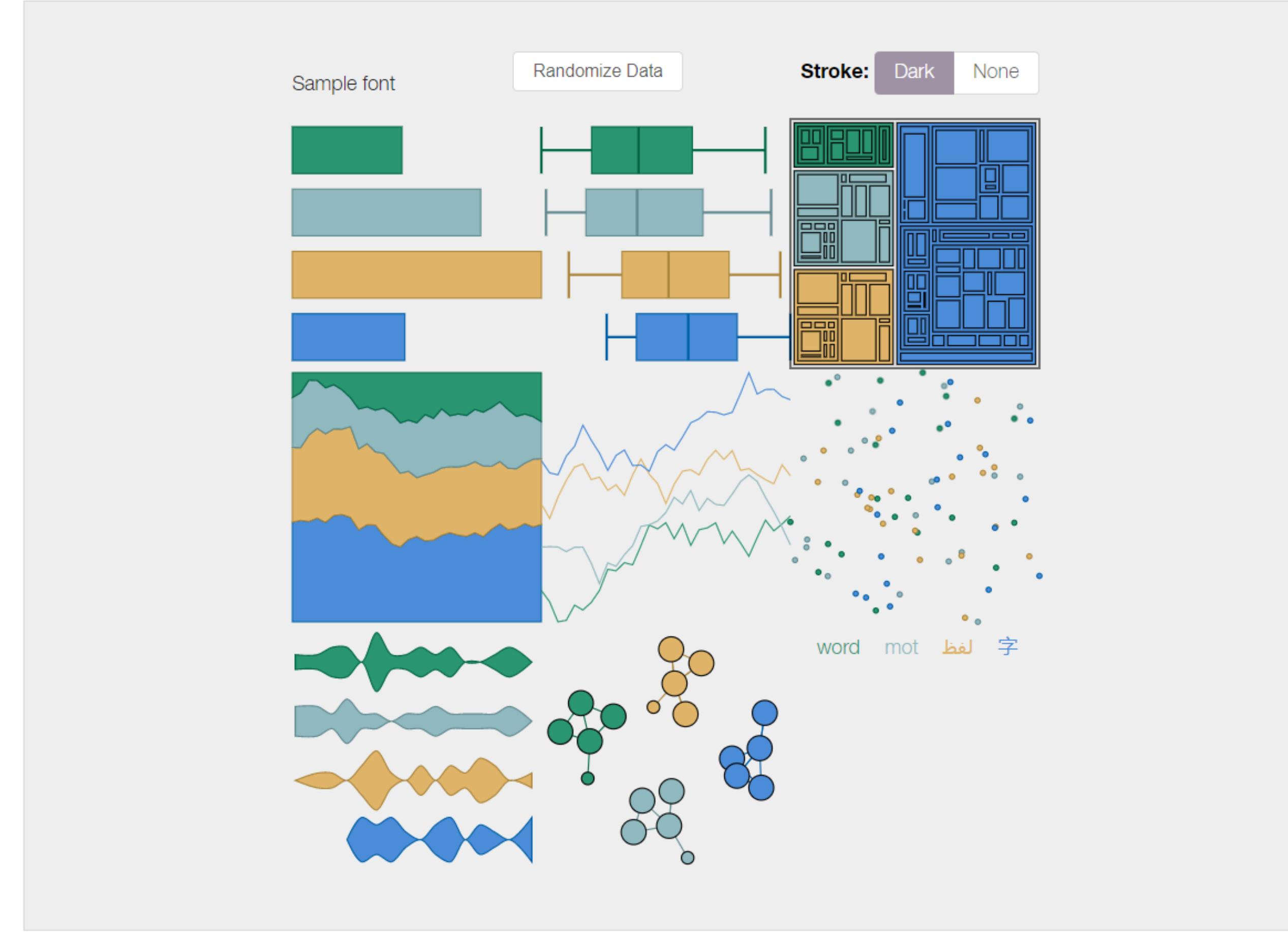
Font color: ↗

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



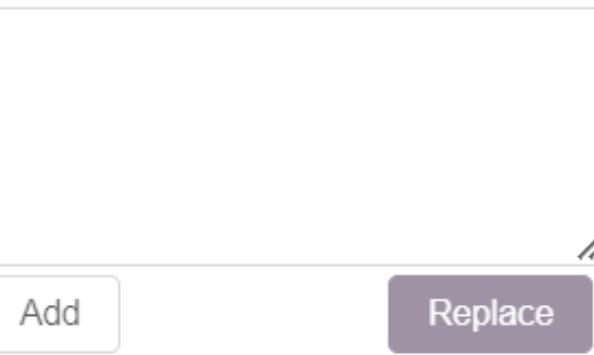
Viz Palette displaying the “colors in action” without color deficiency

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 rgb

hsl

GET

String quotes
 Object with metadata

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

hsl

COLORS IN ACTION

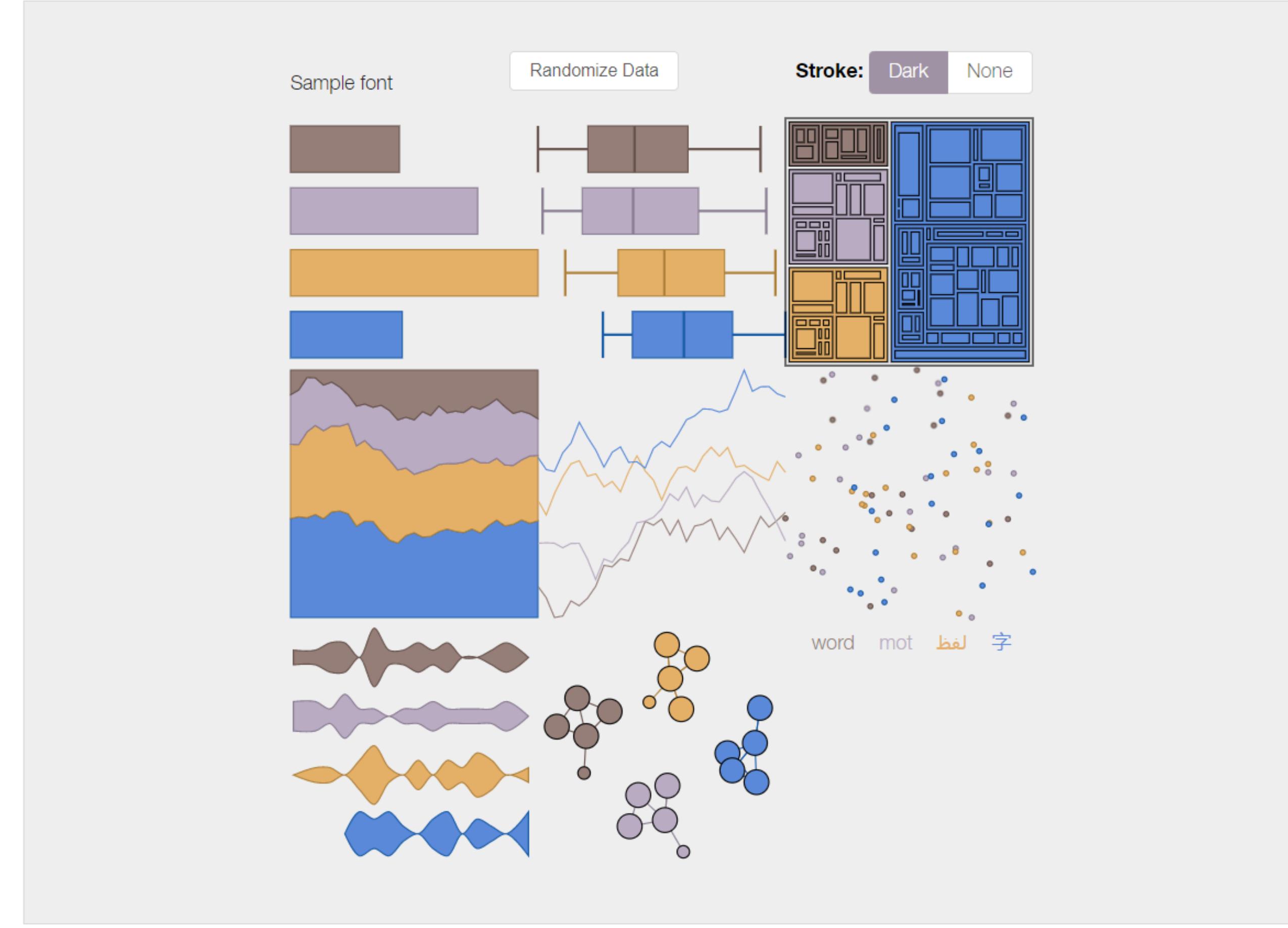
Background color: [🔗](#)

Font color: [🔗](#)

Charts made with [Semiotic](#)

Color Population:

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



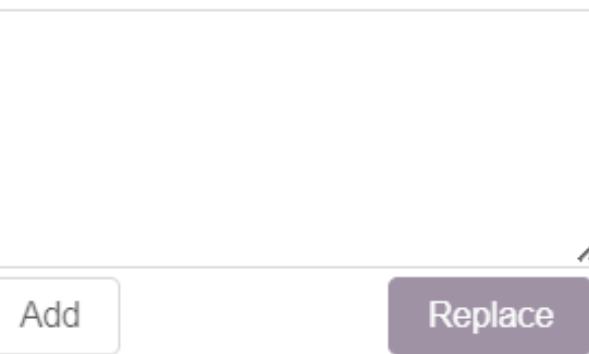
Viz Palette displaying the “colors in action” with deuteranopia

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" ]
```

COLORS IN ACTION

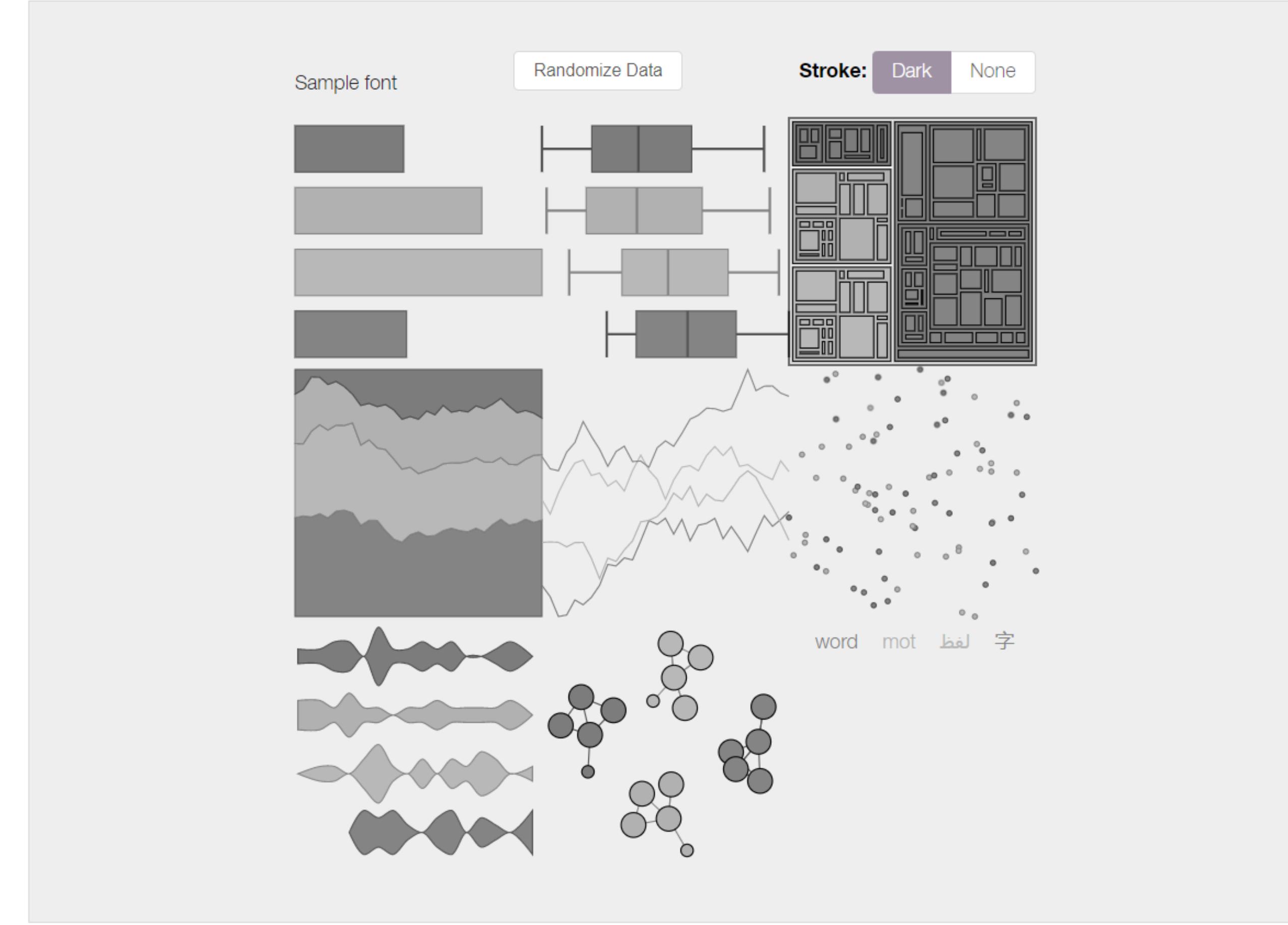
Background color: ↲

Font color: ● ↲

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 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 rgb

hsl

GET

String quotes
 Object with metadata

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

hsl

COLORS IN ACTION

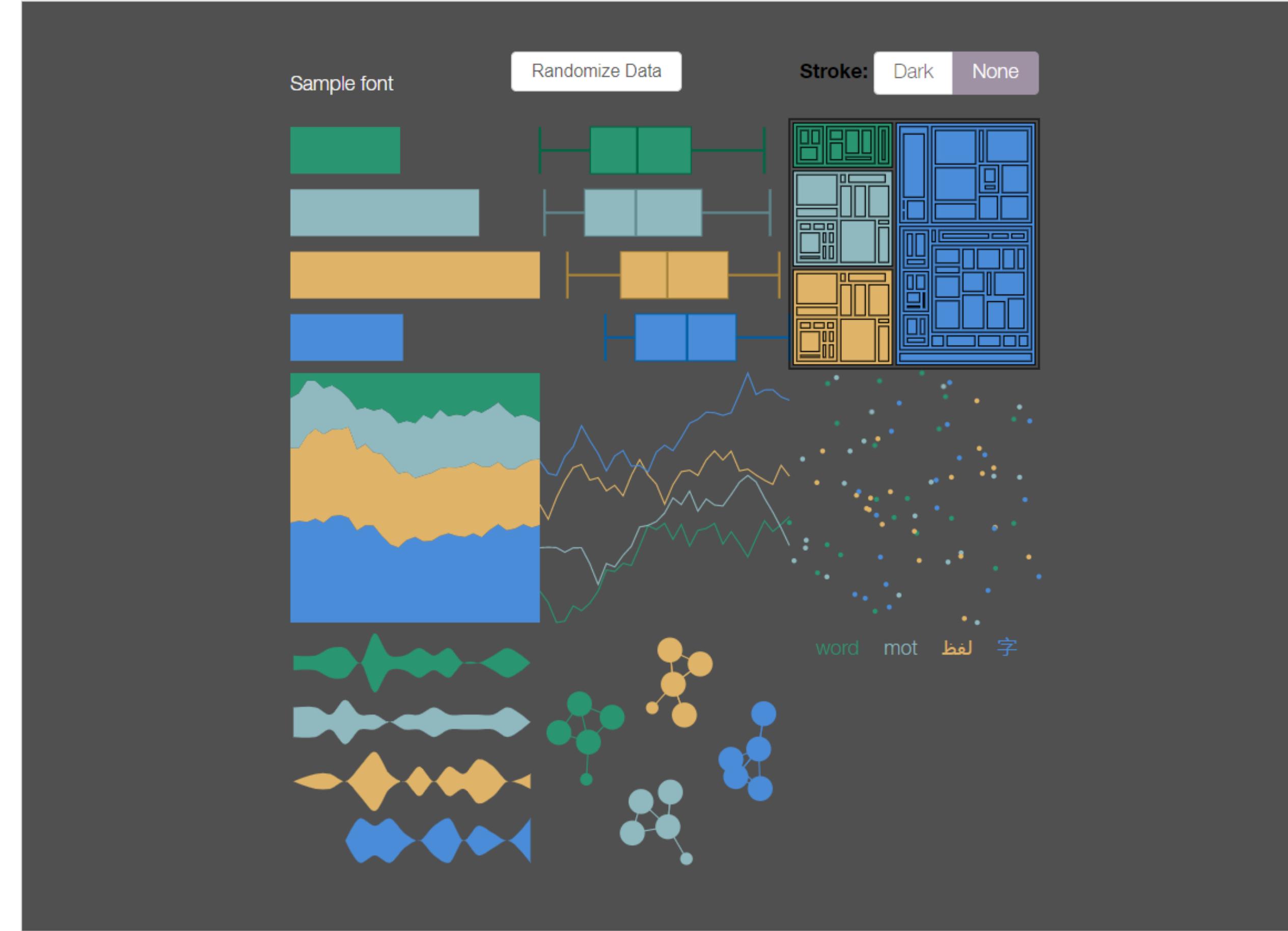
Background color: ● #505050 [🔗](#)

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

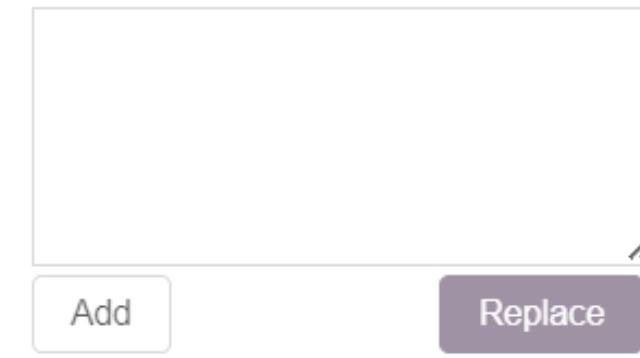


Viz Palette displaying the same “colors in action” on a dark background

VIZ PALETTE

By: Elijah Meeks
& Susie Lu

PICK



Use Chroma.js

Add

Replace

Use Colorgorical

Use ColorBrewer

EDIT

- ≡ 1 ● #2a9571 [🔗](#) 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

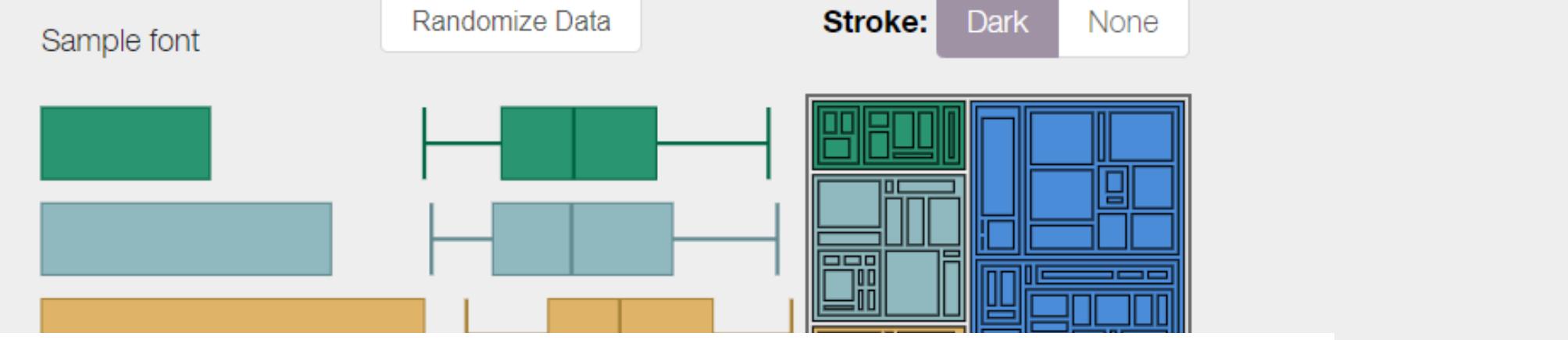
Background color: #eeeeee [🔗](#)

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



COLOR REPORT

No color conflicts

#dfb468

#2a9571

#8fb9bf

#4b8cd8

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 adventure.

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 adventure.

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 adventure.

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 adventure.

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 adventure.

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
the world, wondering if the
would ever wake up so they could
17.5px the lazy grey dog slept as
frisky fox frolicked freely
field of grass without a care
the world, wondering if the
would ever wake up so they could
16.5px the lazy grey dog slept as
frisky fox frolicked freely
field of grass without a care
the world, wondering if the
would ever wake up so they could
15px the lazy grey dog slept as
frisky fox frolicked freely
field of grass without a care
the world, wondering if the
would ever wake up so they could
14px the lazy grey dog slept as
frisky fox frolicked freely
field of grass without a care
the world, wondering if the
would ever wake up so they could

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)

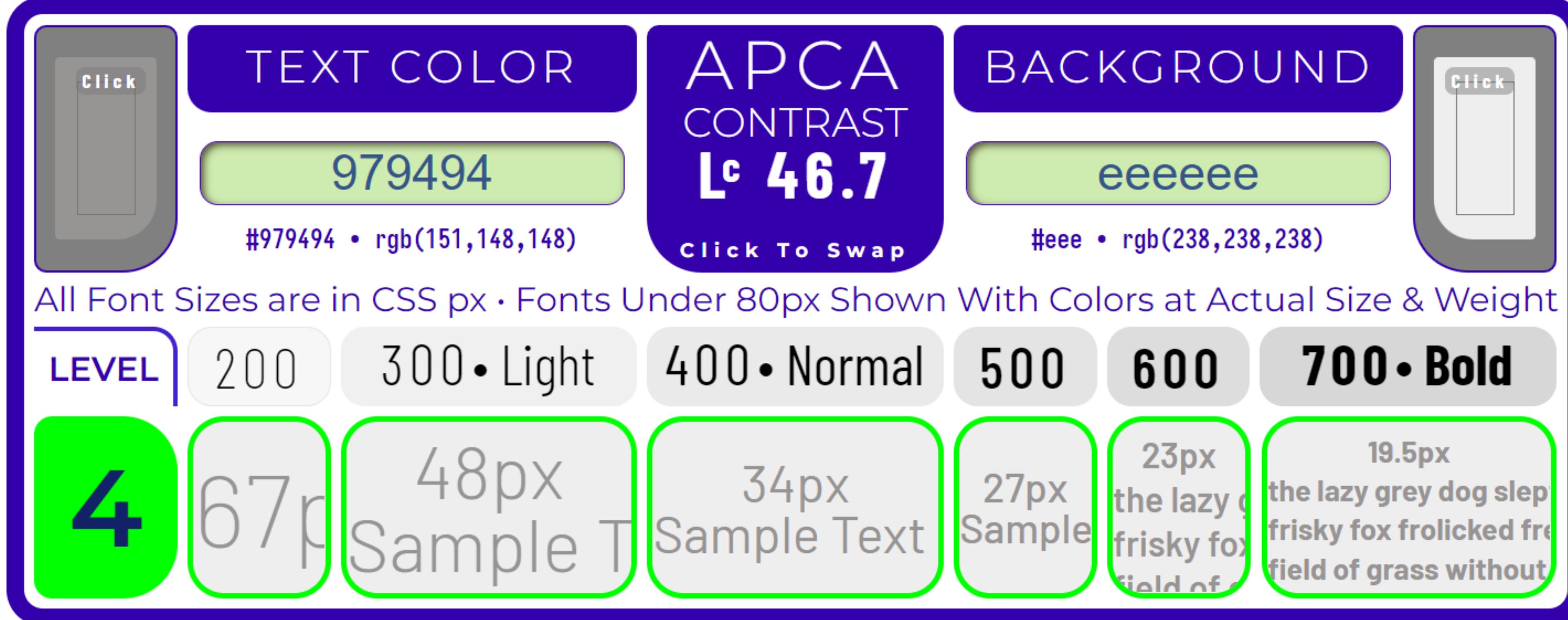
APCA CONTRAST **Lc 46.7**
Click To Swap

BACKGROUND **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 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

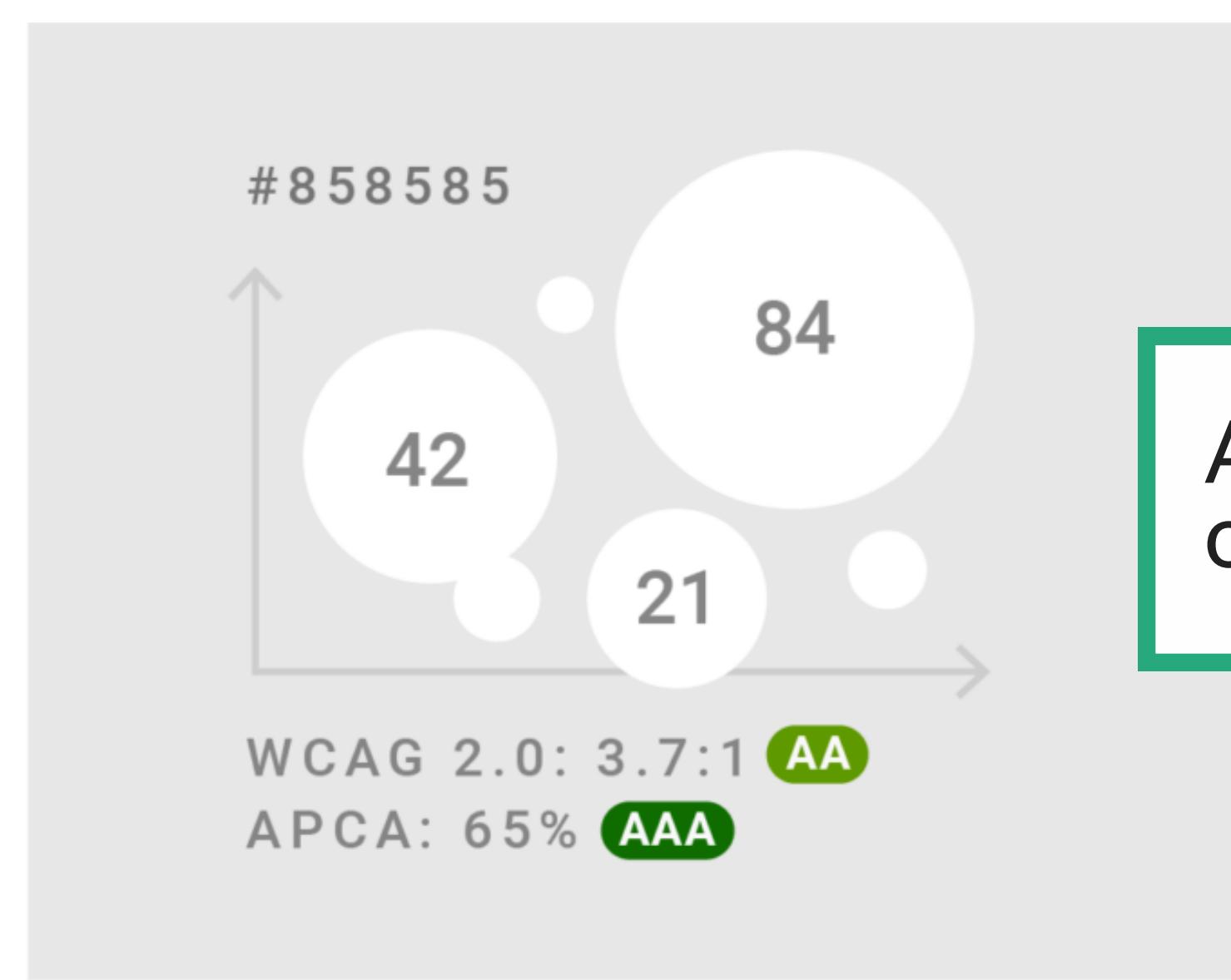
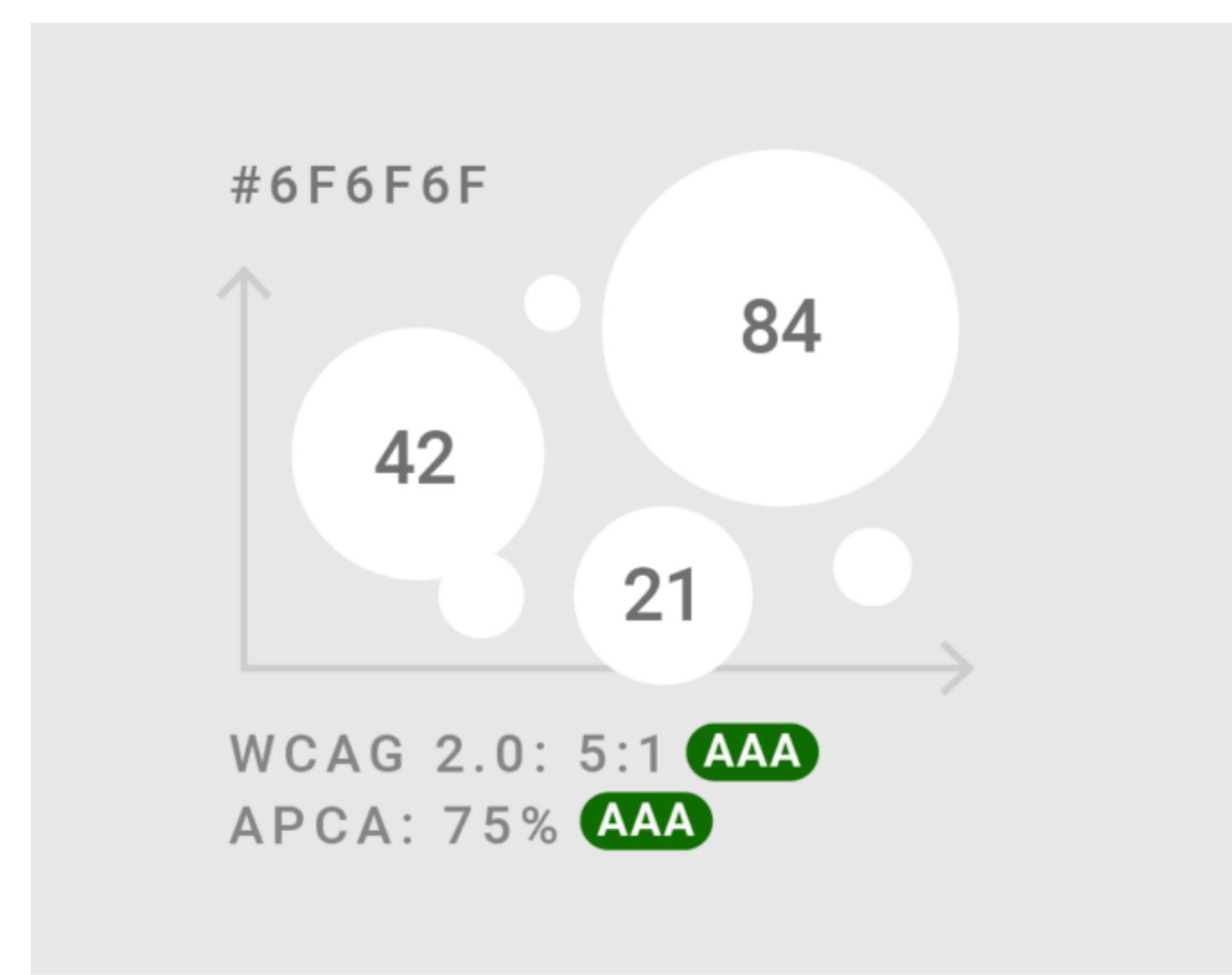
BACKGROUND **eeeeee** #eee • rgb(238,238,238)

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

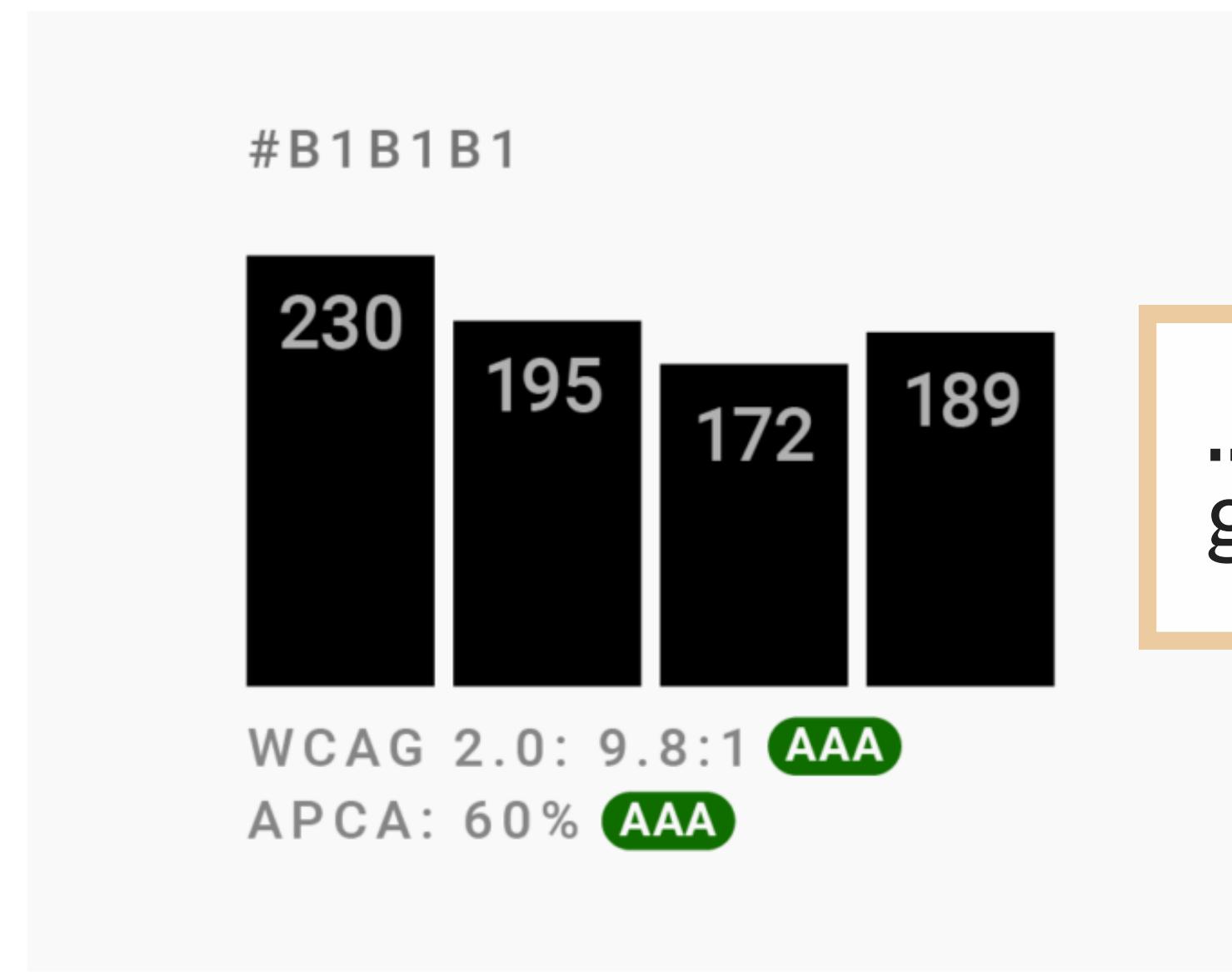
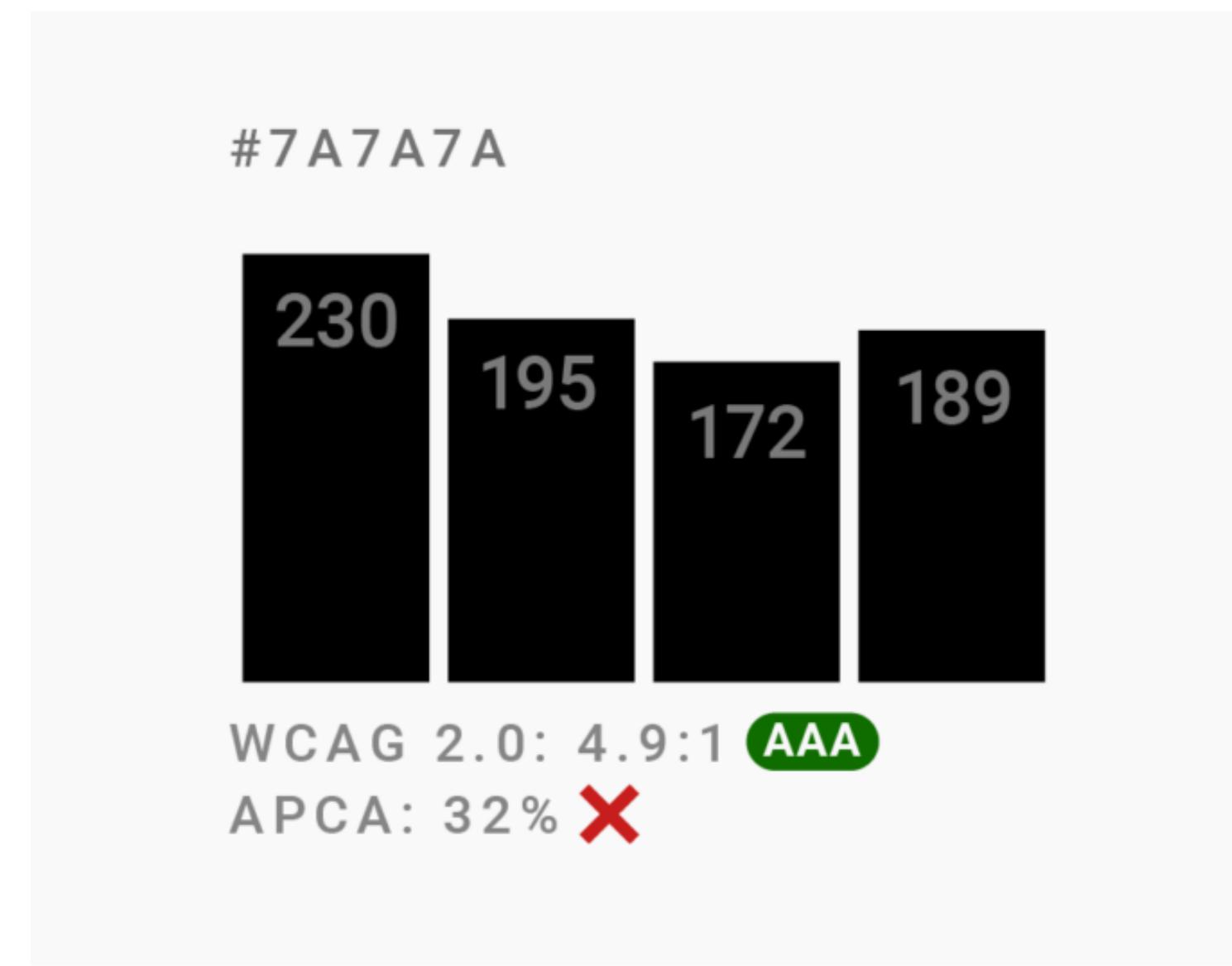
LEVEL 200 300 • Light 400 • Normal 500 600 700 • Bold

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

[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^{a)}

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

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Education and communication

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

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[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

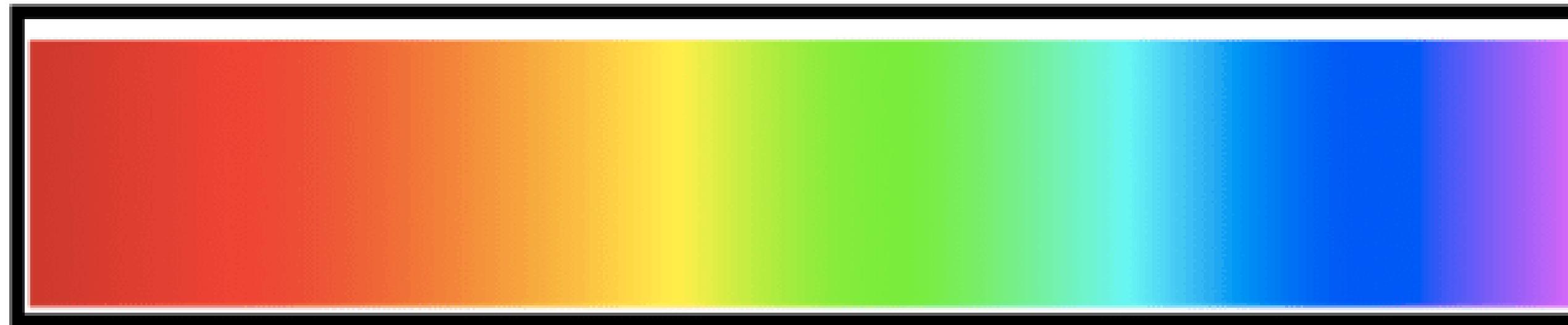
[Silvina Zabala-Travers](#), [Mina Choi](#), [Wei-Chung Cheng](#), and [Aldo Badano](#)^{a)}

“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.”

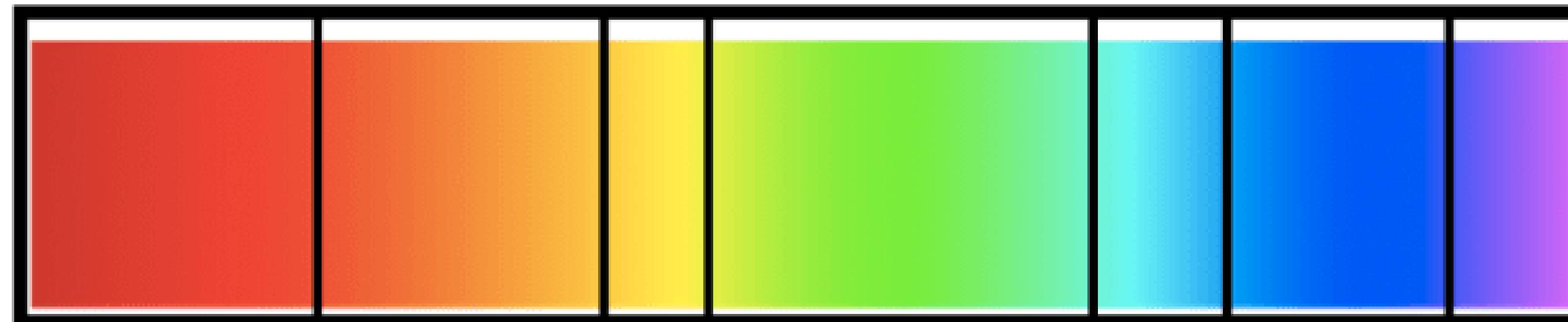
Zabala-Travers, Choi, Cheng & Badano 2015 Med Phys.

Non-Uniform Distances between Hues in the Newton Rainbow Colormap

Red Orange Yellow Green Blue Indigo Purple



Typical Rainbow Colormap

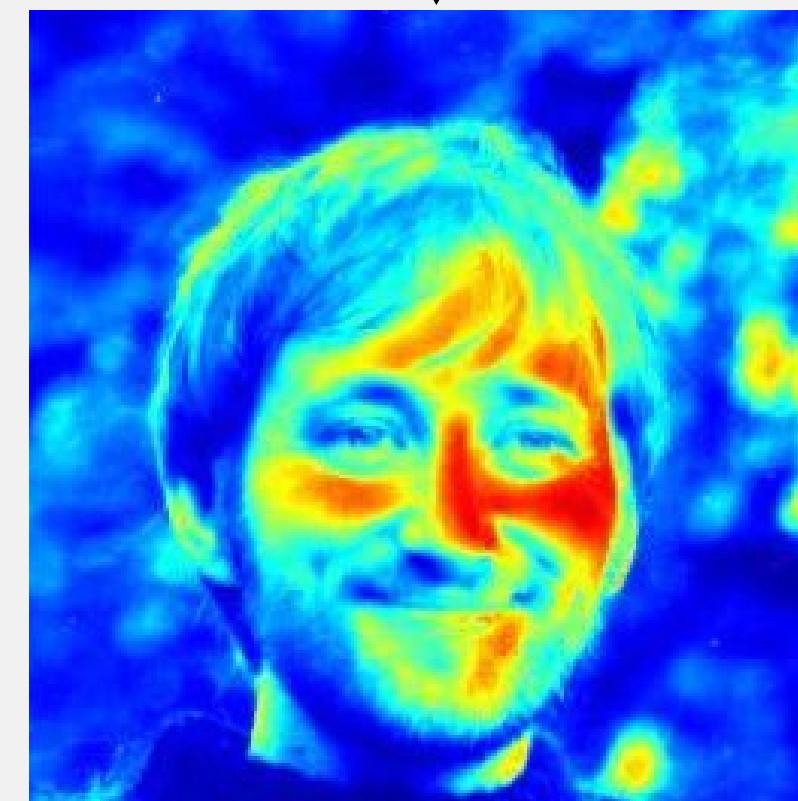


Non-Uniform Distances between Hues.

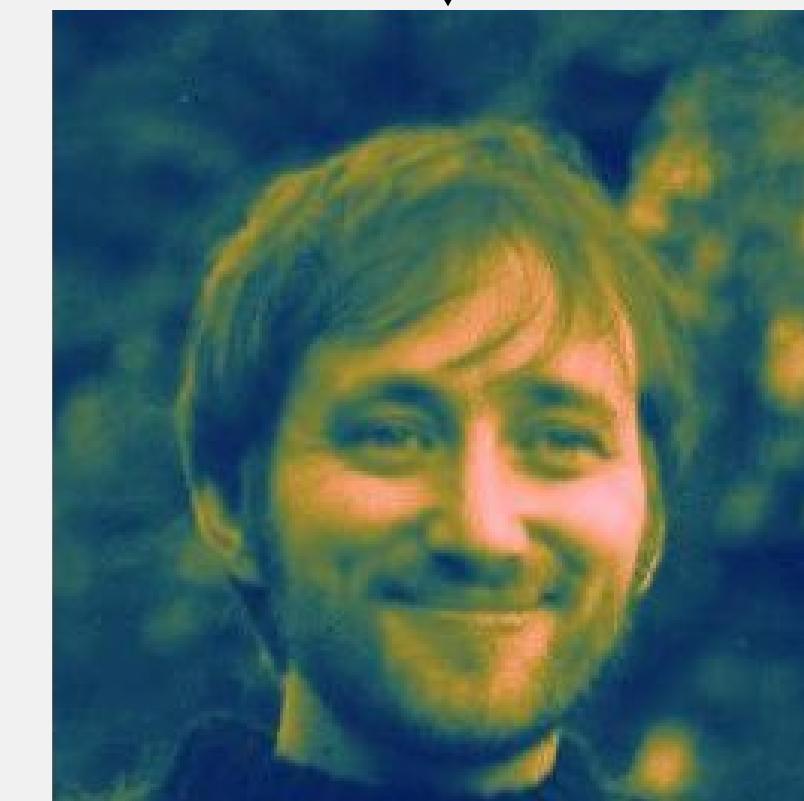
Modified from [Fabio Cramer](#)



true-color Phil



rainbow Phil

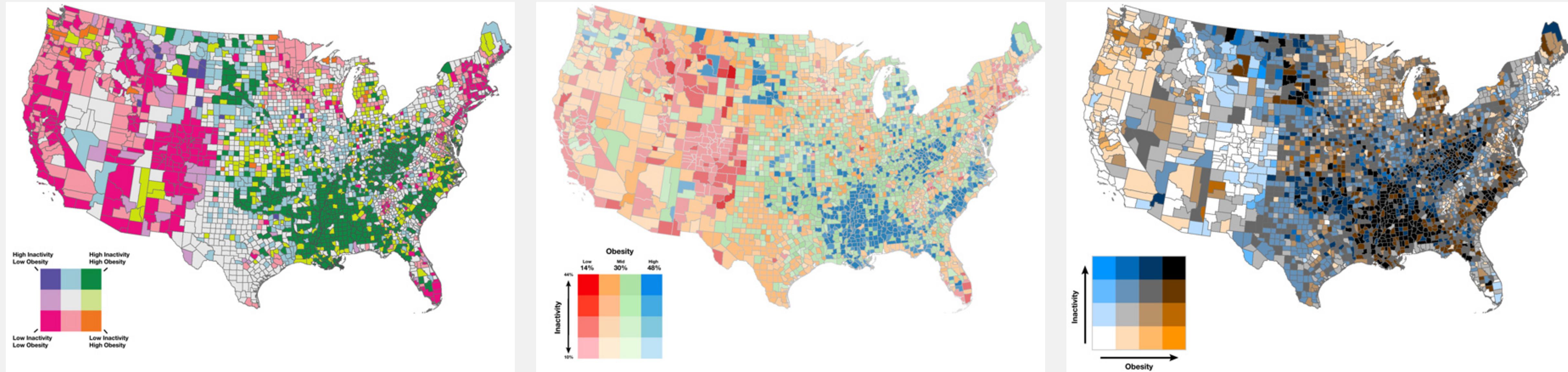


batlow Phil

Modified from [Fabio Cramer](#)

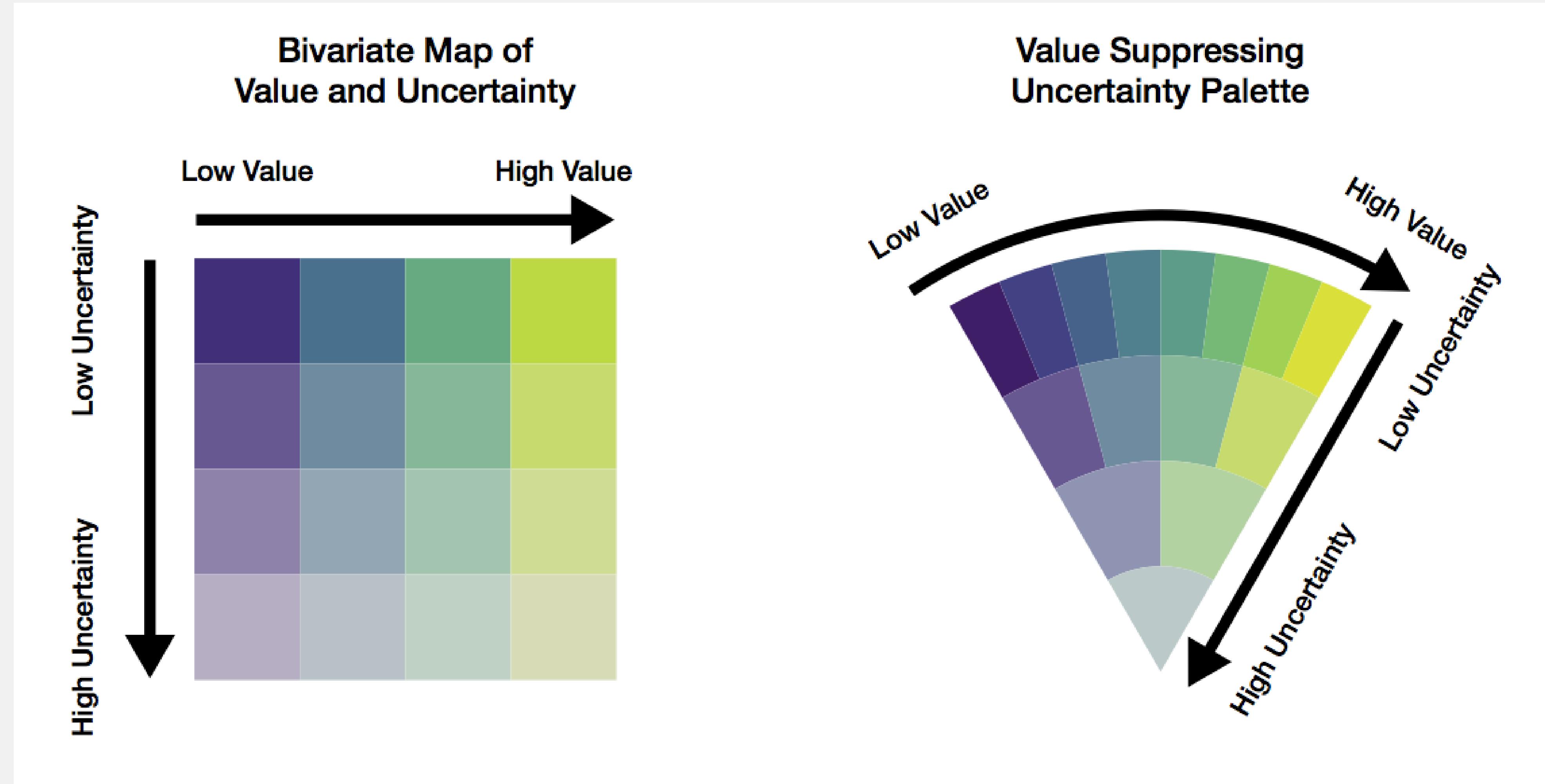
Appendix

Bivariate Color Palettes



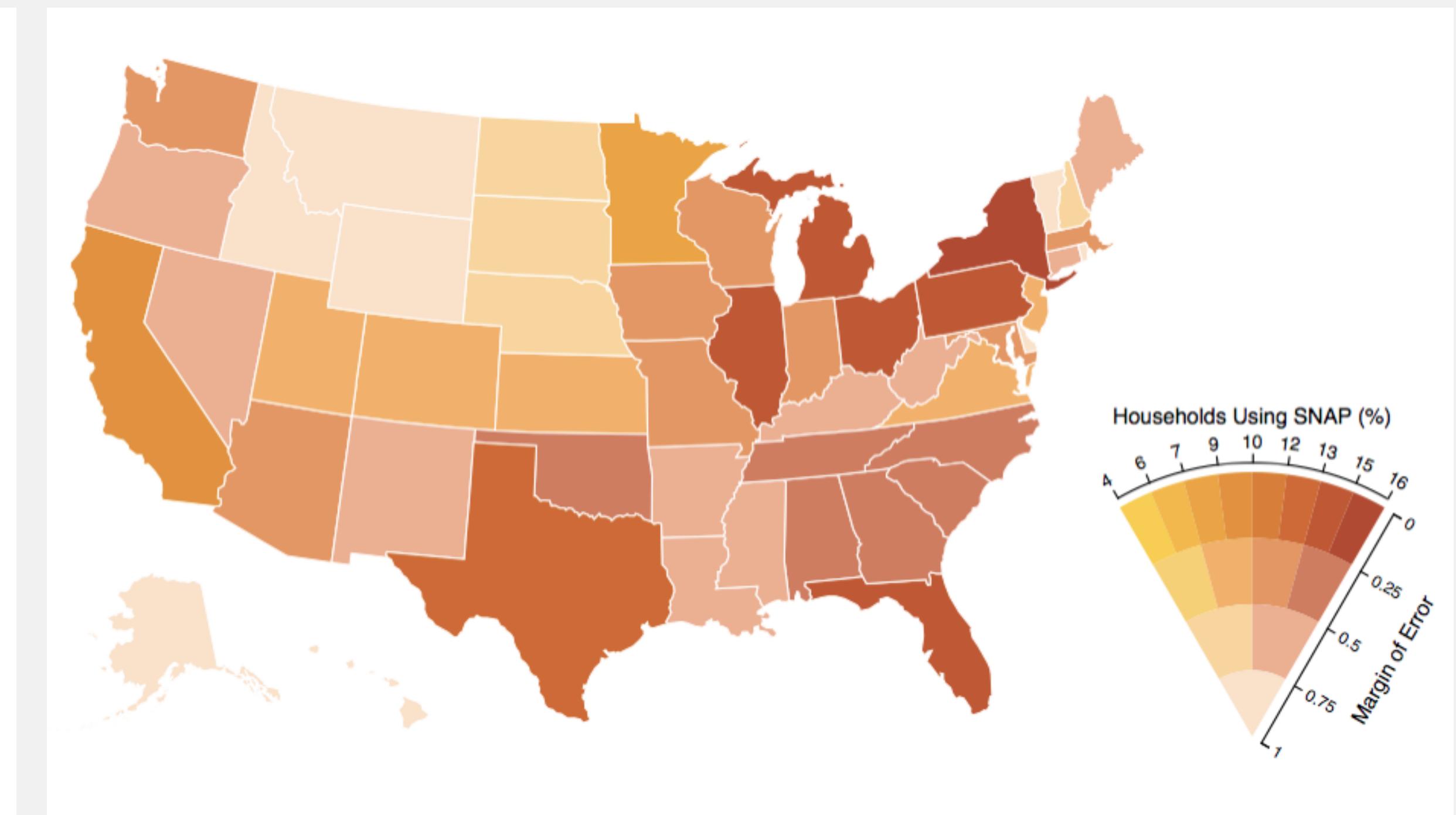
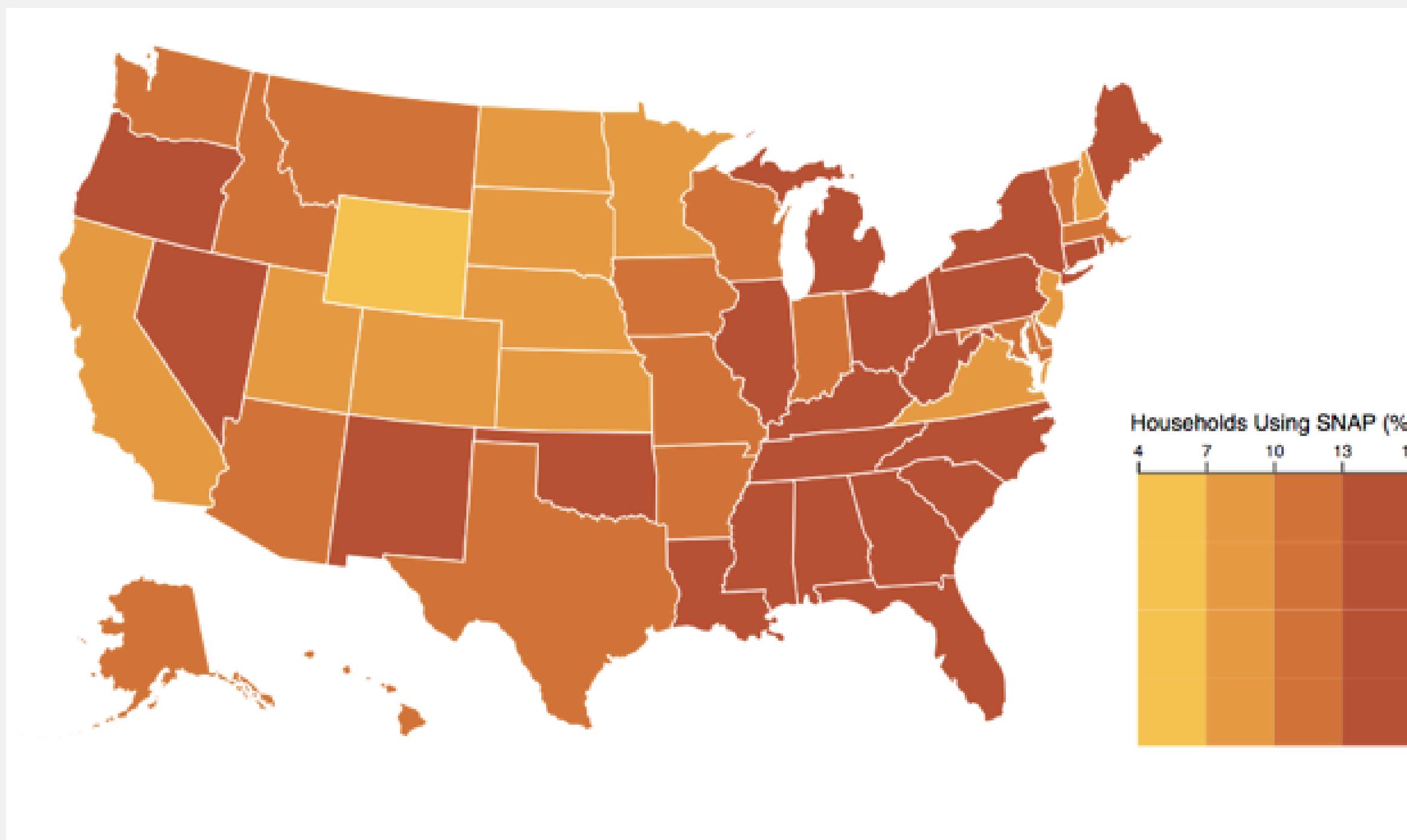
Strode et al. (2020) ["Operationalizing Trumbo's Principles of Bivariate Choropleth Map Design"](#)

Value-Suppressing Uncertainty Palettes

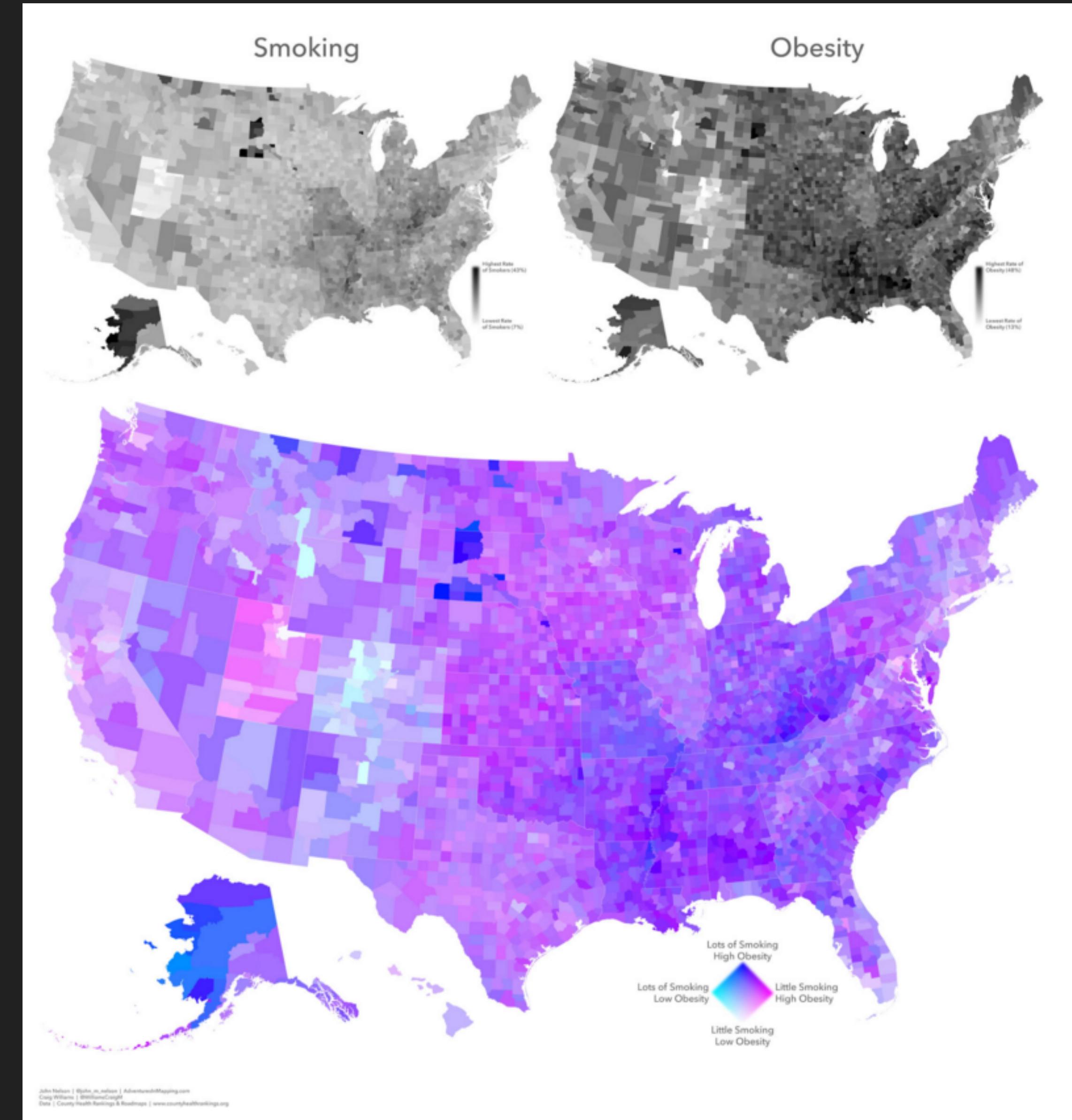


Correll, Moritz & Heer (2018) ["Value-Suppressing Uncertainty Palettes"](#)

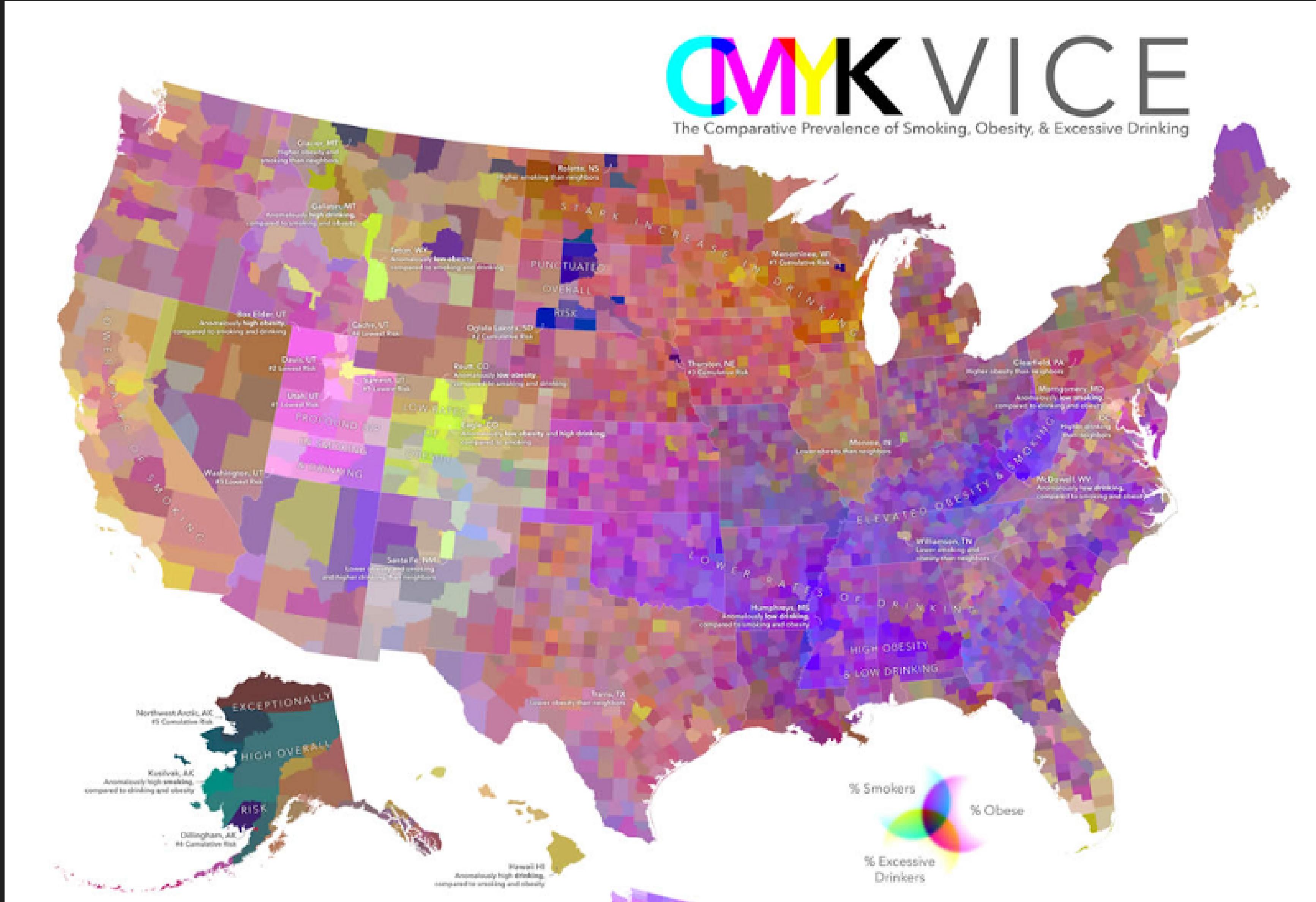
Bivariate Color Palettes versus Value-Suppressing Uncertainty Palettes



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



"CMYK Vice Map" by John Nelson & Craig Williams



“CMYK Vice Map” by John Nelson & Craig Williams