

Key Concepts in Data Visualization

How to Design Effective & Engaging Charts

Dr. Cédric Scherer

MSC Data Visualization Training | March 9 and 11 2021

Photo by Richard Strozyński

RECAP

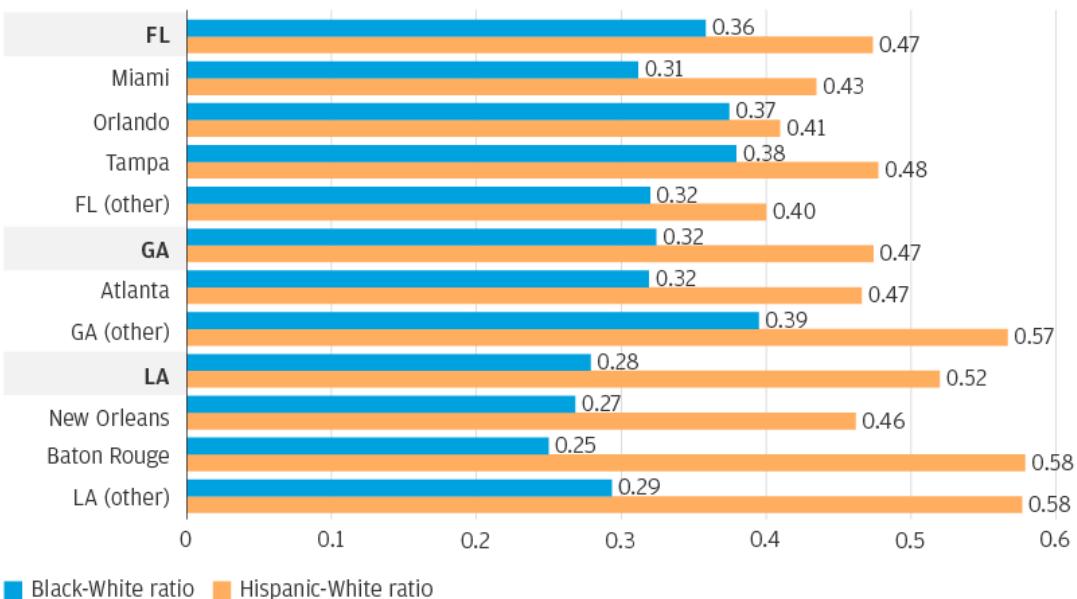
Data Visualization

helps to amplify cognition, gain insights,
discover, explain, and make decisions.

How to improve this visualization?

Finding Four: Across geographies, the financial outcomes of Hispanic families vary the most, while the financial outcomes of Black families vary the least. Black-White gaps in financial outcomes are largest in Louisiana, while Hispanic-White gaps are largest in Florida.

Black-White and Hispanic-White ratios of annual median liquid assets (2018), by geography



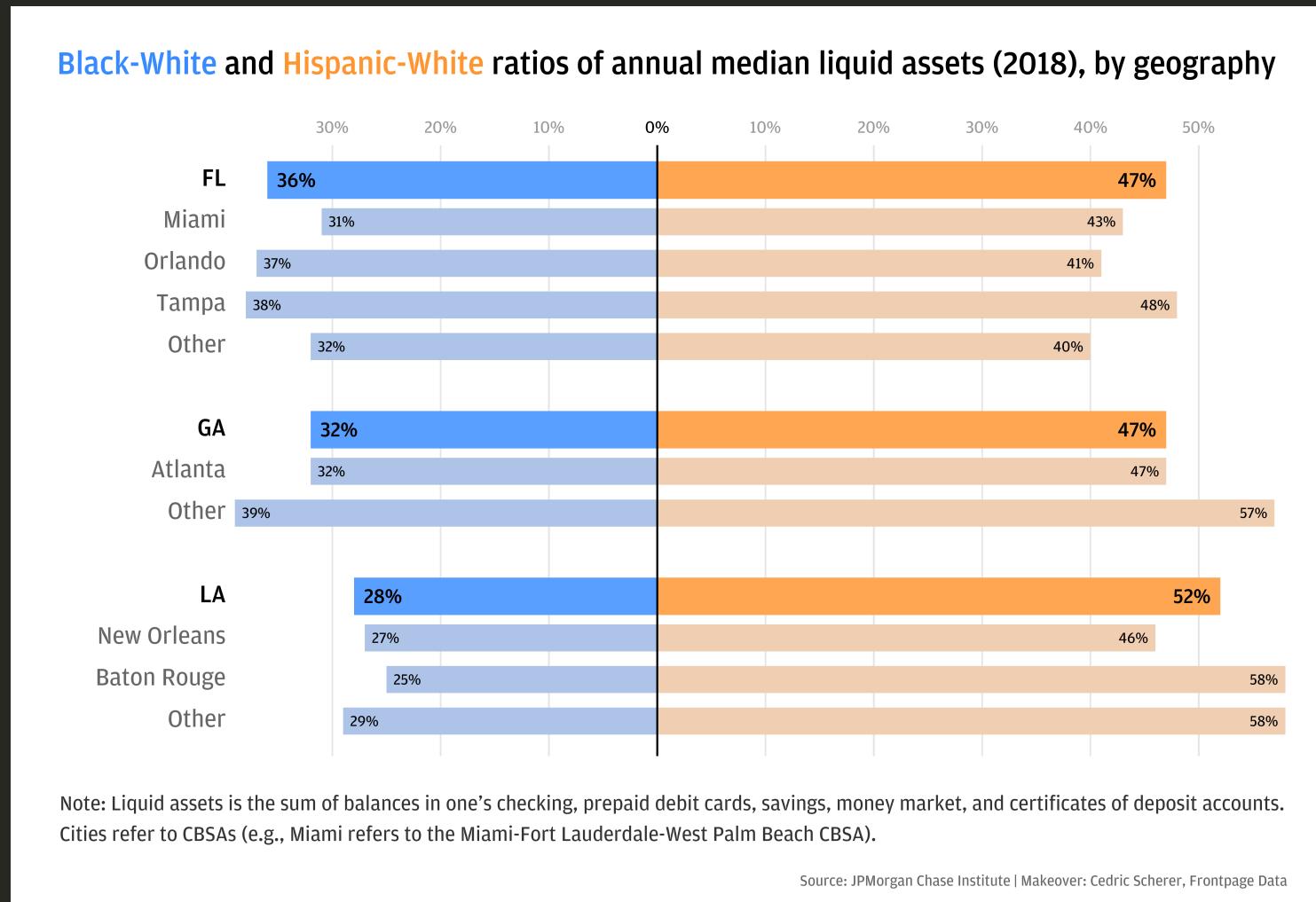
■ Black-White ratio ■ Hispanic-White ratio

Note: Liquid assets is the sum of balances in one's checking, prepaid debit cards, savings, money market, and certificates of deposit accounts. Cities refer to CBSAs (e.g., Miami refers to the Miami-Fort Lauderdale-West Palm Beach CBSA).

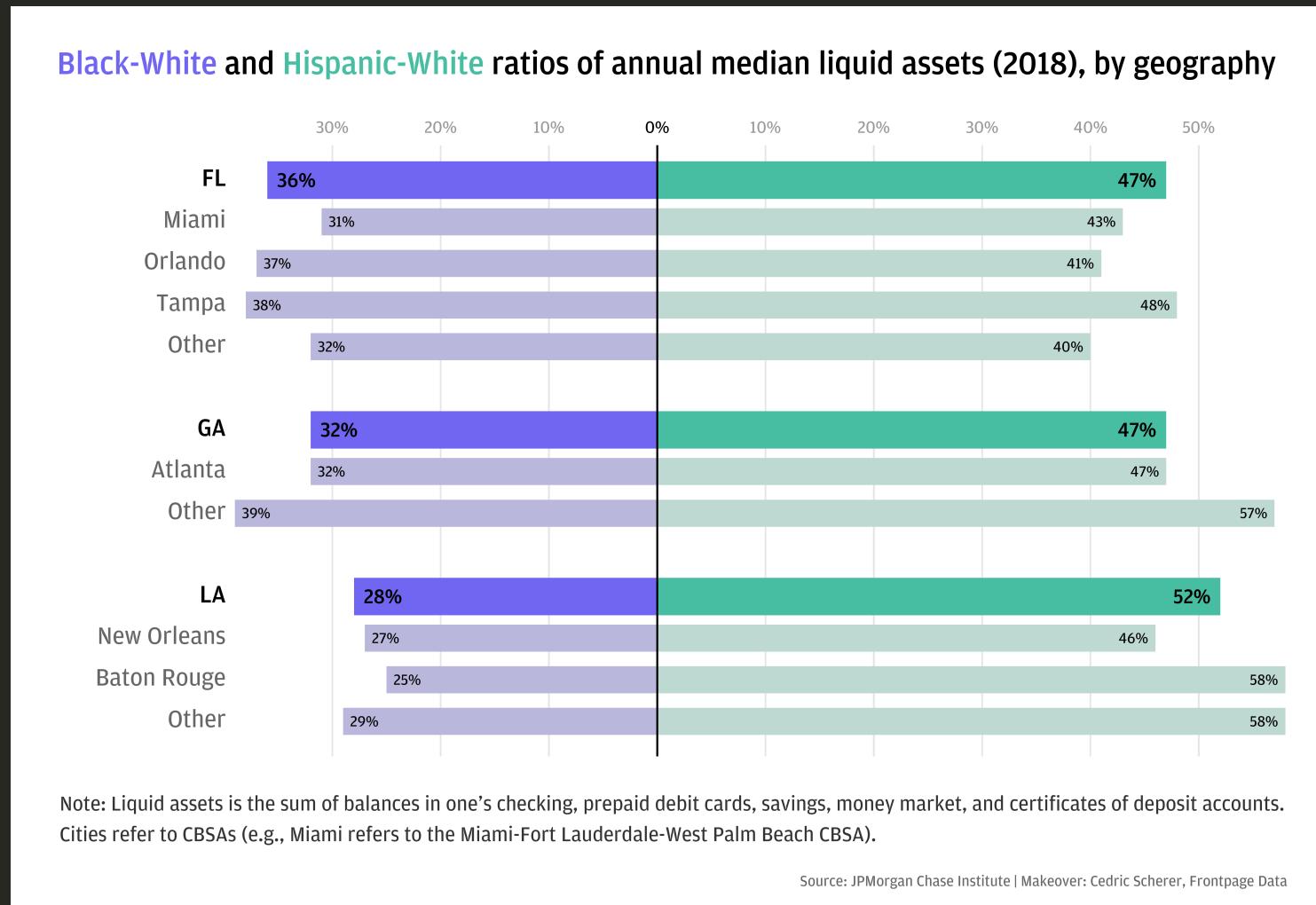
Source: JPMorgan Chase Institute

[View the Text Version >](#)

How to improve this visualization?

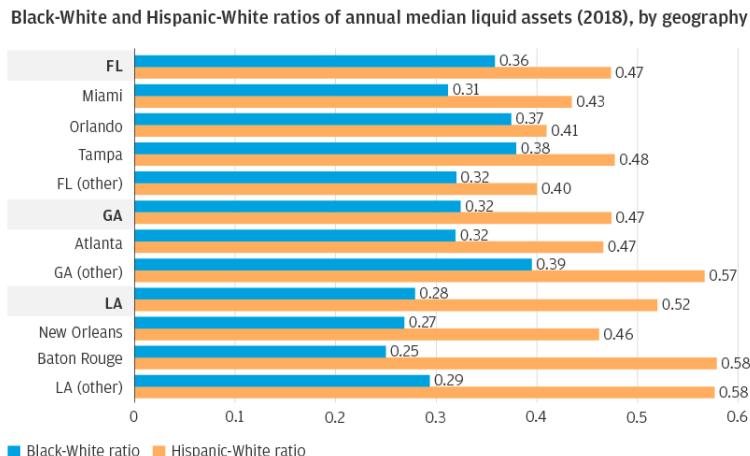


How to improve this visualization?



How to improve this visualization?

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Source: JPMorgan Chase Institute

[View the Text Version >](#)

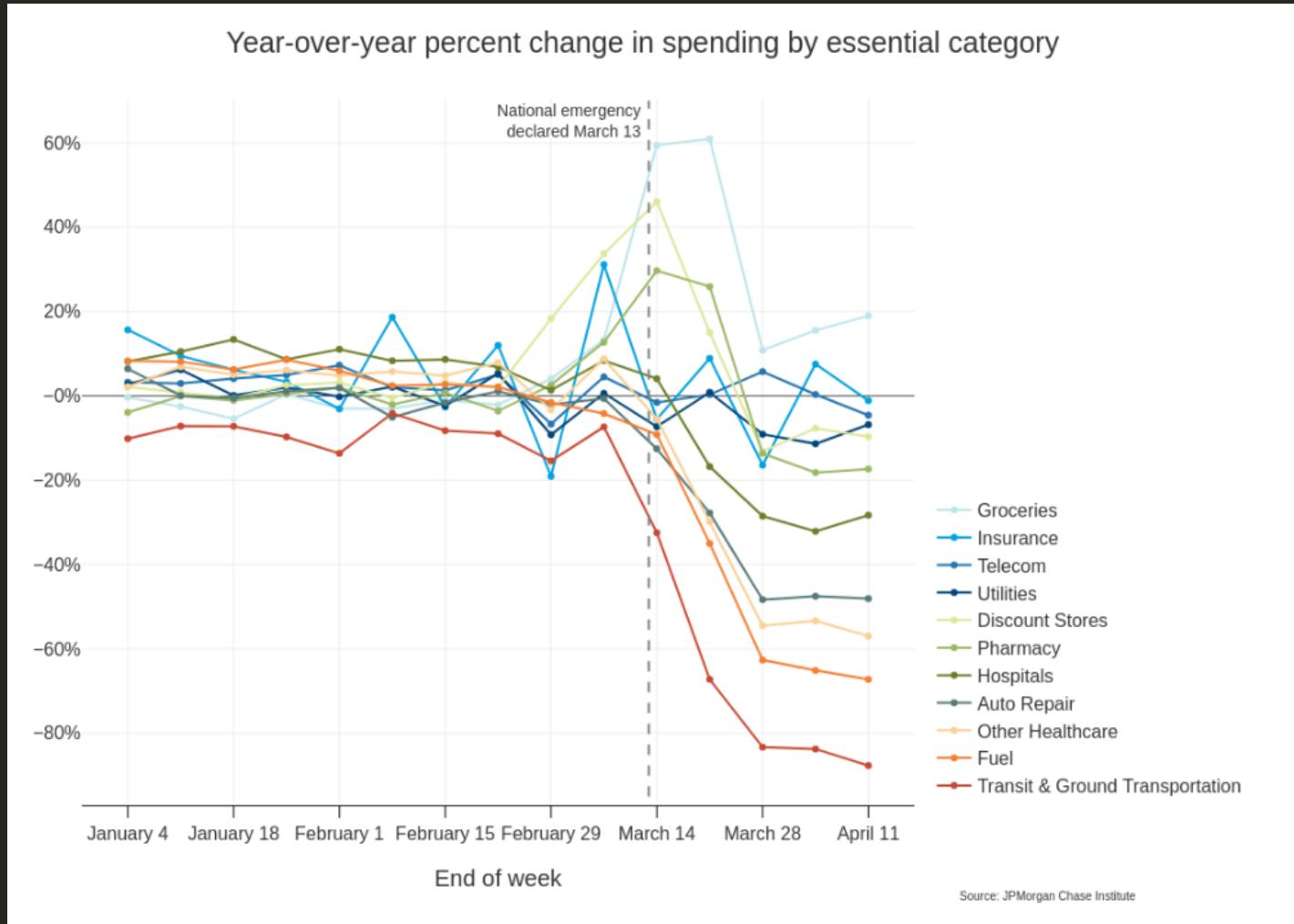
Black-White and Hispanic-White ratios of annual median liquid assets (2018), by geography



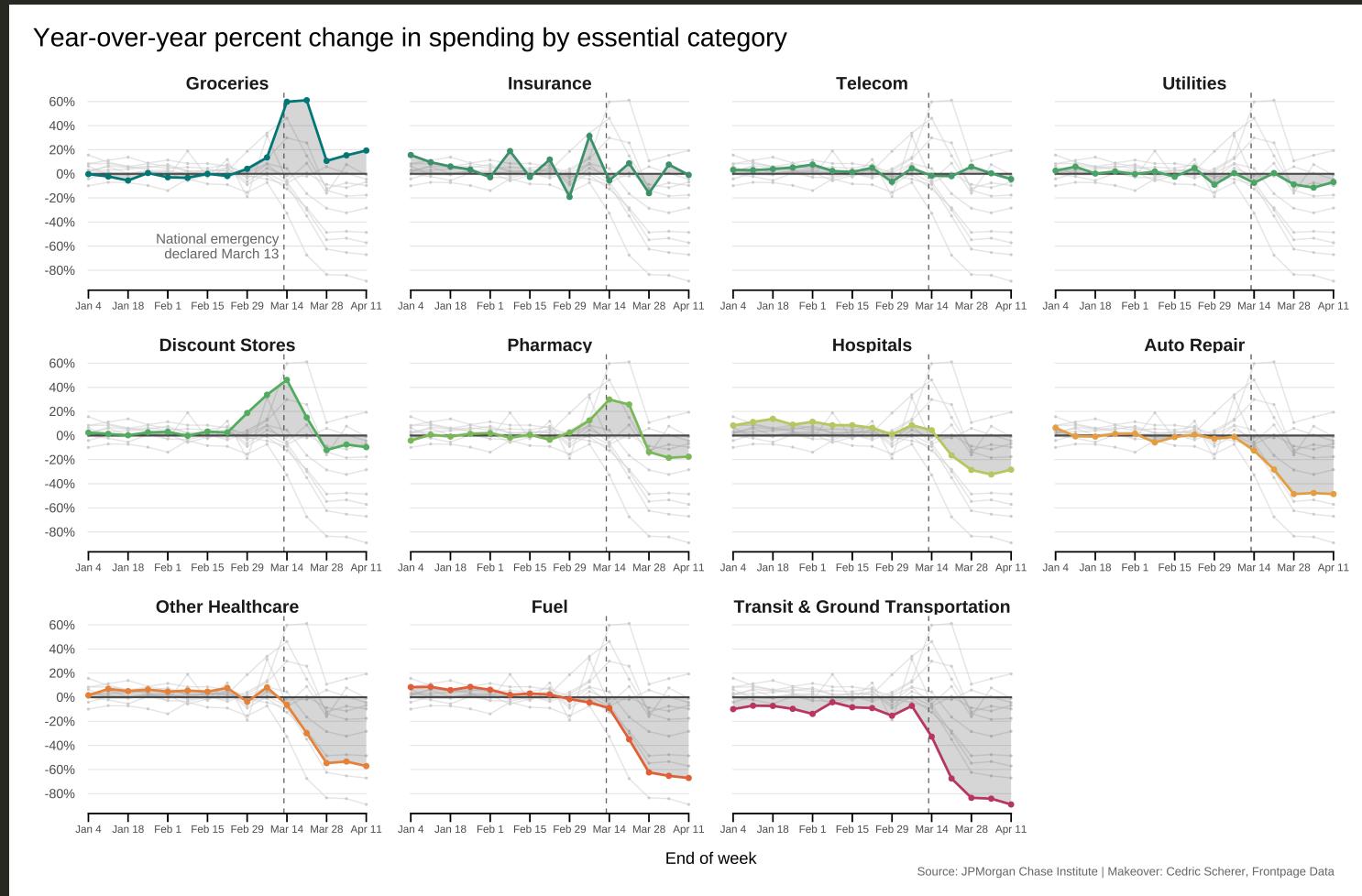
Note: Liquid assets is the sum of balances in one's checking, prepaid debit cards, savings, money market, and certificates of deposit accounts. Cities refer to CBSAs (e.g., Miami refers to the Miami-Fort Lauderdale-West Palm Beach CBSA).

Source: JPMorgan Chase Institute | Makeover: Cedric Scherer, Frontpage Data

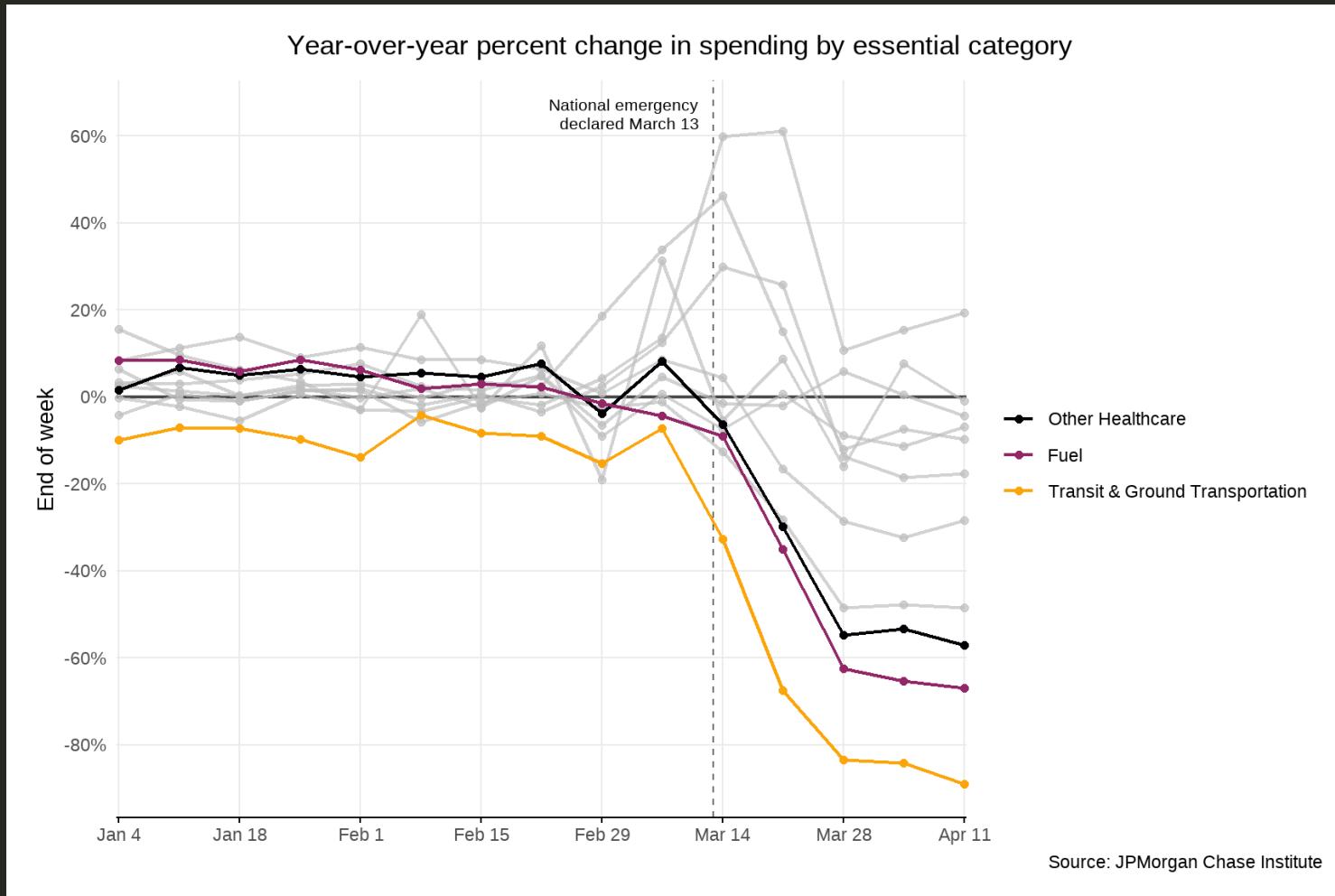
How to improve this visualization?



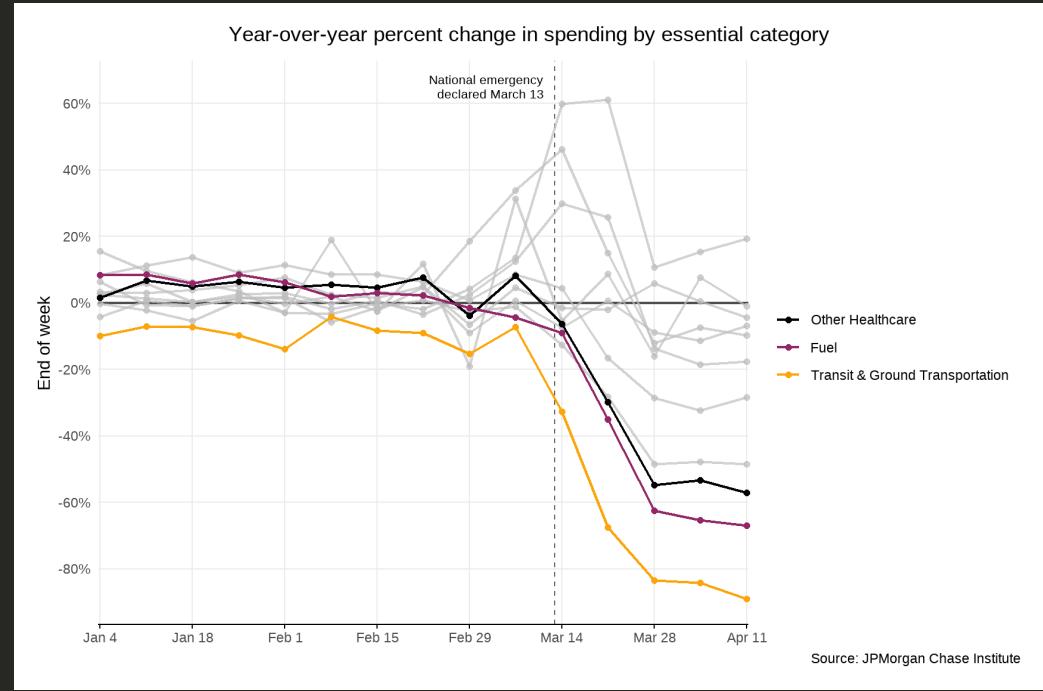
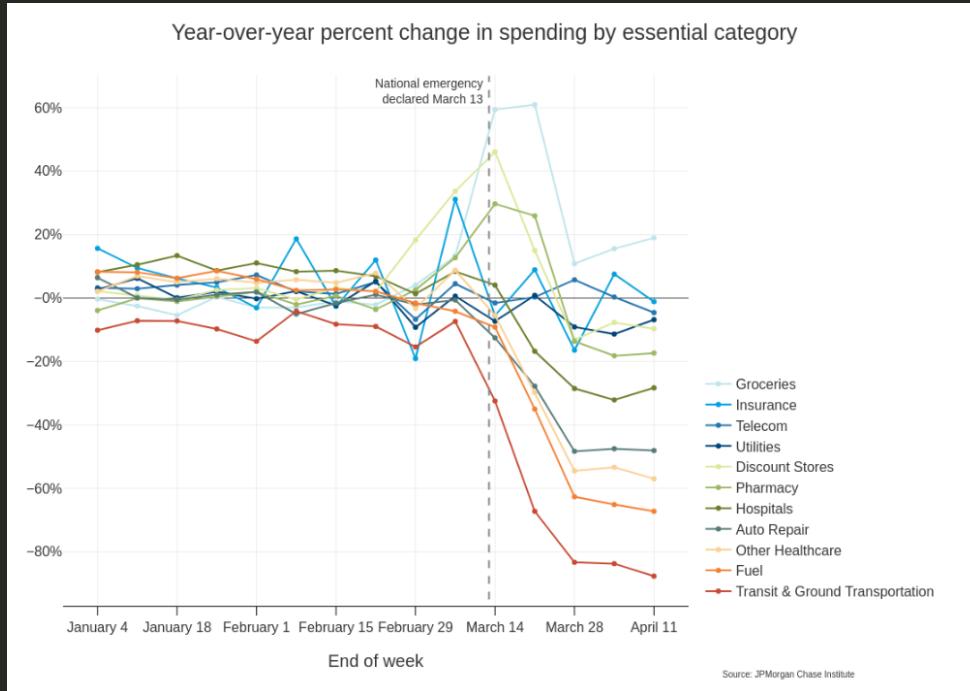
How to improve this visualization?



How to improve this visualization?



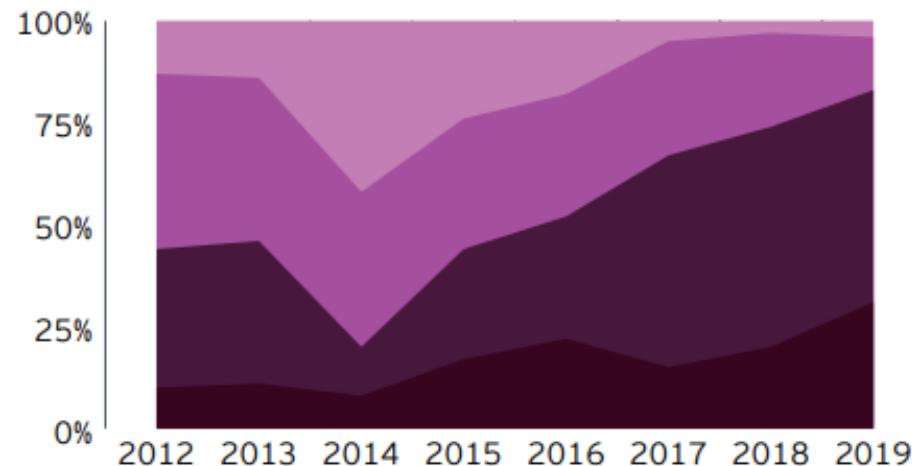
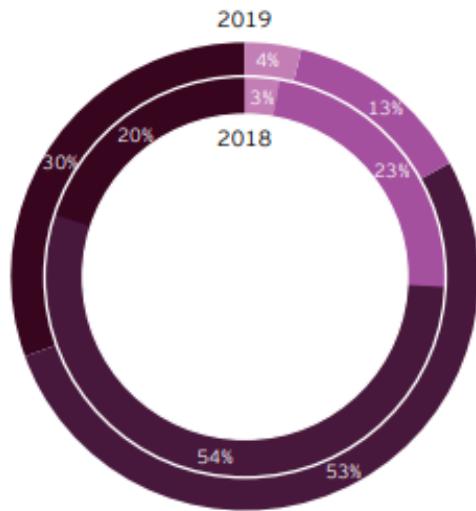
How to improve this visualization?



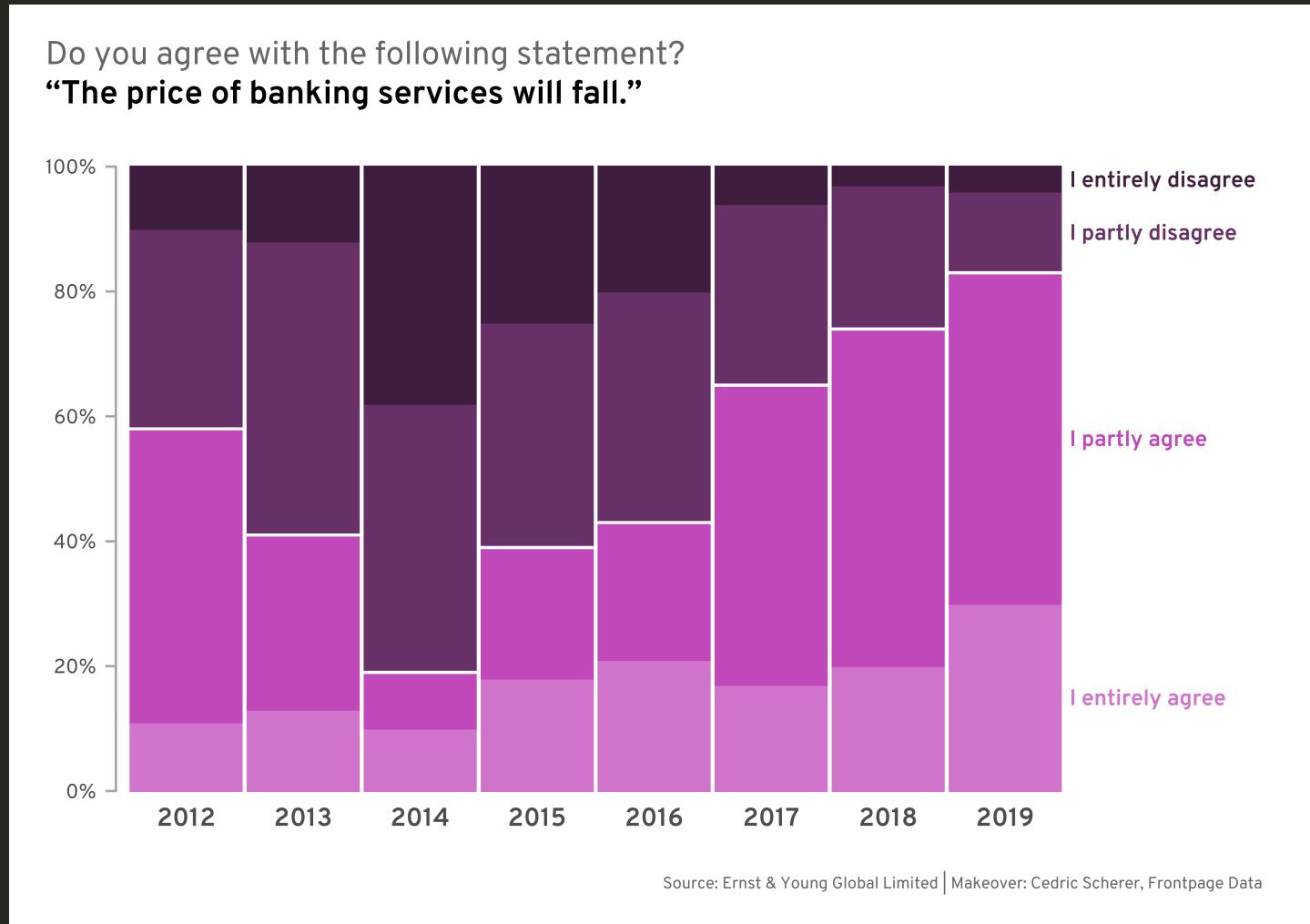
How to improve this visualization?

Do you agree with the following statement?
«The price of banking services will fall.»

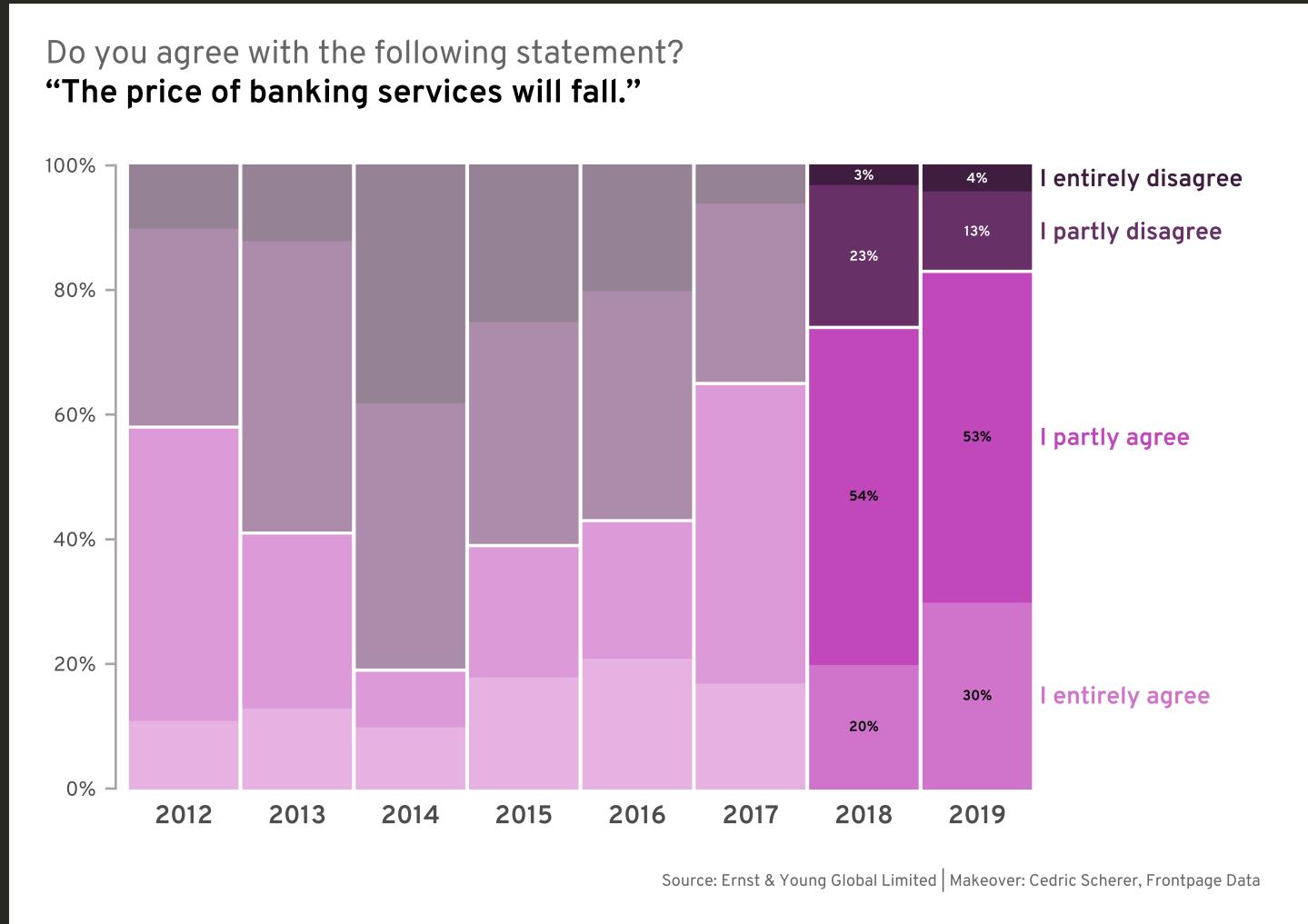
- I entirely disagree
- I partly disagree
- I partly agree
- I agree



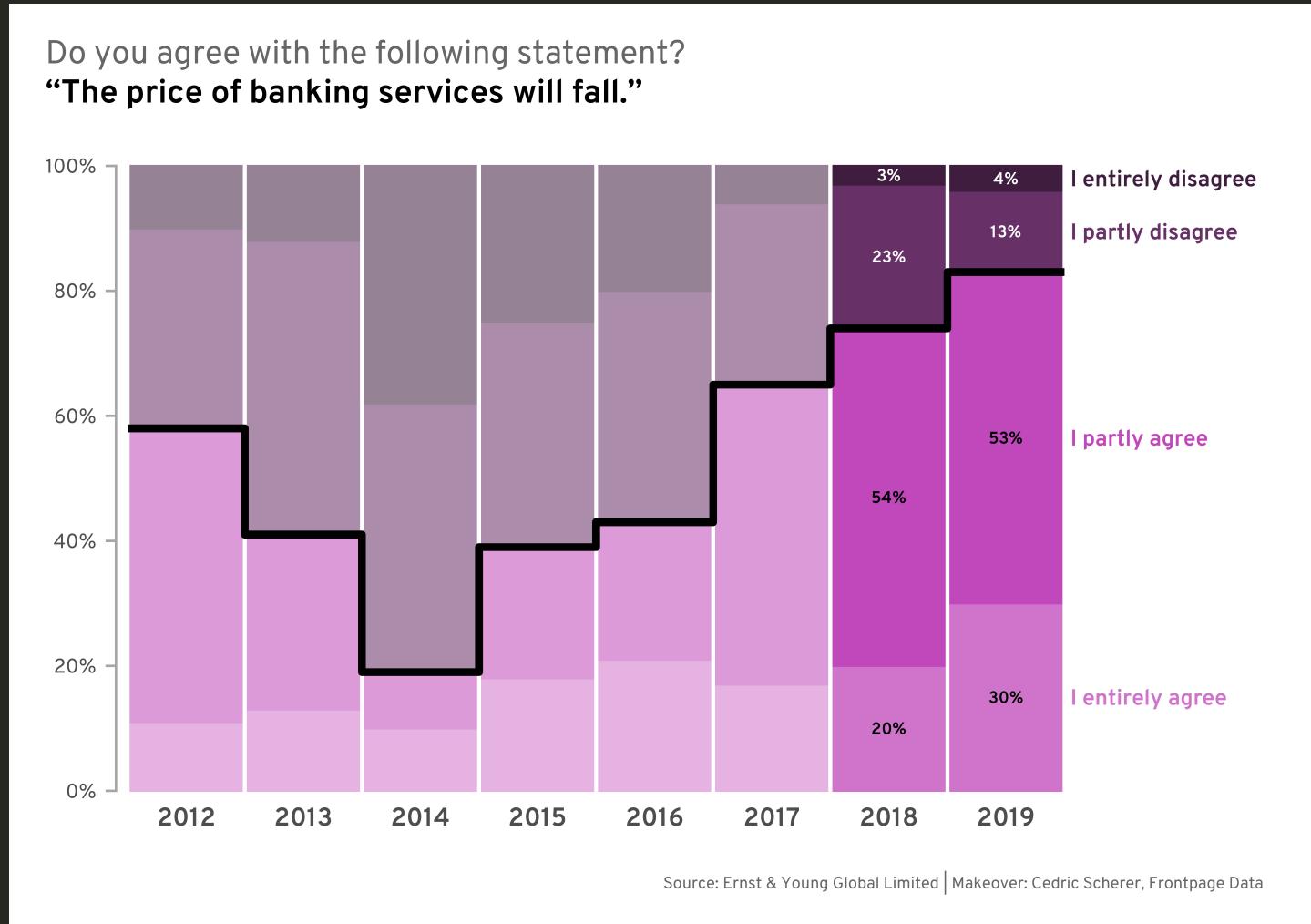
How to improve this visualization?



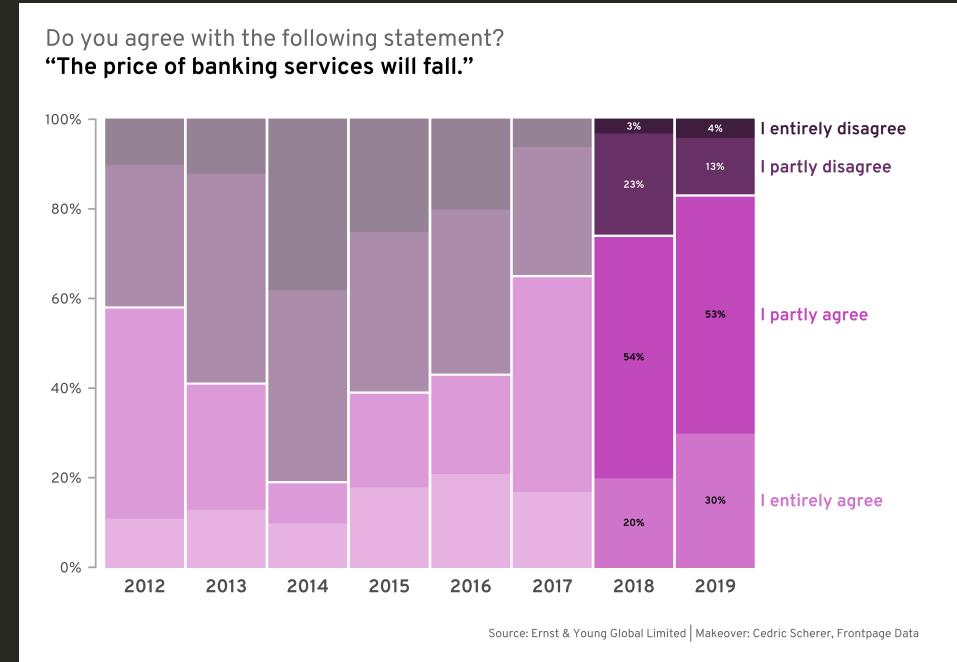
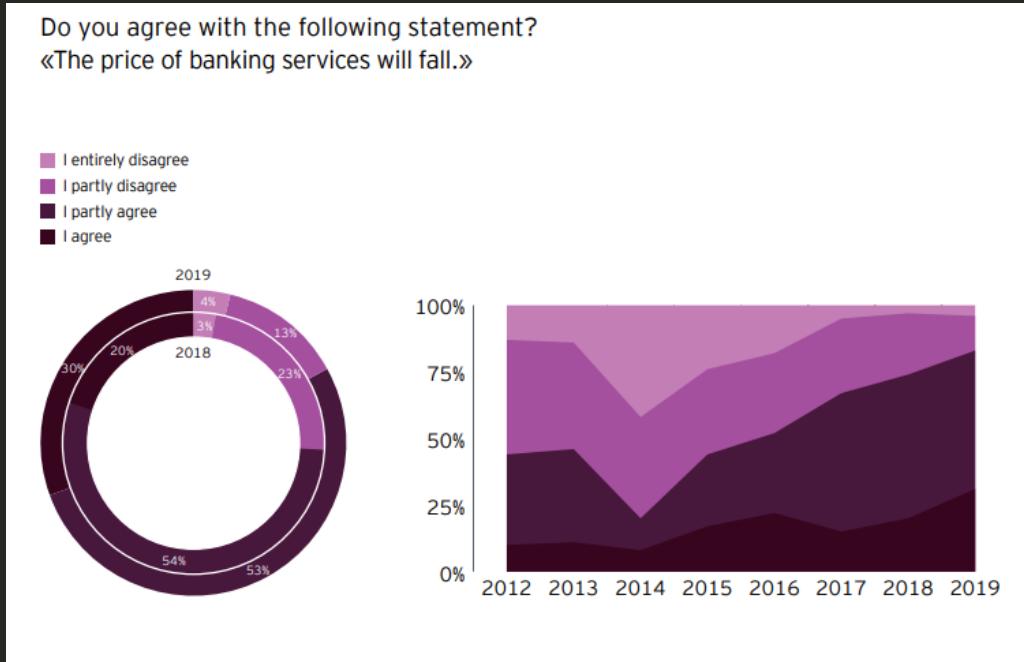
How to improve this visualization?



How to improve this visualization?



How to improve this visualization?



What Makes It a Good Data Visualization

- **Information** (Integrity)
- **Story** (Interestingness)
- **Goal** (Usefulness)
- **Visual Form** (Beauty)

VISUAL FORM

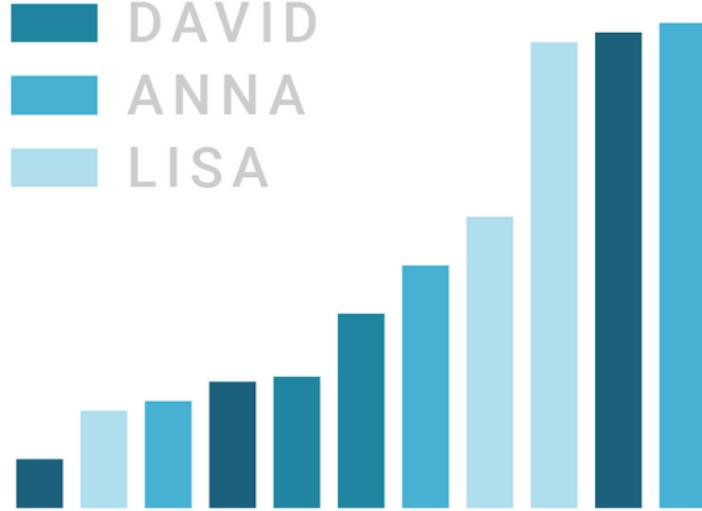
Follow design rules and data visualization principles



Colors and Common Pitfalls

Color Choice & Accessibility

NOT IDEAL



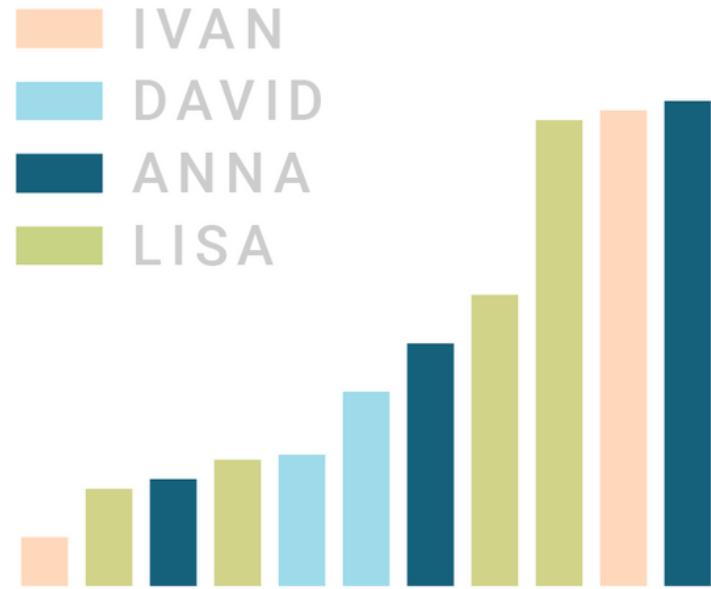
What to consider when choosing colors for data visualization by Lisa Charlotte Rost/DataWrapper

Color Choice & Accessibility

NOT IDEAL



BETTER



What to consider when choosing colors for data visualization by Lisa Charlotte Rost/DataWrapper

Color Palette Types

Categorical



Color Palette Types

Categorical



Sequential: Single-Hue



Color Palette Types

Categorical



Sequential: Single-Hue



Sequential: Multi-Hue



Color Palette Types

Categorical



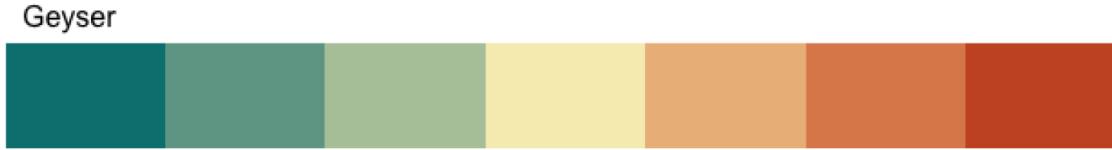
Sequential: Single-Hue



Sequential: Multi-Hue



Diverging



Color Palette Types

Categorical



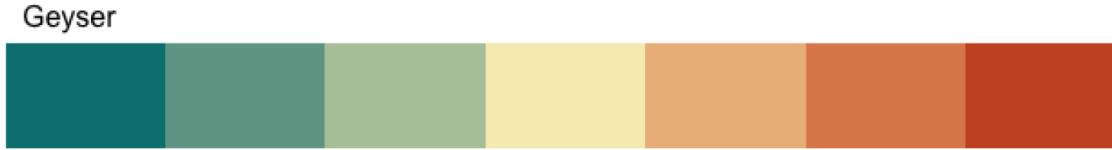
Sequential: Single-Hue



Sequential: Multi-Hue



Diverging



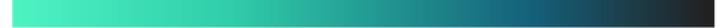
Cyclical



Color Choice & Accessibility

NOT IDEAL

POOR RICH



PEOPLE IN GROUP A

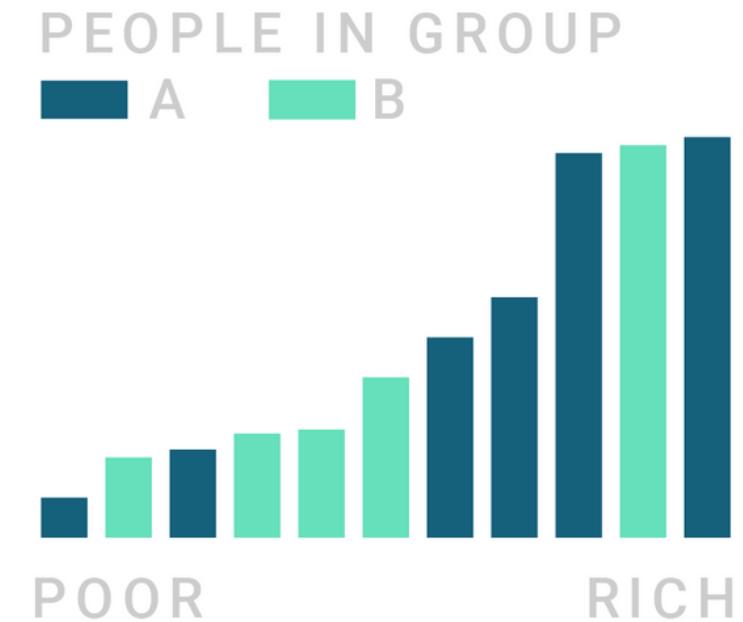


PEOPLE IN GROUP B



What to consider when choosing colors for data visualization by Lisa Charlotte Rost/DataWrapper

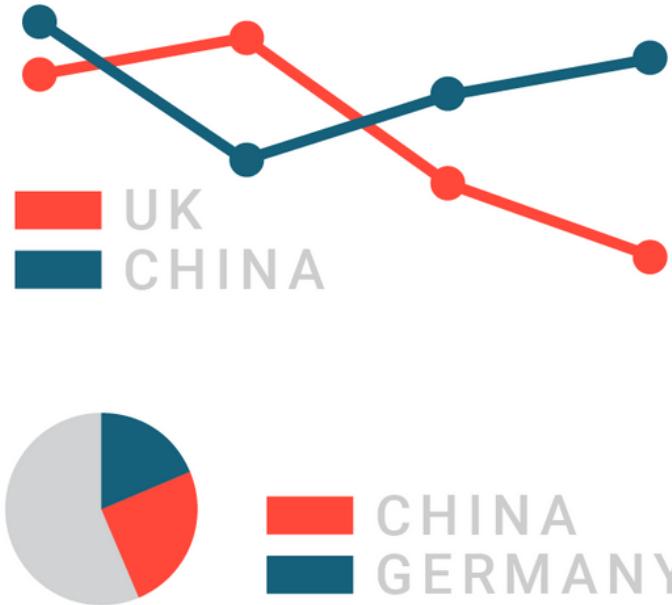
Color Choice & Accessibility



What to consider when choosing colors for data visualization by Lisa Charlotte Rost/DataWrapper

Color Choice & Accessibility

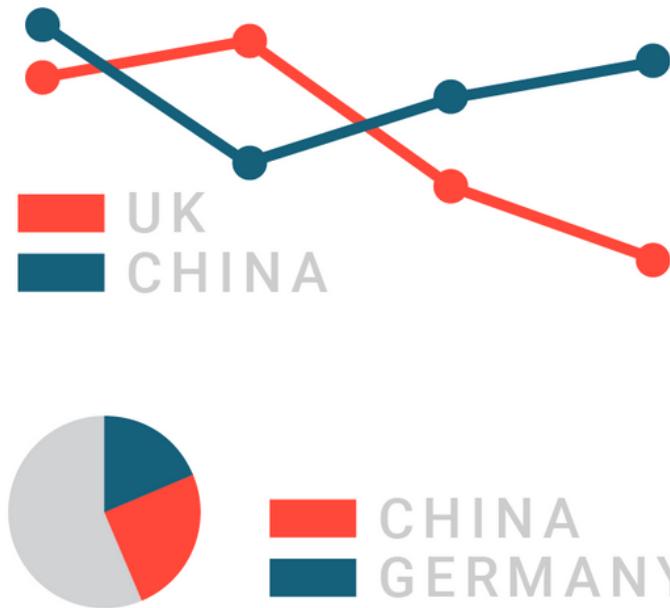
NOT IDEAL



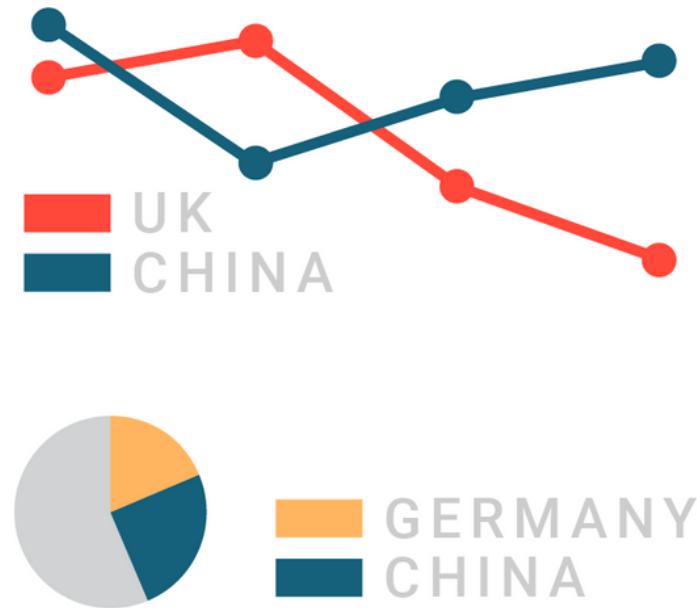
What to consider when choosing colors for data visualization by Lisa Charlotte Rost/DataWrapper

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NOT IDEAL



BETTER



What to consider when choosing colors for data visualization by Lisa Charlotte Rost/DataWrapper

Rainbow Color Map (Still) Considered Harmful

Publisher: IEEE

2 Author(s)

David Borland ; Russell M. Taylor li View All Authors

172
Paper
Citations

3
Patent
Citations

9091
Full
Text Views



Medical Physics

Current Issue Authors Submissions Advertise Search

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\)}](#)

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](#)

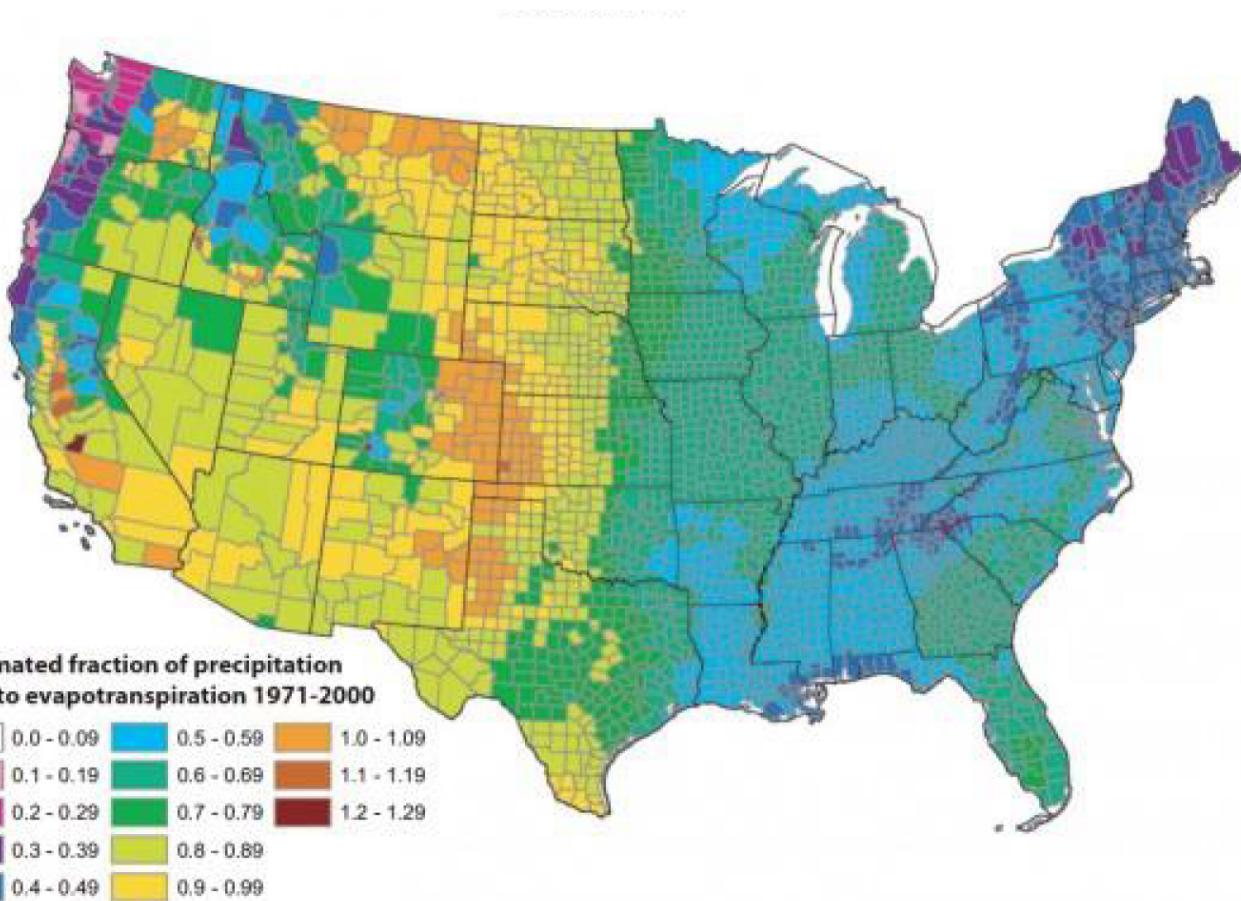


FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM climate data. The mean values for the counties (shown) were then calculated by averaging the 800-m values within each county. Areas with fractions >1 are agricultural counties that either import surface water or mine deep groundwater.

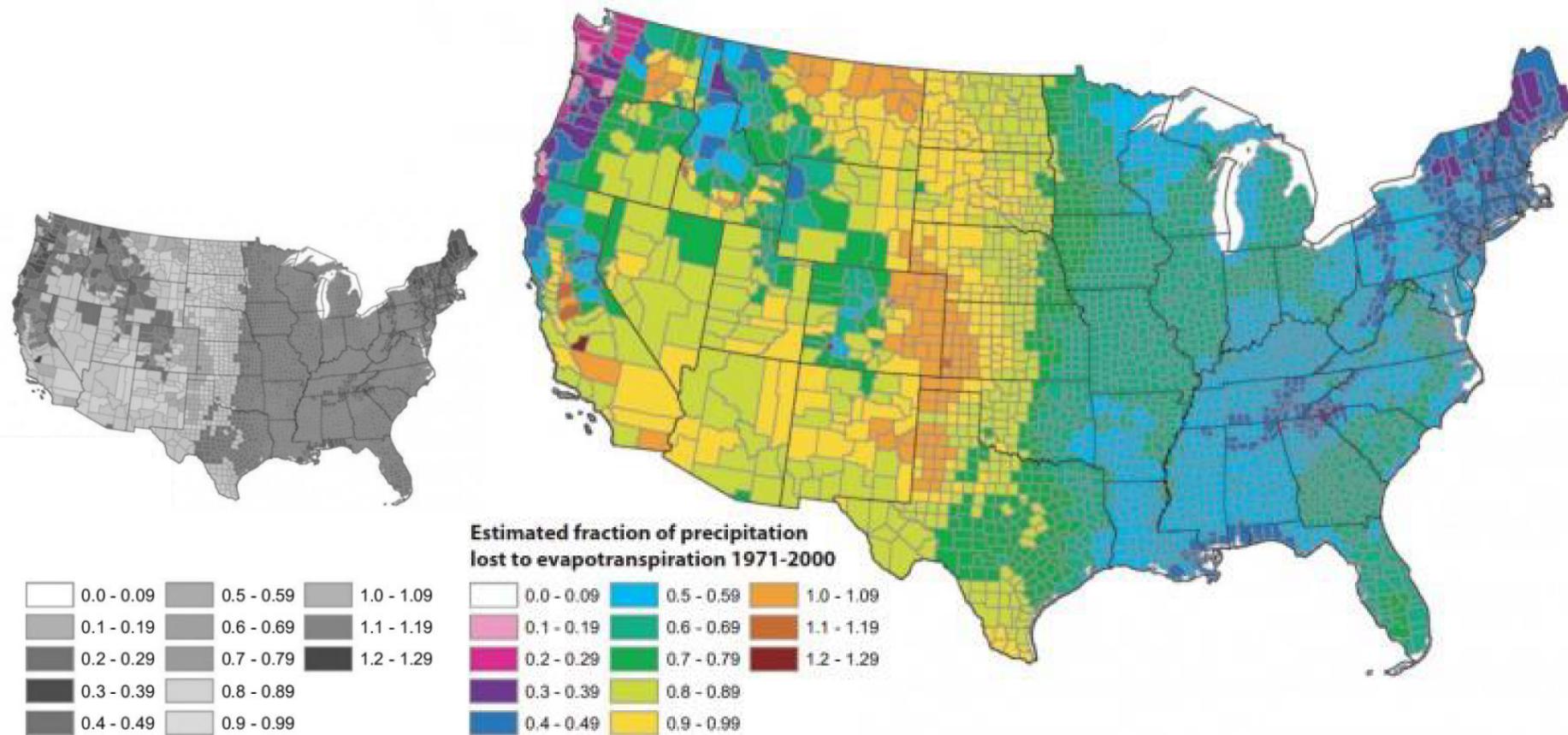


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Modified from eagereyes.org/basicss/rainbow-color-map

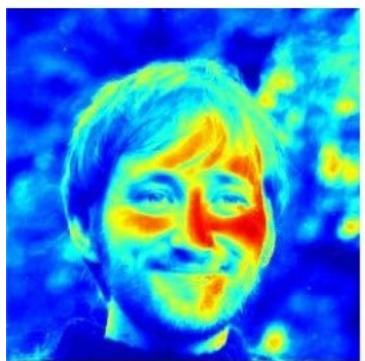


true-colour Phil

Fabio Cramer



true-colour Phil

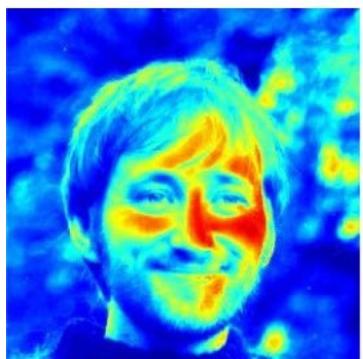


rainbow Phil
is distorted

Fabio Cramer



true-colour Phil



rainbow Phil
is distorted



batlow Phil
is flawless

Fabio Cramer

Color Choice & Accessibility



Vignette {viridis} package

Color Choice & Accessibility



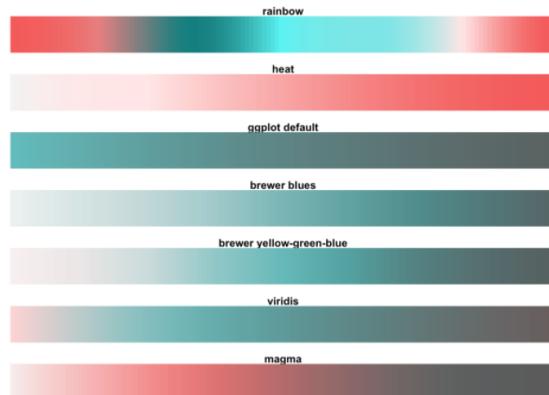
Deutranopia: present in 6% of males



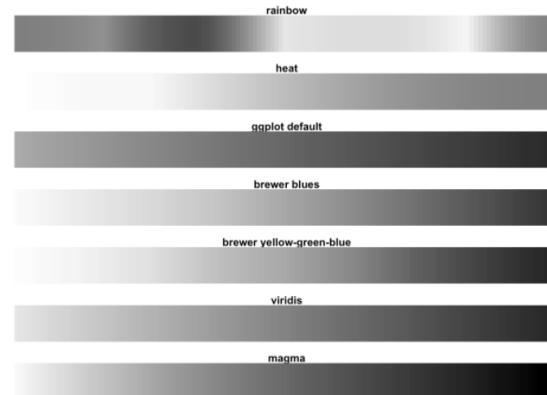
Protanopia: present in 1% of males



Tritanopia: present in 0.008% of humans



Monochromacy: present in 0.001% of humans



... and present in ~75% of university printers! 😊

Choice of the Color Palette & Accessibility

original



deuteranomaly



protanomaly

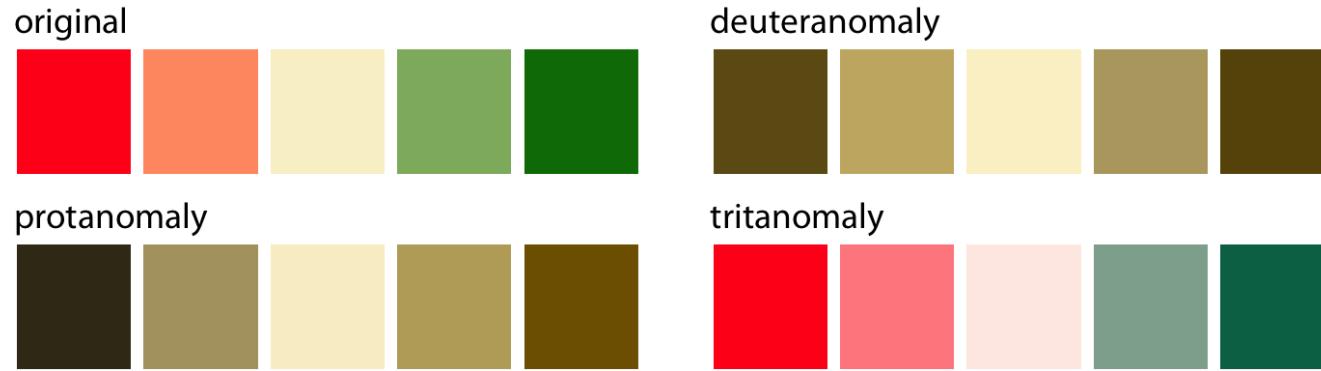


tritanomaly



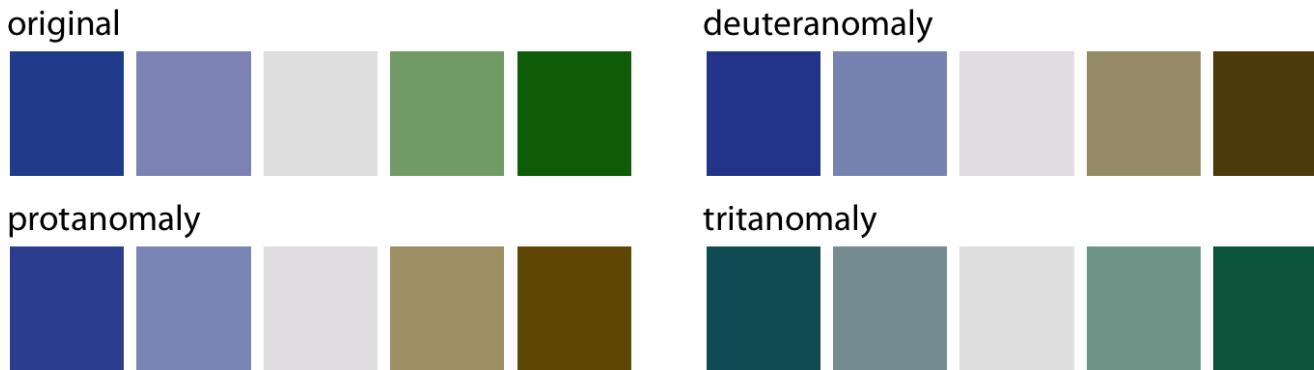
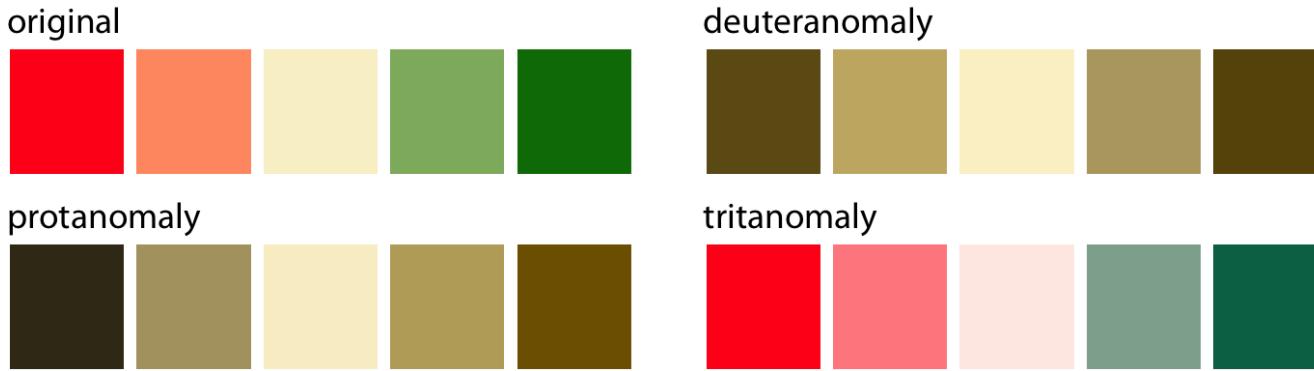
“Fundamentals of Data Visualization” by Claus Wilke

Choice of the Color Palette & Accessibility



“Fundamentals of Data Visualization” by Claus Wilke

Choice of the Color Palette & Accessibility



To make sure your visualizations work for people with CVD don't just rely on provided color palettes.

Instead, test your figures in a color-blindness simulator!

Color Choice & Accessibility

Choose color-blind friendly palettes:
projects.susielu.com/viz-palette

Test your final visualization:
color-blindness.com/coblis-color-blindness-simulator

Create a CVD-version of your ggplot in R:
github.com/clauswilke/colorblindr

Color Choice & Accessibility

VIZ PALETTE

By: Elijah Meeks & Susie Lu

PICK

Use Chroma.js

Use Colorgorical

Use ColorBrewer

EDIT

7 Colors

- 1. #ffd700
- 2. #ffb14e
- 3. #fa8775
- 4. #ea5f94
- 5. #cd34b5
- 6. #9d02d7
- 7. #0000ff

Add

Replace

GET

String quotes

Object with metadata

```
[ "#ffd700", "#ffb14e", "#fa8775", "#ea5f94", "#cd34b5", "#9d02d7", "#0000ff" ]
```

#hex

rgb

hsl

COLORS IN ACTION

Color Population: No Color Deficiency - 96% Deuteranomaly - 2.7% Protanomaly - 0.66% Protanopia - 0.59% Deutanopia - 0.56% Greyscale

Background color: #ffffff

Font color: #000000

Charts made with [Semitic](#)

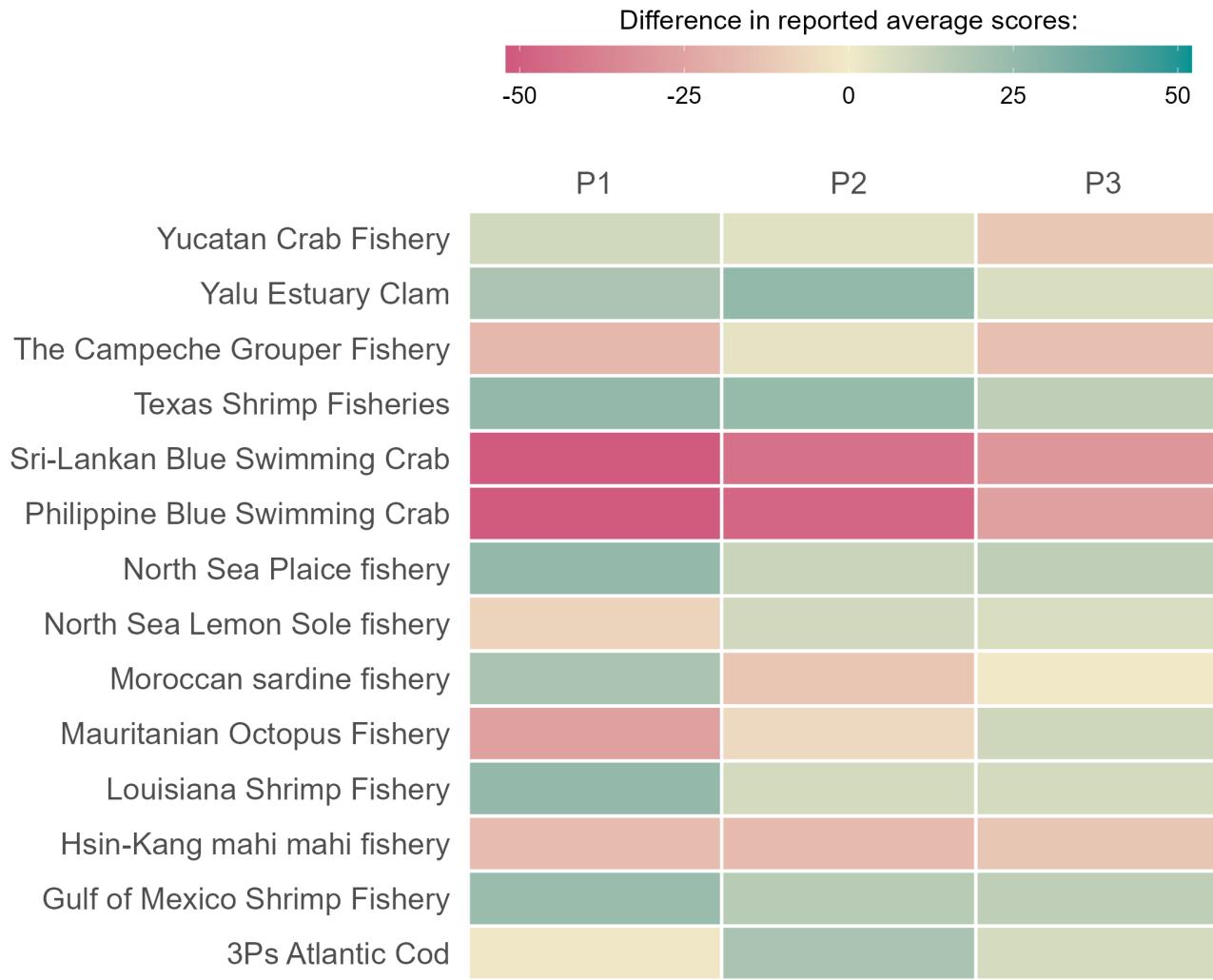
Sample font

Randomize Data

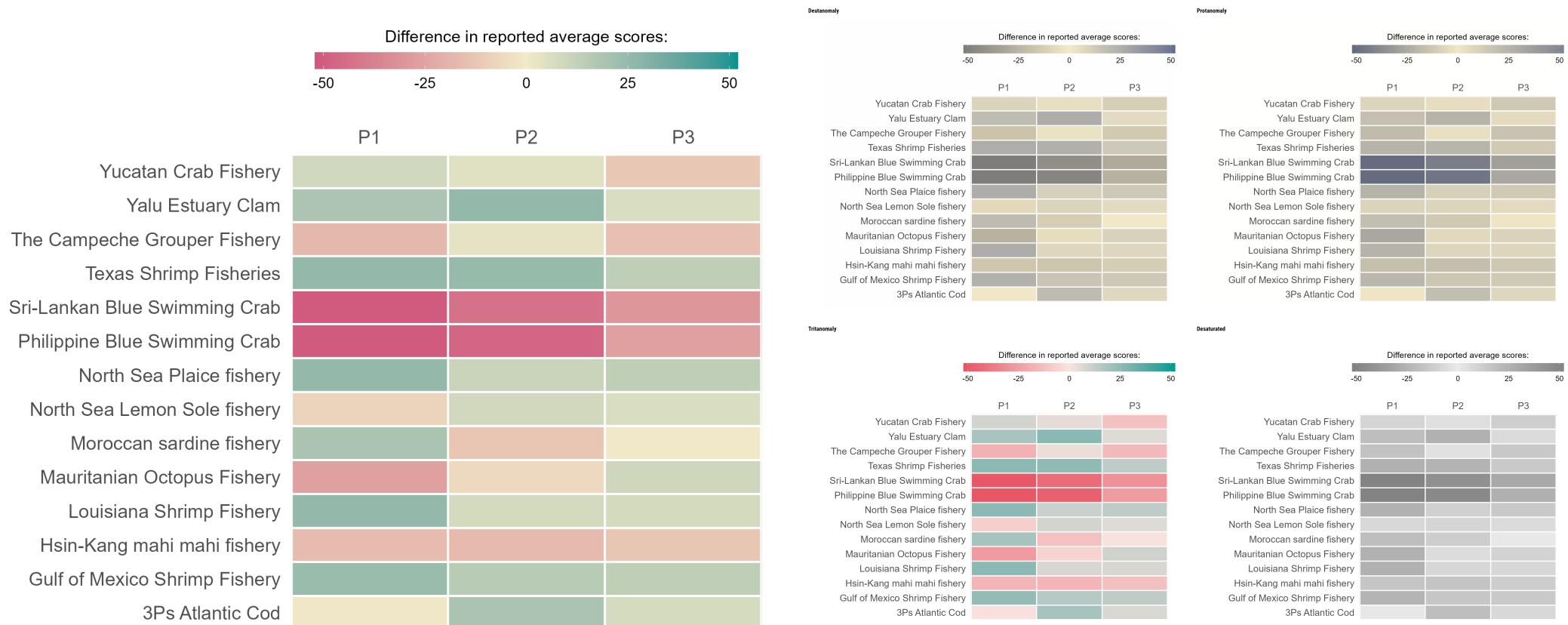
Stroke: Dark None

projects.susielu.com/viz-palette

Color Choice & Accessibility

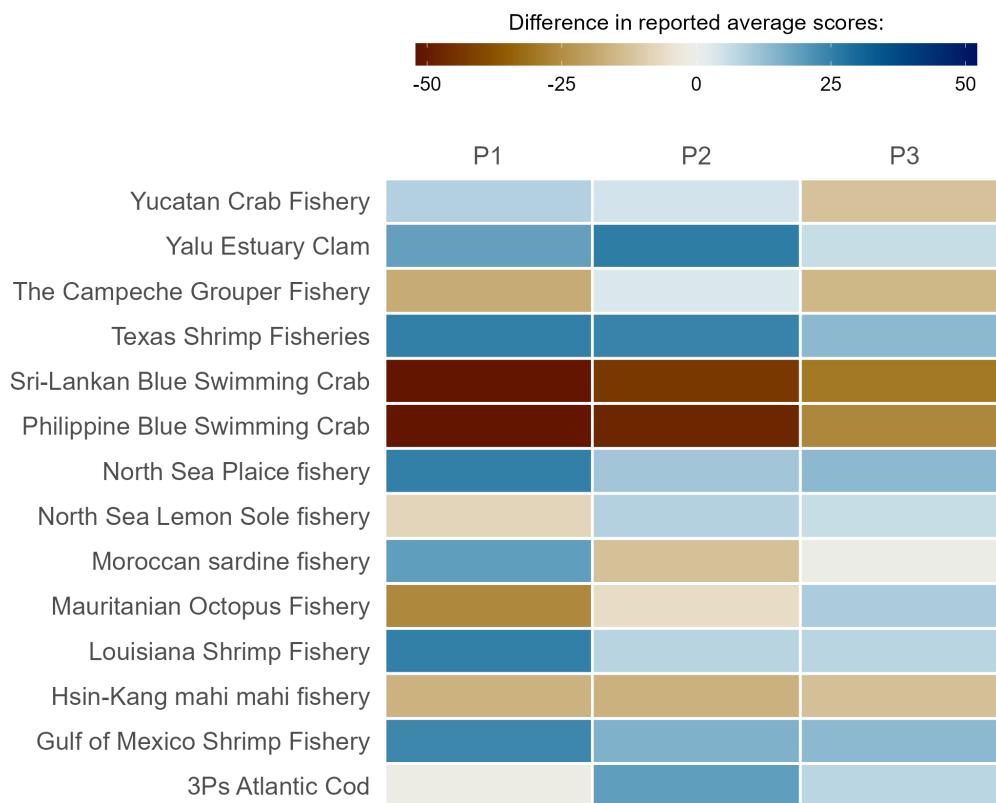
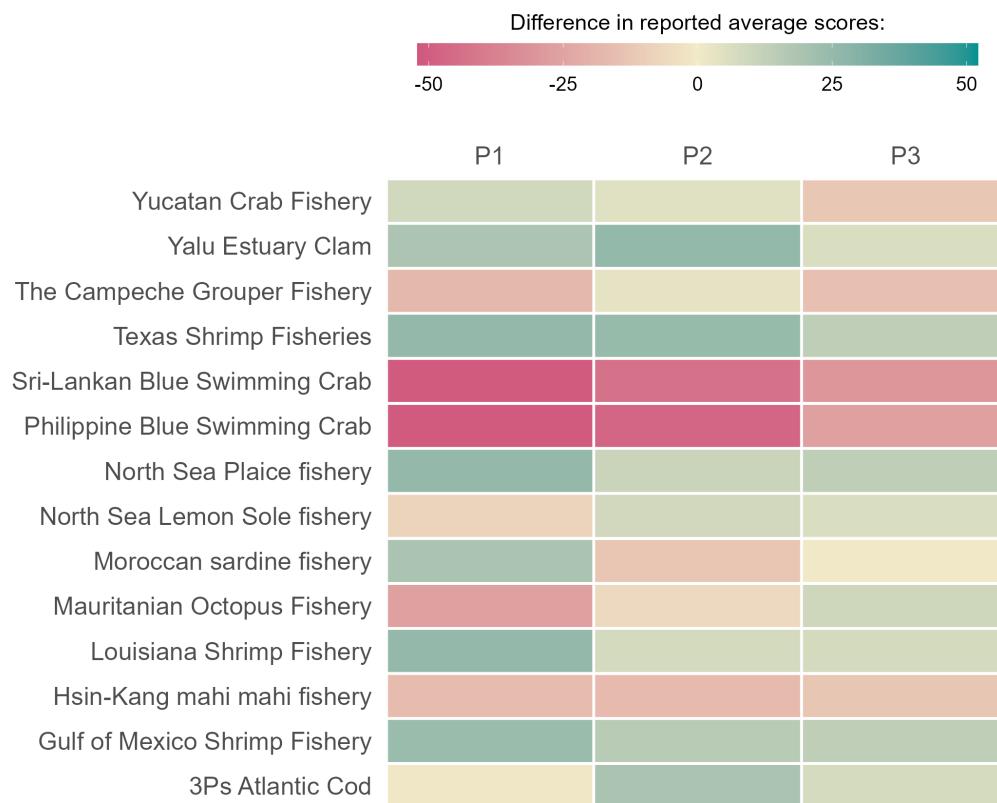


Color Choice & Accessibility

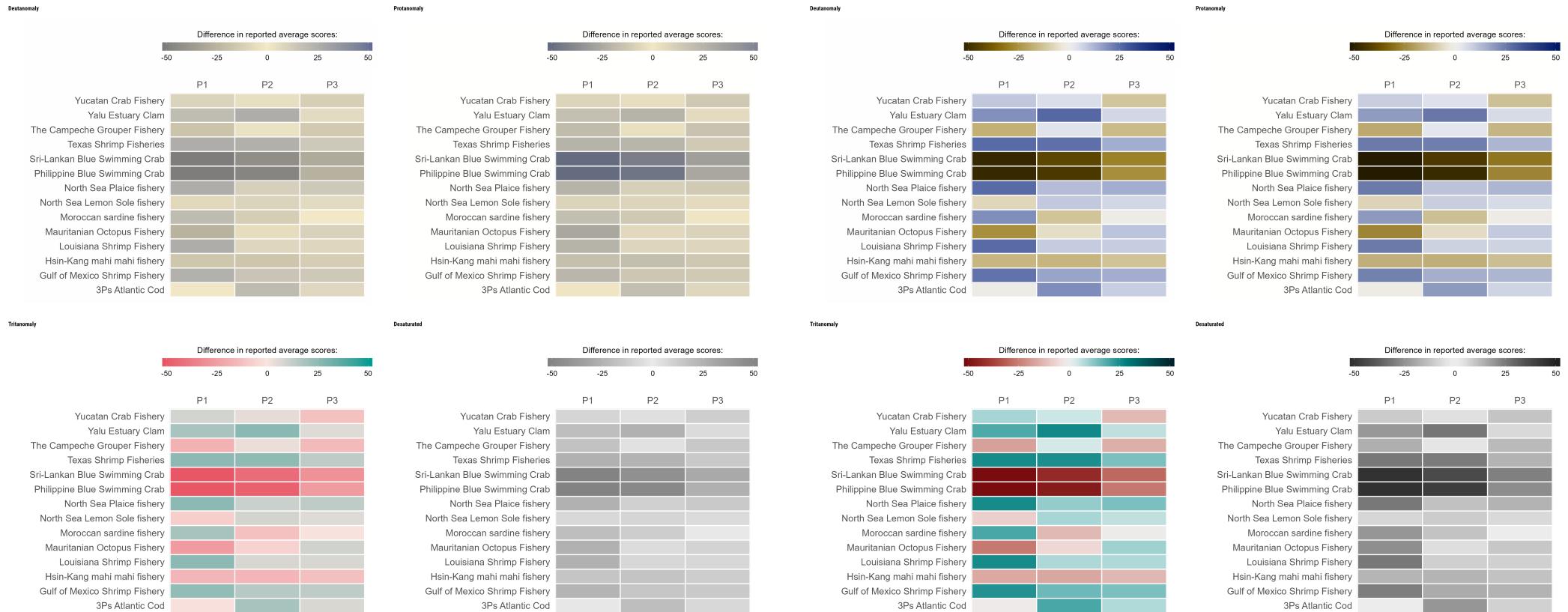


Created with [colorblindr](#)

Color Choice & Accessibility

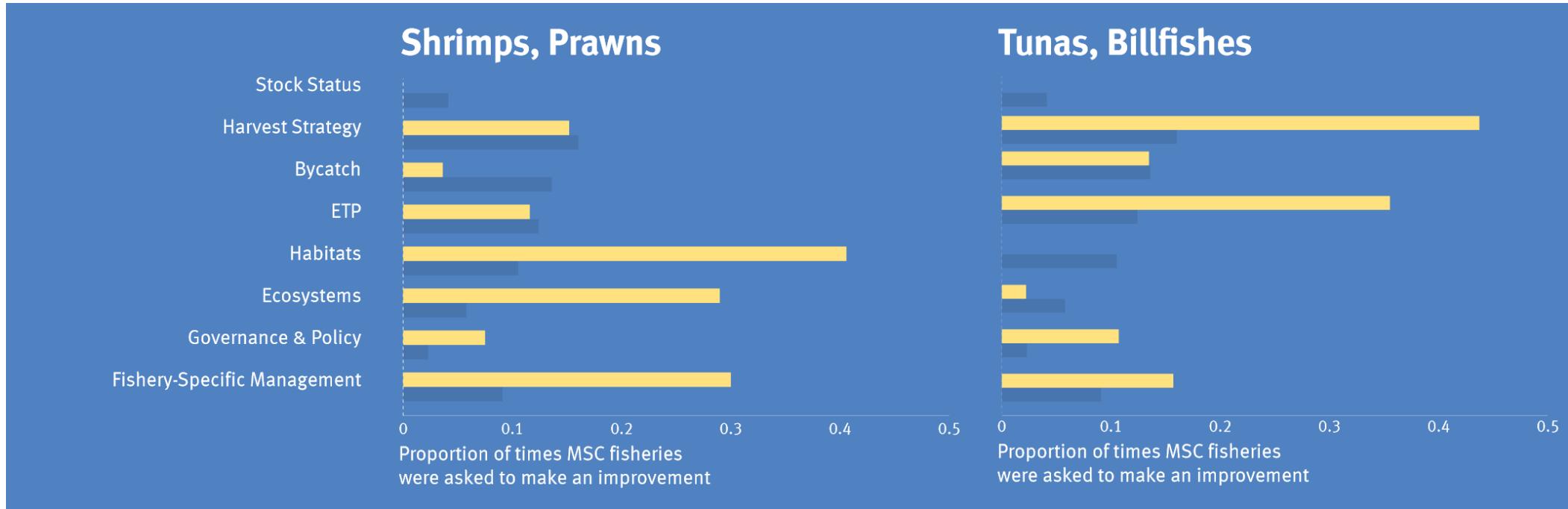


Color Choice & Accessibility



Created with [colorblindr](#)

Color Choice & Accessibility



The image is a collage of typography-related content. At the top, the word "TYPOGRAPHY" is written in large, bold, white serif letters. Below it, the word "TYPOGRAPHY" appears again in a smaller, white sans-serif font. To the left, the word "TYPOGRAPHY" is written vertically in a white serif font. In the center, the word "TYPOGRAPHY" is written in a large, bold, white serif font. Below the central text, there is a row of small, decorative ligature characters (such as 'ff', 'fl', 'lh', etc.) followed by the word "TYPOGRAPHY" in a smaller, white serif font. At the bottom, the word "Typography" is written in a large, bold, yellow serif font, followed by the phrase "(and everything text-related)" in a smaller, white sans-serif font.

Typography

(and everything text-related)

The Choice of the Font(s)

- The font(s) should fit the topic and audience - **context matters**.
- **Avoid fancy fonts and squiggle letters.**
- Use ways to **visualize hierarchy**.
- Avoid using **ALL CAPS**.
- Use a **monospaced font with lining for numbers**.

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- Use ways to **visualize hierarchy**.
- Avoid using **ALL CAPS**.
- Use a **monospaced font with lining for numbers**.
- **Consistency is key!**

How to Visualize Hierarchy

I am important!

I am important, too!

Oh, hi there. Thanks for reading me...

Yeah, I know I am kinda boring. Sorry.

How to Visualize Hierarchy

I am important!

I am important, too!

Oh, hi there. Thanks for reading me...

Yeah, I know I am kinda boring. Sorry.

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Keep it Simple

**Using lots of fonts
can make for a design
that is cluttered,
overcomplicated,
AND JUST NOT VERY NICE**

*But if you just use
a small selection,
you can keep your
design cleaner, clearer
and just much easier
to digest*

The 1I1 Test

1II Calibri

1II Bitter

1II Open Sans

1II Monda

1II Roboto

1II Chivo

1II Avenir Next Condensed

1II Fira Sans

1II Lato

1II Noto Sans

1II Oswald

1II Bahnschrift

Tabular (Monospaced) Numbers

32154

Montserrat
proportional numbers

32154

Open Sans
tabular numbers

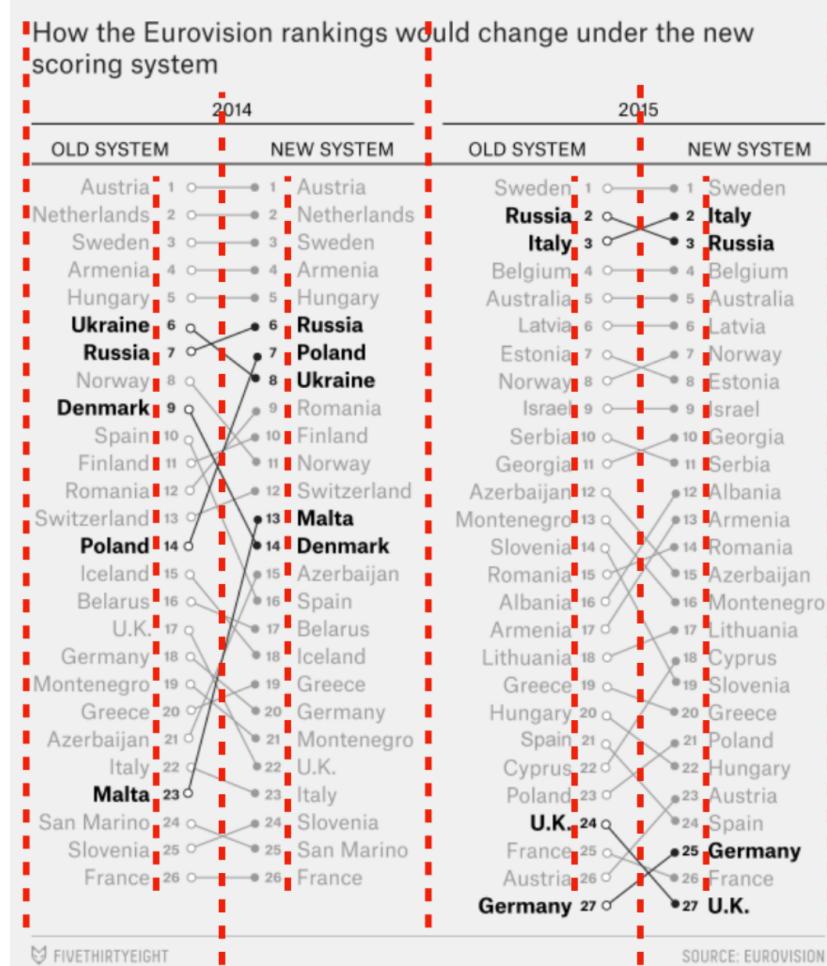
32154

Lato
tabular numbers

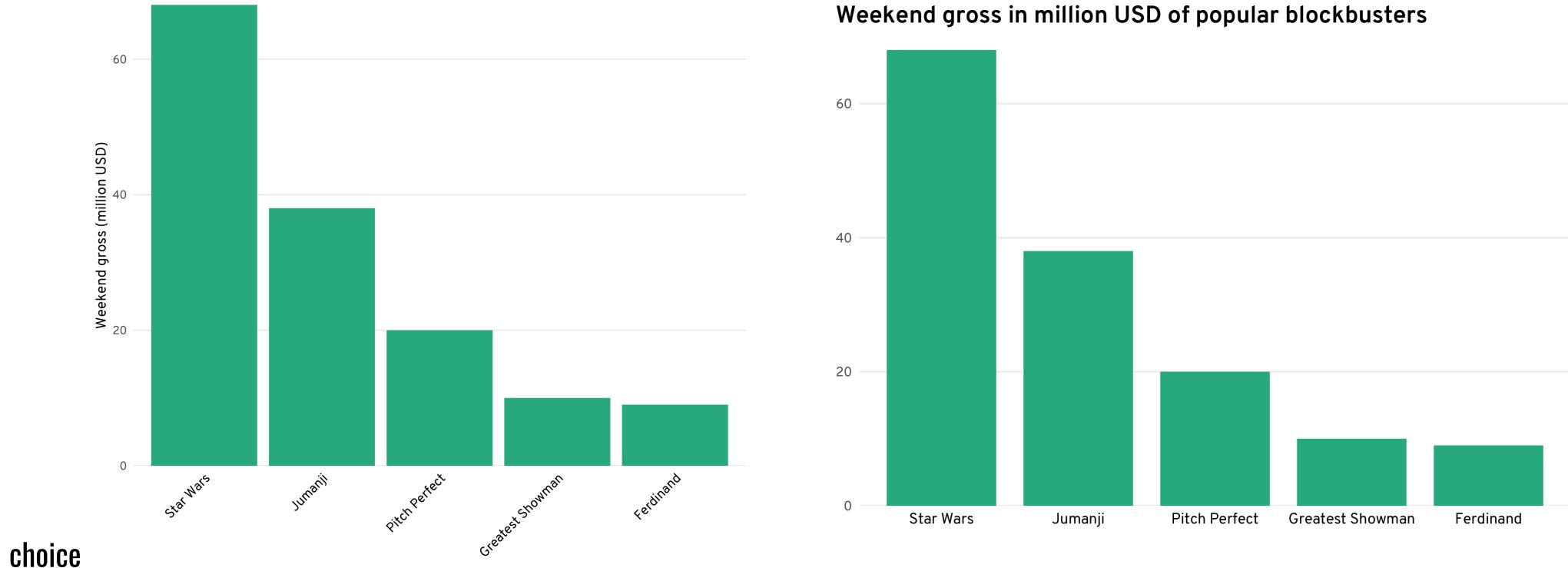
Choosing Fonts for Your Data Visualization by Tiffany France

Allign Your Text

- Left-align most text
- Title should be left aligned
- Labels and subtitles can be center or right aligned

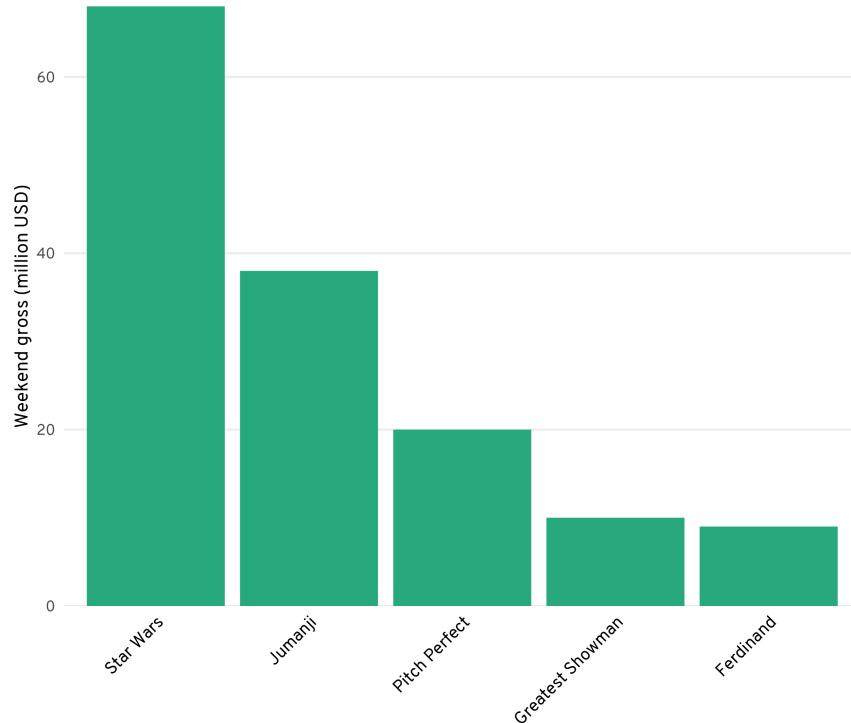


(Don't) Rotate Your Text

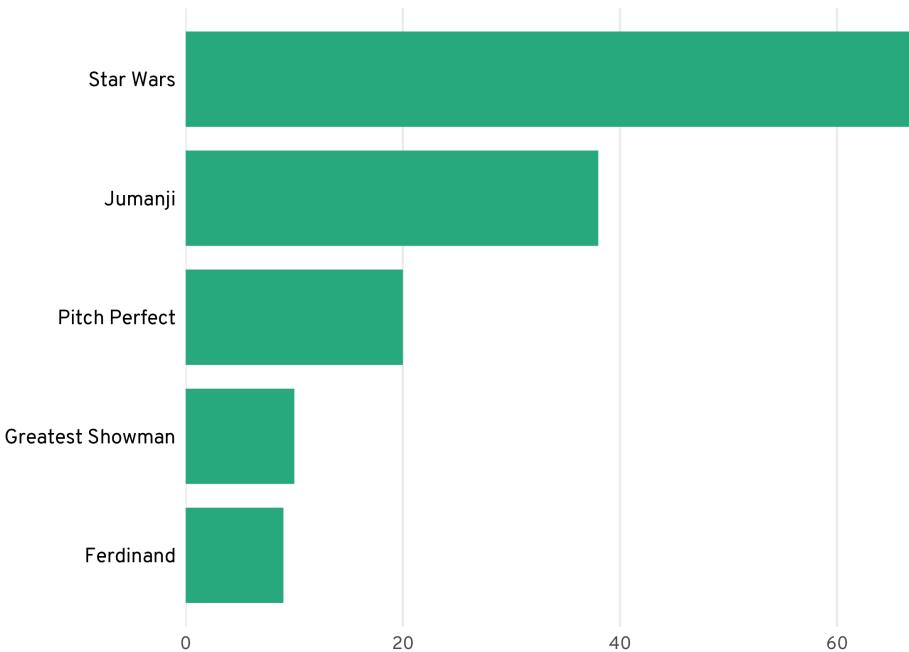


Modified from “**Fundamentals of Data Visualization**” by Claus Wilke

(Don't) Rotate Your Text

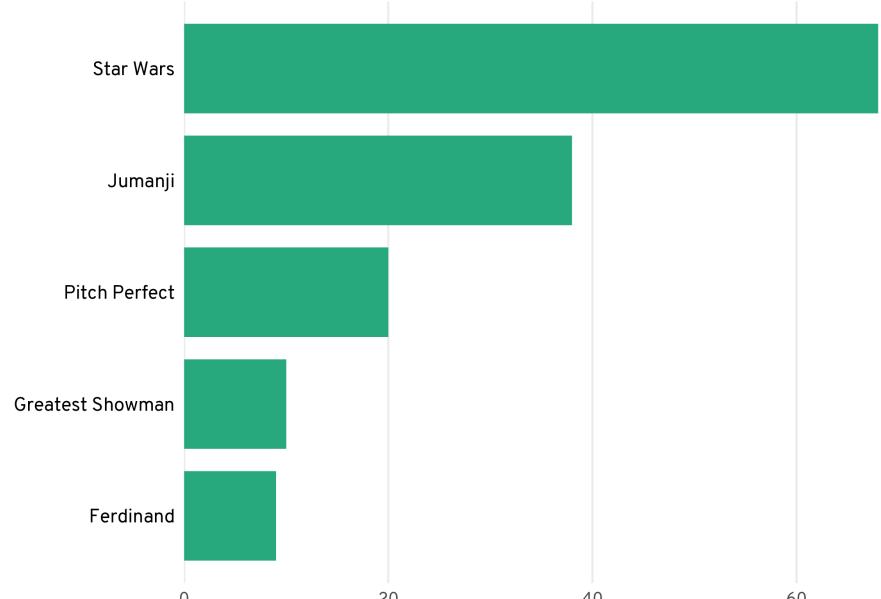


Weekend gross in million USD of popular blockbusters

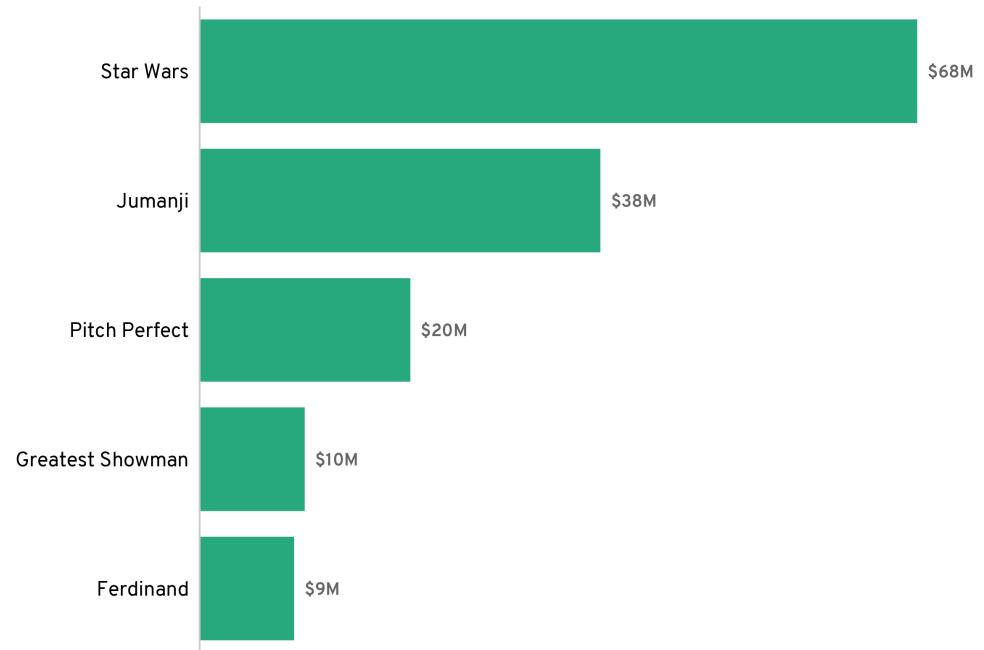


Use Annotations

Weekend gross in million USD of popular blockbusters

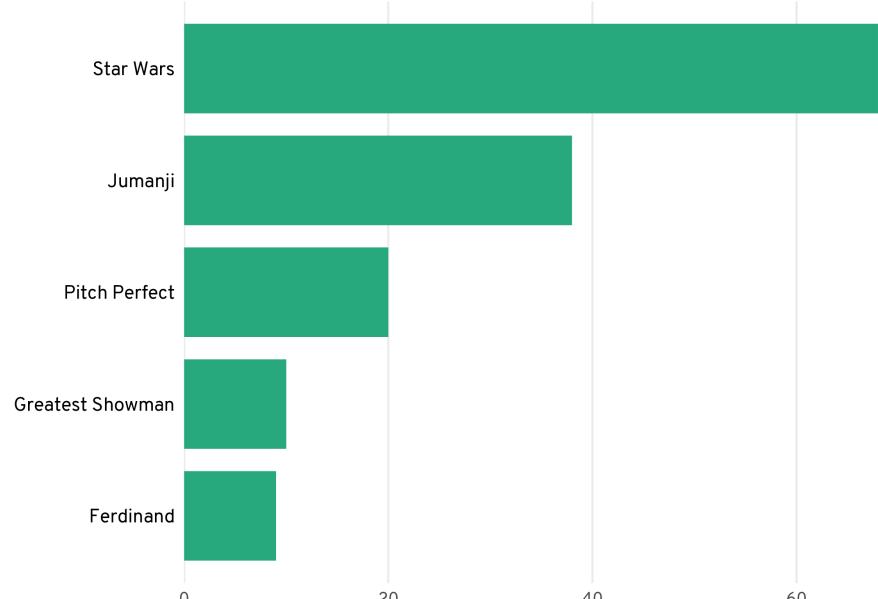


Weekend gross in million USD of popular blockbusters

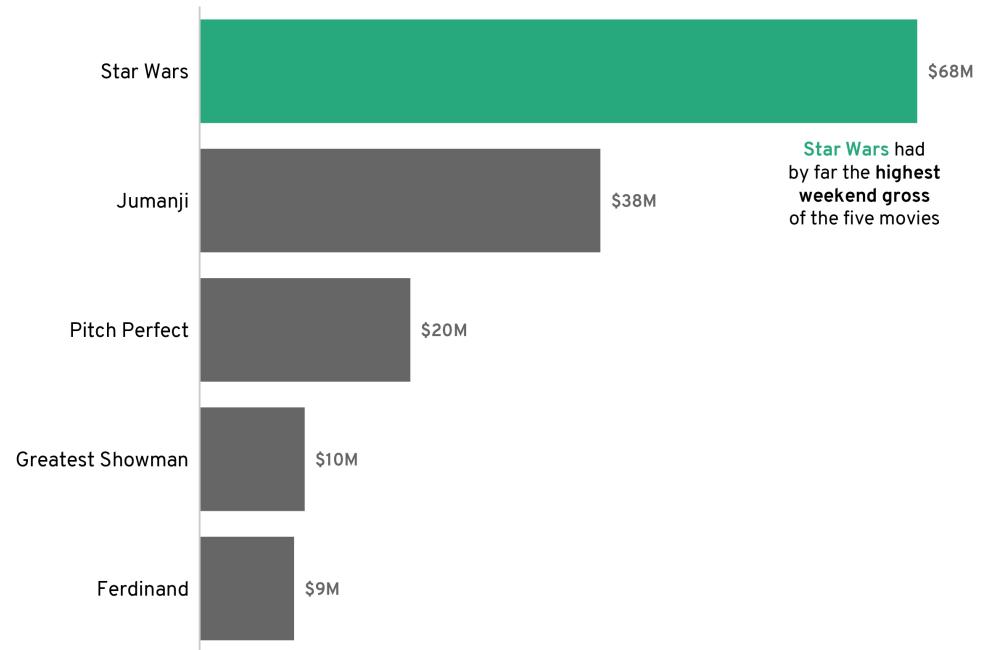


Use Annotations

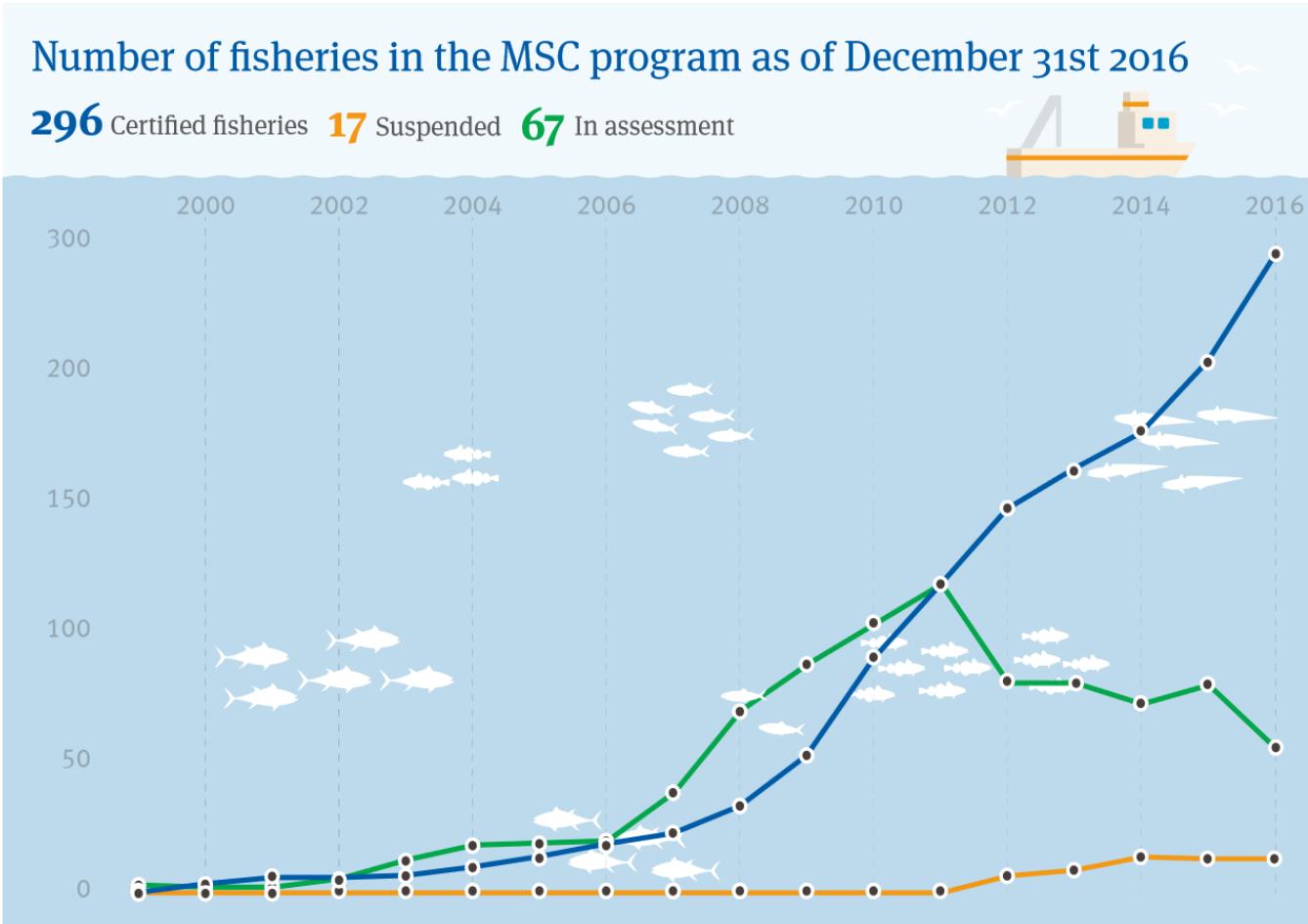
Weekend gross in million USD of popular blockbusters



Weekend gross in million USD of popular blockbusters



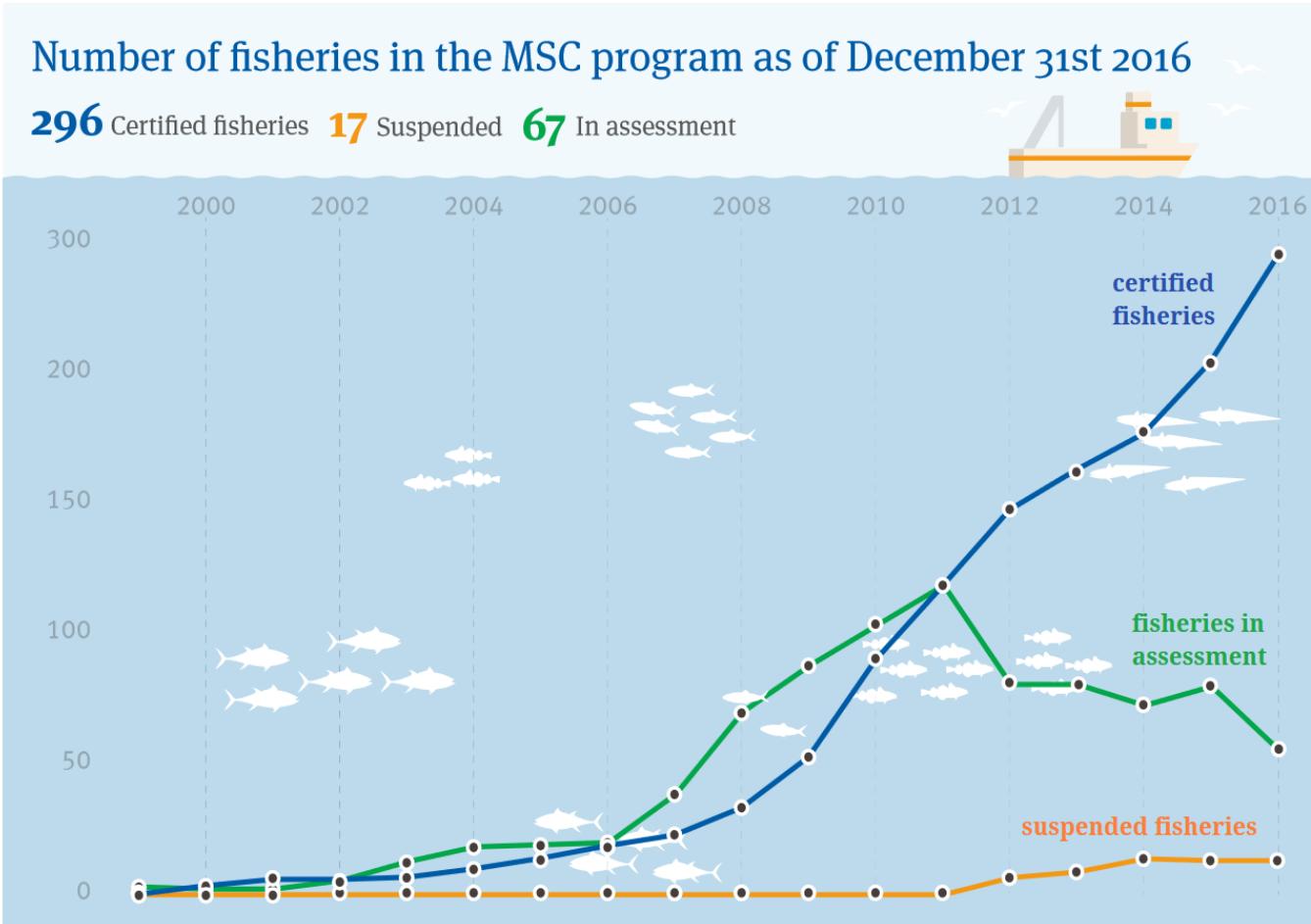
Use Annotations



100s

of fisheries are
not yet ready for
assessment and
are engaged in
pre-assessment
activities and FIPs

Use Annotations

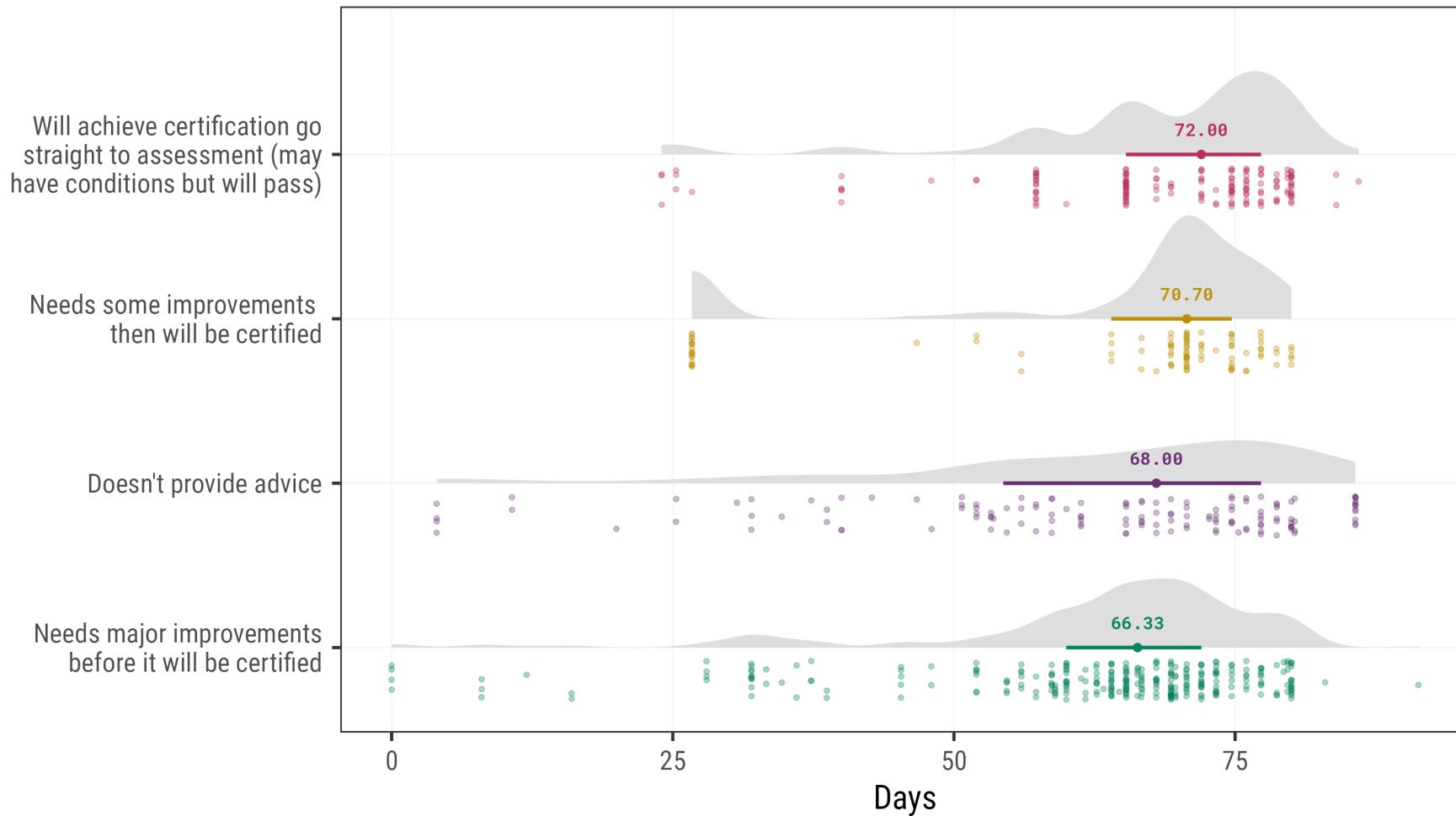


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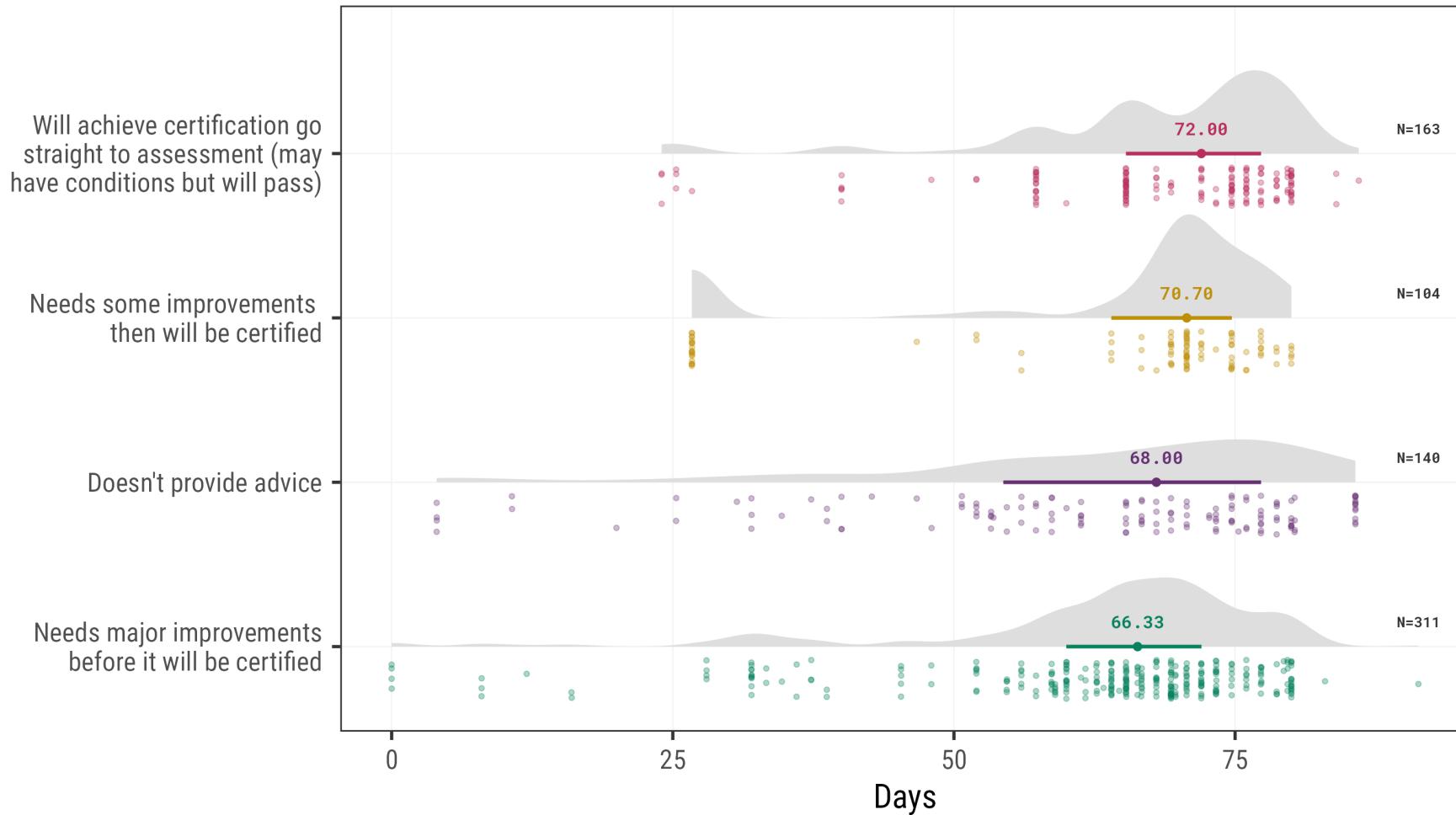
Use Annotations

P2 Score (combined)



Use Annotations

P2 Score (combined)



Use Color Consistency in Labels

P2 Score (combined)

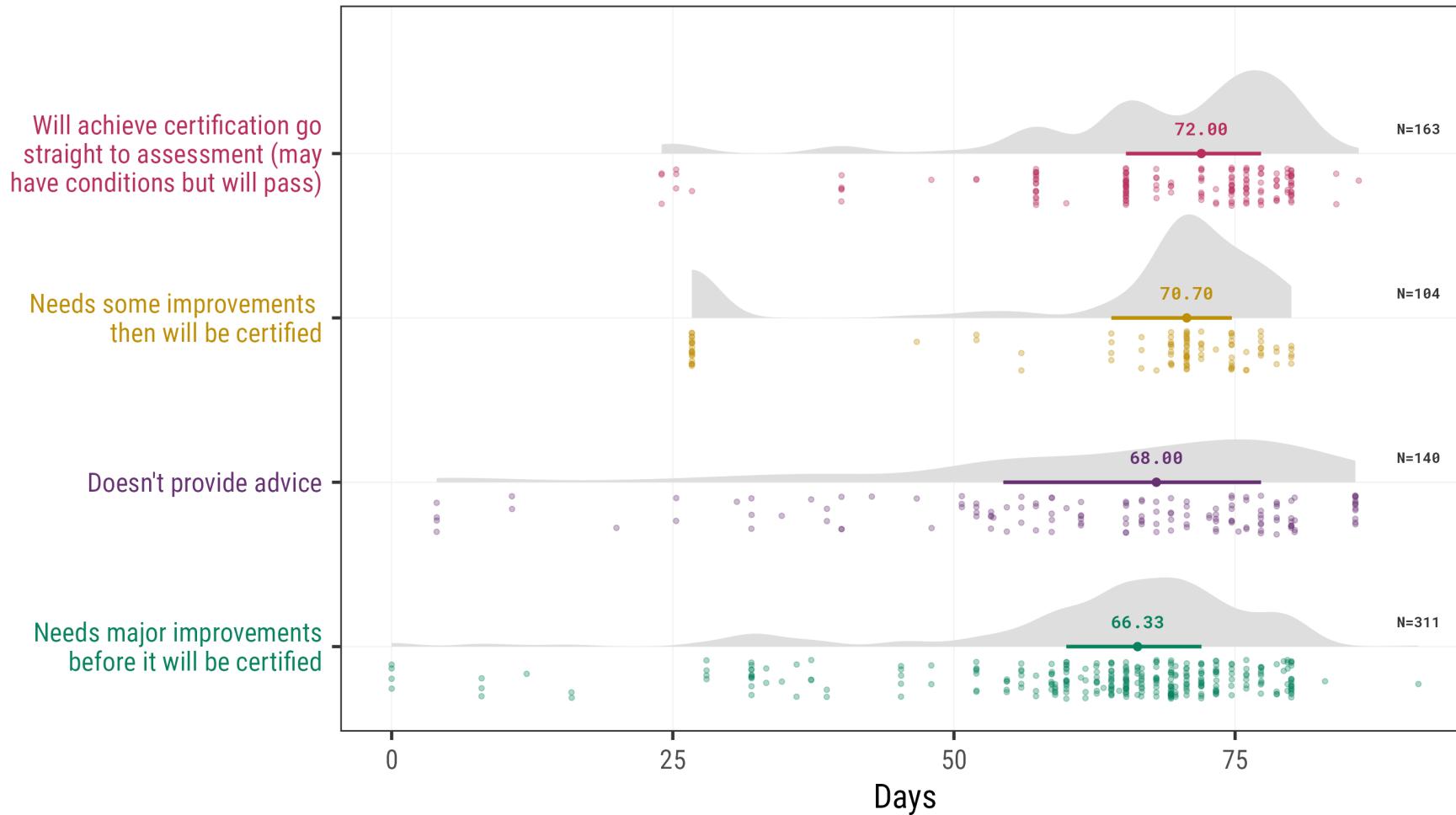
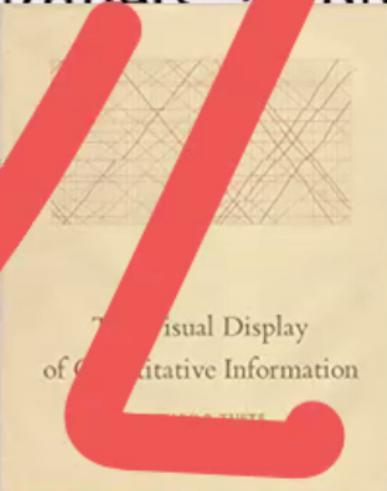


Chart Design Principles

Graphical integrity is more likely to result if these six principles are followed:

The presentation of numbers or physically measured on the surface of the graphic itself should be directly proportional to the numerical quantities.

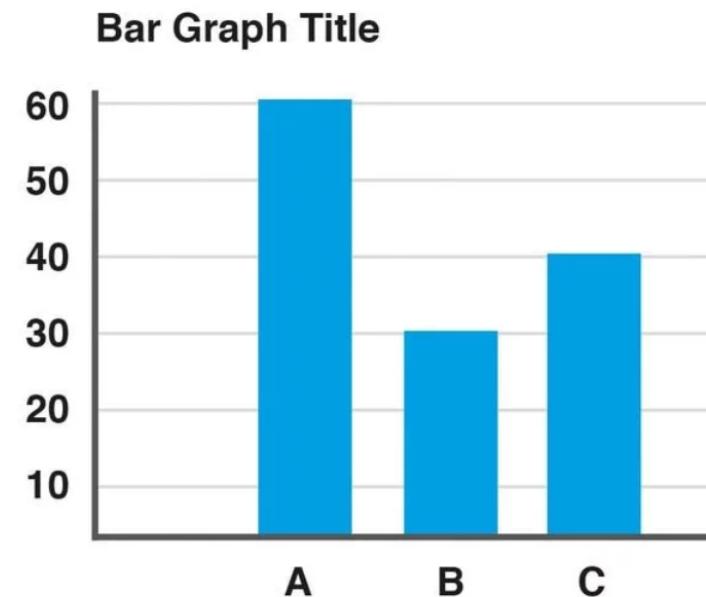
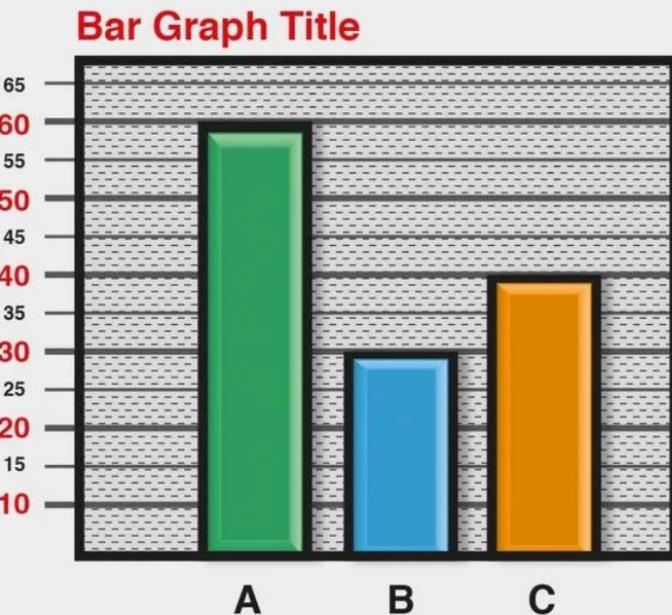
Clear, detailed, and color-coded legends should be used to defeat graphical distortion and the data on the graphic itself. Label important events in the data.

The image shows the front cover of a book titled "The Visual Display of Quantitative Information" by Edward Tufte. The cover is light beige with a grid pattern. The title and author's name are printed at the top. Below the title, there is a small section of text and a copyright notice.

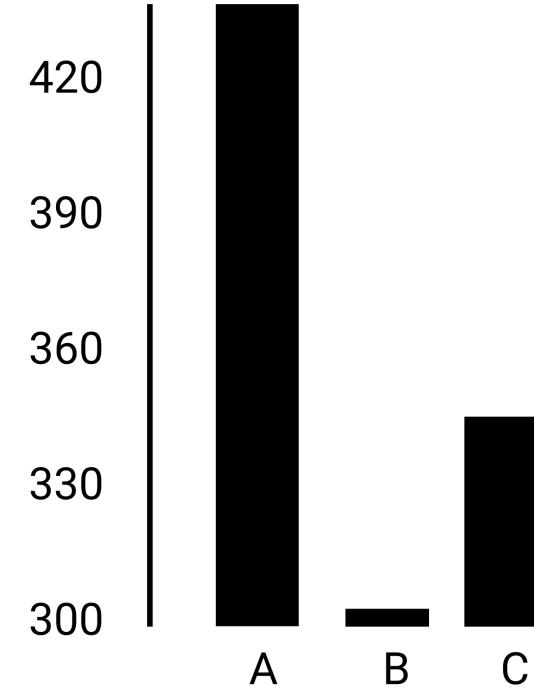
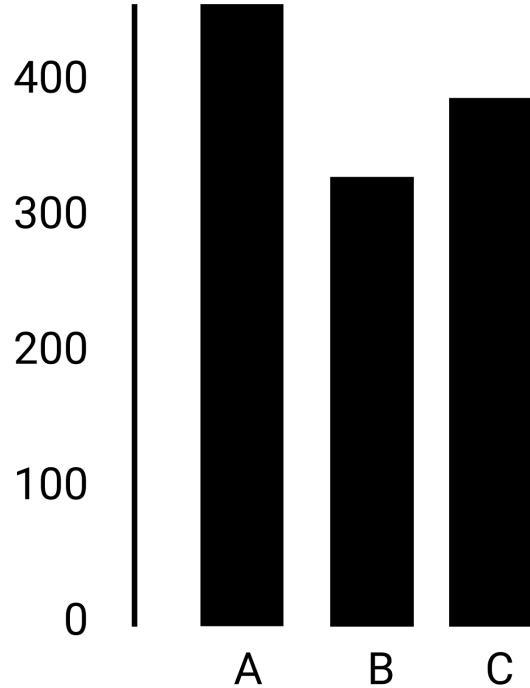
Show data variation, not design variation.

In time-series displays of money, deflated and standardized units

Don't Clutter Your Plot

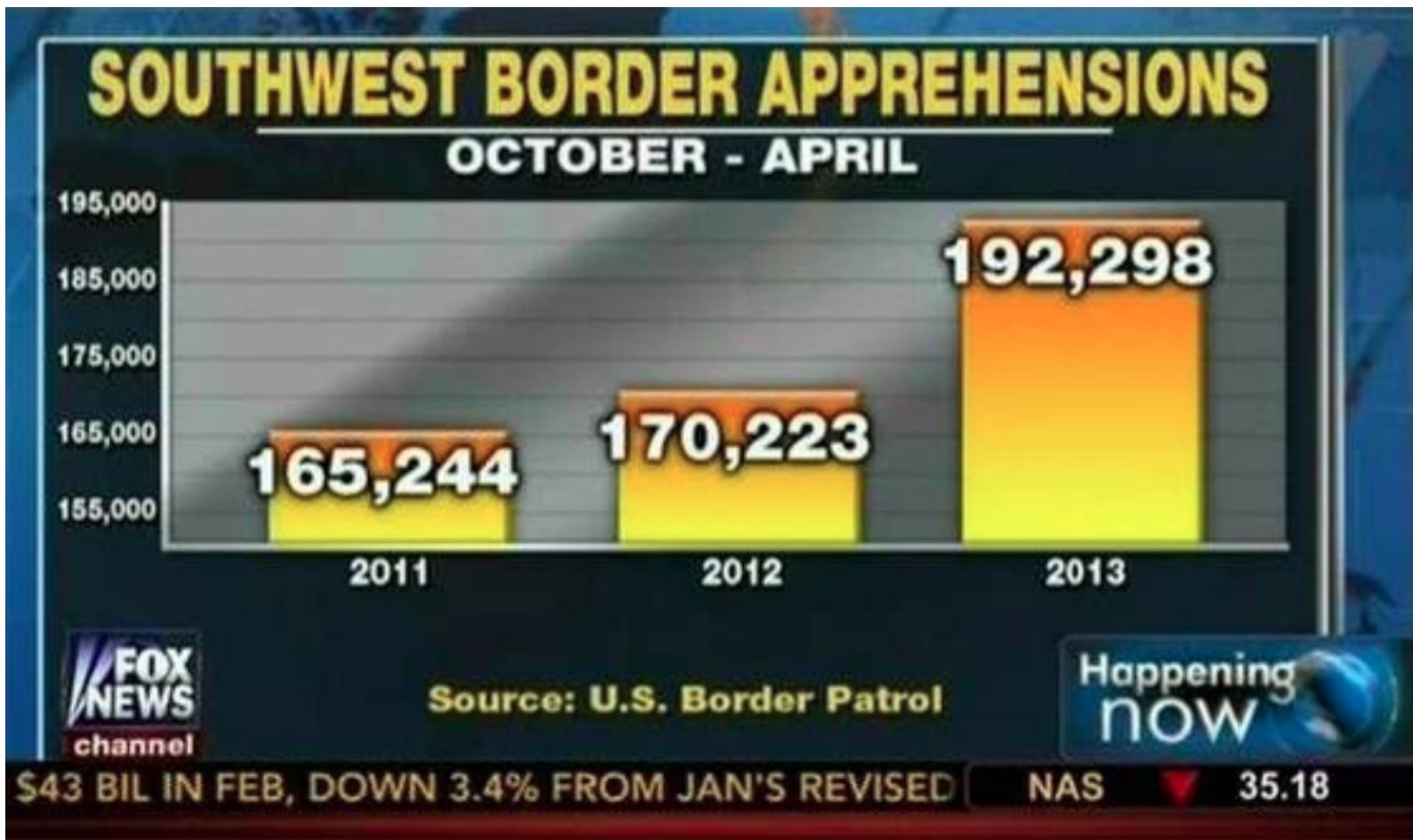


Start at Zero



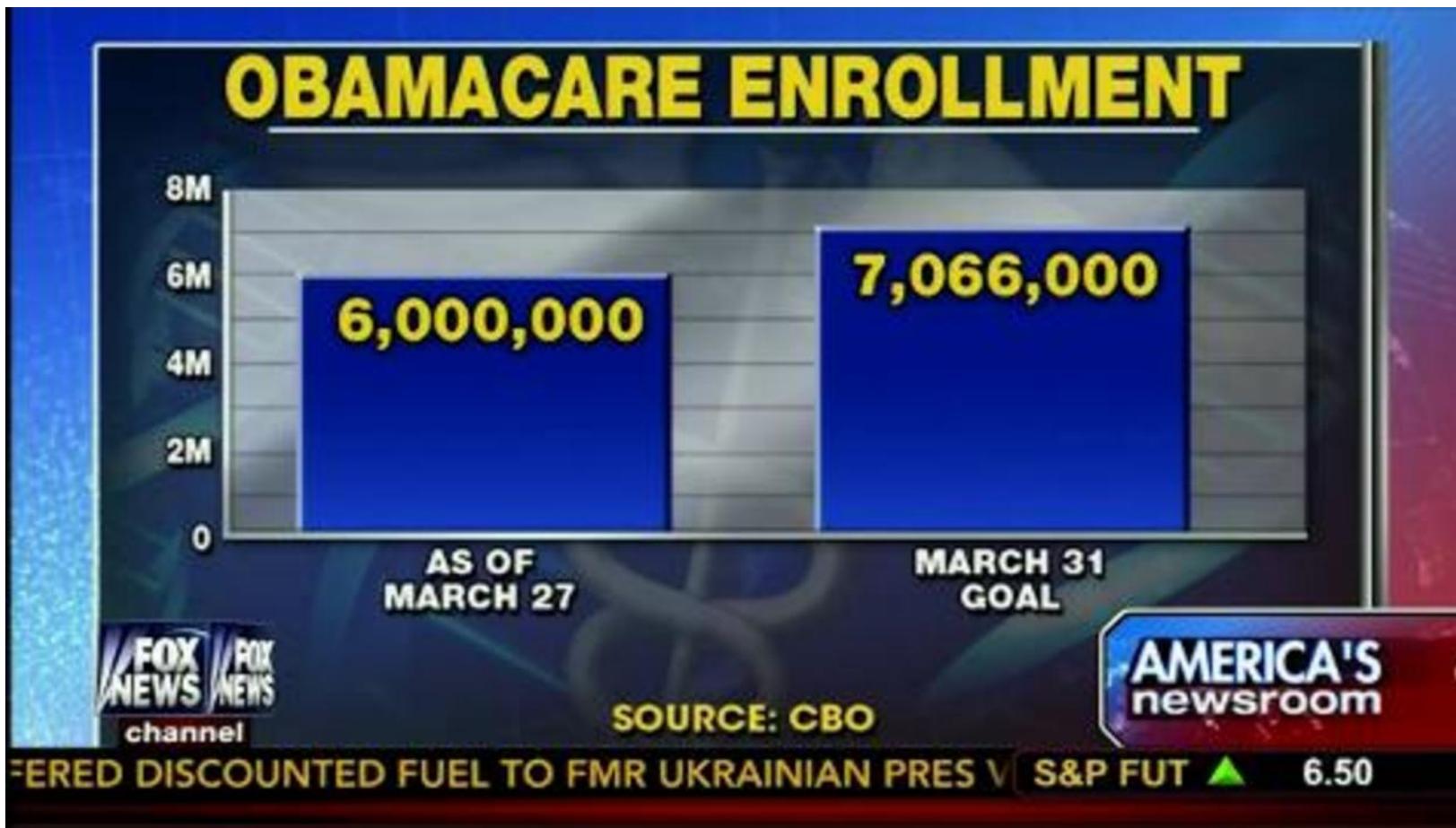
“Hands-On Data Visualization” by Jack Dougherty & Ilya Illyankou

Always Start at Zero



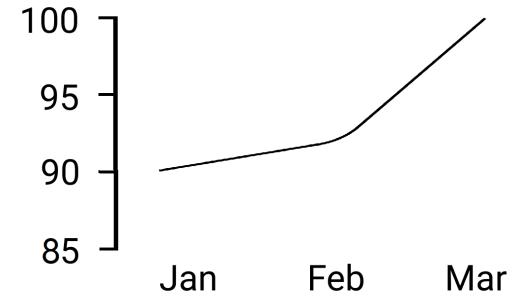
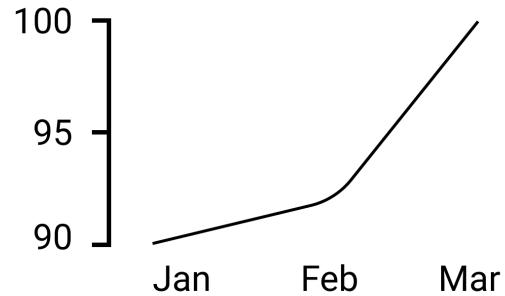
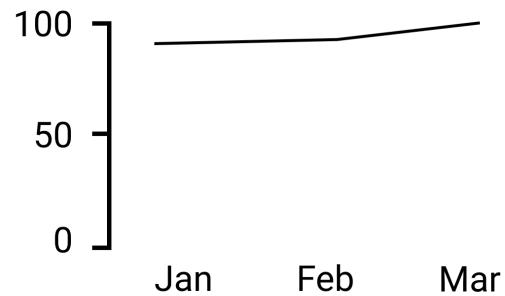
Fox News

Always Start at **Zero**?



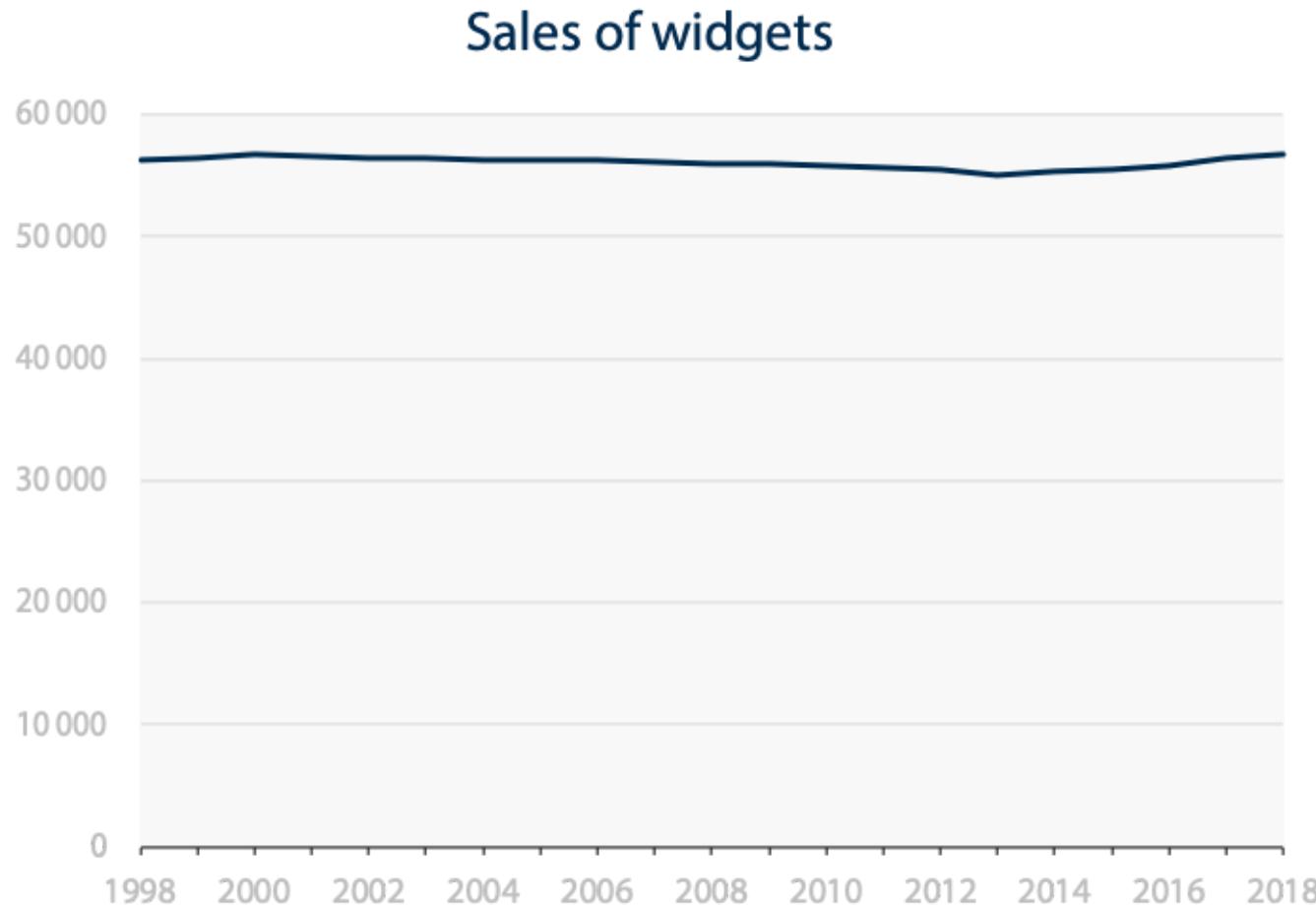
Fox News

(Always) Start at Zero?



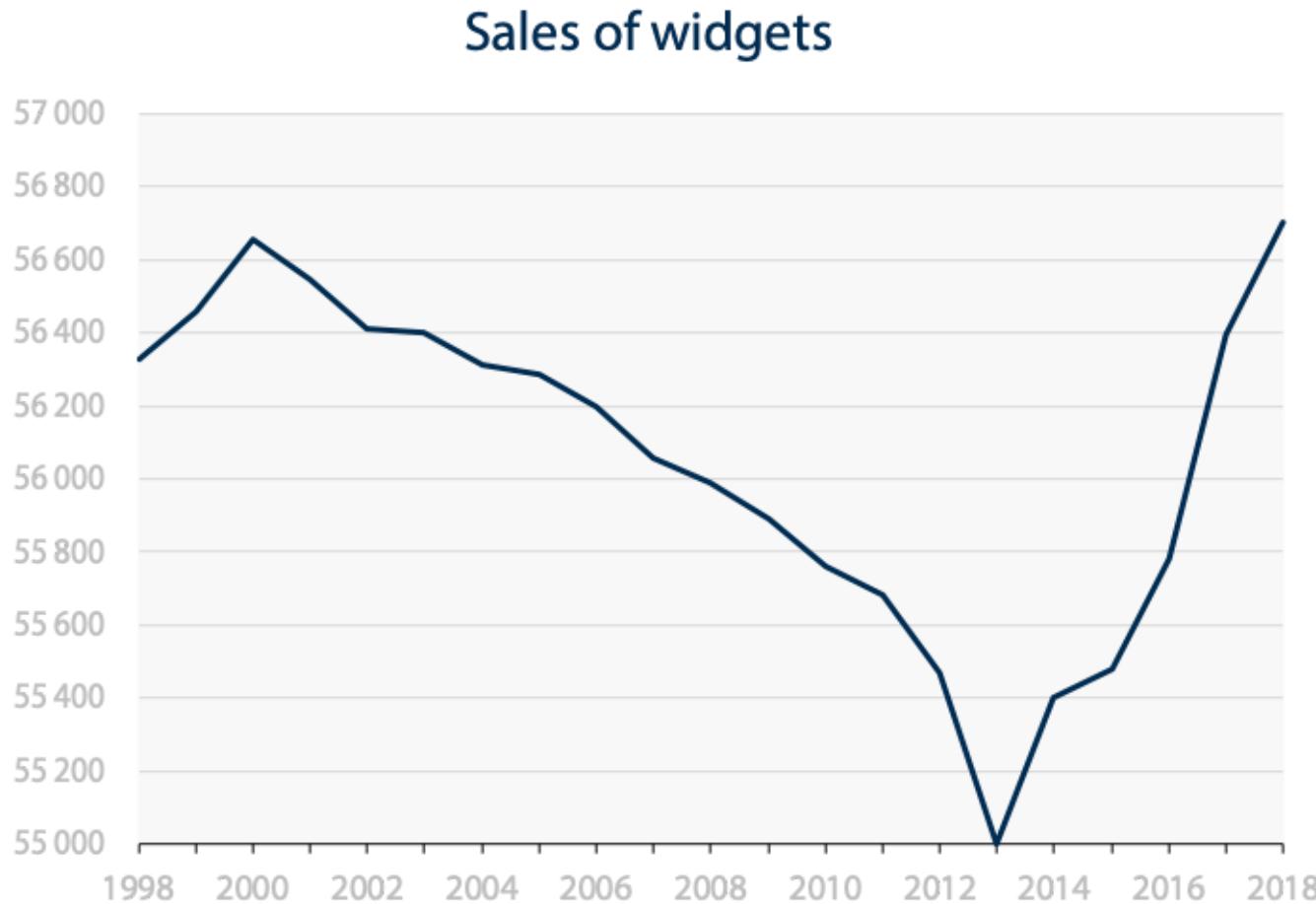
“Hands-On Data Visualization” by Jack Dougherty & Ilya Illyankou

(Always) Start at Zero?



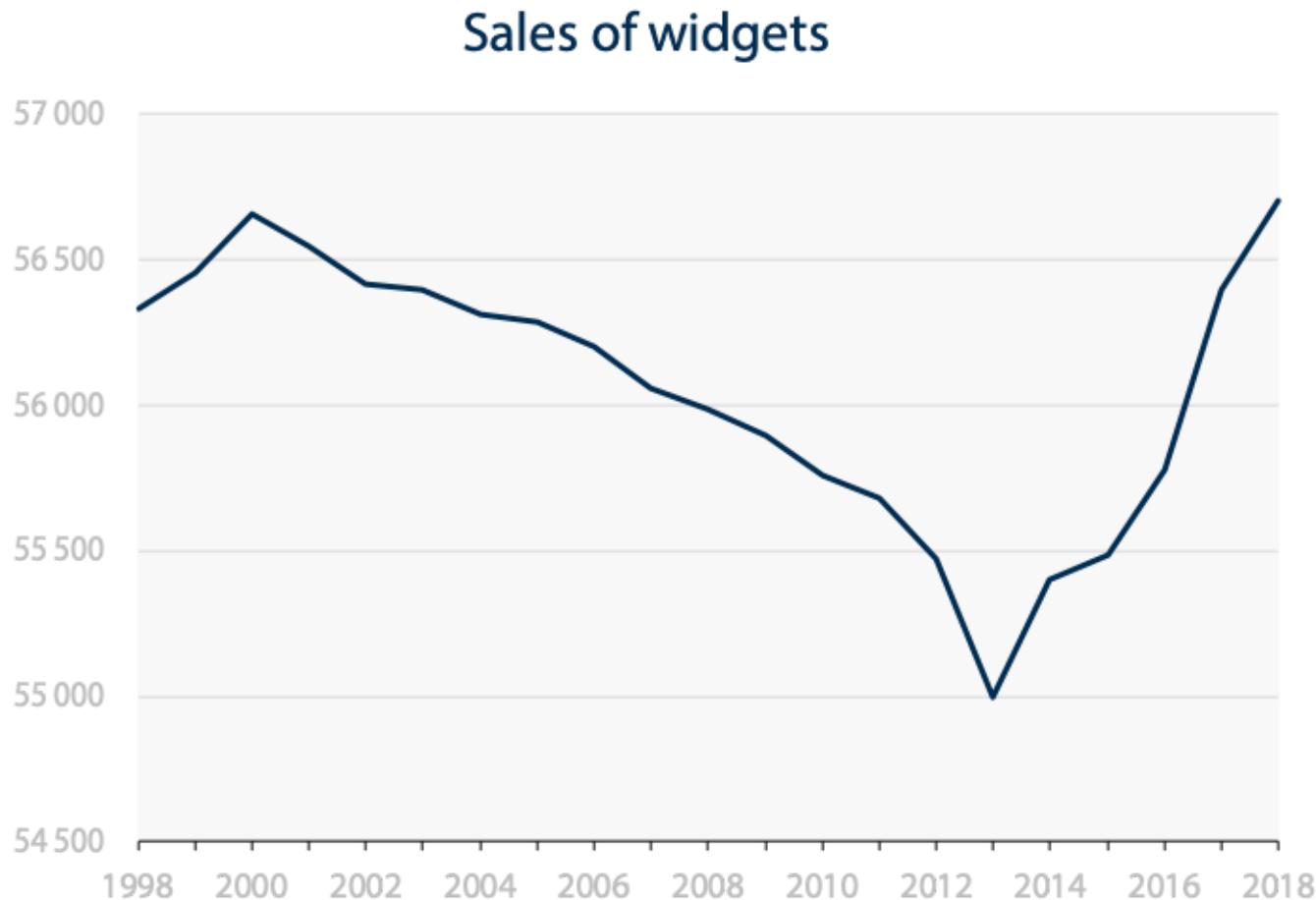
Francis Gagnon, Voilà

(Always) Start at Zero?



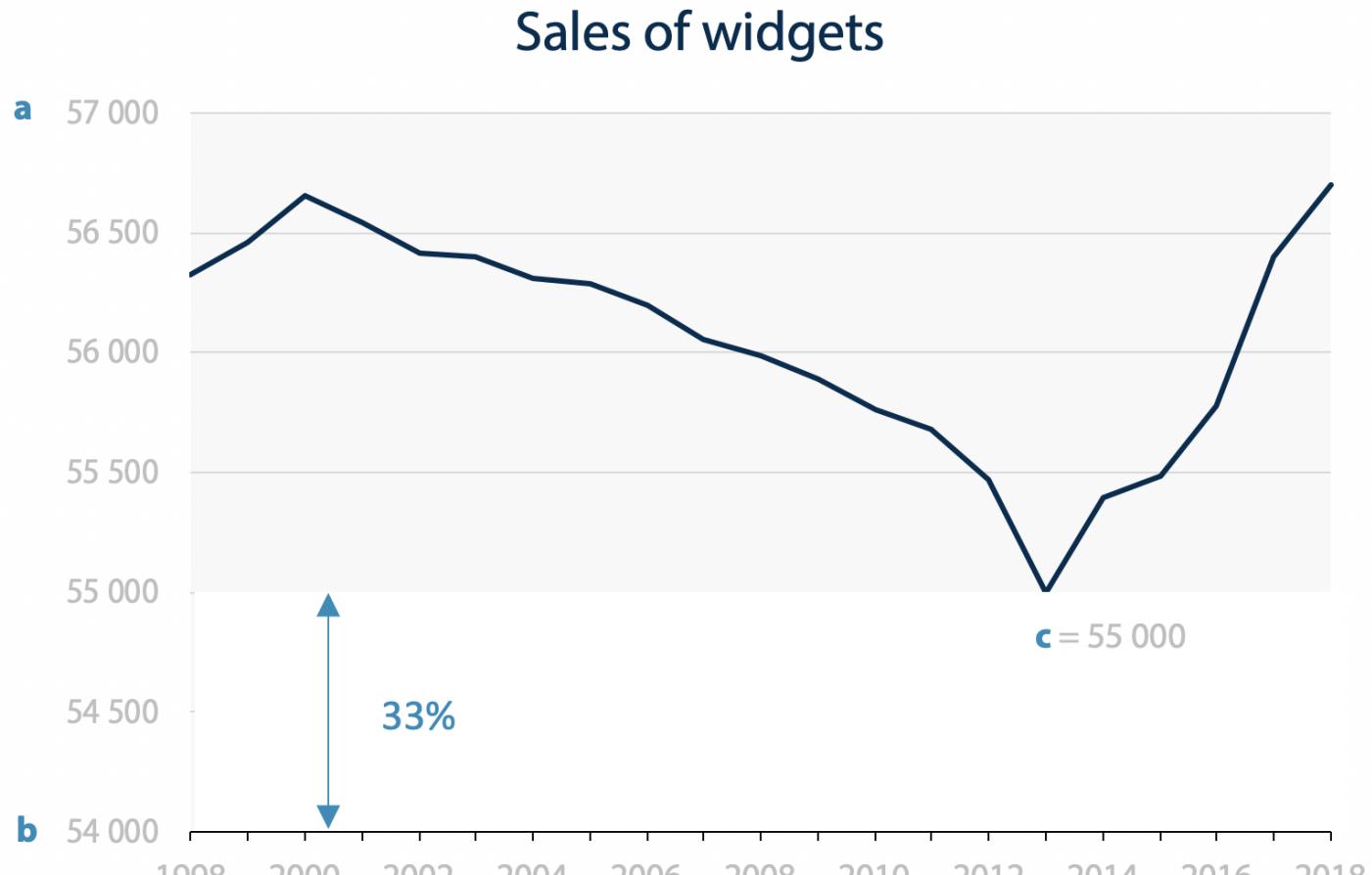
Francis Gagnon, Voilà

The Golden Ratio



Francis Gagnon, Voilà

The Golden Ratio



Francis Gagnon, Voilà

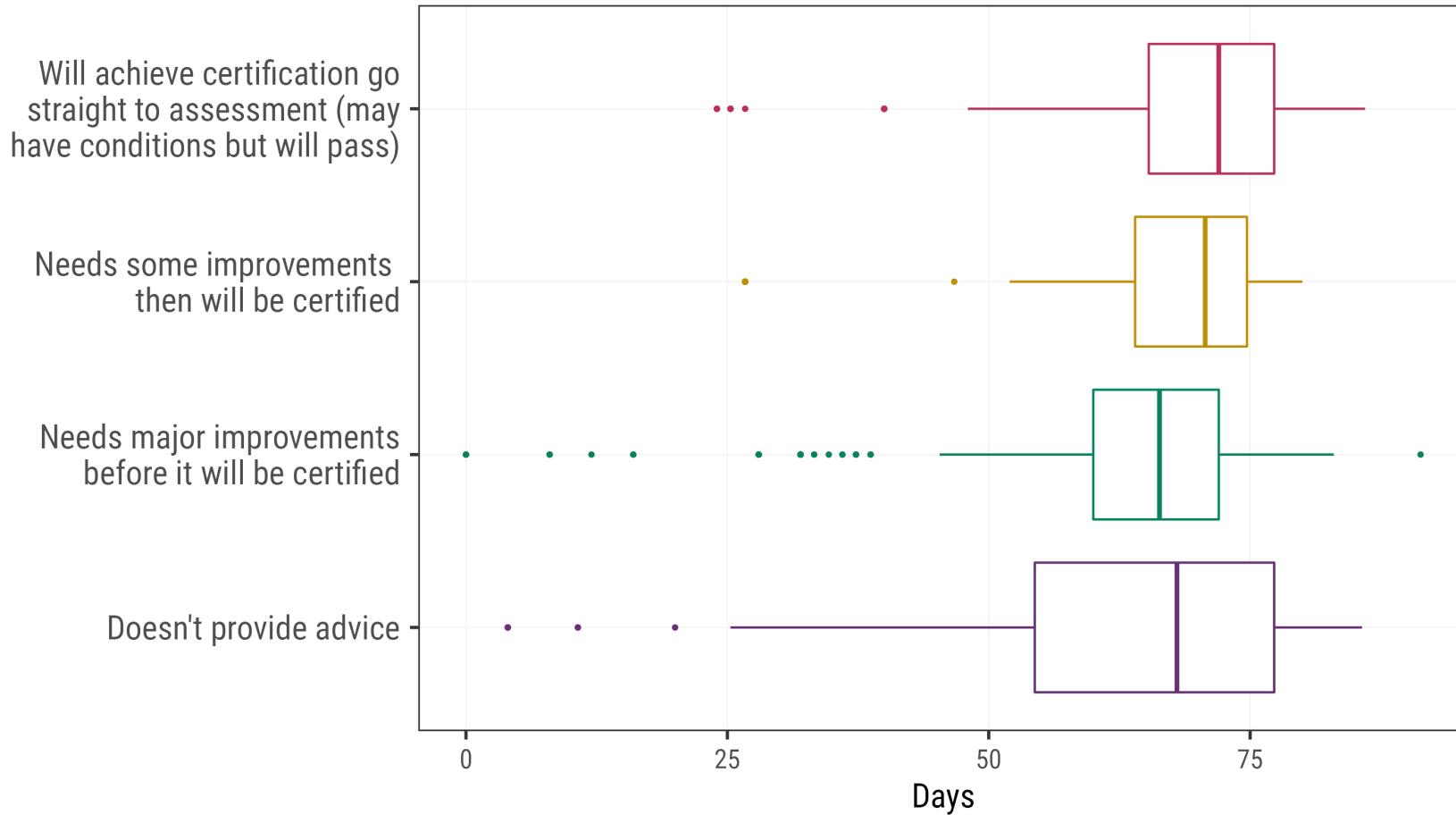
Order Your Data



"Hands-On Data Visualization" by Jack Dougherty & Ilya Illyankou

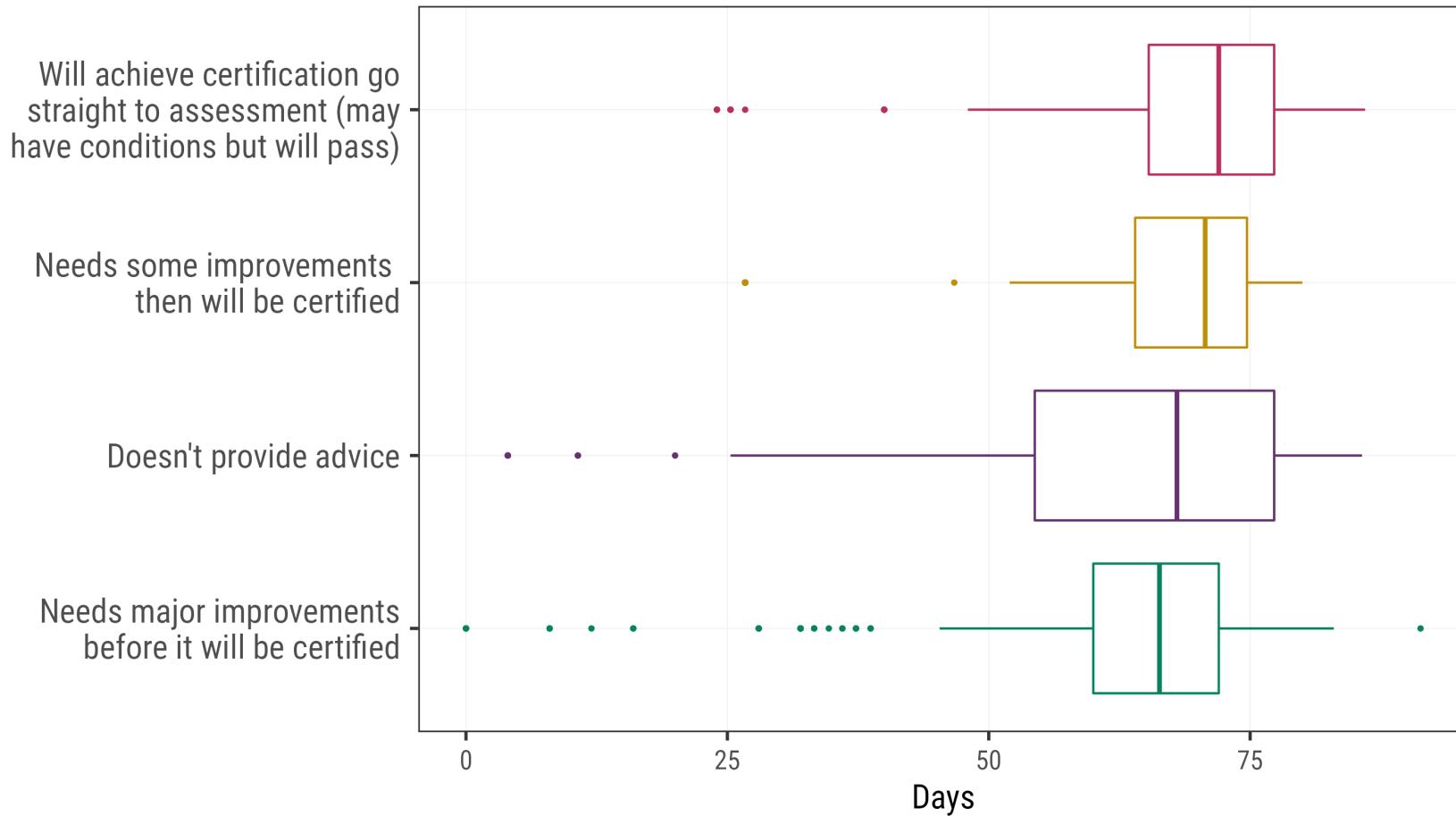
Order Your Data

P2 Score (combined)



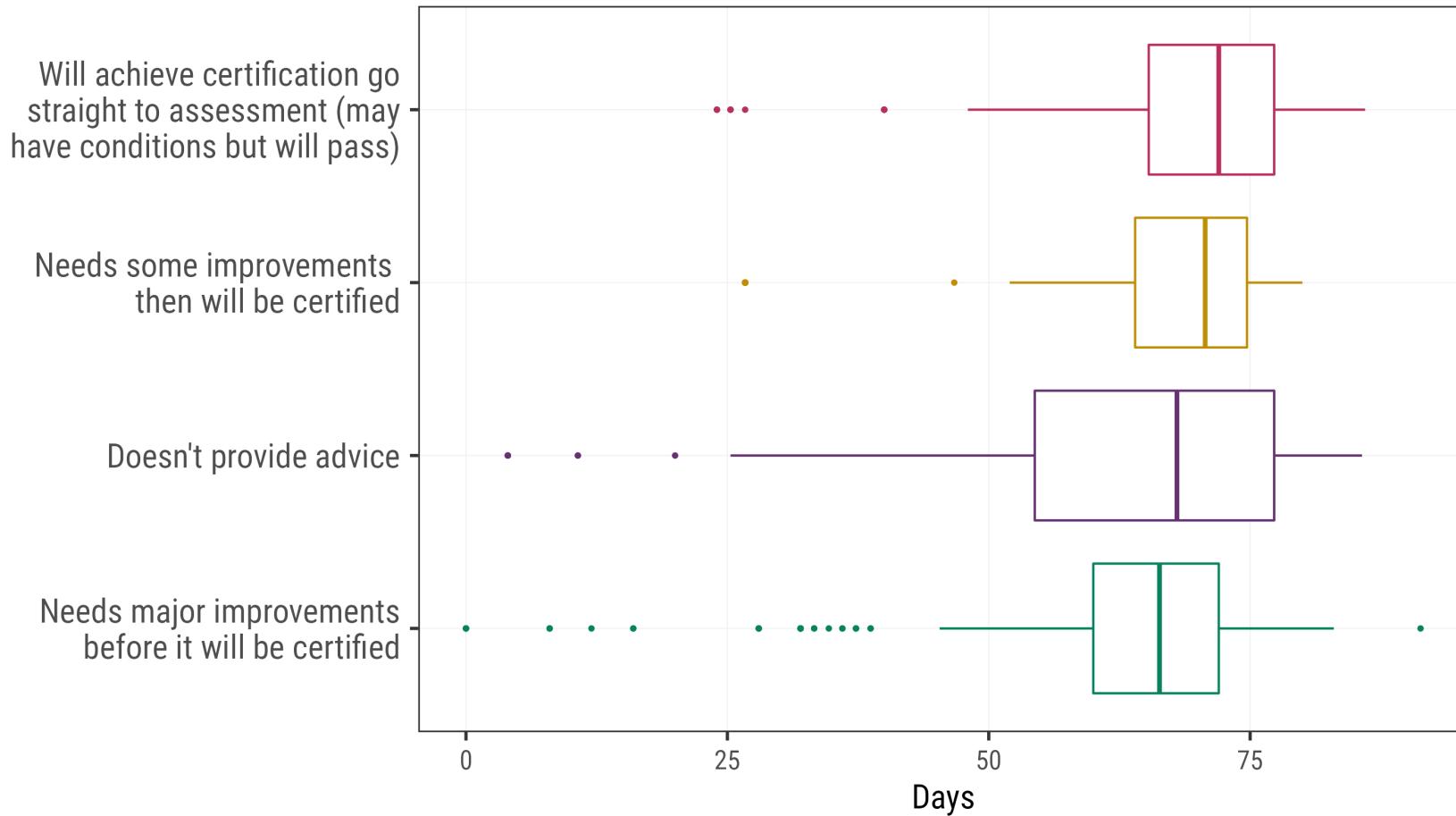
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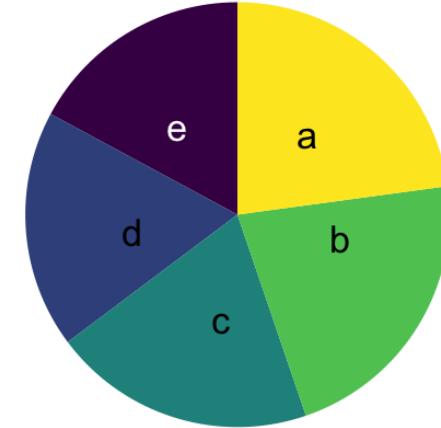
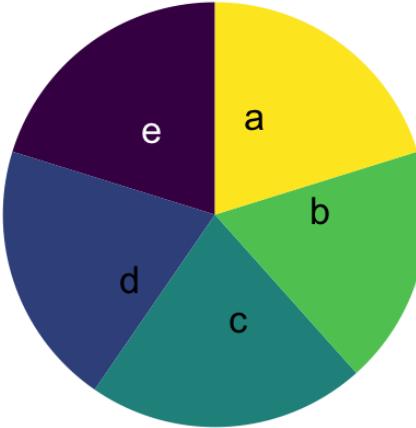
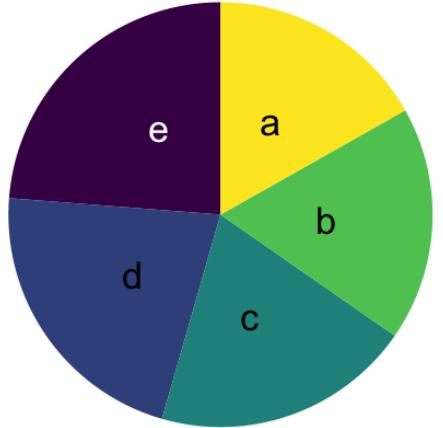


Order Your Data

P2 Score (combined)

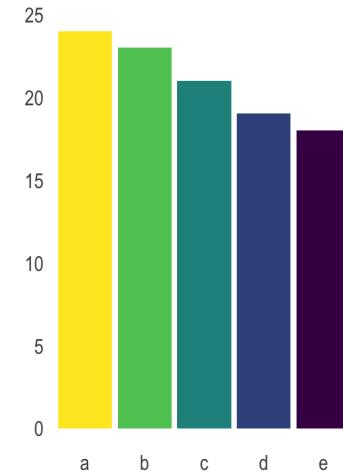
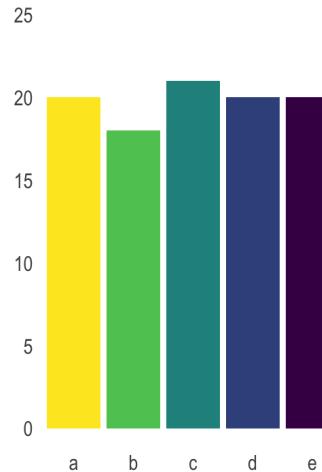
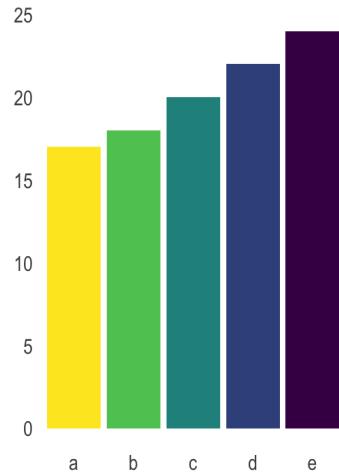
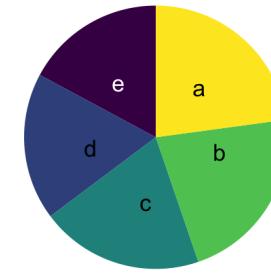
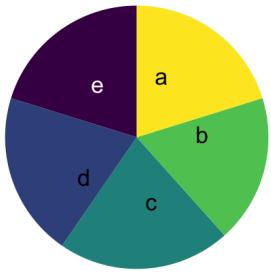
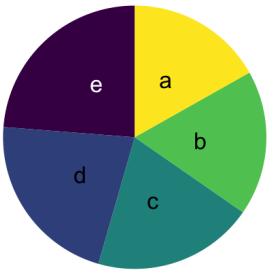


Beware of Pie Charts (almost ever)



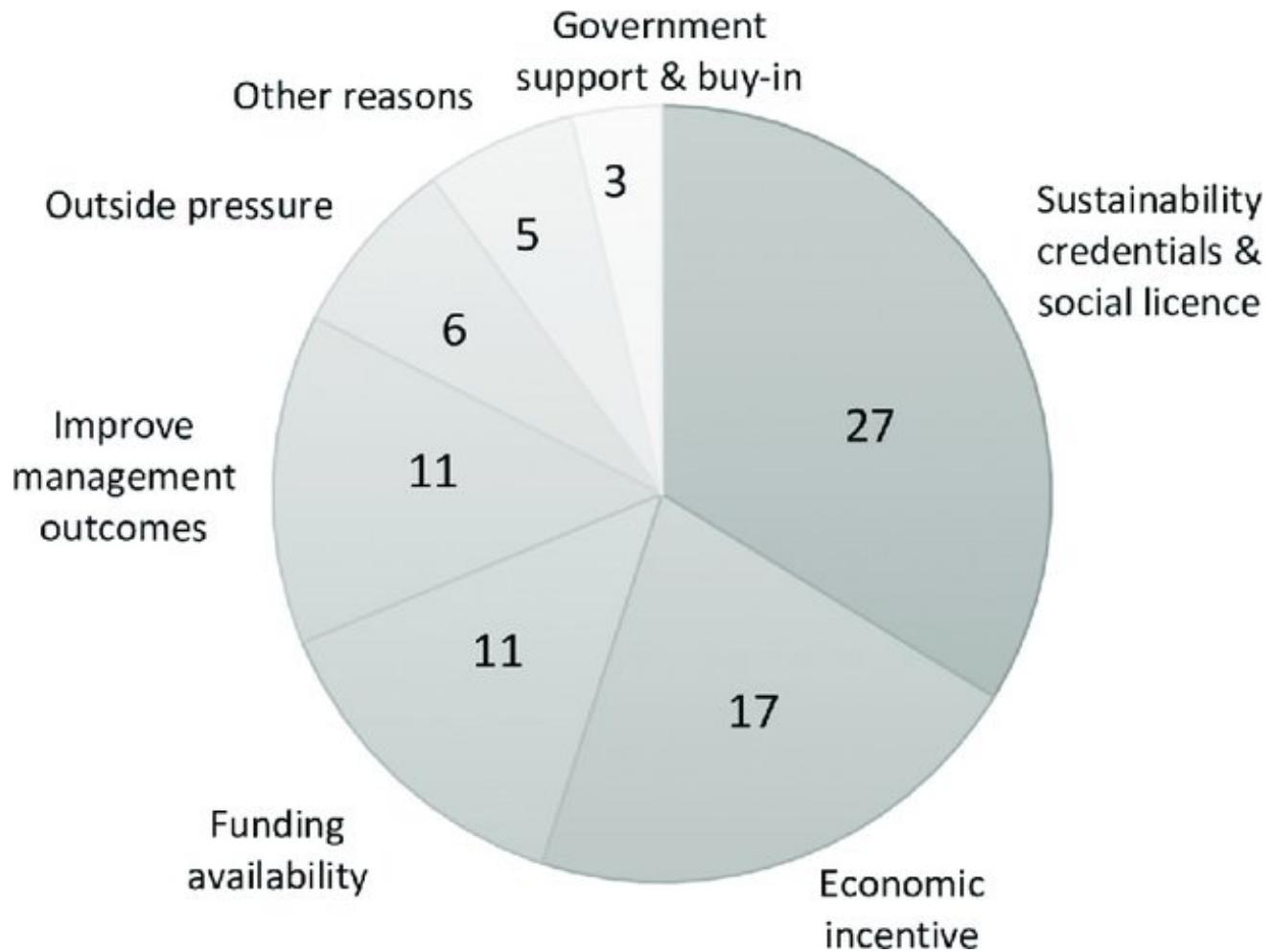
From Data to Viz

Beware of Pie Charts (almost ever)

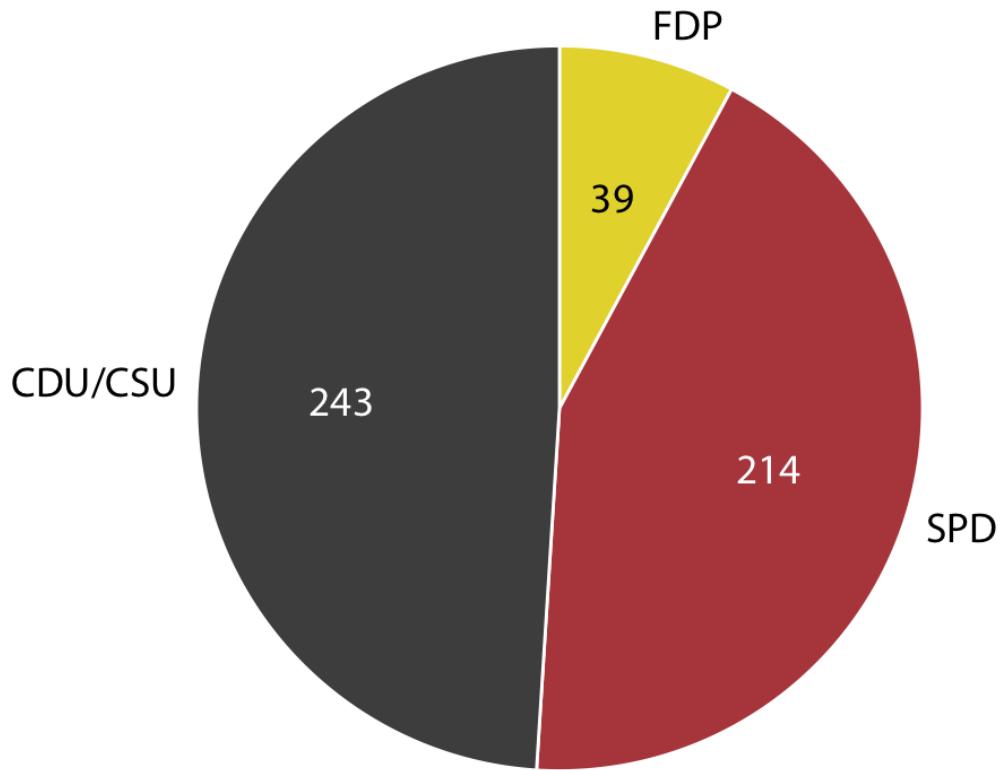


From Data to Viz

Beware of Pie Charts (almost ever)

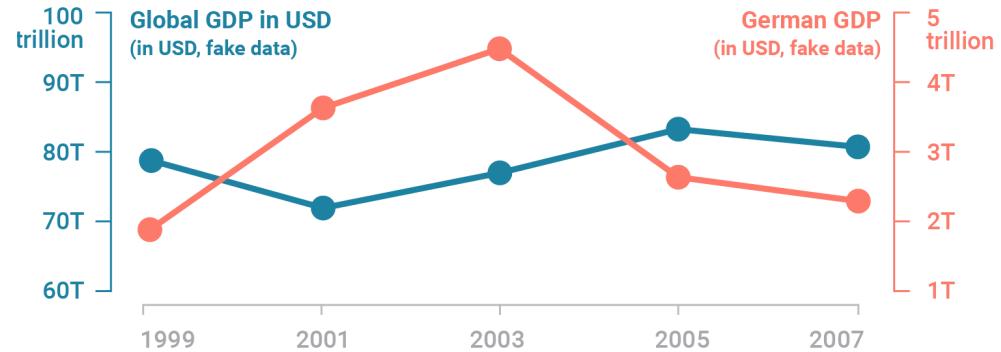


An Use Case for a Pie Chart



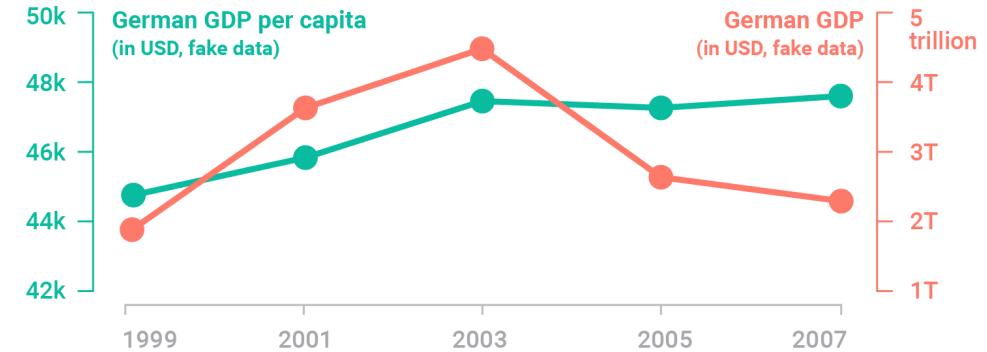
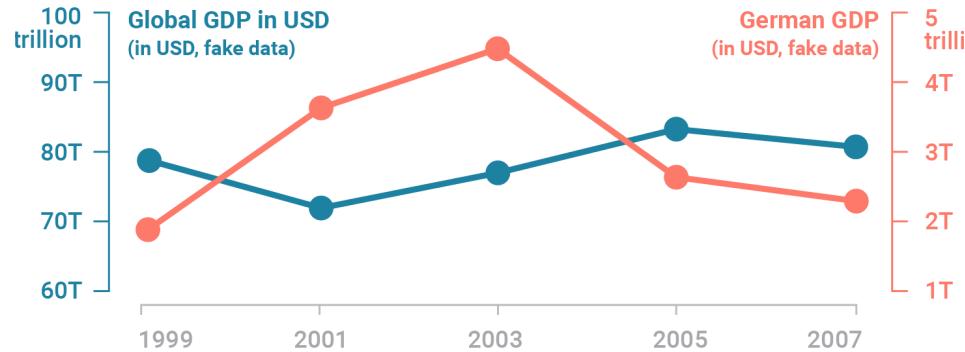
“Fundamentals of Data Visualization” by Claus Wilke

Avoid Dual Axes



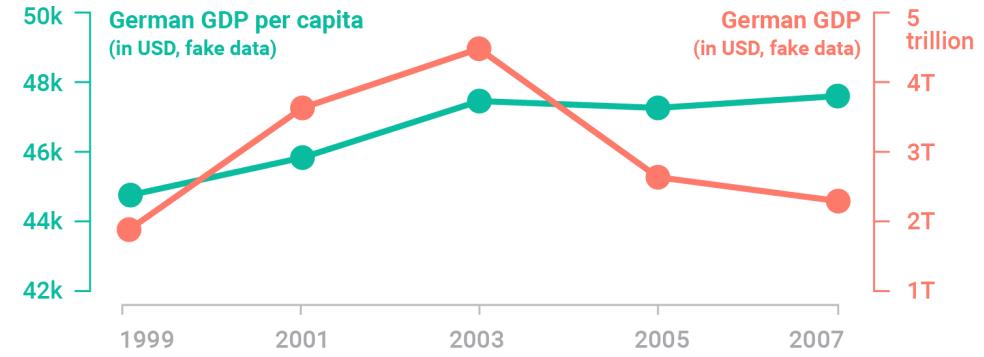
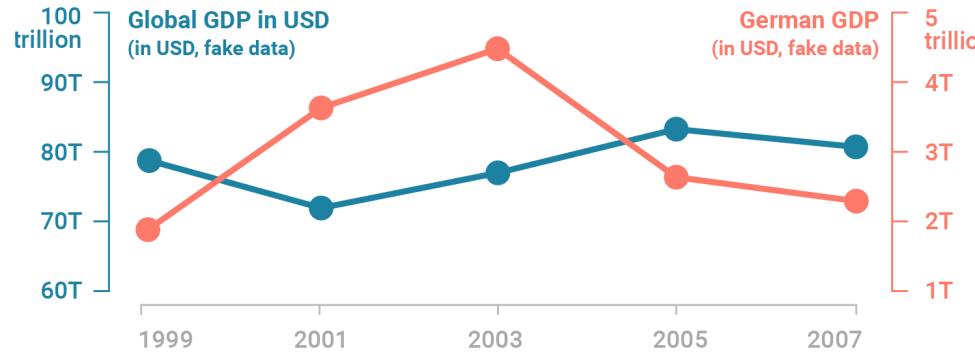
Why not to use two axes, and what to use instead by Lisa Charlotte Rost/DataWrapper

Avoid Dual Axes



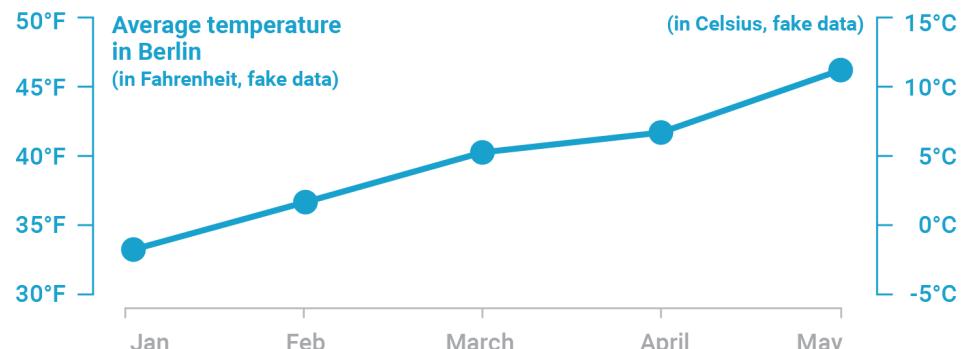
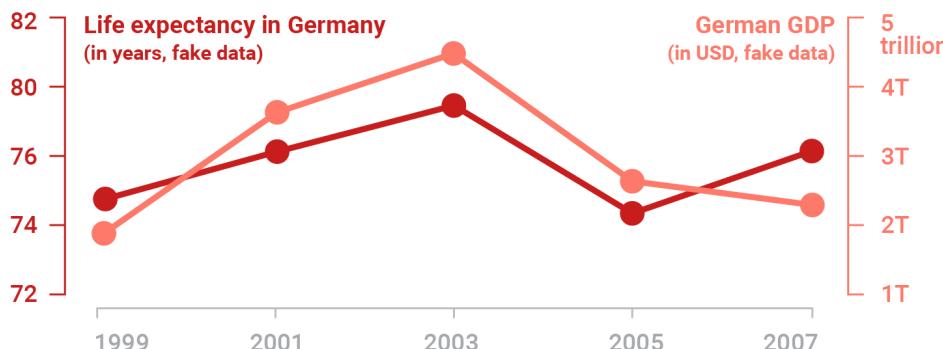
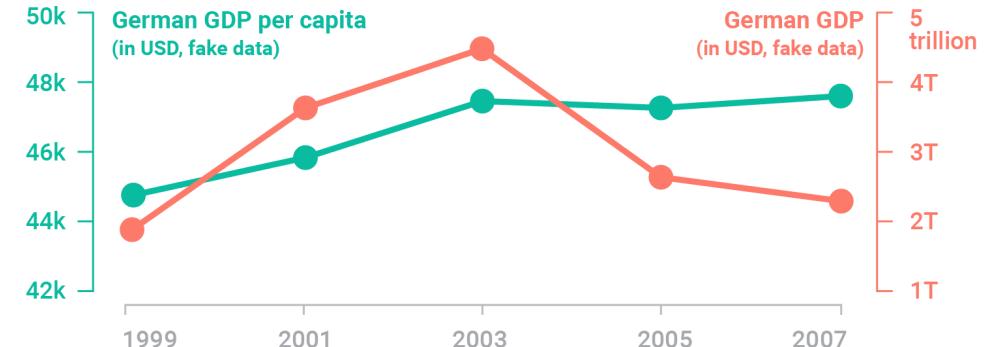
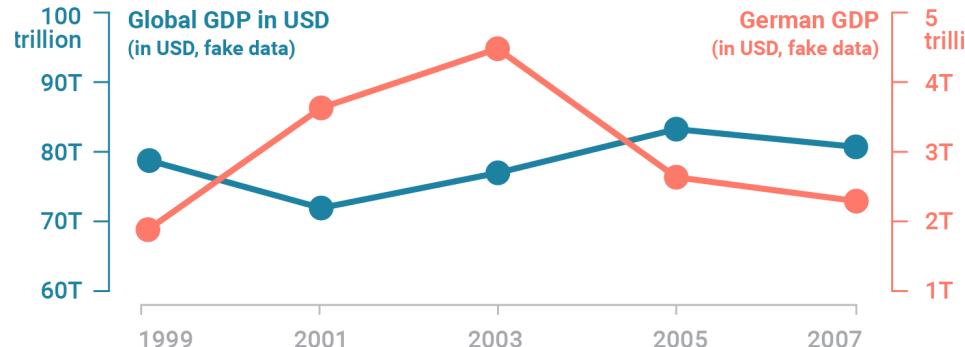
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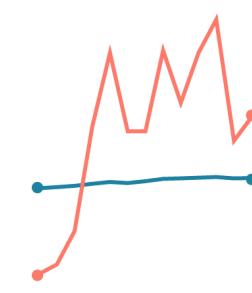


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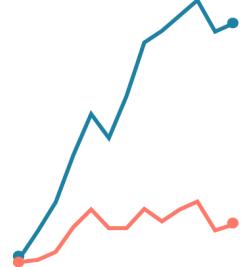
Orange steady,
Blue massively increasing.



Blue steady,
Orange increasing.



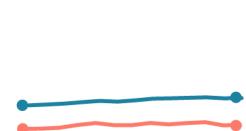
Both started at the same
level, but Orange increased
far more than Blue.



Both started at the same
level, but Blue increased far
more than Orange.



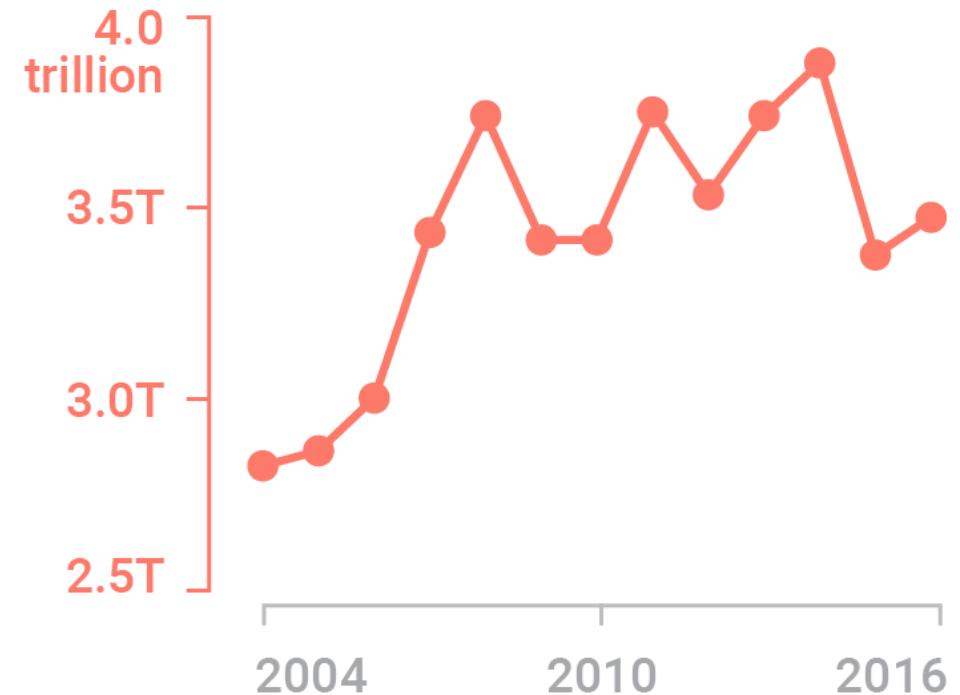
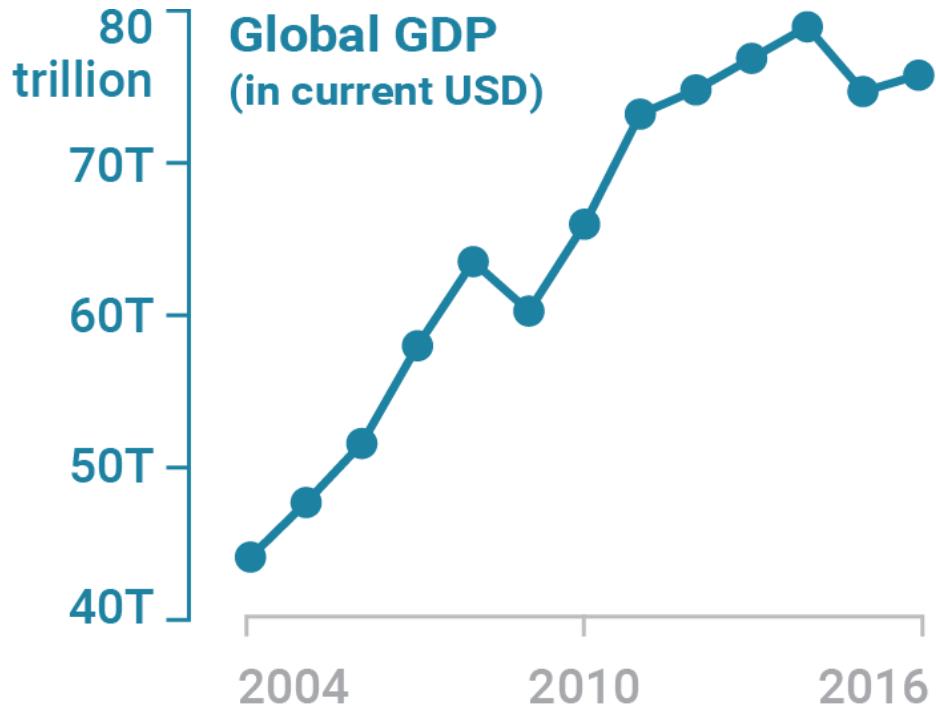
Both started with the
same increase, then Blue
raced to the top.



Both steady.

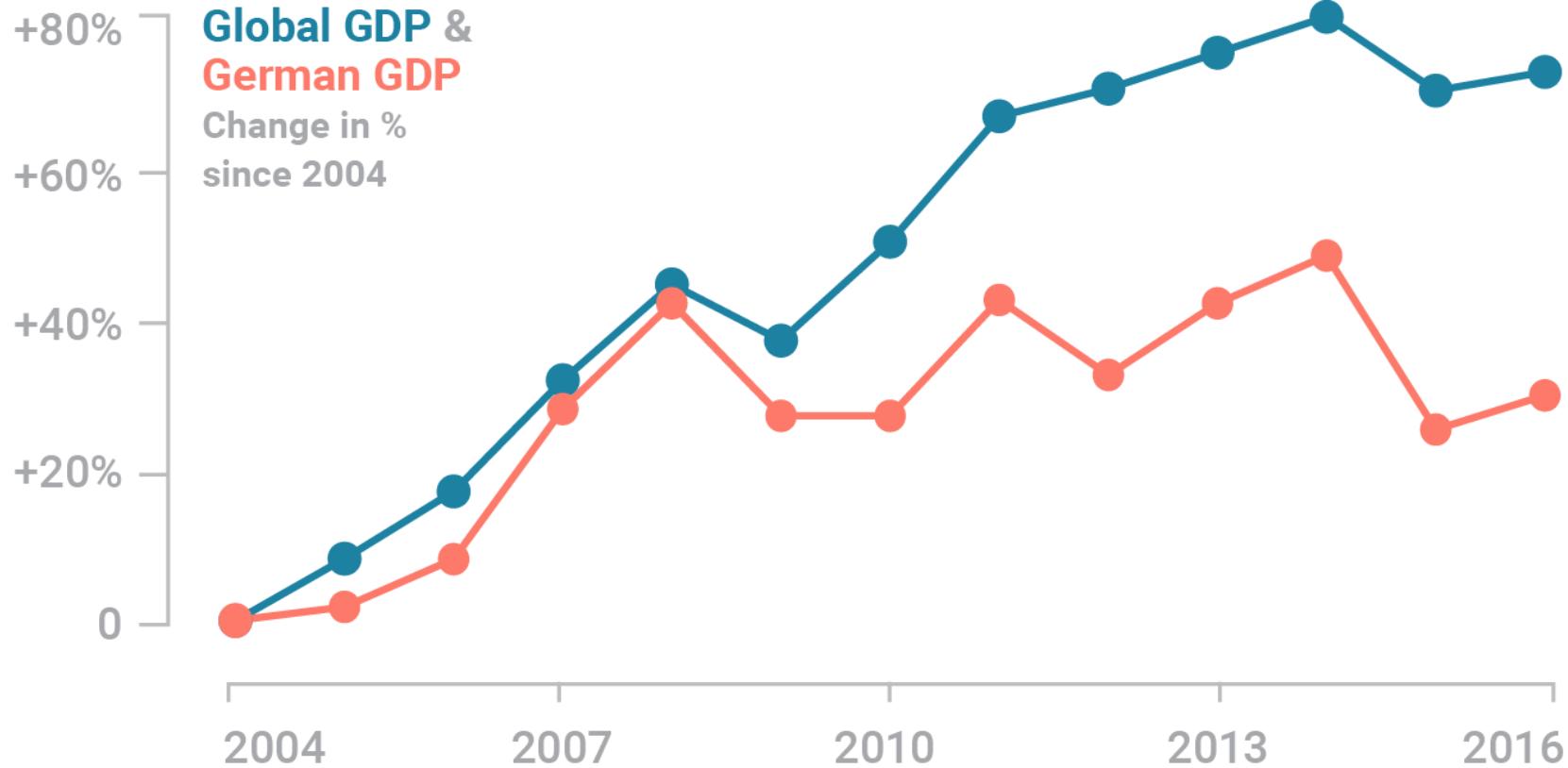
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Avoid Dual Axes



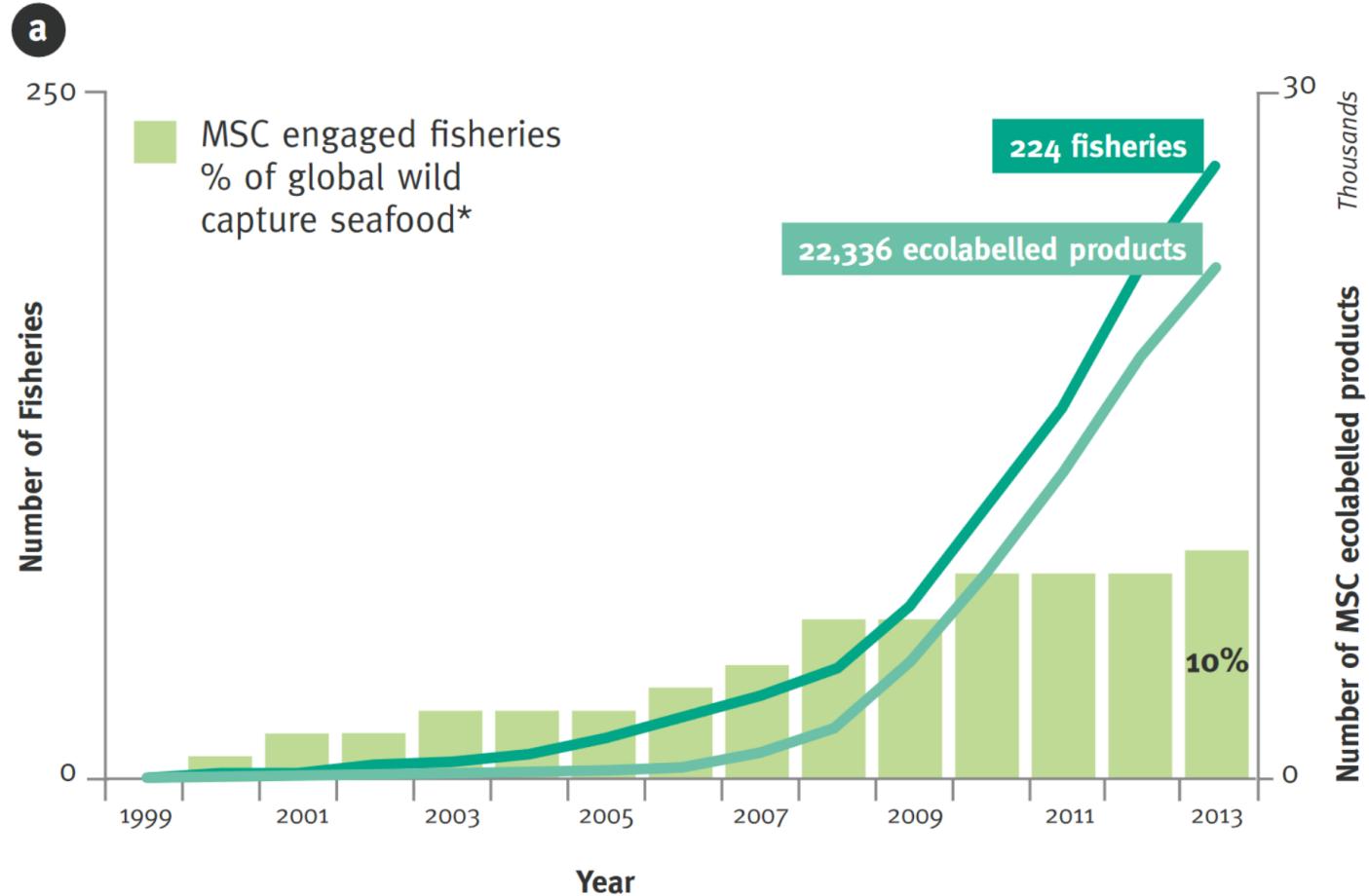
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Avoid Dual Axes



Why not to use two axes, and what to use instead by Lisa Charlotte Rost/DataWrapper

Avoid Dual Axes



Avoid Dual Axes

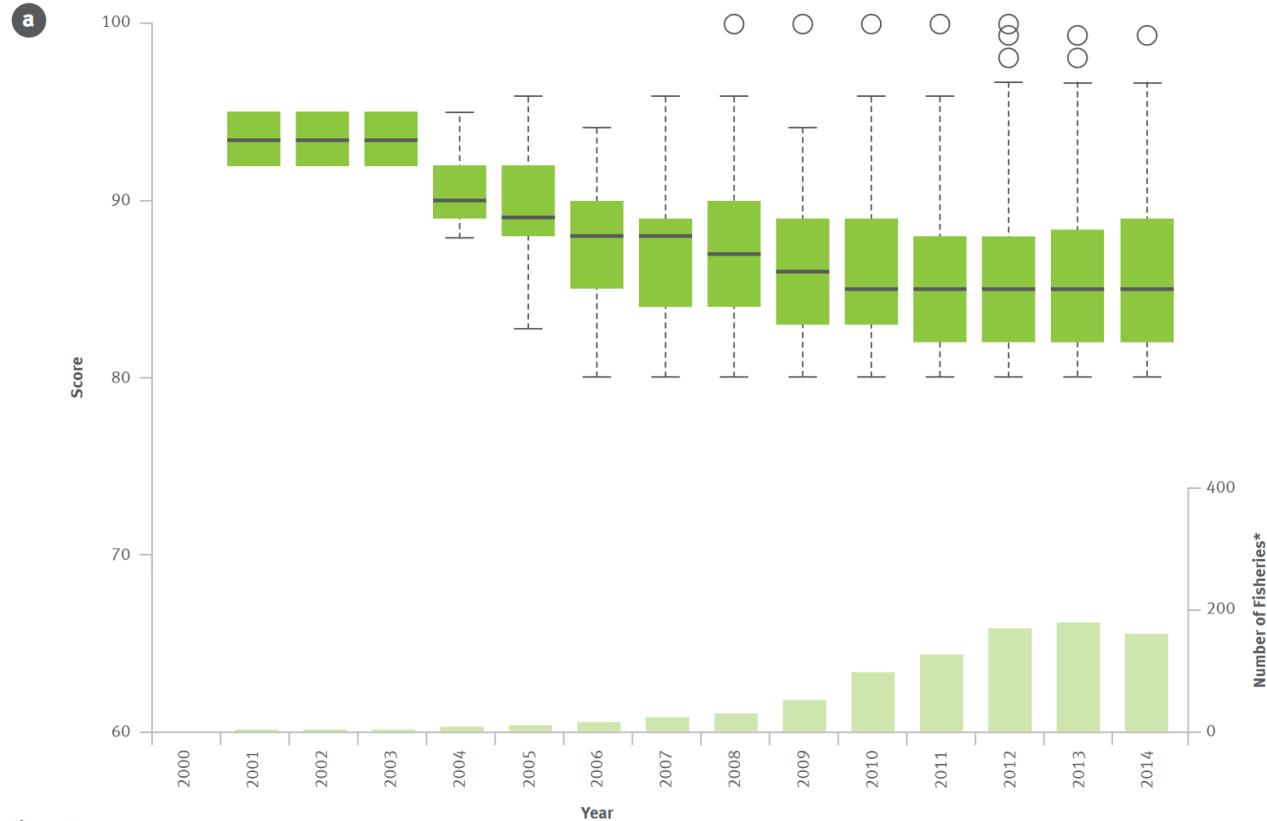


Figure 1.1

Figure 1.1 Median, interquartile range, and maximum and minimum scores of certified fisheries at time of certification (a) Principle 1: Sustainable fish stocks; (b) Principle 2: Minimising environmental impact; and (c) Principle 3: Effective management. Pale green bars represent the number of fisheries* scored by year.



A word about Tables

Make Your Data Tables More Visual

Table 1: Change in household wealth 2018–19 by region

	Total wealth	Change in total wealth		Wealth per adult	Change in wealth per adult	Change in financial assets		Change in non- financial assets		Change in debts	
	2019	2018–19	2018–19	2019	2018–19	2018–19	2018–19	2018–19	2018–19	2018–19	2018–19
	USD bn	USD bn	%	USD	%	USD bn	%	USD bn	%	USD bn	%
Africa	4,119	130	3.3	6,488	0.4	1	0.1	164	6.6	35	7.7
Asia-Pacific	64,778	825	1.3	54,211	-0.3	539	1.5	672	1.9	386	4.2
China	63,827	1,889	3.1	58,544	2.6	88	0.2	2,273	7.5	471	10.9
Europe	90,752	1,093	1.2	153,973	1.2	127	0.8	1,156	2.0	190	1.4
India	12,614	625	5.2	14,569	3.3	37	1.4	708	6.9	120	11.5
Latin America	9,906	463	4.9	22,502	3.2	193	4.0	340	5.7	70	5.0
North America	114,607	4,061	3.7	417,694	2.7	3,934	3.6	1,353	3.8	626	3.8
World	360,608	9,087	2.6	70,849	1.2	4,319	2.0	6,666	3.7	1,898	4.0

Source: James Davies, Rodrigo Lluberas and Anthony Shorrocks, Global wealth databook 2019

Make Your Data Tables More Visual

Table 1: Change in household wealth 2018–2019 by region

Overall total wealth and mean wealth per adult refer to 2019 only. Triangles pointing upwards indicate the highest proportional change per category triangles pointing downwards the lowest change.

	TOTAL WEALTH			WEALTH PER ADULT		FINANCIAL ASSETS		NON-FINANCIAL ASSETS		DEBTS	
	OVERALL (USD bn)	CHANGE^ (USD bn)	(prop.)	MEAN (USD)	CHANGE (prop.)	(USD bn)	CHANGE (prop.)	(USD bn)	CHANGE (prop.)	(USD bn)	CHANGE (prop.)
World	360,603	9,087	2.6%	70,849	1.2%	4,319	2.0%	6,666	3.7%	1,898	4.0%
North America	114,607	4,061	3.7%	417,694	2.7%	3,334	3.6%	1,353	3.8%	626	3.8%
Europe	90,752	1,093	1.2% ▽	153,973	1.2%	127	3.0%	1,156	2.0%	190	1.4% ▽
Asia-Pacific	64,778	825	1.3%	54,211	-0.3% ▽	539	1.5%	672	1.9% ▽	386	4.2%
China	63,827	1,889	3.1%	58,544	2.6%	88	2.0%	2,273	7.5% △	471	10.9%
India	12,614	615	5.2% △	14,569	3.3% △	37	1.4%	708	6.9%	120	11.5% △
Latin America	9,906	463	4.9%	22,502	3.2%	193	4.0% △	340	5.7%	70	5.0%
Africa	4,119	130	3.3%	6,488	0.4%	1	1.0% ▽	164	6.6%	35	7.7%

Source: James Davies, Rodrigo Lluberas and Anthony F. Shorrocks, Global Wealth Databook, 2019 | Makeover: Cedric Scherer, Frontpage Data



Jonathan A. Schwabish

Ten Guidelines for Better Tables

Abstract: Tables are a unique form of visualizing data because, unlike many charts, they are not usually intended to give a quick, visual representation of data. Instead, tables are useful when you want to show the exact values of your data or estimates. They are not the best solution if you want to show a lot of data or if you want to show the data in a compact space, but a well-designed table can help your reader find specific numbers and discover patterns and outliers. In this article, I present 10 guidelines for creating better, more effective tables; I then model these lessons by redesigning six tables from articles previously published in the *Journal of Benefit-Cost Analysis*.

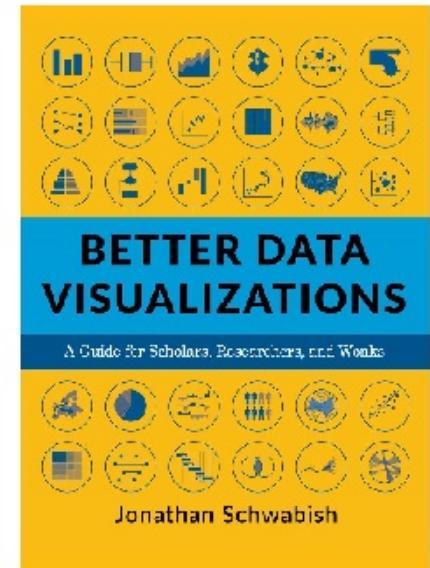
John Schwabisch



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John Schwabish

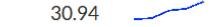
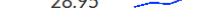
Country	Potato Yield in Tonnes/Hectare		
	2013	2017	2013-2017
Brazil	27.75	30.94	
China	17.09	18.21	
Denmark	41.57	43.68	
El Salvador	42.60	29.22	
France	43.16	44.05	
Germany	39.83	46.79	
India	22.76	22.31	
Indonesia	16.02	15.40	
Ireland	38.33	44.83	
Italy	25.25	27.73	
Lebanon	26.08	25.14	
Mexico	26.78	28.95	
Netherlands	42.21	45.97	
Pakistan	21.81	21.45	
United States	46.36	48.39	

Table: @thomas_mock | Data: OurWorldInData.org

Inspiration: @jschwabish

Country	Potato Yield in Tonnes/Hectare				
	2013	2014	2015	2016	2017
United States	46.36	47.15	46.90	48.64	48.39
France	43.16	47.98	42.51	38.83	44.05
El Salvador	42.60	26.25	26.01	25.54	29.22
Netherlands	42.21	45.66	42.73	42.00	45.97
Denmark	41.57	43.12	41.41	42.48	43.68
Germany	39.83	47.42	43.81	44.40	46.79
Ireland	38.33	40.32	42.36	39.11	44.83
Brazil	27.75	27.94	29.32	29.66	30.94
Mexico	26.78	27.34	27.14	27.93	28.95
Lebanon	26.08	25.23	24.82	25.07	25.14
Italy	25.25	26.08	27.16	28.44	27.73
India	22.76	22.92	23.13	20.51	22.31
Pakistan	21.81	18.15	23.44	22.43	21.45
China	17.09	17.14	17.27	17.69	18.21
Indonesia	16.02	17.67	18.20	18.25	15.40

Table: @thomas_mock | Data: OurWorldInData.org

Inspiration: @jschwabish

Thomas Mock

Wrap-Up

Information

→ Understand your data and be accurate.

Story

→ Be clear about the message of your visualization.

Goal

→ Select charts that successfully transport your story.

Visual Form

→ Follow design rules and data visualization principles.

Design for Your Audience

- Choose charts based on your goal not tradition or novelty (only).
- Make sure your visualization is accessible for everyone (colors, readability).
- Use visual contrast to highlight important information.
- Provide meaningful labels and titles.

Be Honest

- Show raw data if possible.
- Don't truncate bar charts. Add spacing to truncated axes.
- Be consistent with axis scaling.

Lend A Helping Hand

- Use annotations and direct labels instead of/in addition to text and legends.
- Order your data, either by value or intrinsic ranking.
- Reveal information step by step (if applicable).

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Books

- “[Fundamentals of Data Visualization](#)”, an open-access book by Claus Wilke
- “[Data Visualization](#)”, an open-access book by Kieran Healy
- “[Avoiding Data Pitfalls](#)” by Ben Jones
- “[The Functional Art](#)”, “[The Truthful Art](#)”, and “[How Charts Lie](#)” by Alberto Cairo
- “[Better Data Visualizations](#)” by John Schwabisch
- “[Storytelling with Data](#)” by Cole Nussbaumer Knaflic
- “[Data Visualization Handbook](#)” by Juuso Koponen & Jonatan Hildén

Blogs

- “[Nightingale](#)”, the journal of the Data Visualization Society
- “[Chartable](#)”, the blog by DataWrapper

Chart Choice Helpers

- [From Data to Viz](#)
- [DataViz Project](#)
- [Visualizaiton Universe](#)
- [Material Design](#)

Color Choice Helpers

- [Viz Palette](#) by Elijah Meeks & Susie Lu
- “[How to pick more beautiful colors for your data visualizations](#)” by Lisa Charlotte Rost