

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

Data Visualization
is any graphical representation
of information and data.

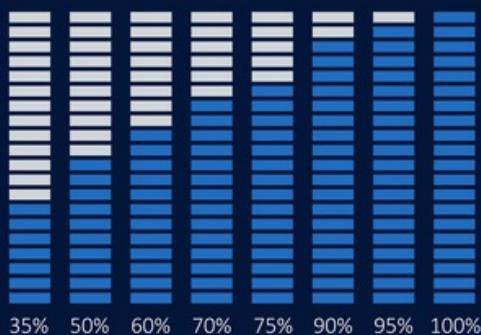
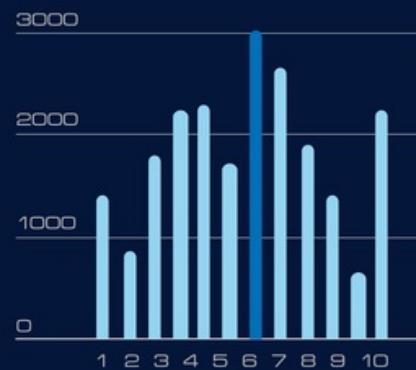
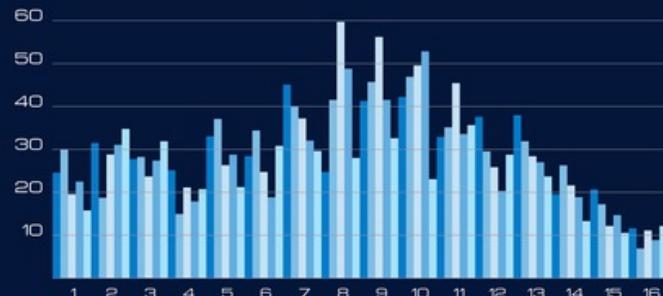
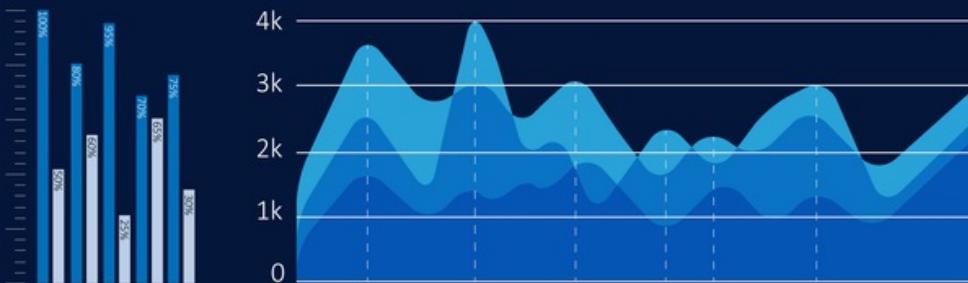
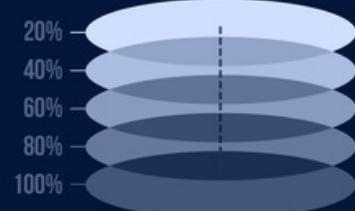
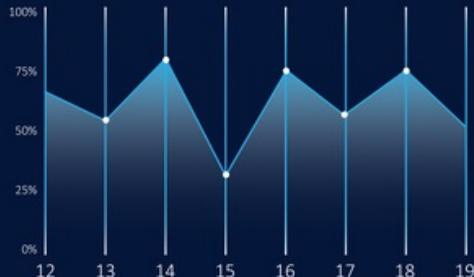
Data Visualization

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

Data Visualization is part art and part science.

Claus O. Wilke, "Fundamentals of Data Visualization"





Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.

Dessinée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite
Paris, le 20 Novembre 1869.

Les nombres d'hommes perdus sont représentés par les largeurs des zones colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en lettres des zones. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. — Les renseignements qui ont servi à desser la carte ont été puisés dans les ouvrages de M. Chiers, de Séguir, de Fezensac, de Chambray et le journal médical de Jacob, pharmacien de l'Armée depuis le 28 Octobre.

Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davout, qui avaient été détachés sur Minsk et Mogilow et se rejoignaient vers Osscha et Witelisk, avaient toujours marché avec l'armée.

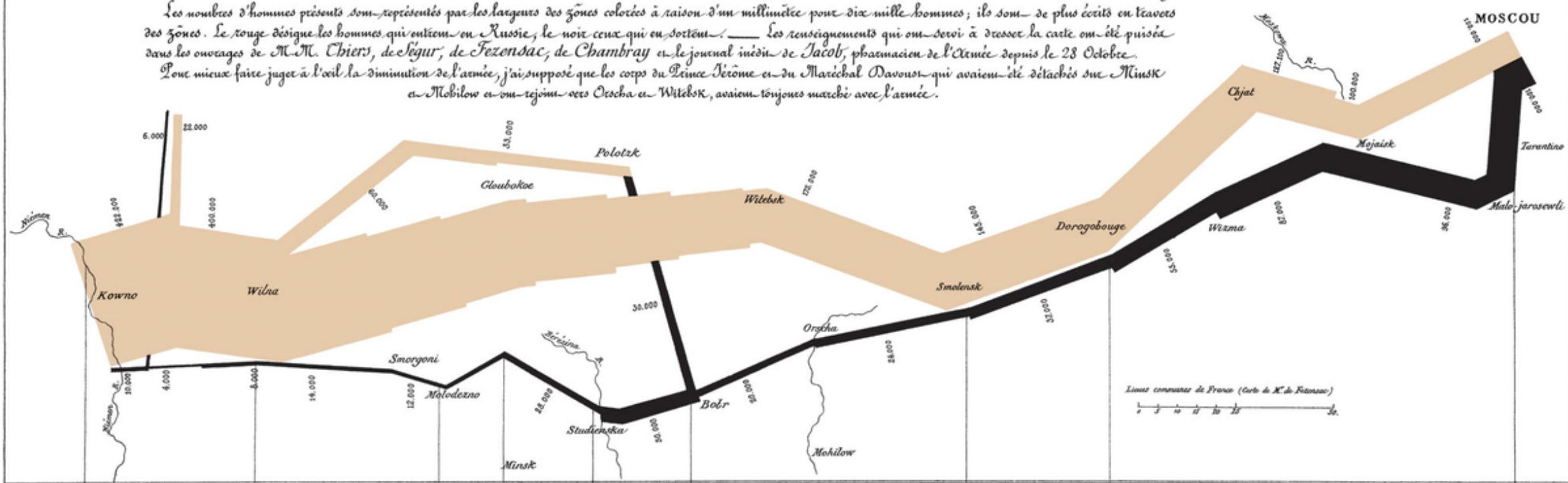
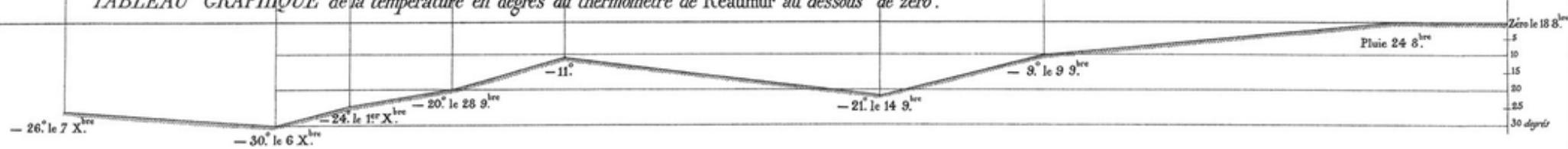
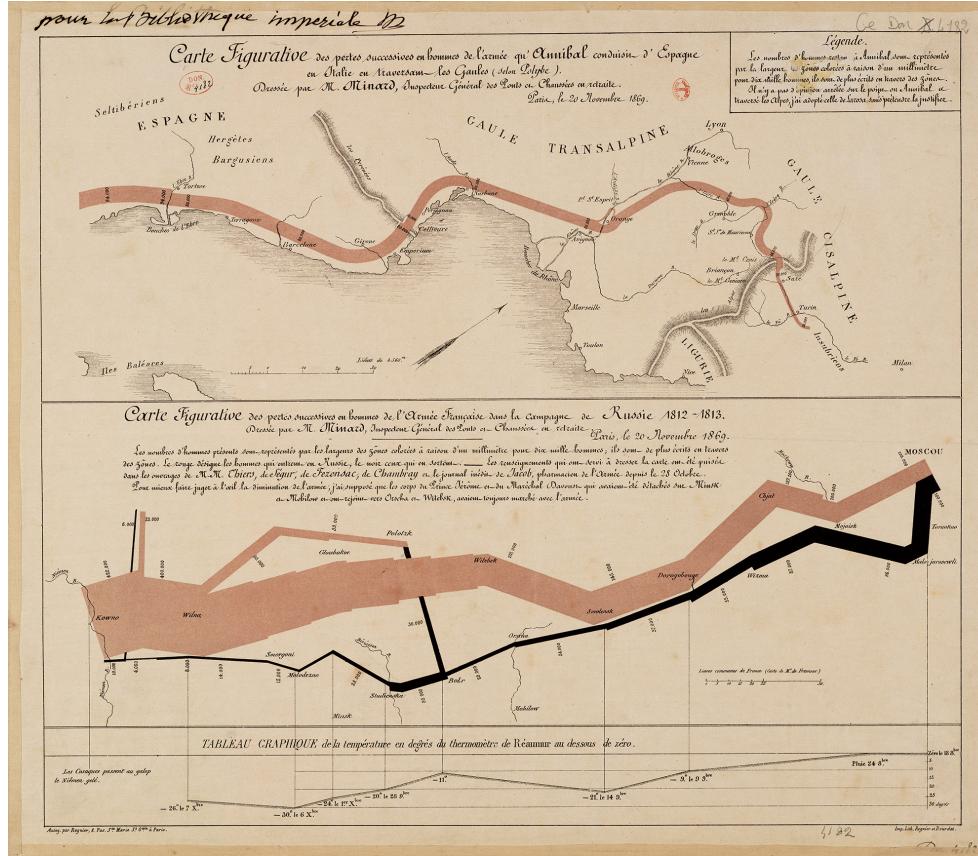


TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.

Les cosaques passent au galop
le Niemen gelé.

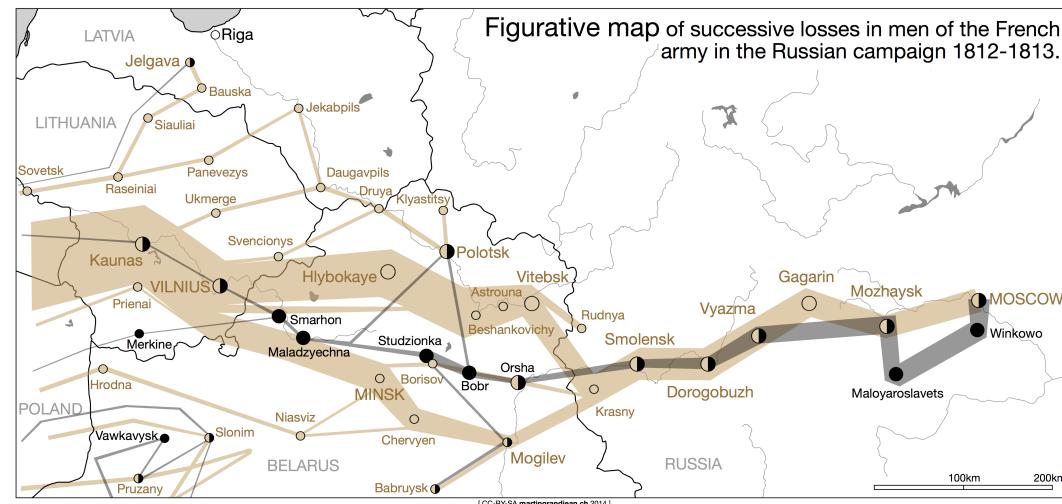
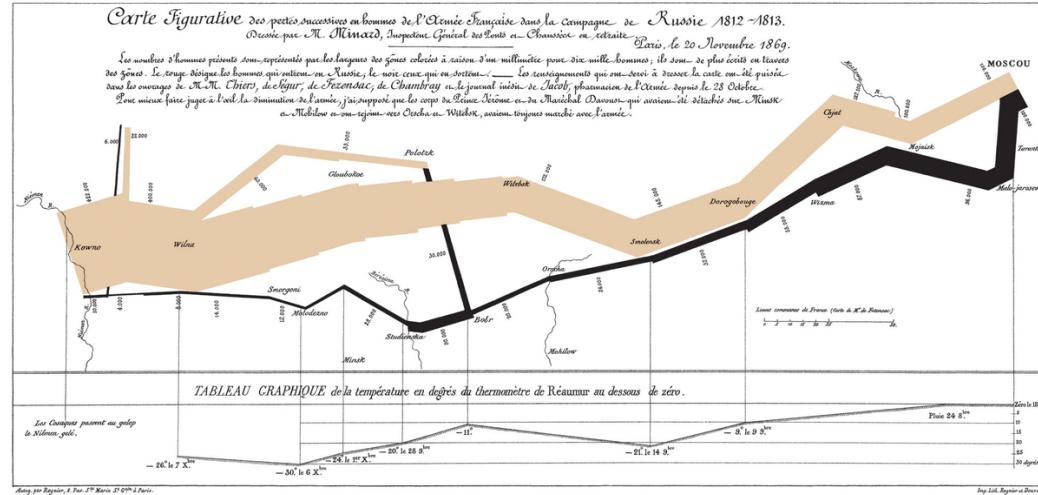




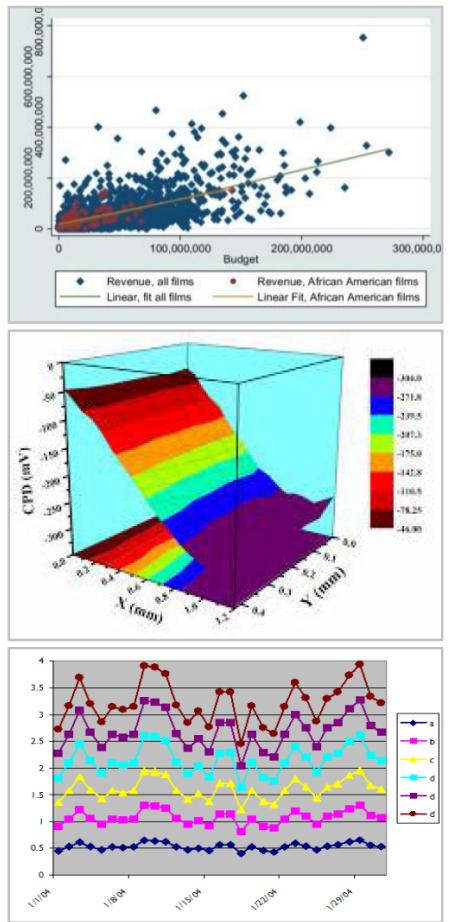
Carte figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813 and

Carte figurative des pertes successives en hommes de l'Armée qu'Annibal conduisit d'Espagne en Italie en traversant les Gaules (selon Polybe) by Charles Joseph Minard

- displays the progress of the troops of Hannibal (218 BC) and Napoleon (1812-1813) in the form of a stream
- often considered as the **best statistical graphic ever drawn**



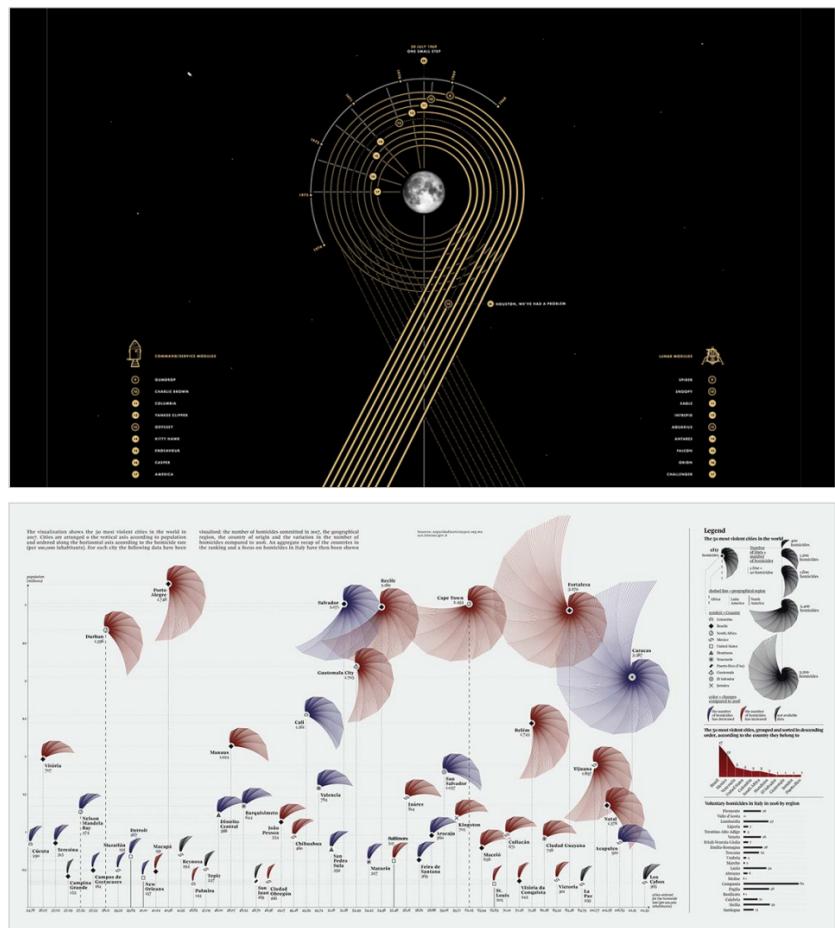
The map created by Charles Joseph Minard projected in the geographical reality with the most accurate information on the actual route of different corps by Martin Grandjean



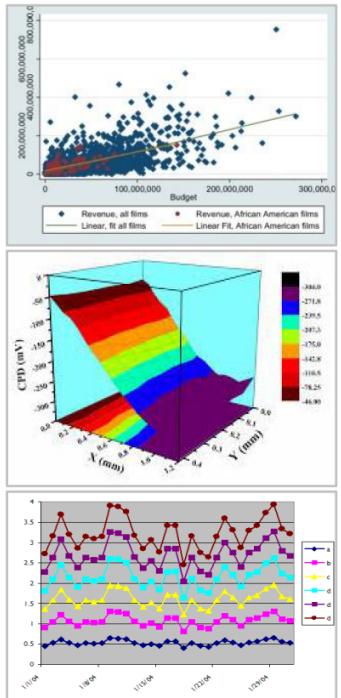
Anonymous



Sonia Kuijpers



Upper: Paul Button
Lower: Frederica Fragapane



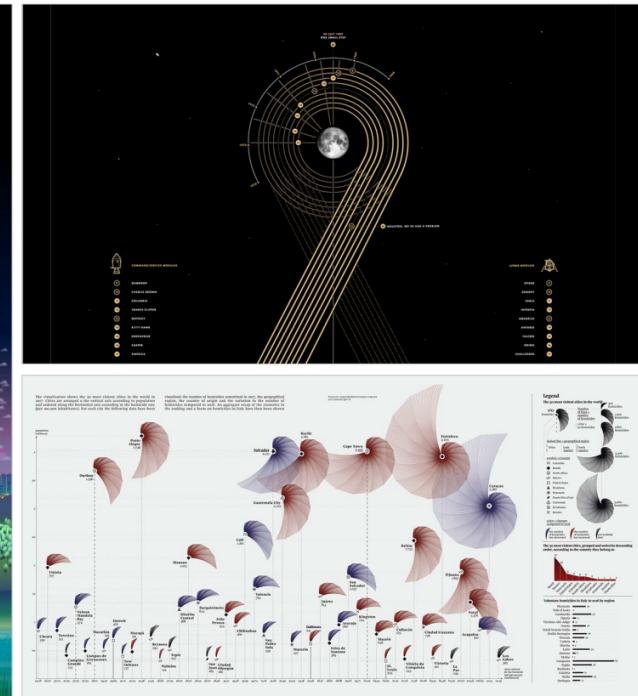
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We aim for DataViz that:

- is informative
- is truthful
- is easy to grasp
- is visually appealing
- draws attention



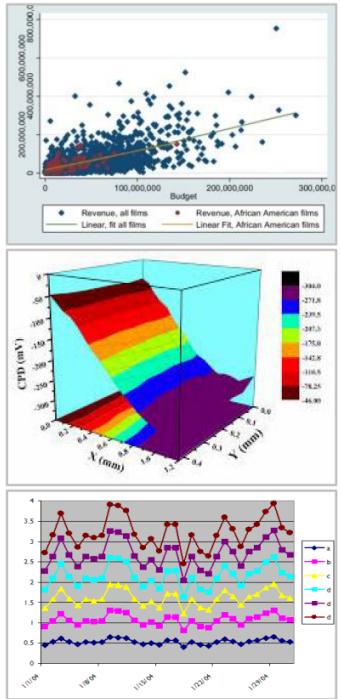
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Gradient from uninformative & poorly designed data visualizations to data art



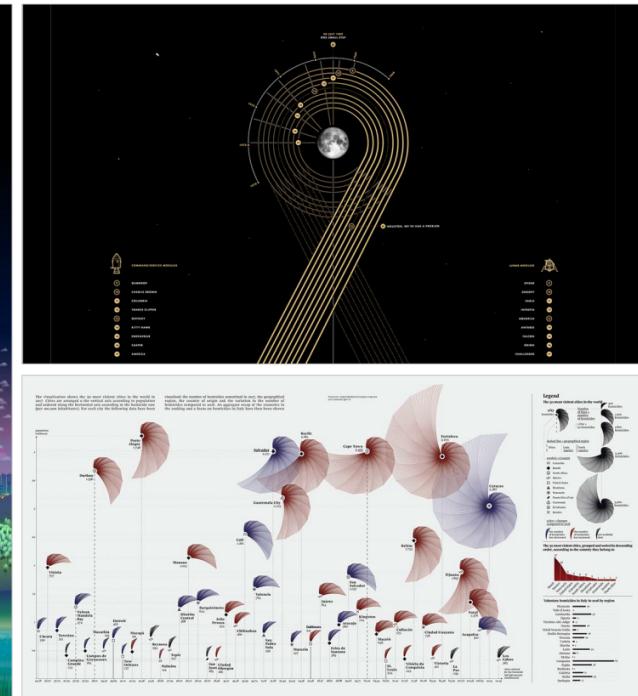
Anonymous

We aim for DataViz that:

- is informative
 - is truthful
 - is easy to grasp
 - is visually appealing
 - draws attention
- but:
- is not abstract
 - is not too unusual



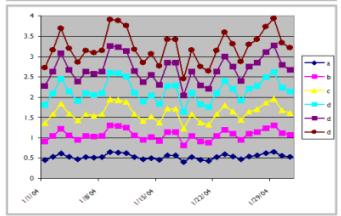
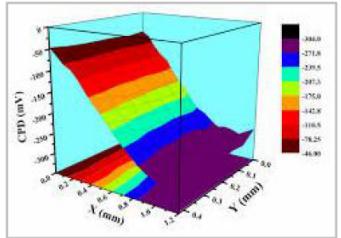
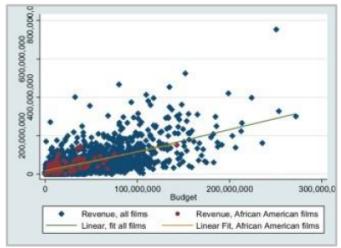
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Gradient from uninformative & poorly designed data visualizations to data art



Anonymous

Average Life Expectancy per Continent, 2015

Continent	Mean Life Expectancy (years)
Africa	62.3
Oceania	72.9
Asia	74.2
Americas	75.8
Europe	80.6

N = 57

Most western countries are on the same coronavirus trajectory. Hong Kong and Singapore have managed to slow the spread

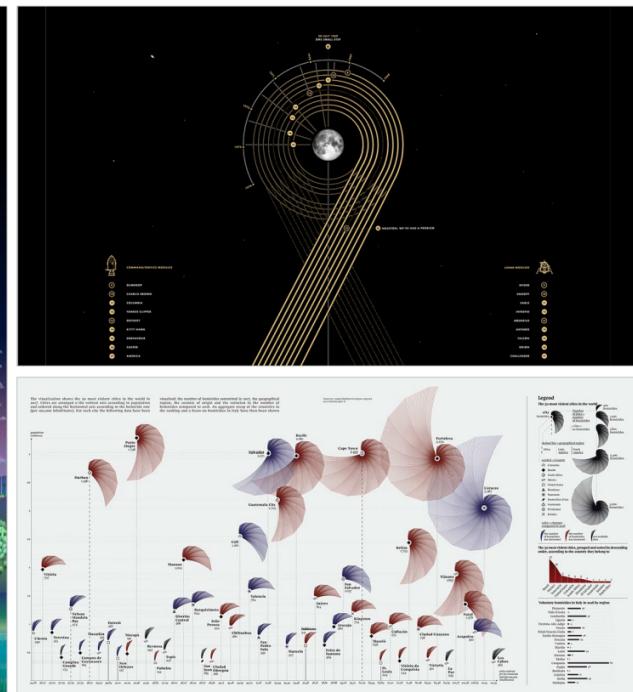
Cumulative number of cases, by number of days since 100th case



Upper: Cédric Scherer
Lower: John Burn-Murdoch



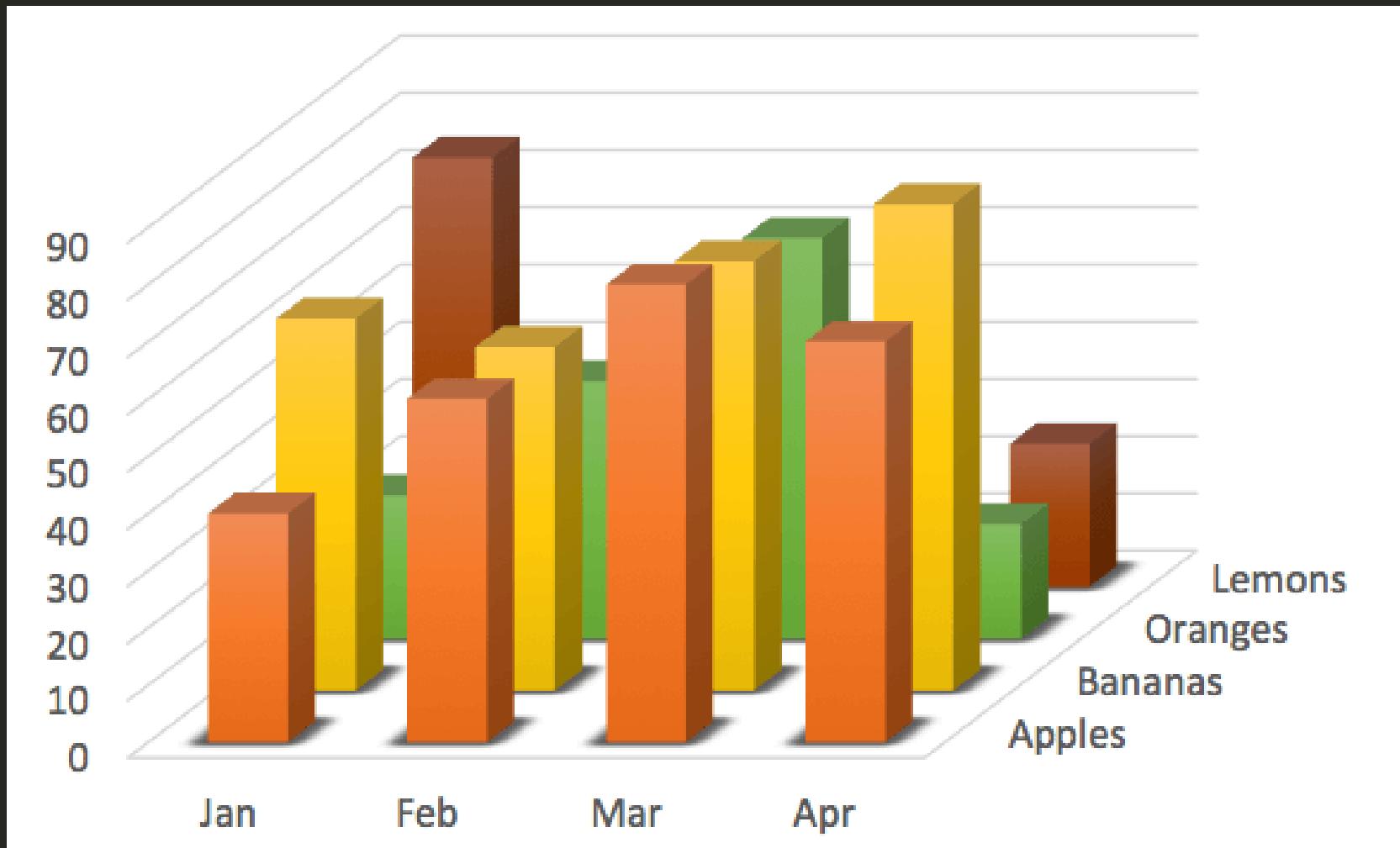
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Gradient from uninformative & poorly designed data visualizations to data art

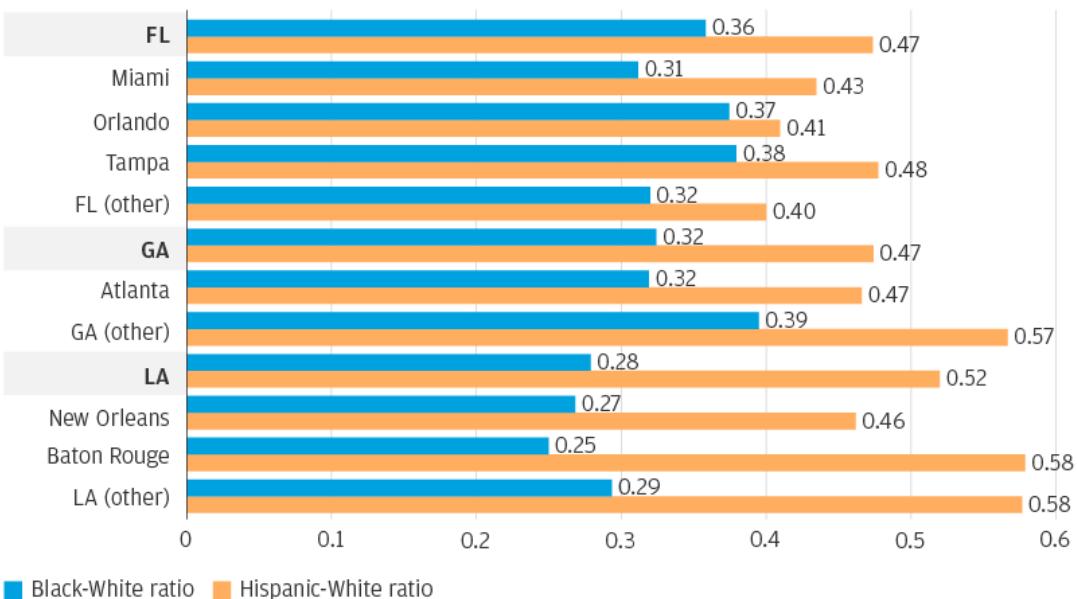
What Makes It a Bad Data Visualization?



What Makes It a Bad Data 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



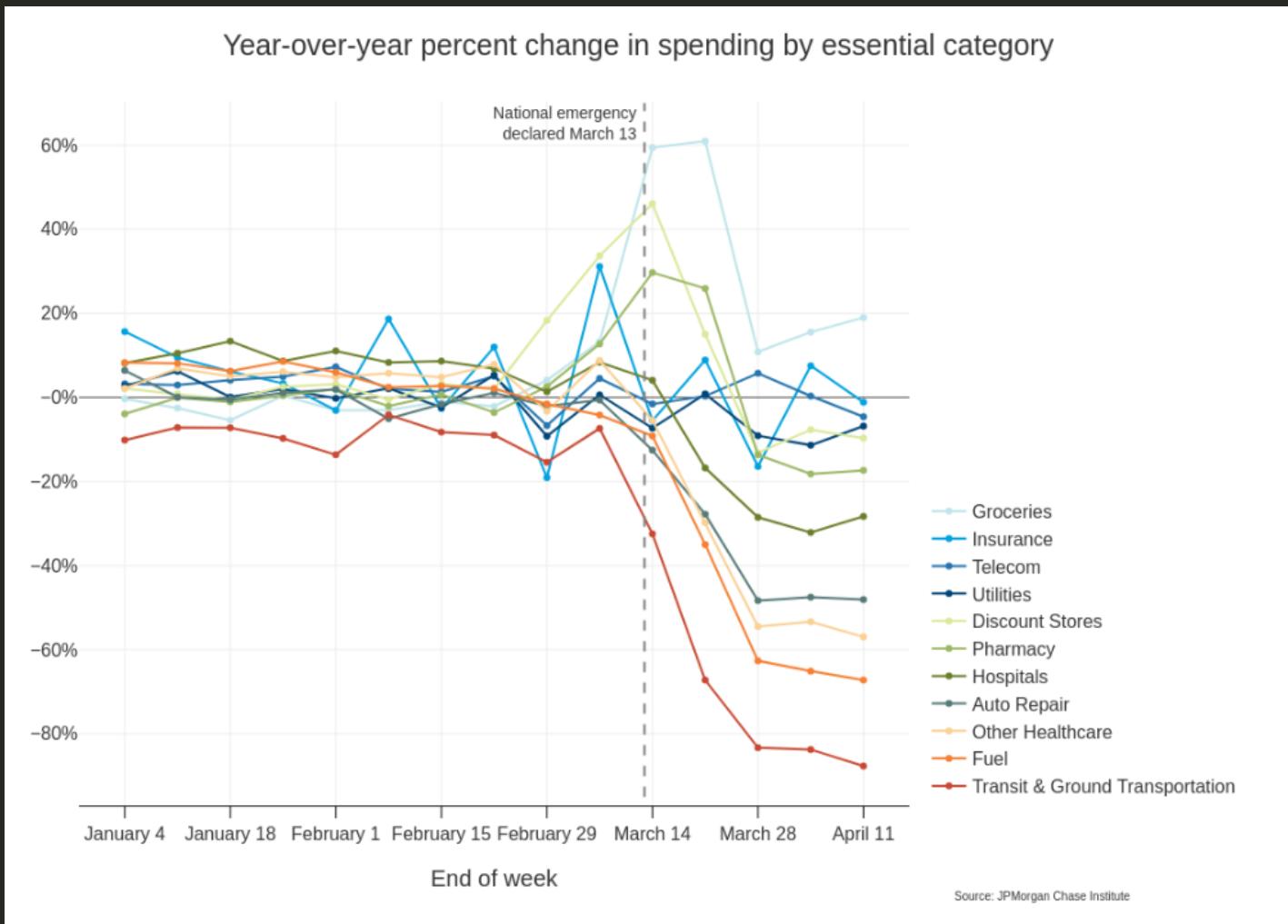
■ Black-White ratio ■ Hispanic-White ratio

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 >](#)

What Makes It a Bad Data Visualization?



What Makes It a Bad Data Visualization

What Makes It a Bad Data Visualization

→ **Substantive problems** (bad data/story)

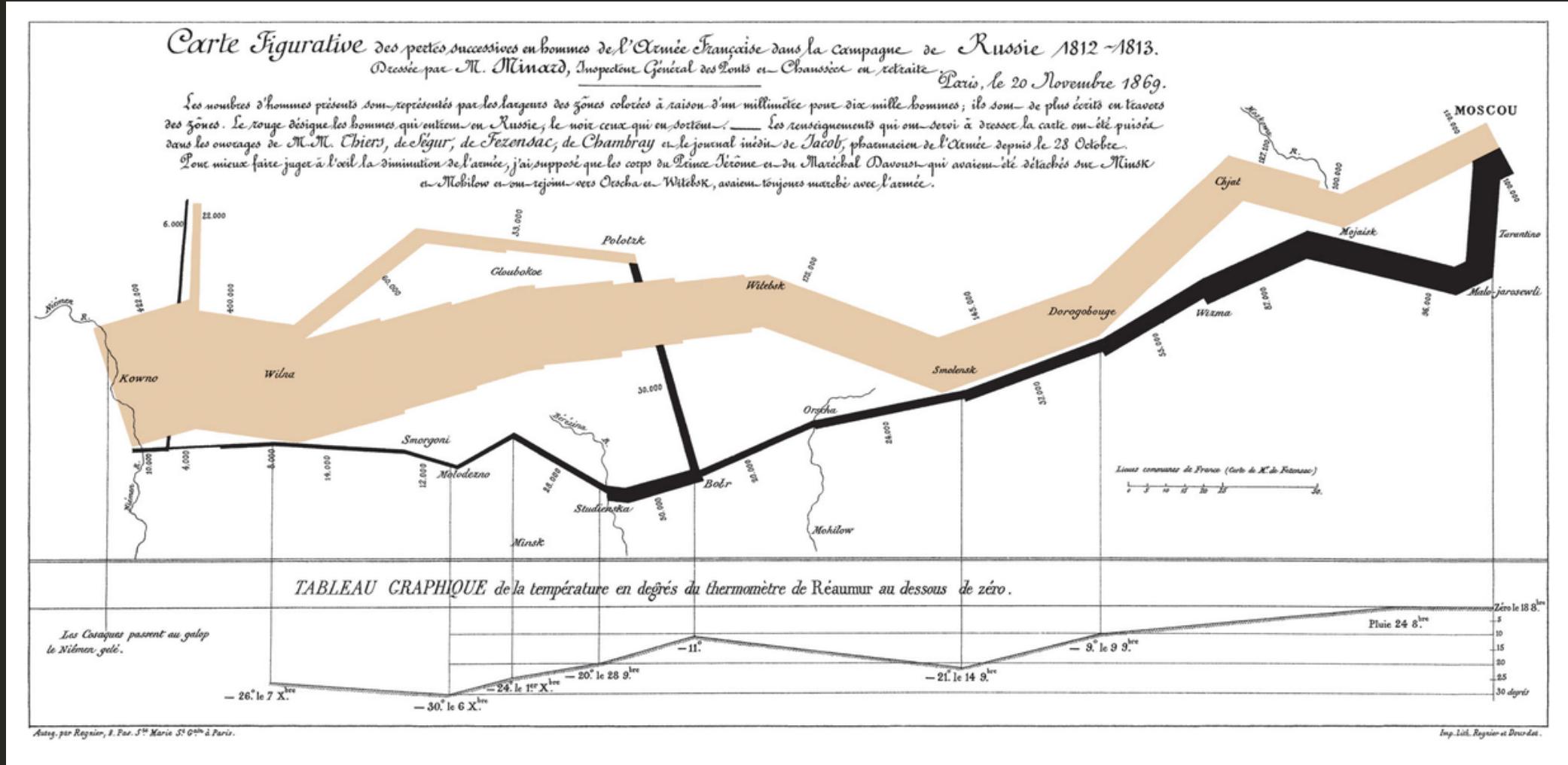
What Makes It a Bad Data Visualization

- **Substantive problems** (bad data/story)
- **Aesthetic problems** (bad design)

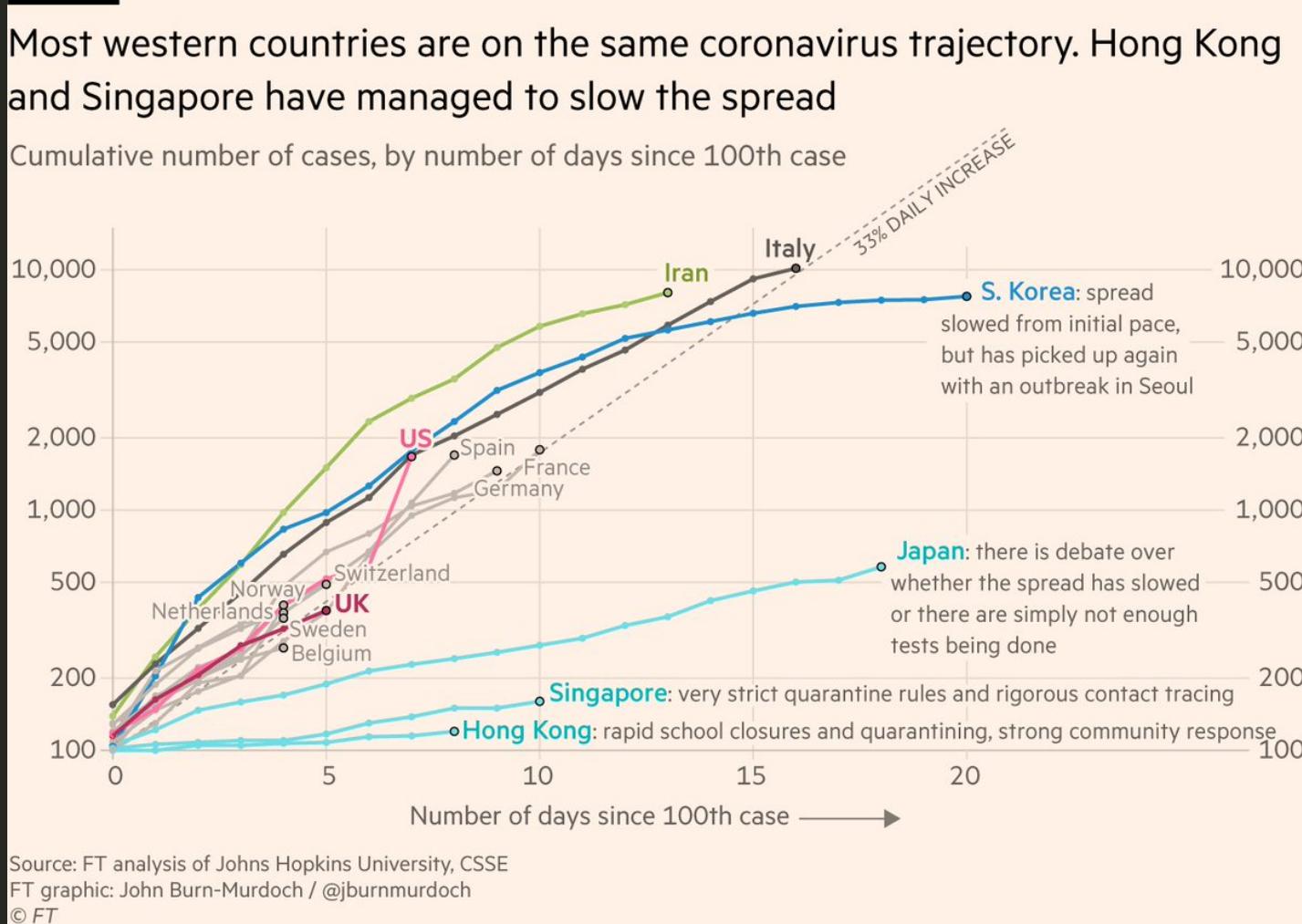
What Makes It a Bad Data Visualization

- **Substantive problems** (bad data/story)
- **Aesthetic problems** (bad design)
- **Perceptual problems** (bad perception)

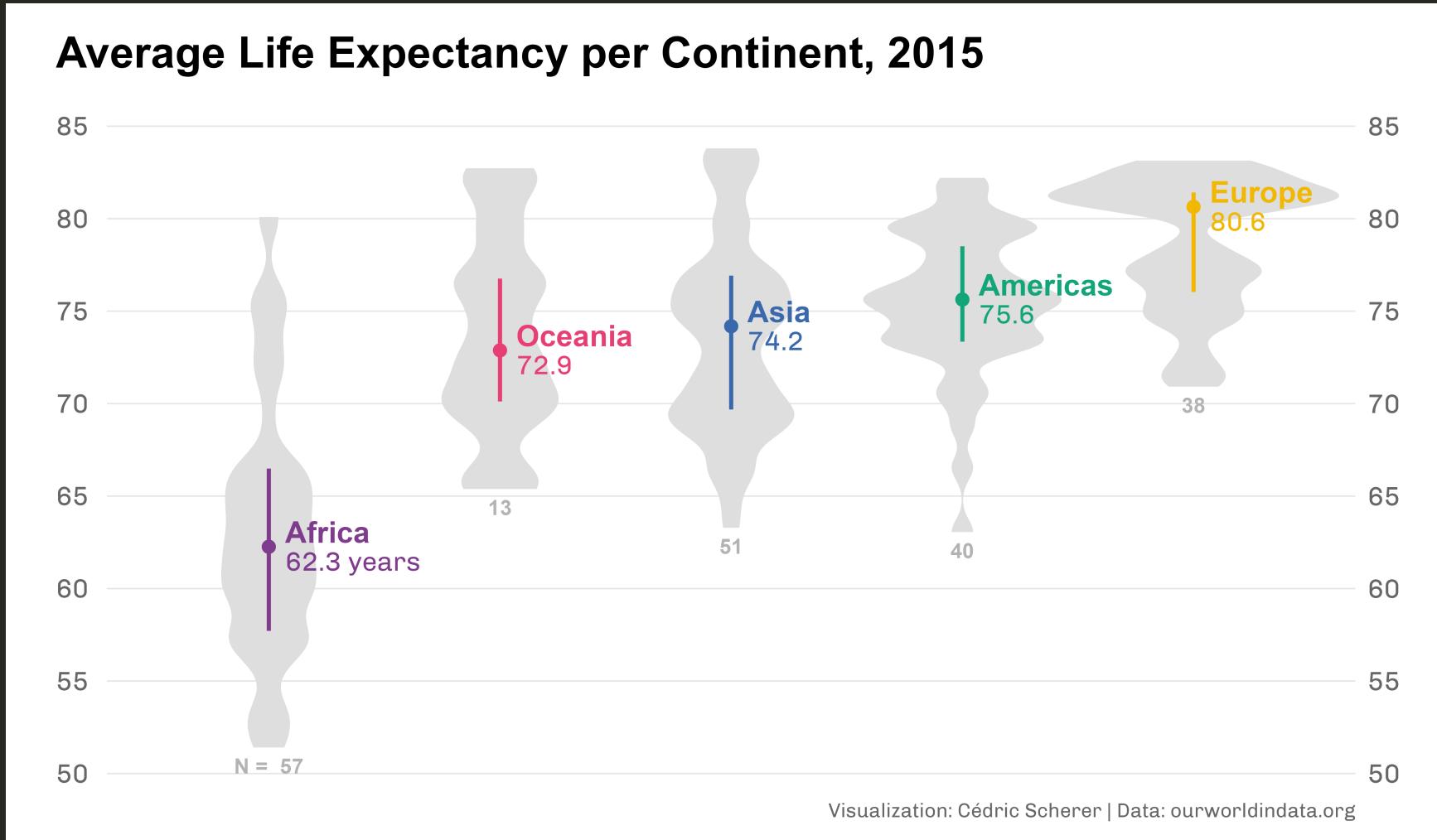
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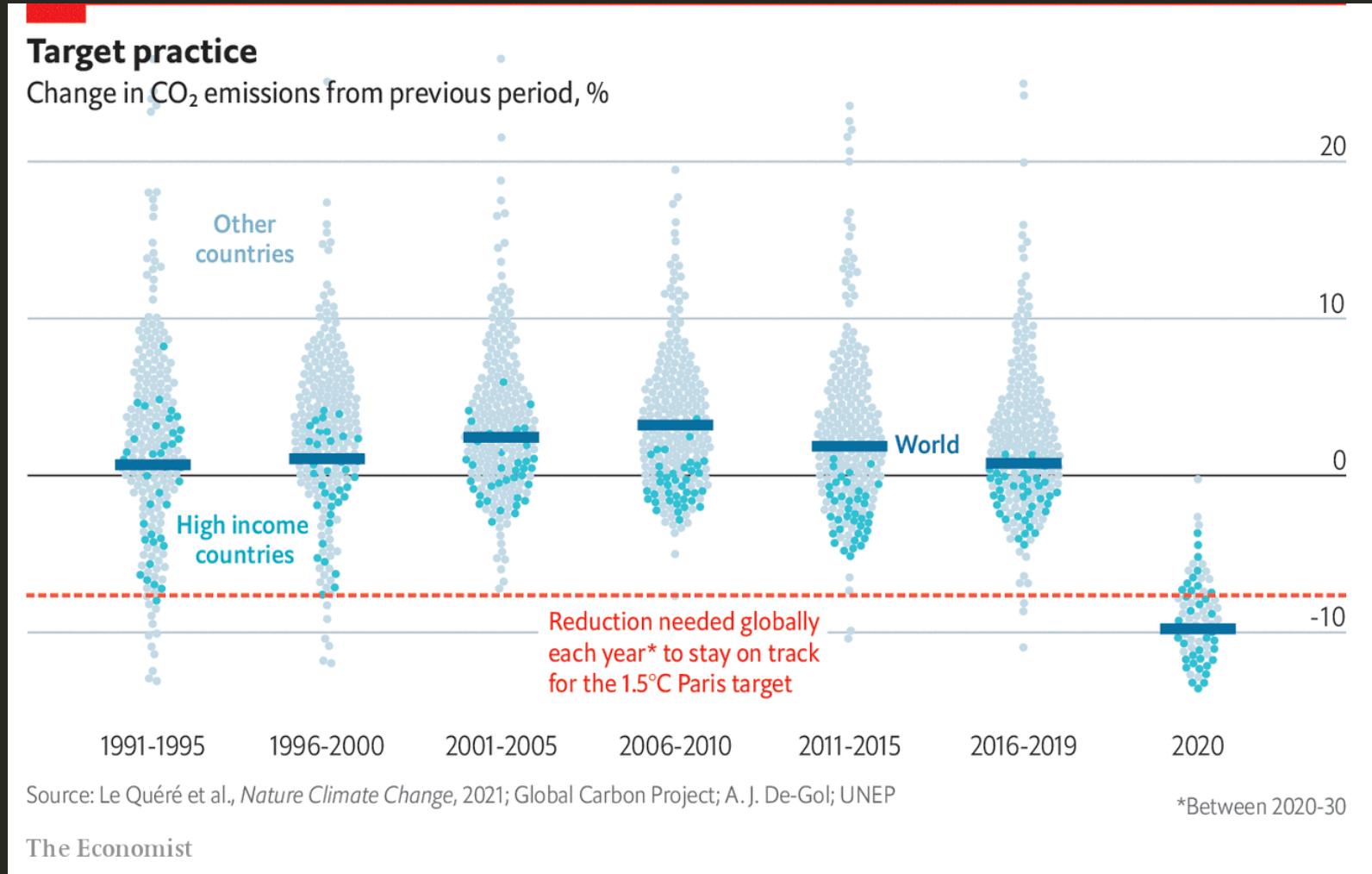
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What Makes It a Good Data Visualization

What Makes It a Good Data Visualization

→ **Information** (Integrity)

What Makes It a Good Data Visualization

- **Information** (Integrity)
- **Story** (Interestingness)

What Makes It a Good Data Visualization

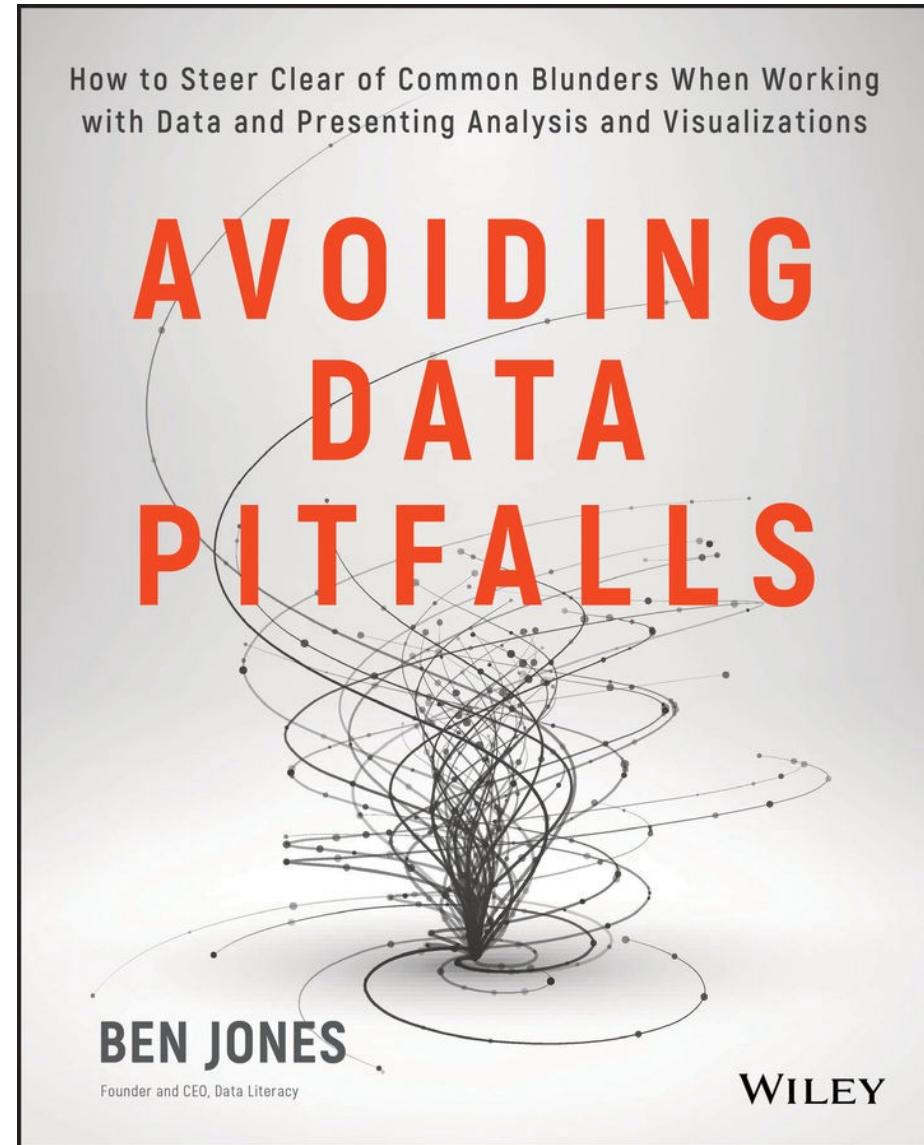
- **Information** (Integrity)
- **Story** (Interestingness)
- **Goal** (Usefulness)

What Makes It a Good Data Visualization

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

INFORMATION

Understand your data and be accurate

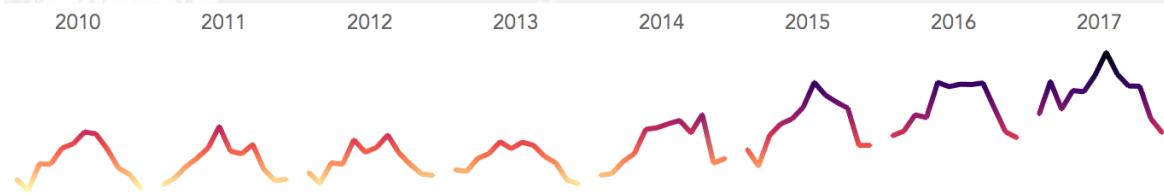
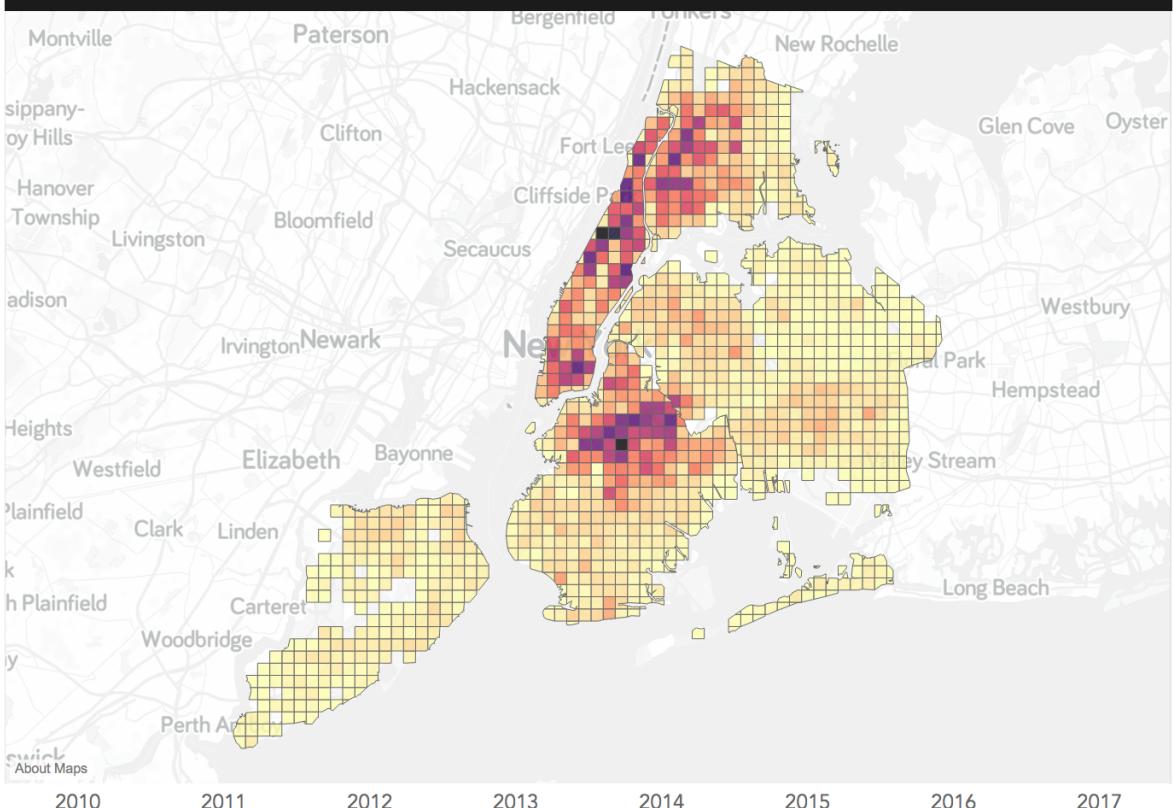


Our data is never a perfect reflection of the real world.

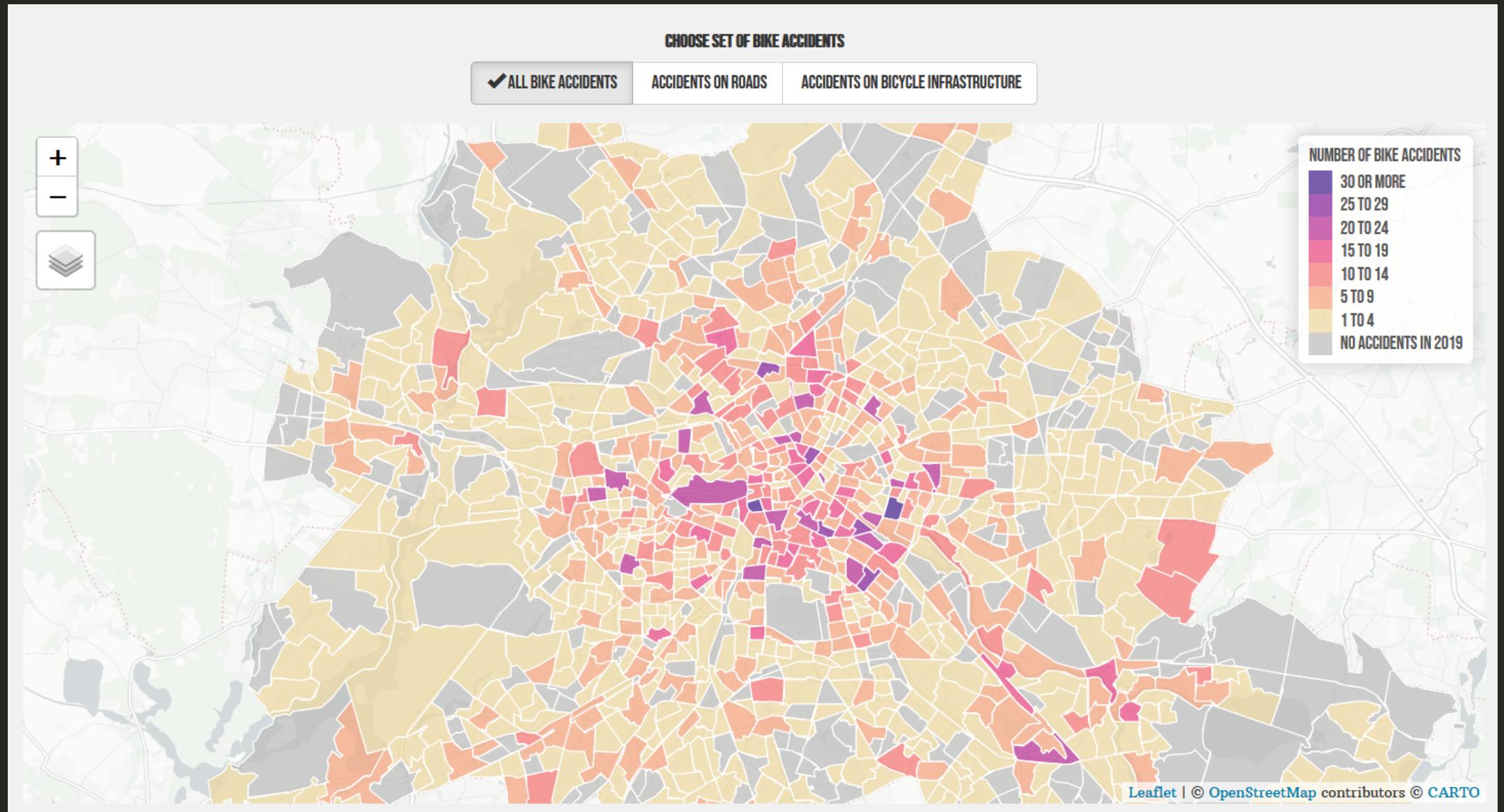
Where are New York's rats?

Choose a Borough

(All)



DATA SOURCE: NYC Open Data | DESIGNED BY: Andy Kriebel @VizWizBI



**The best use of data is to
teach us what *isn't* true.**



Source: inhomelandsecurity.com/risk-management-and-black-swan-events



A photograph of a flock of white swans swimming in a body of water. A single black swan stands out from the crowd, positioned centrally in the middle ground. The swans have long necks and orange beaks. The background shows more swans and a cloudy sky.

- "The swan is white" (singular statement)
- "All swans are white" (universal statement)

Know Your Types of Data

Types of Data

- Quantitative (numerical) versus qualitative (categorical) data

Types of Data

- Quantitative (numerical) versus qualitative (categorical) data
- Ordered versus unordered data

Types of Data

- Quantitative (numerical) versus qualitative (categorical) data
- Ordered versus unordered data
- Continuous versus discrete data

Types of Data – Your Turn!

- Quantitative (numerical) versus qualitative (categorical) data
- Ordered versus unordered data
- Continuous versus discrete data
- What are the data types of:
 - "female"
 - 2019/09/26 "17:01:35"
 - 1

Types of Data – Your Turn!

- Quantitative (numerical) versus qualitative (categorical) data
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 - 2019/09/26 "17:01:35" → quantitative + continuous + ordered
 - 1 → quantitative + continuous + ordered
or: quantitative + discrete + ordered
or: qualitative + discrete + ordered
or: qualitative + discrete + unordered

NOMINAL

UNORDERED DESCRIPTIONS



ORDINAL

ORDERED DESCRIPTIONS



BINARY

ONLY 2 MUTUALLY EXCLUSIVE OUTCOMES



@allison_horst

CONTINUOUS

measured data, can have ∞ values within possible range.



I AM 3.1" TALL

I WEIGH 34.16 grams

DISCRETE

OBSERVATIONS CAN ONLY EXIST
AT LIMITED VALUES, OFTEN COUNTS.



I HAVE 8 LEGS
and
4 SPOTS!

@allison_horst

STORY

Be clear about the message of your visualization

*It is hard to effectively design for others.
It is harder if you don't even care to try.*

Andy Kirk

Who is my audience?

Who is my audience?

Which story is **interesting** for my audience?

Who is my audience?

Which story is **interesting** for my audience?

What are **relevant** details to include?

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What are **relevant** details to include?

Which variables are **meaningful** to my audience?

Who is my audience?

Which story is **interesting** for my audience?

What are **relevant** details to include?

Which variables are **meaningful** to my audience?

How will they **encounter** the visualization?

Who is my audience?

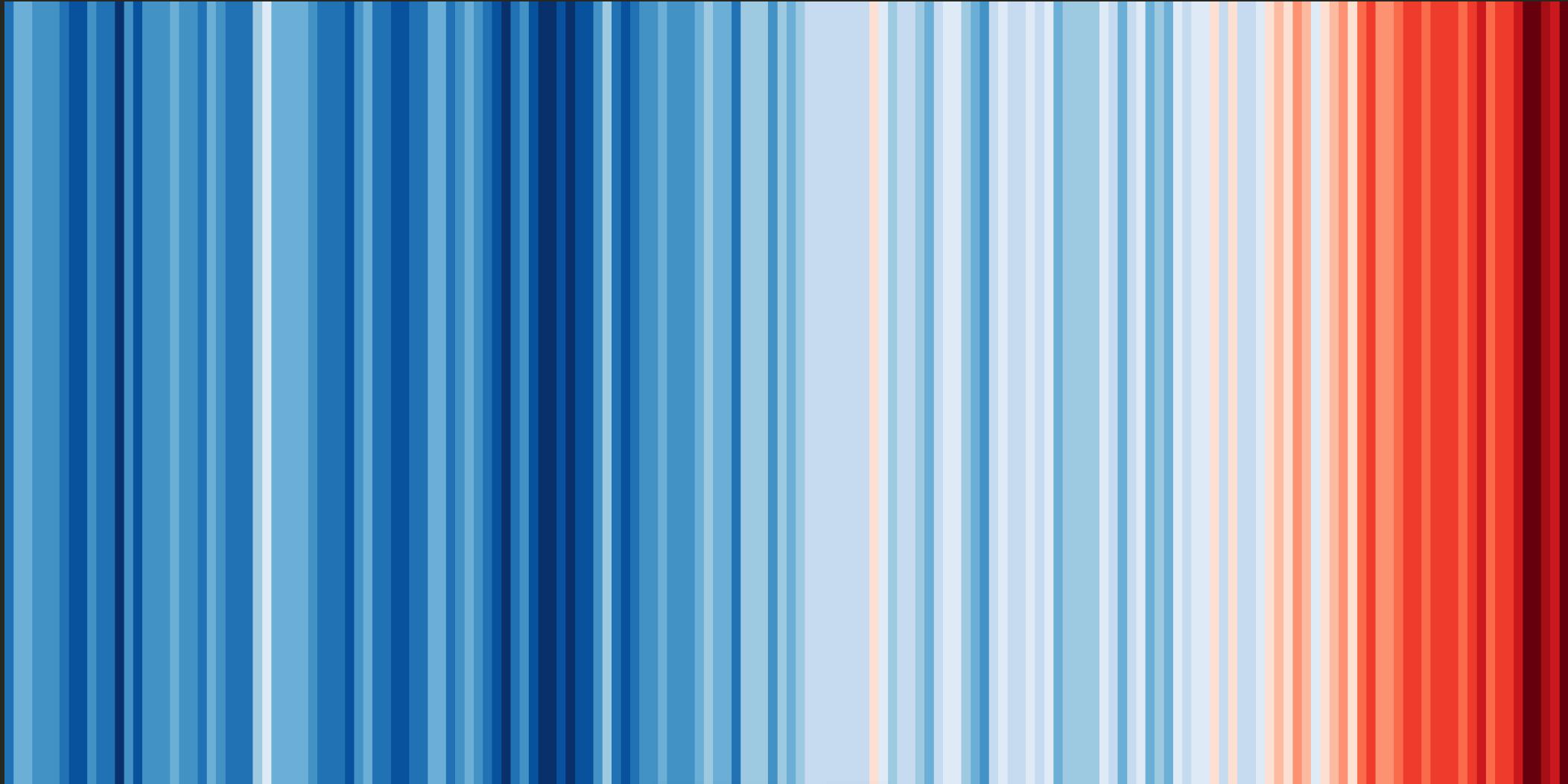
Which story is **interesting** for my audience?

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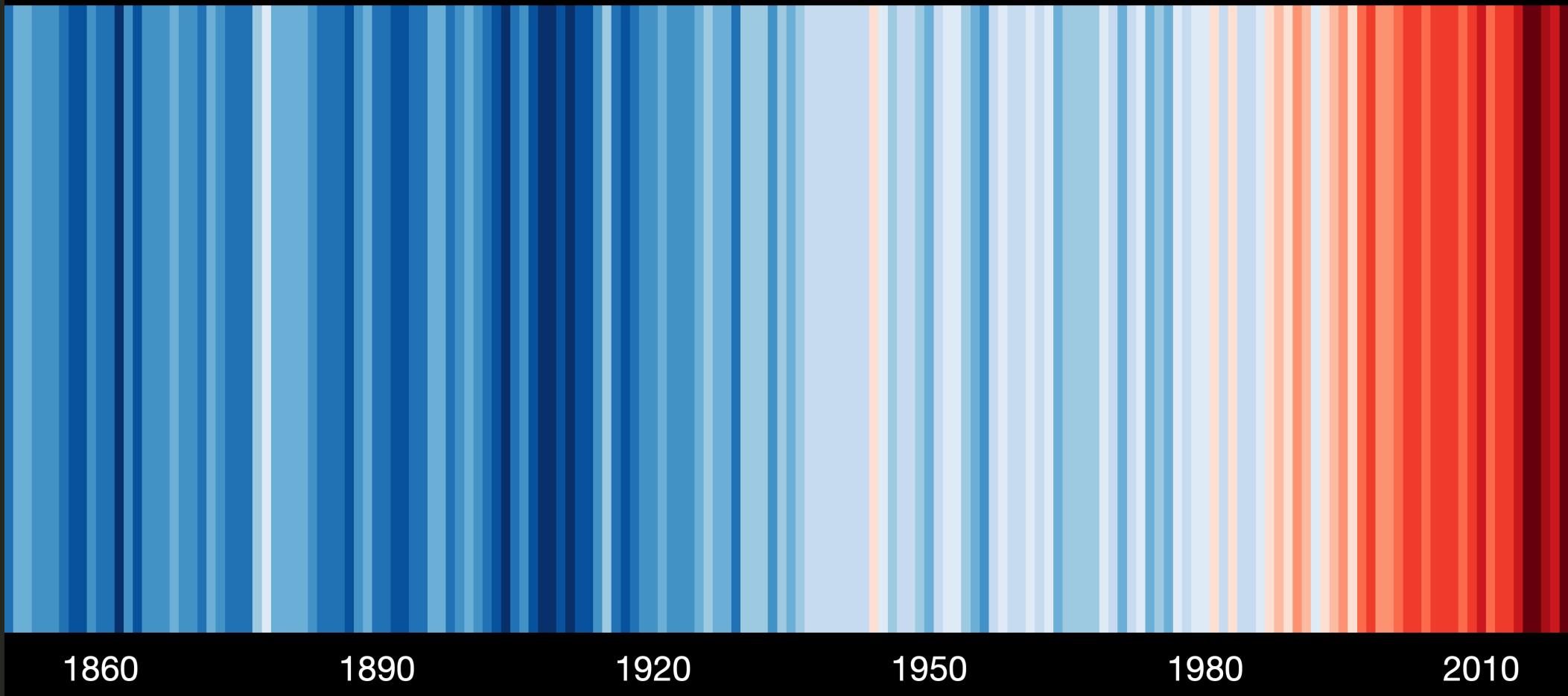
How will they **encounter** the visualization?

Do I need a visualization at all??

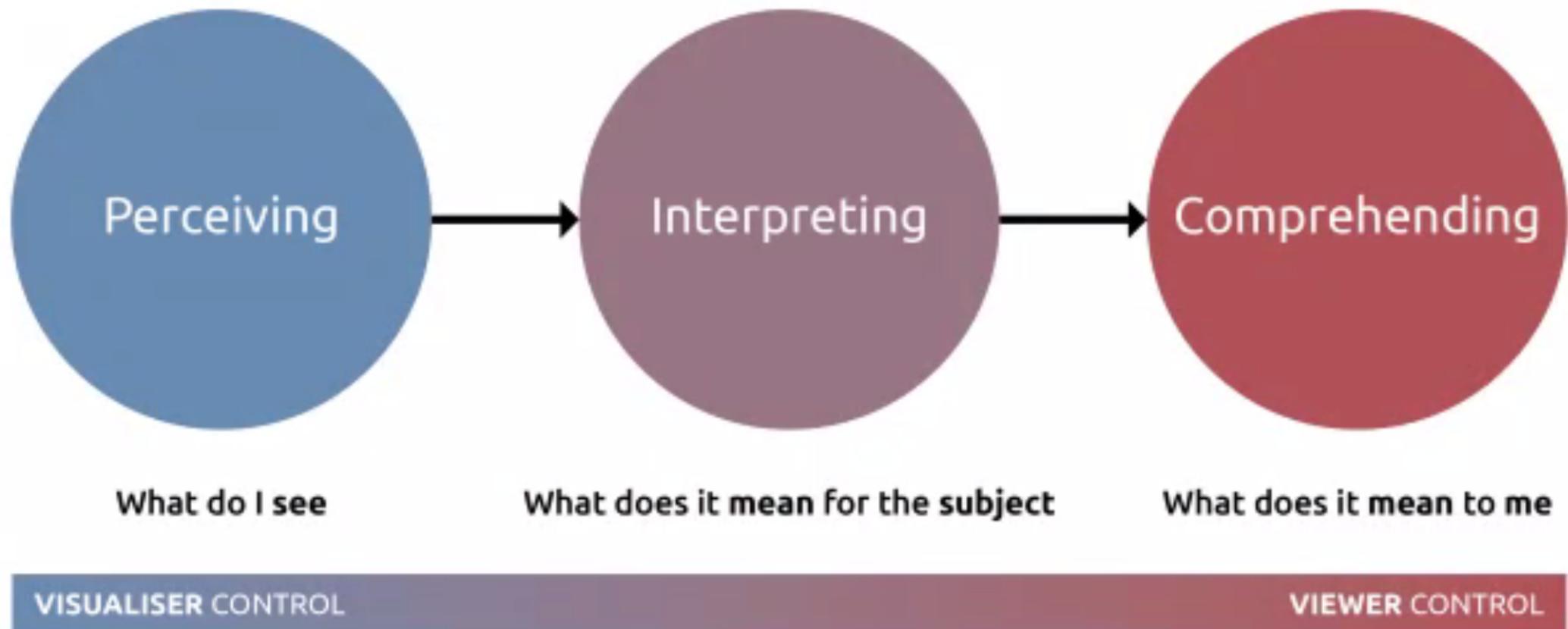


Warming Stripes by Ed Hawkins

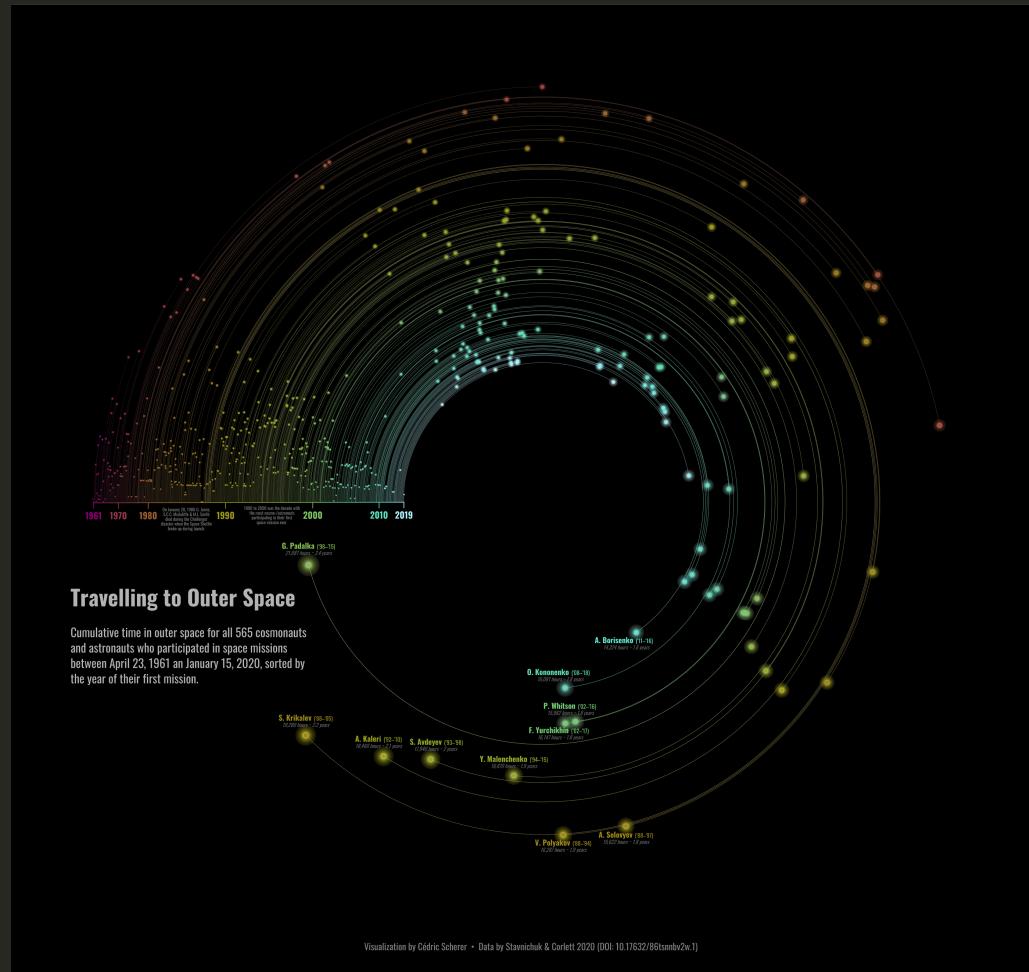
Global temperature change (1850-2019)



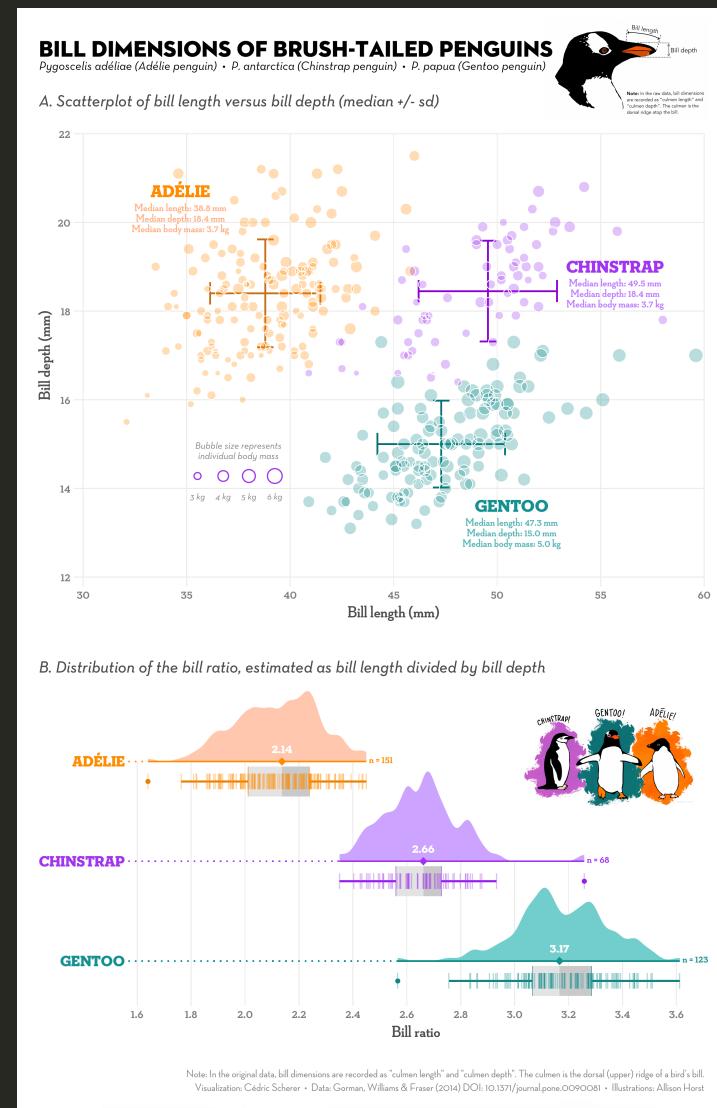
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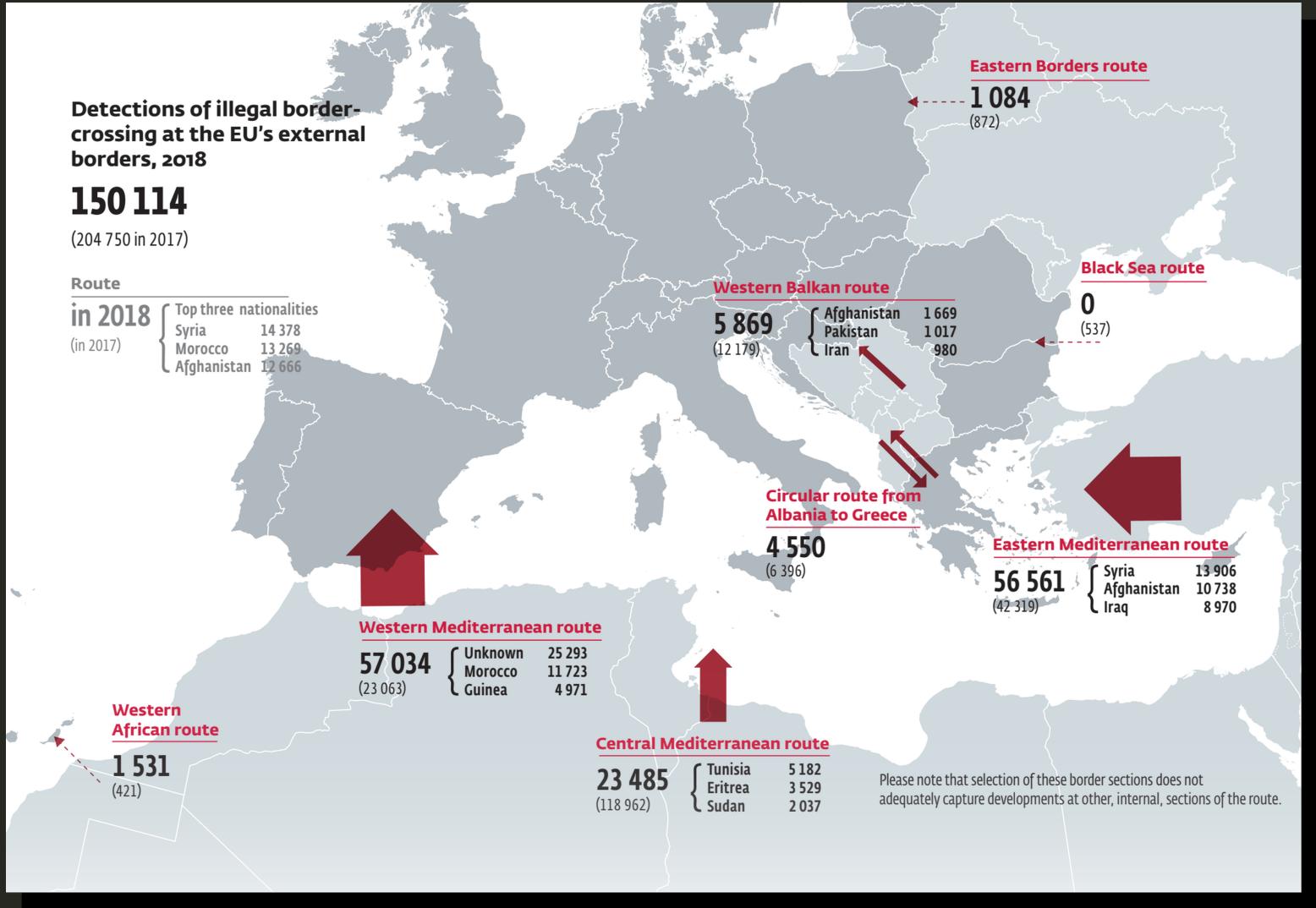
Source: Andy Kirk, S-H-O-W Feb 2021

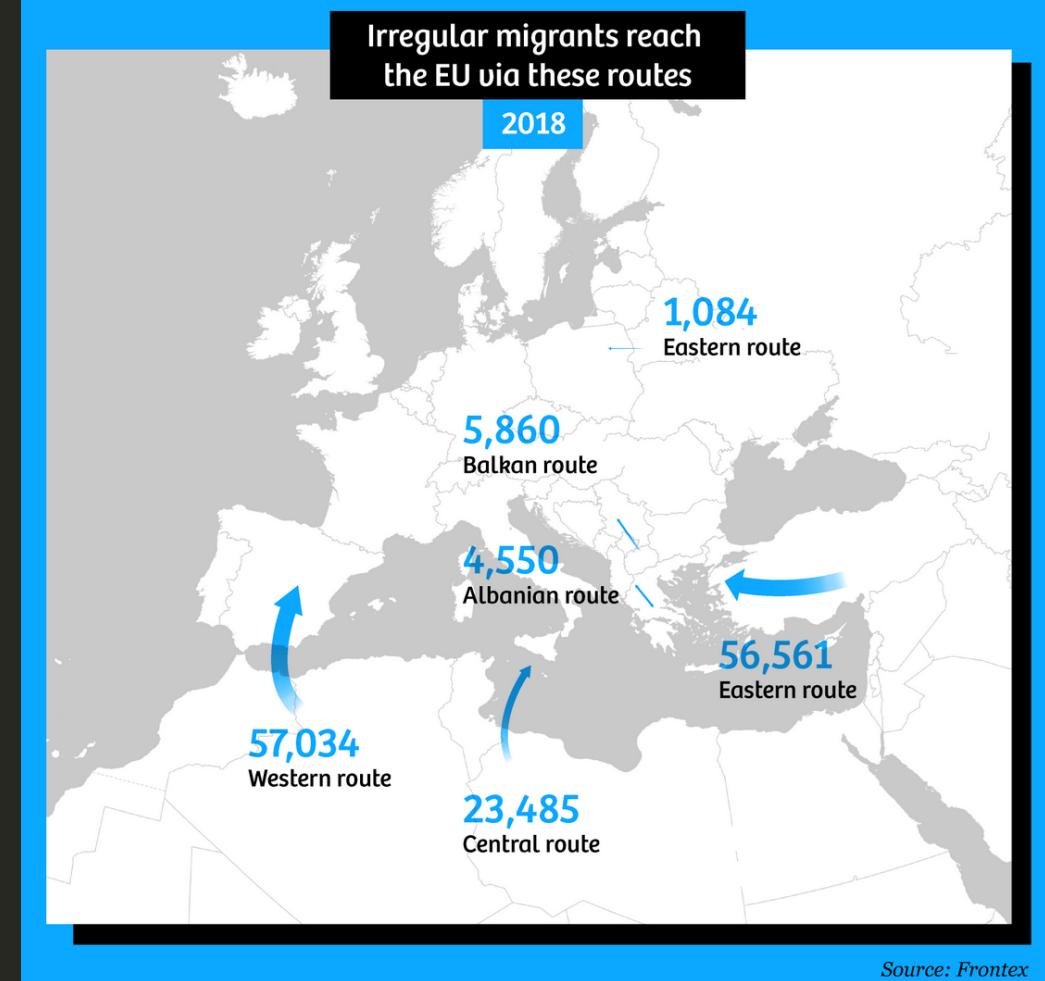
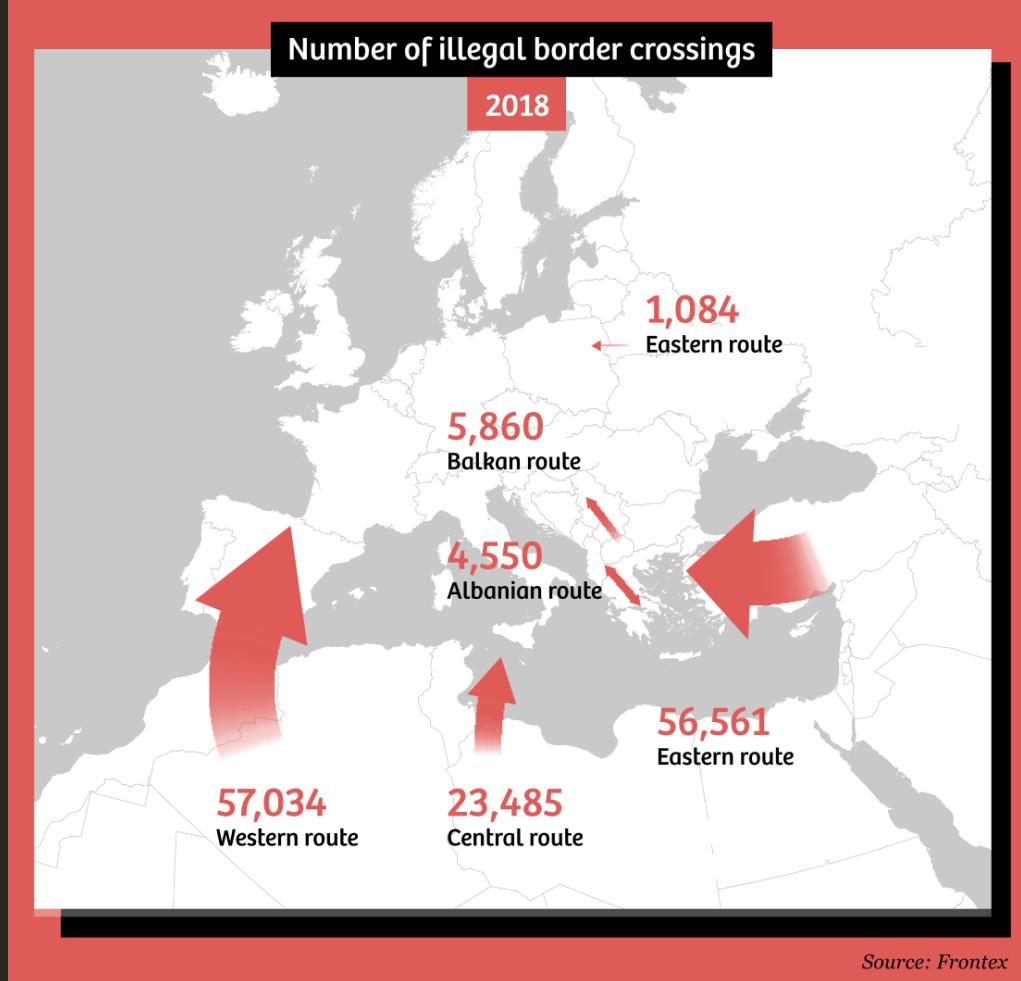


#TidyTuesday contribution Week 2020/29

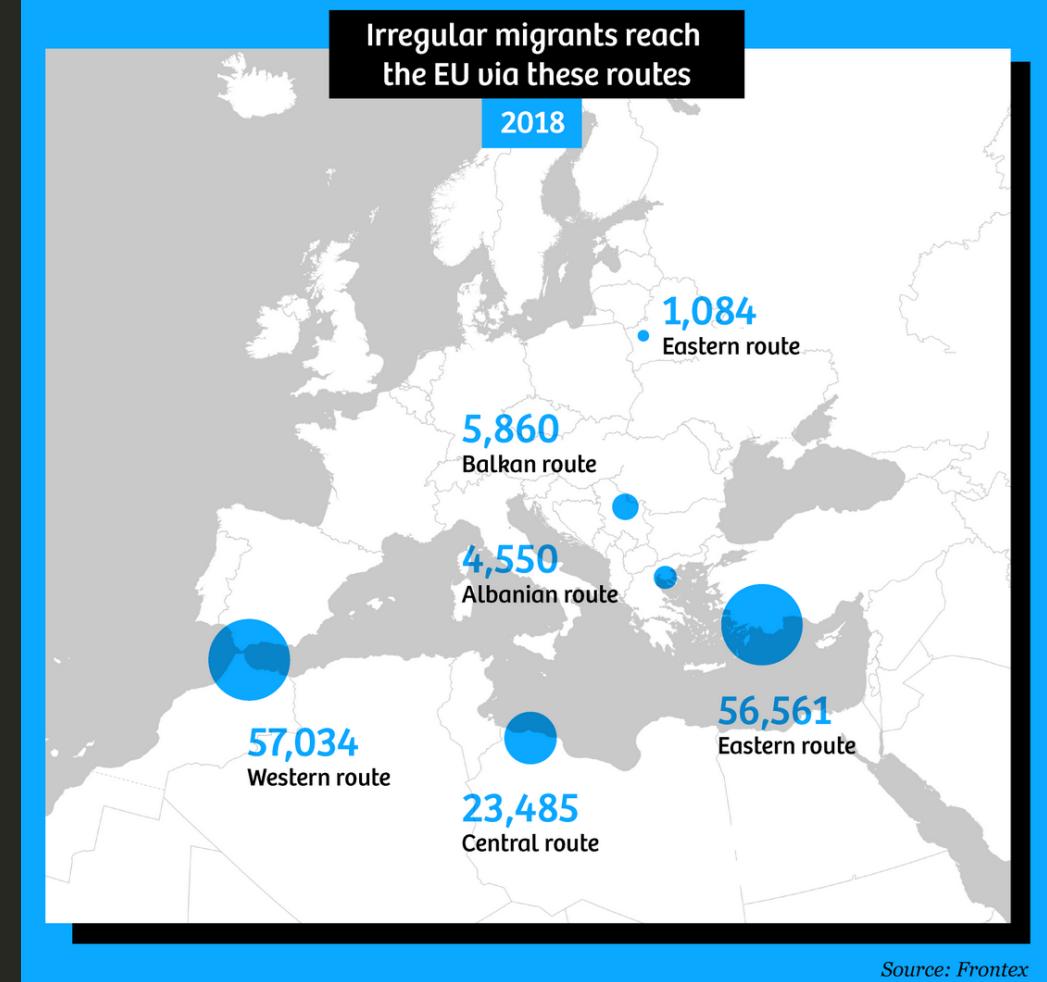


#TidyTuesday contribution Week 2020/31

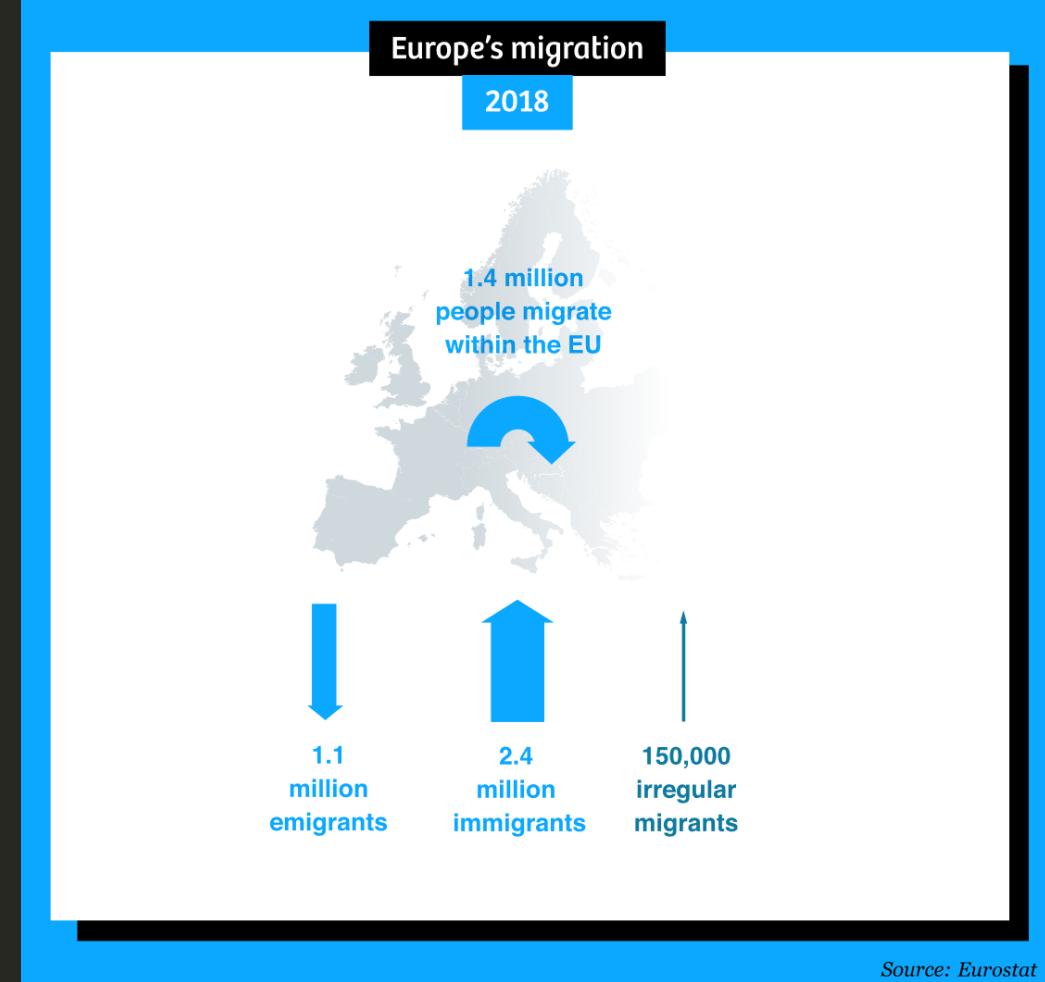




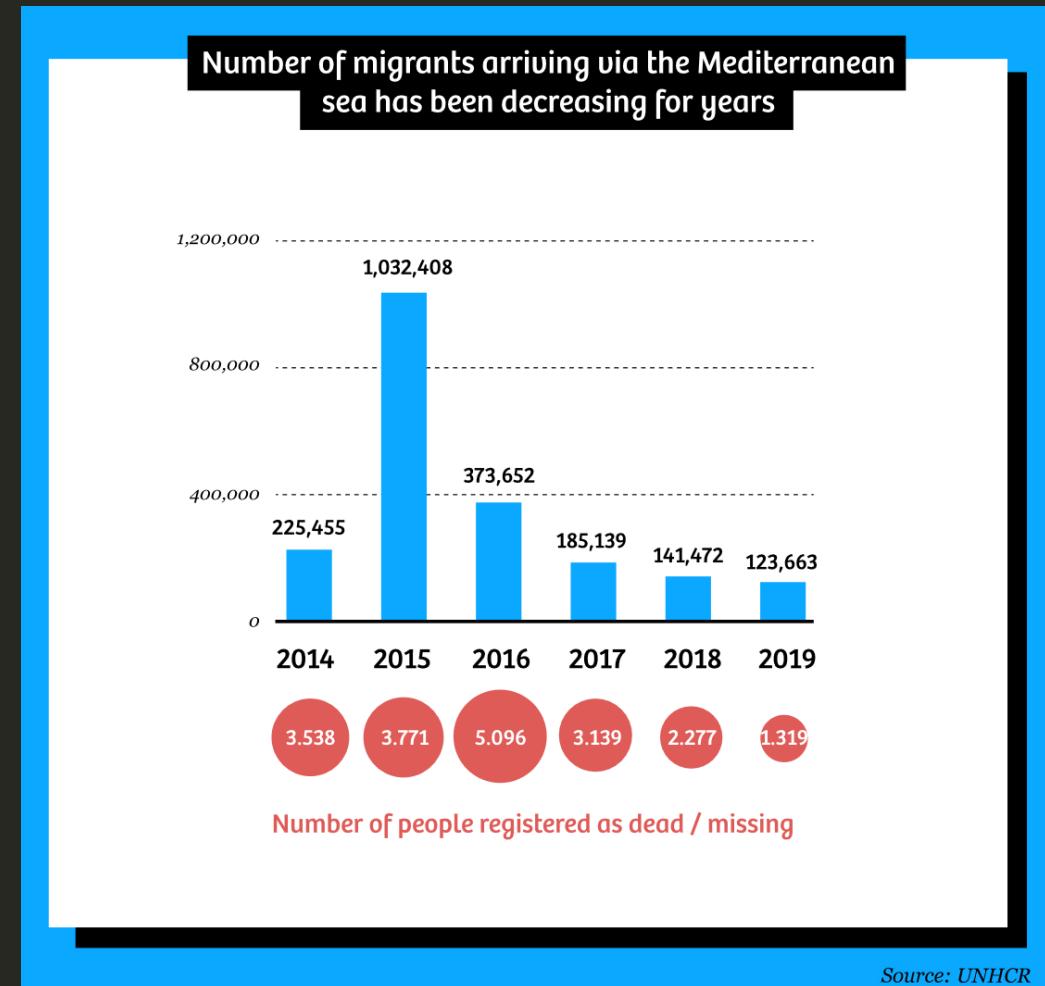
How maps in the media make us more negative about migrants by Maite Vermeulen, Leon de Korte & Henk van Houtum



How maps in the media make us more negative about migrants by Maite Vermeulen, Leon de Korte & Henk van Houtum



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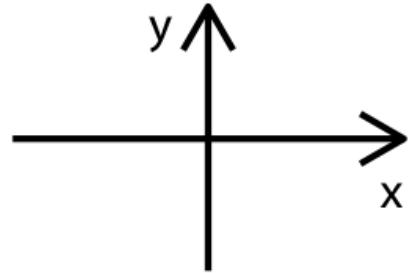
How maps in the media make us more negative about migrants by Maite Vermeulen, Leon de Korte & Henk van Houtum

GOAL

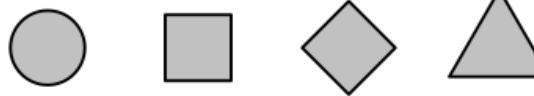
Select charts that successfully transport your story

Data visualizations map values into quantifiable features

position



shape



size



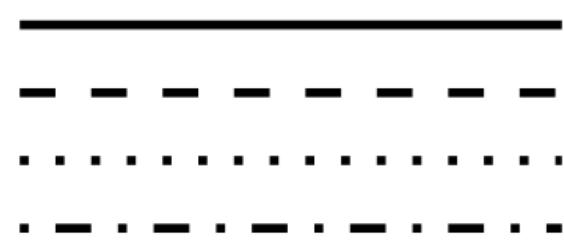
color



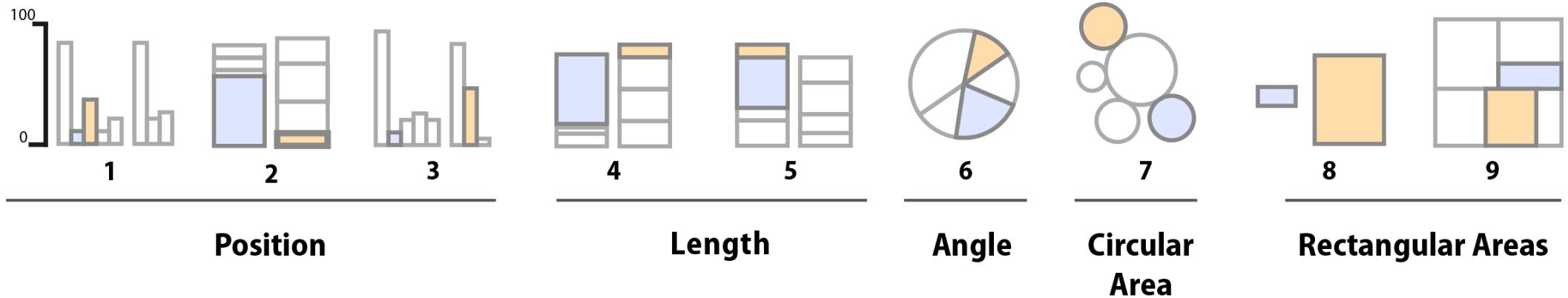
line width



line type



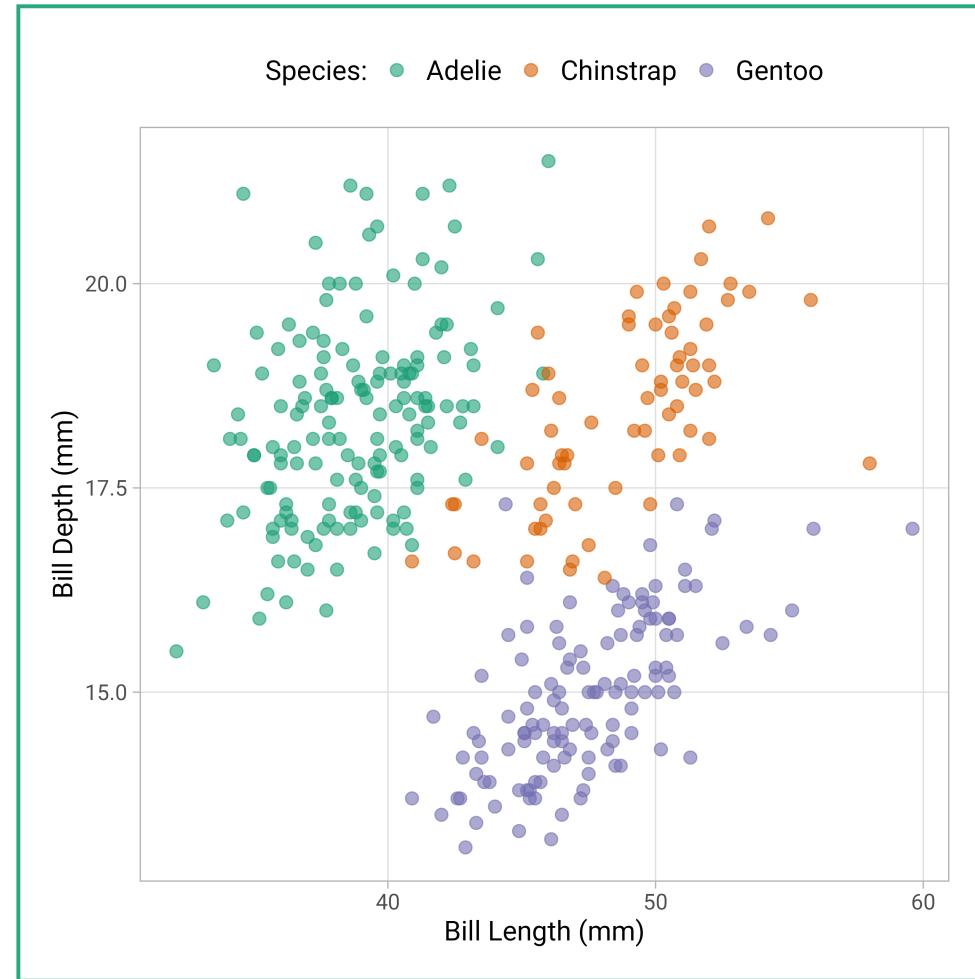
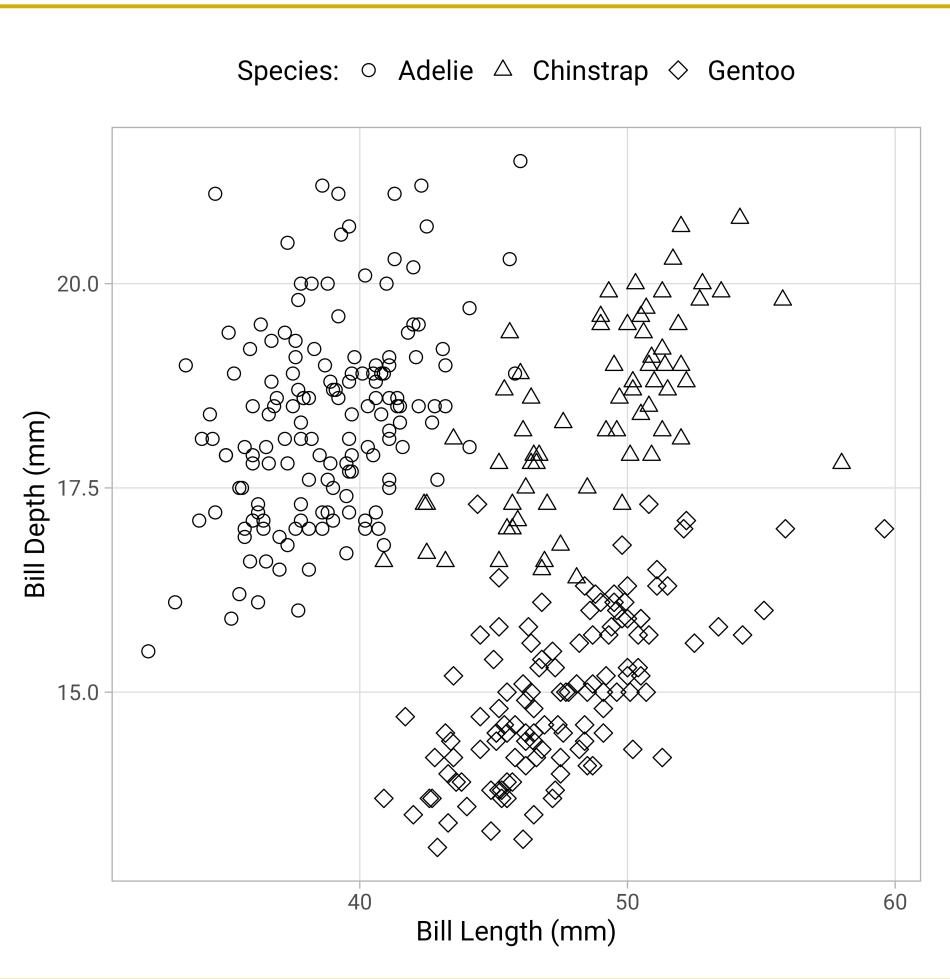
Data visualizations map values into quantifiable features

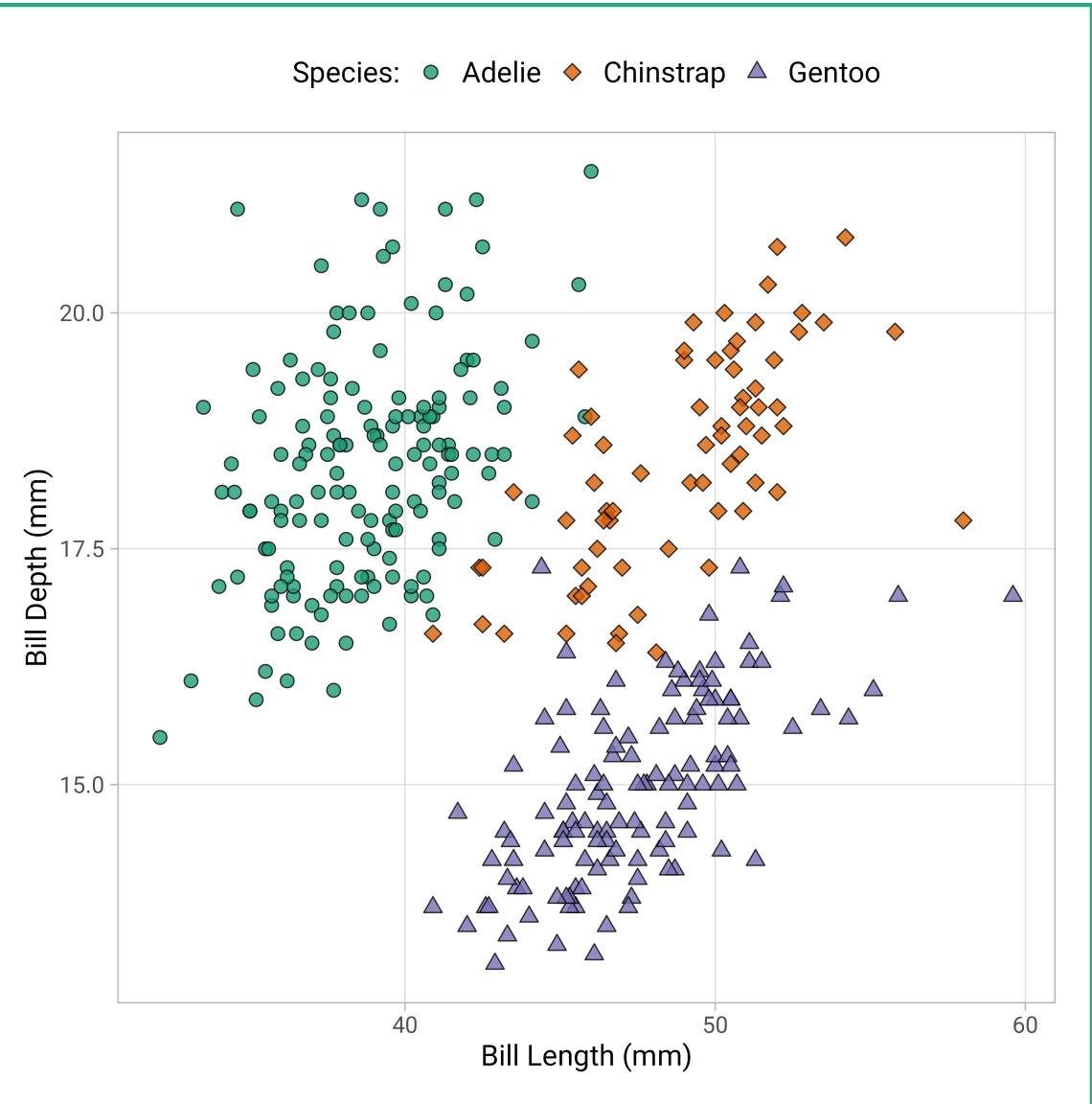


Kieran Healy based on Heer and Bostock, following Cleveland and McGill

Qualitative Nominal	Qualitative Ordinal	Quantitative Interval/Ratio
Position	Position	Position
Colour (Hue)	Pattern (Density)	Size (Length)
Pattern (Texture)	Colour (Lightness)	Angle
Connection	Colour (Hue)	Size (Area)
Pattern (Density)	Pattern (Texture)	Size (Volume)
Colour (Lightness)	Connection	Pattern (Density)
Symbol	Size (Length)	Colour (Lightness)
Size (Length)	Angle	Colour (Hue)
Angle	Size (Area)	Pattern (Texture)
Size (Area)	Size (Volume)	Connection
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Angle	Size (Area)	Pattern (Texture)
Size (Area)	Size (Volume)	Connection
Size (Volume)	Symbol	Symbol



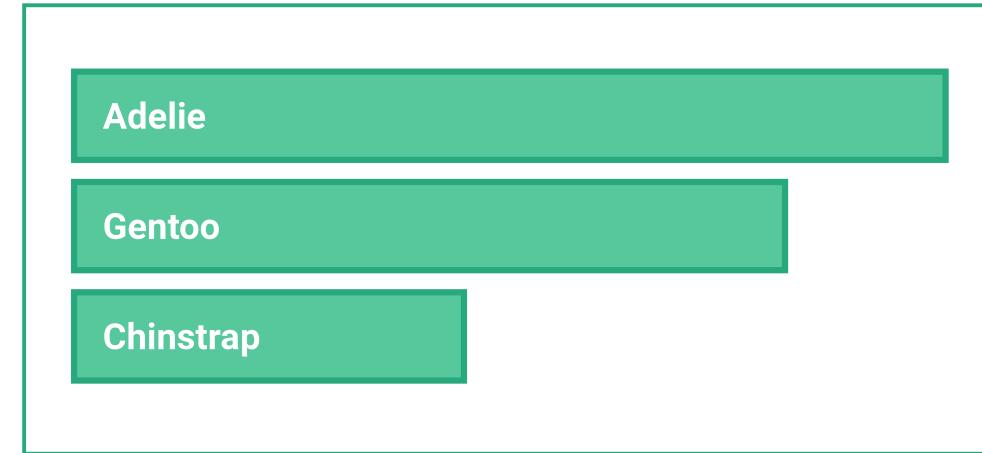
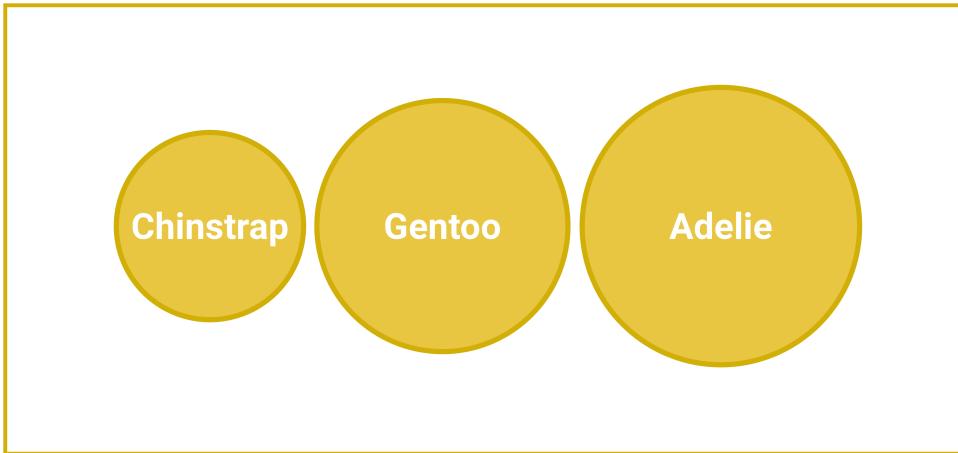


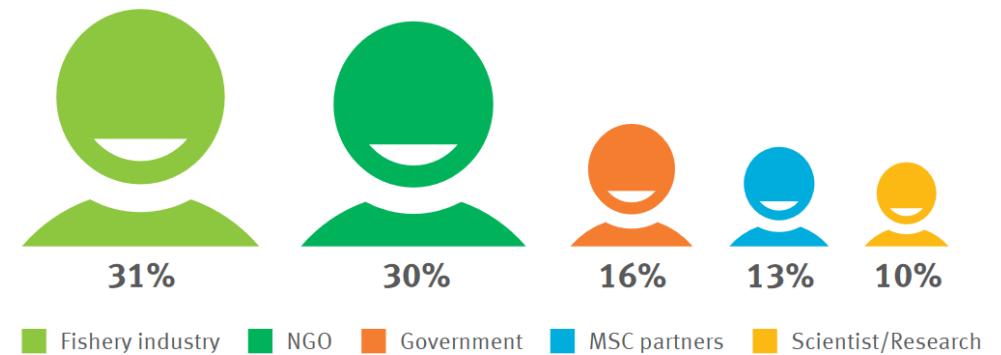
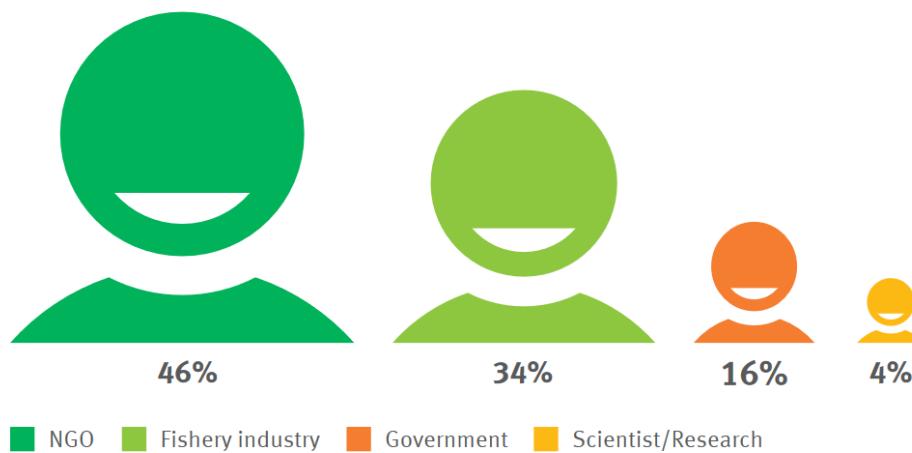
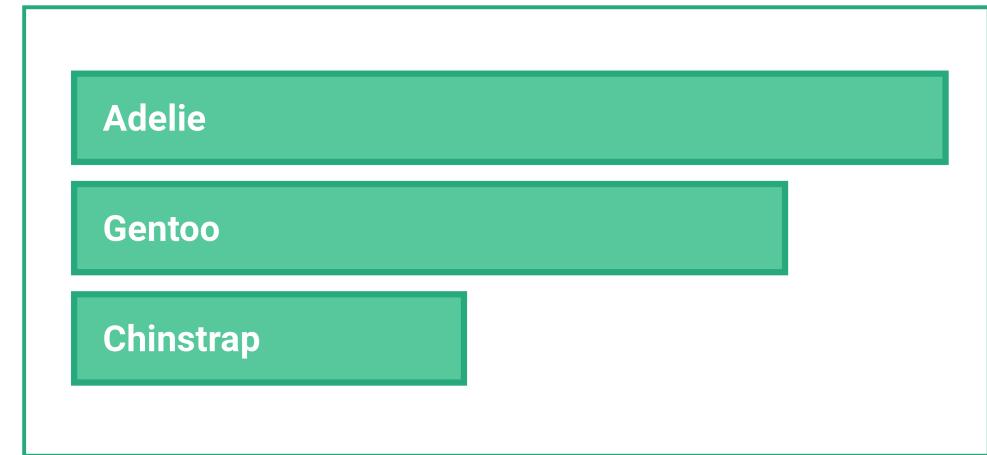
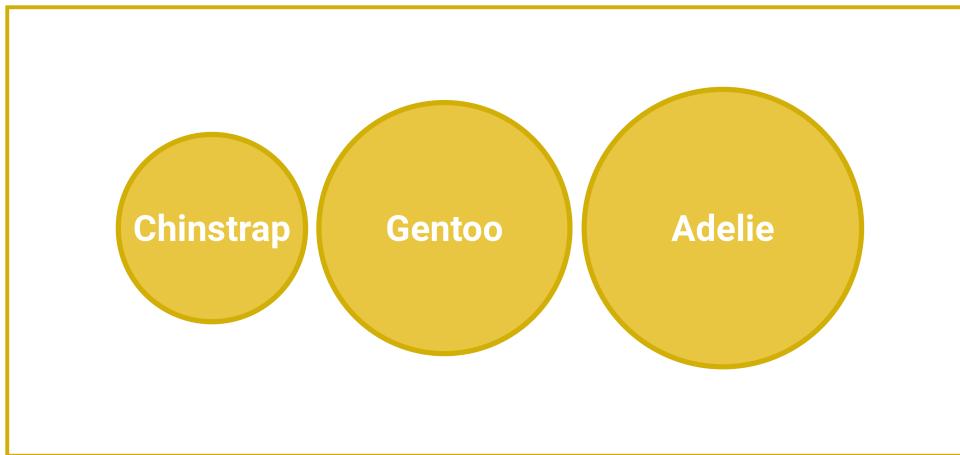
Qualitative Nominal	Qualitative Ordinal	Quantitative Interval/Ratio
Position	Position	Position
Colour (Hue)	Pattern (Density)	Size (Length)
Pattern (Texture)	Colour (Lightness)	Angle
Connection	Colour (Hue)	Size (Area)
Pattern (Density)	Pattern (Texture)	Size (Volume)
Colour (Lightness)	Connection	Pattern (Density)
Symbol	Size (Length)	Colour (Lightness)
Size (Length)	Angle	Colour (Hue)
Angle	Size (Area)	Pattern (Texture)
Size (Area)	Size (Volume)	Connection
Size (Volume)	Symbol	Symbol

Chinstrap

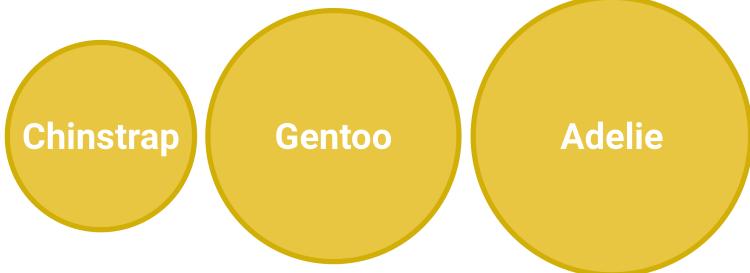
Gentoo

Adelie





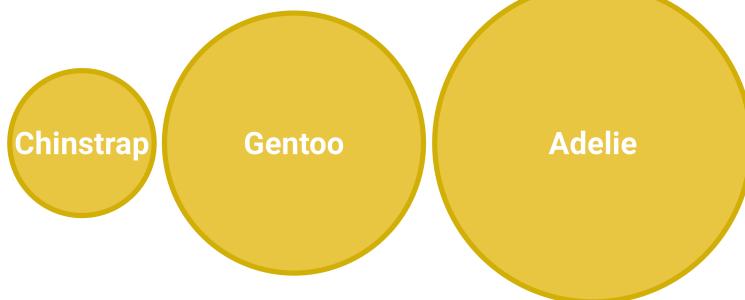
Always use area. Never use radius!



Adelie

Gentoo

Chinstrap

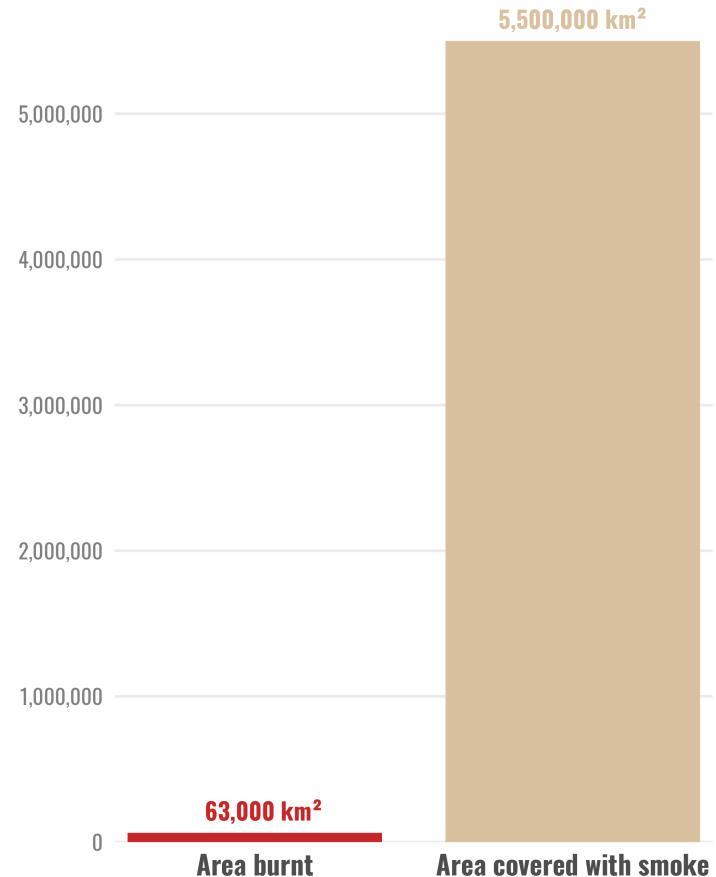


Adelie

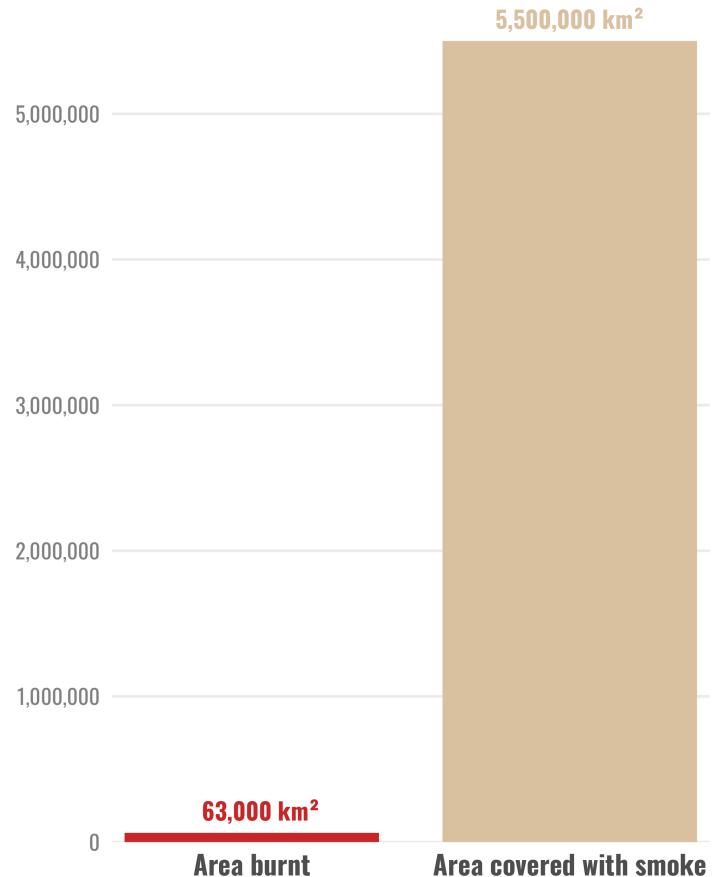
Gentoo

Chinstrap

**Burnt land and plume of smoke caused
by the Australian bushfires in 2019/20**
(as of 6th of January 2020)



**Burnt land and plume of smoke caused
by the Australian bushfires in 2019/20**
(as of 6th of January 2020)

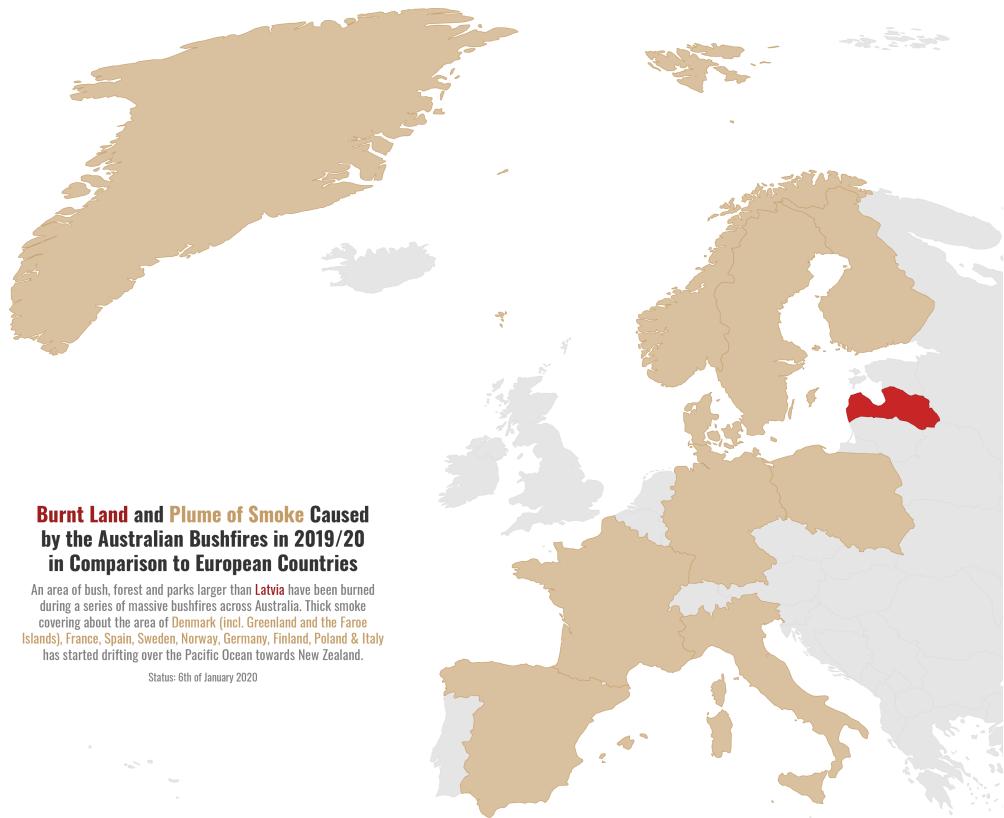


**Burnt Land and Plume of Smoke Caused
by the Australian Bushfires in 2019/20
in Comparison to European Countries**

An area of bush, forest and parks larger than Latvia have been burned during a series of massive bushfires across Australia. Thick smoke covering about the area of Denmark (incl. Greenland and the Faroe Islands), France, Spain, Sweden, Norway, Germany, Finland, Poland & Italy has started drifting over the Pacific Ocean towards New Zealand.

Status: 6th of January 2020

Visualization by Gédric Scherer · Data by NASA FIRMS & The Independent



#TidyTuesday contribution Week 2020/02

Typology of Charts

by Scott Berinato, "Good Charts" (2016), pp. 54–63

Is the information **conceptual** or **data-driven**?

Is the purpose to **declare** or to **explore** the information?

Typology of Charts

by Juuso Koponen & Jonatan Hildén, "Data Visualization Handbook" (2020), p. 25

Is the information **conceptual** or **measurable**?

Is the purpose to **explain** or to **explore** the information?

Typology of Charts

by Juuso Koponen & Jonatan Hildén, "Data Visualization Handbook" (2020), p. 25

Is the information **conceptual** or **measurable**?

→ Type of Information

Is the purpose to **explain** or to **explore** the information?

→ Purpose of the Graphic

Typology of Charts

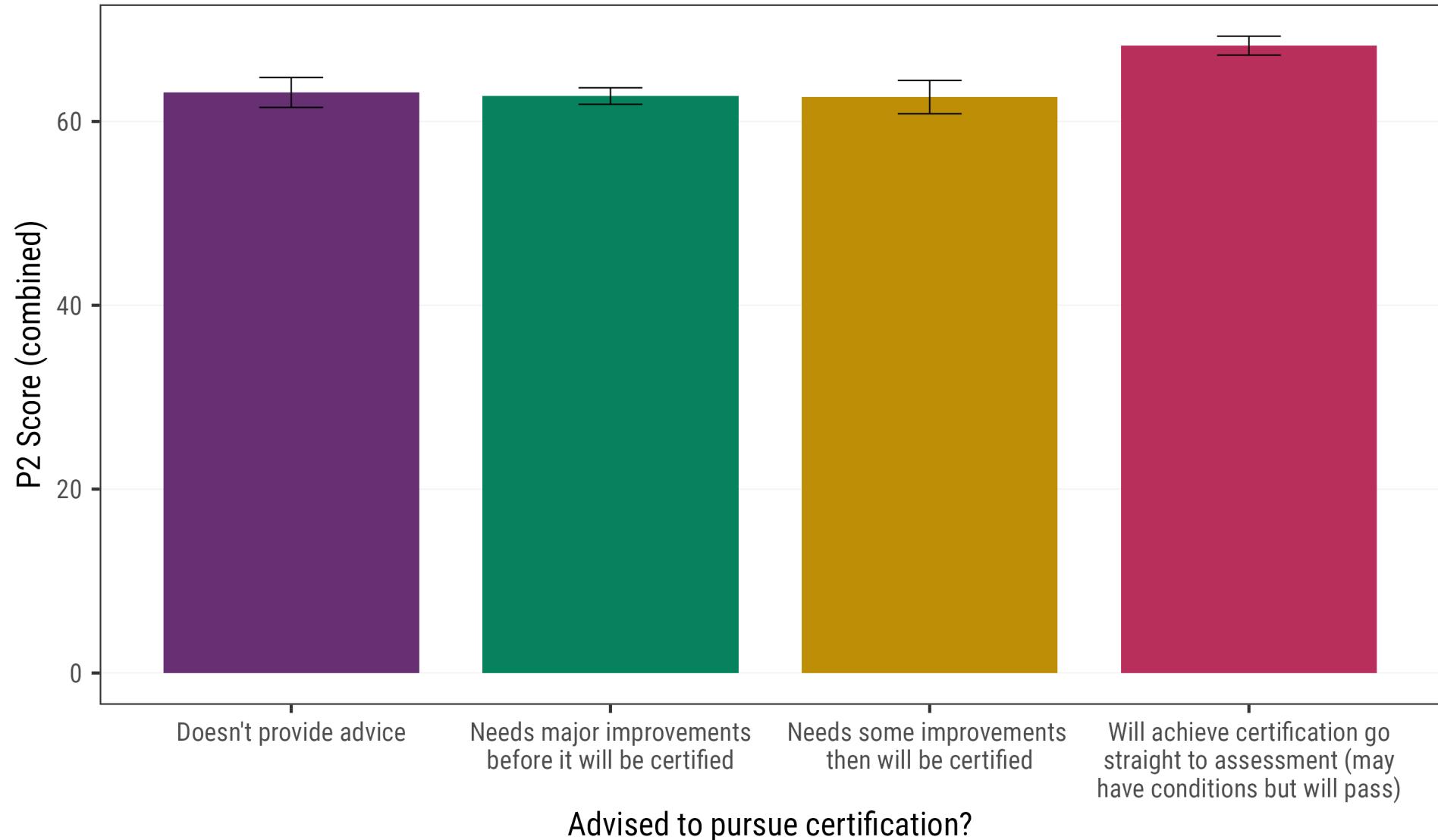
by Juuso Koponen & Jonatan Hildén, "Data Visualization Handbook" (2020), p. 25

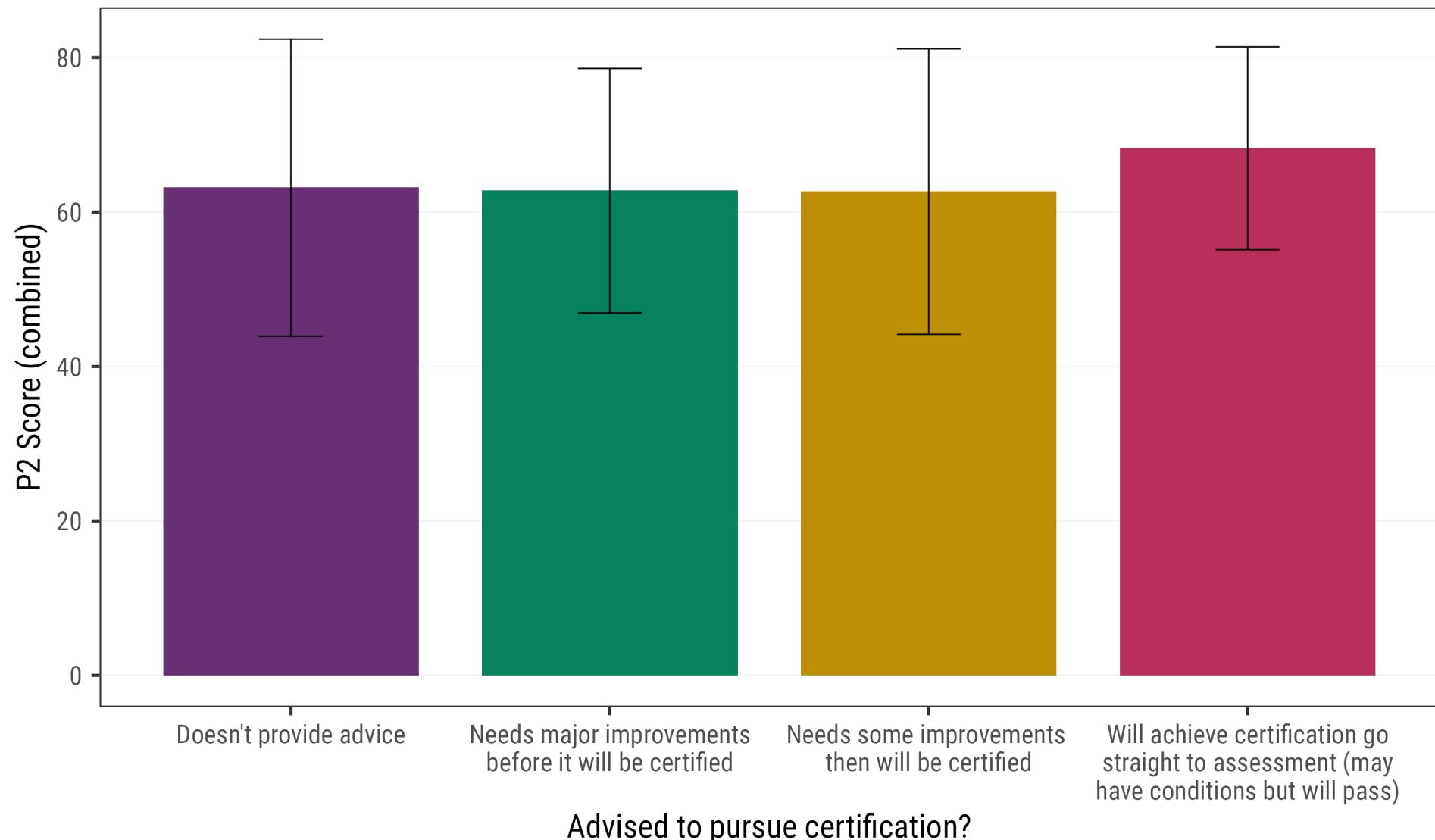
Is the information **conceptual** or **measurable**?

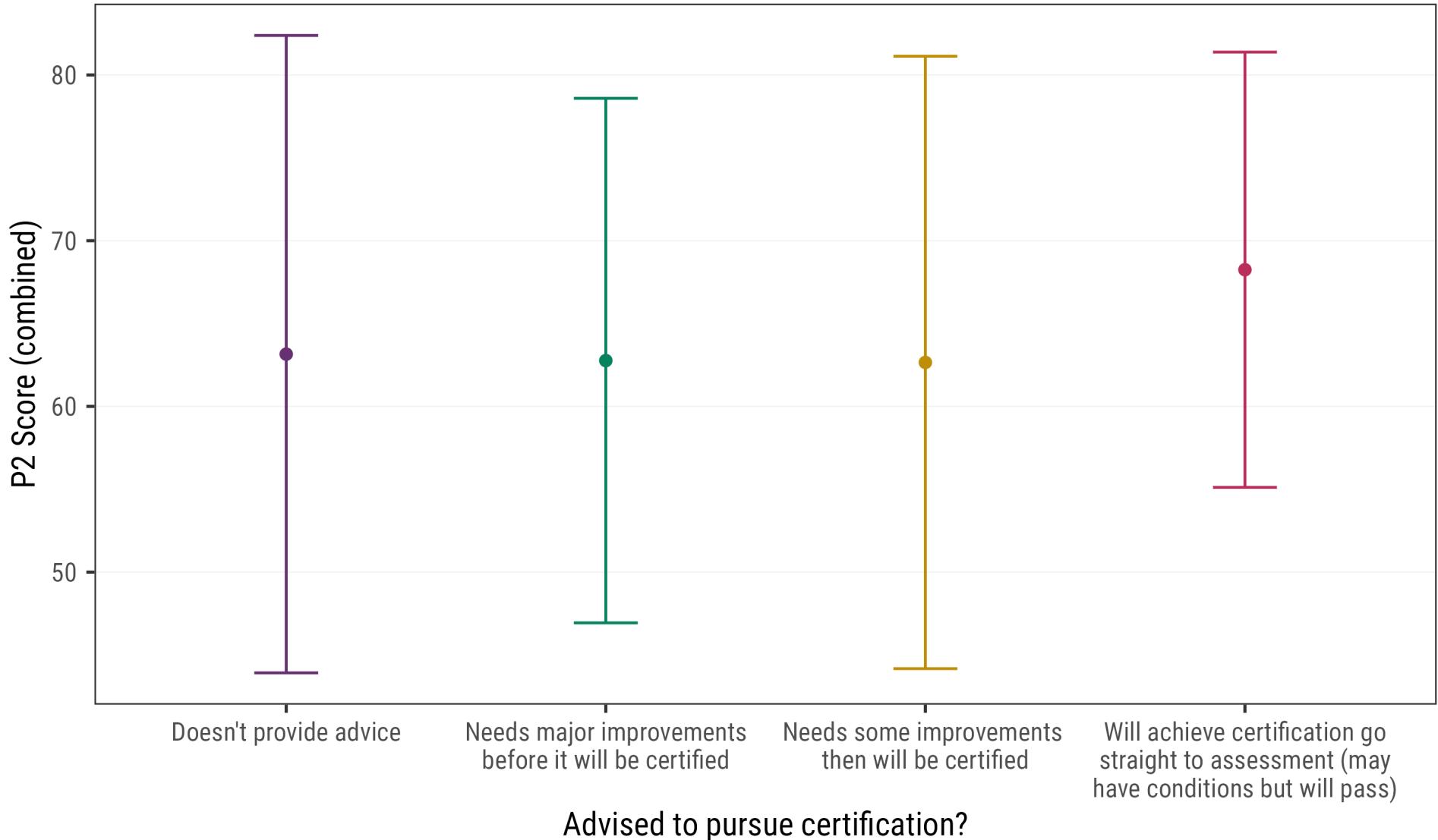
→ conceptual information *versus* convert information into visual forms

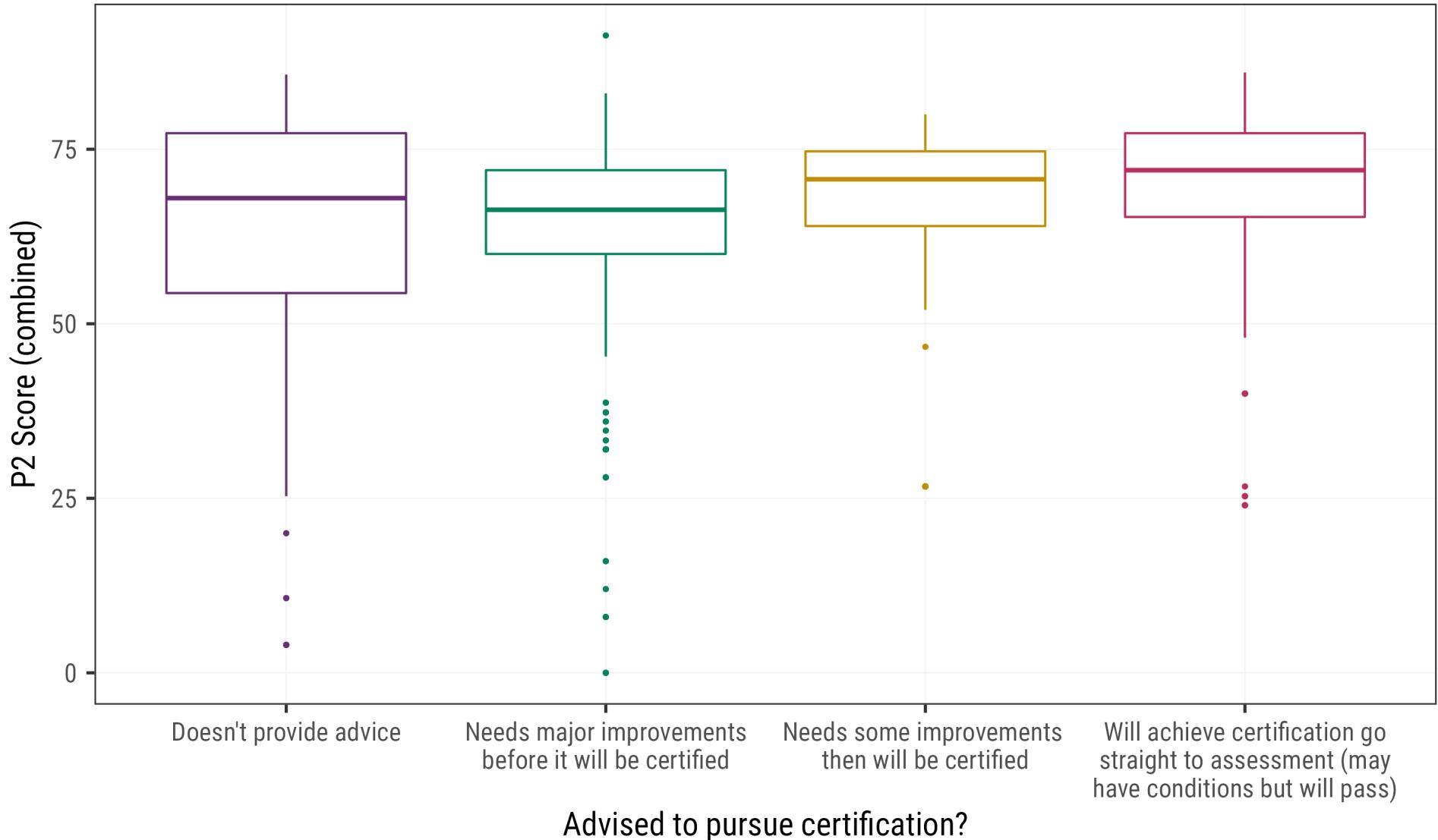
Is the purpose to **explain** or to **explore** the information?

→ Communicate information *versus* facilitate discovery

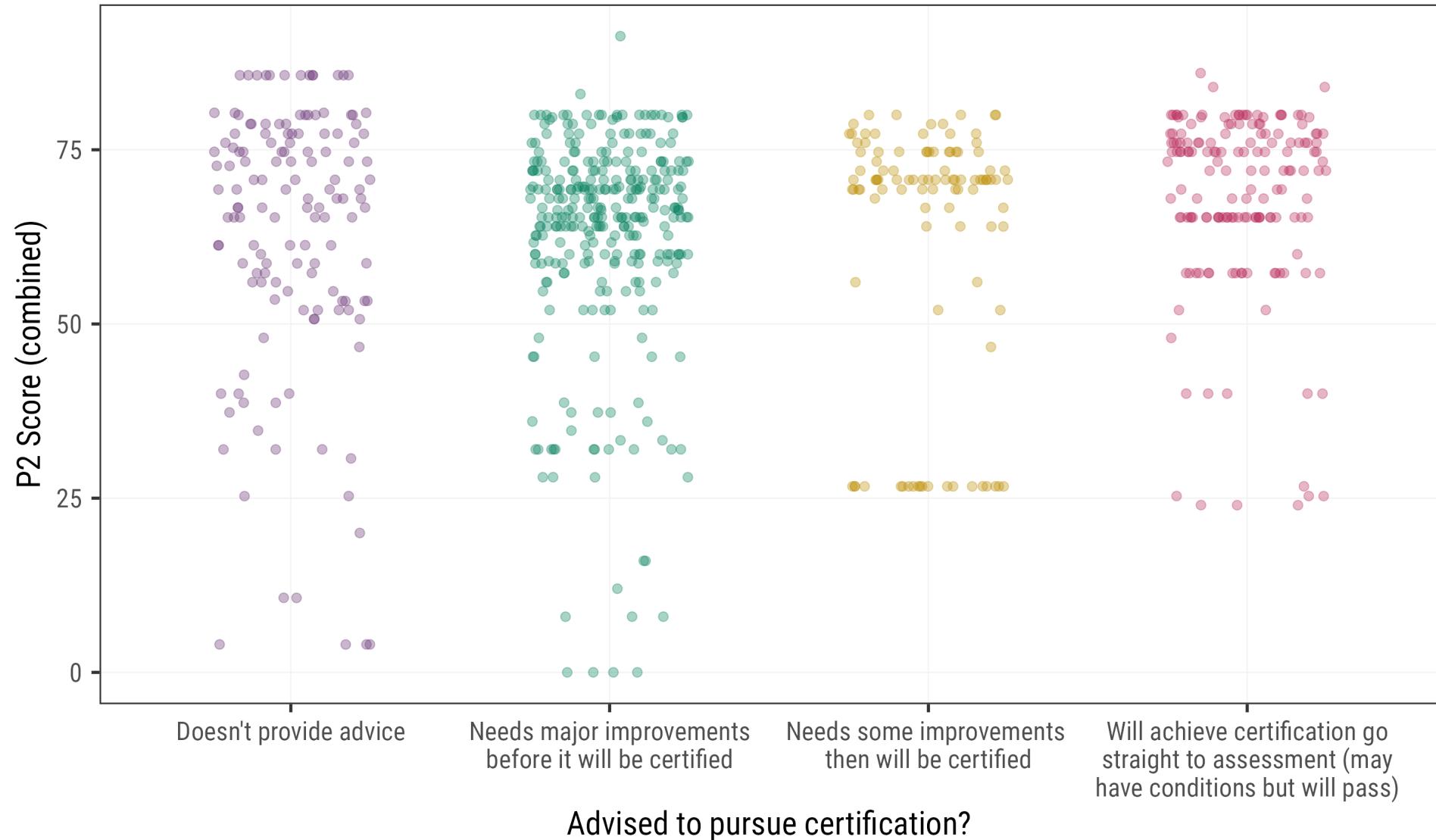


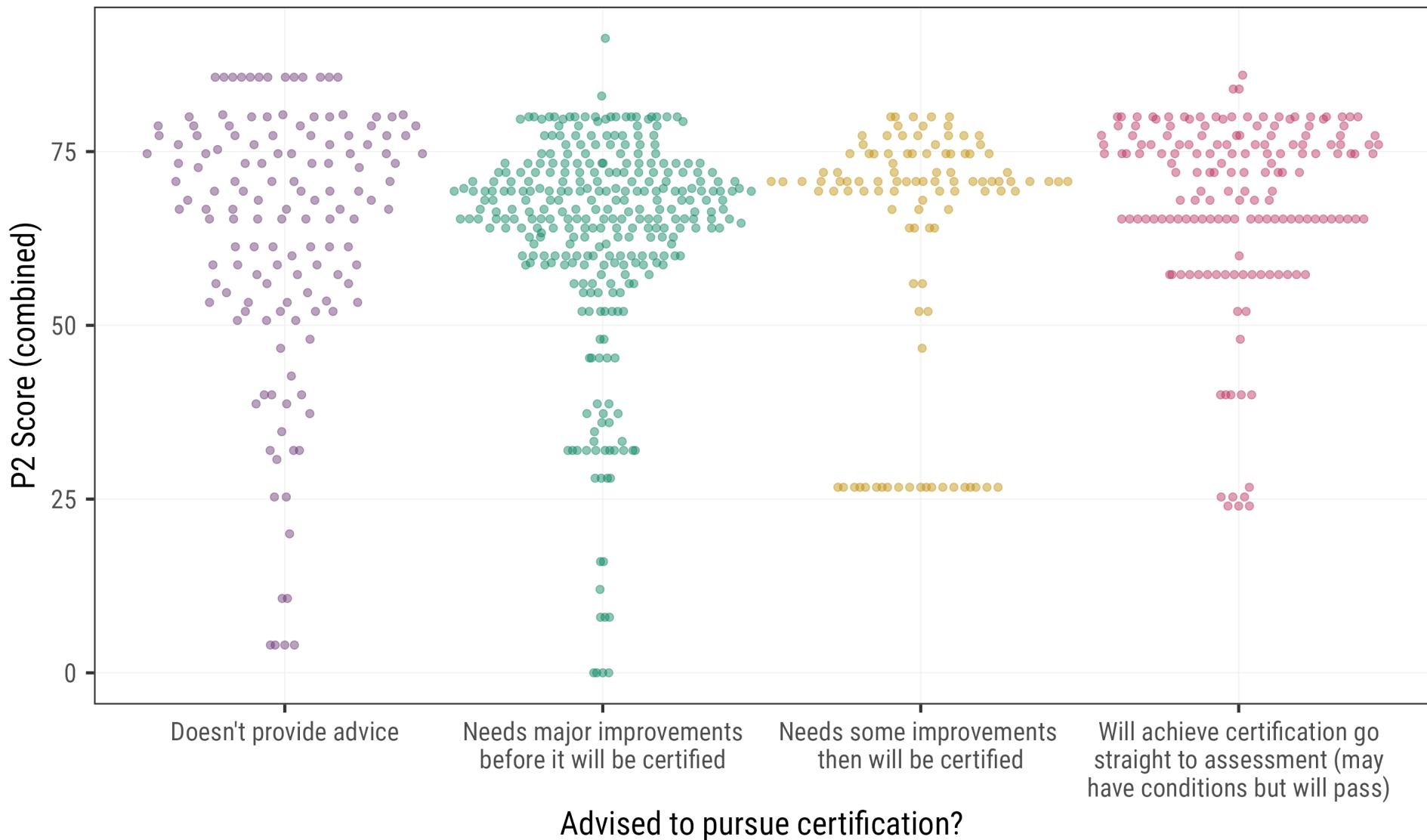


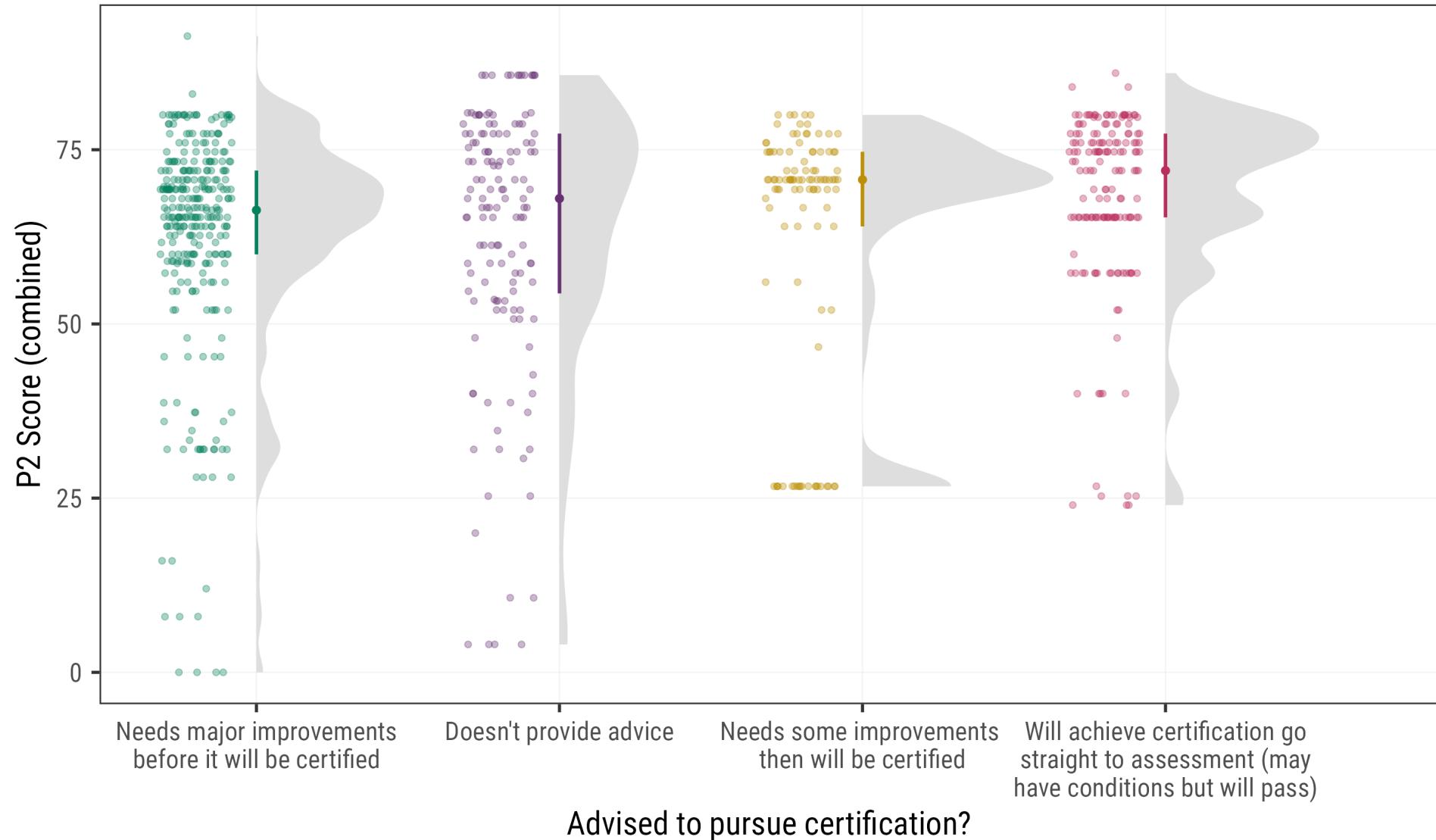


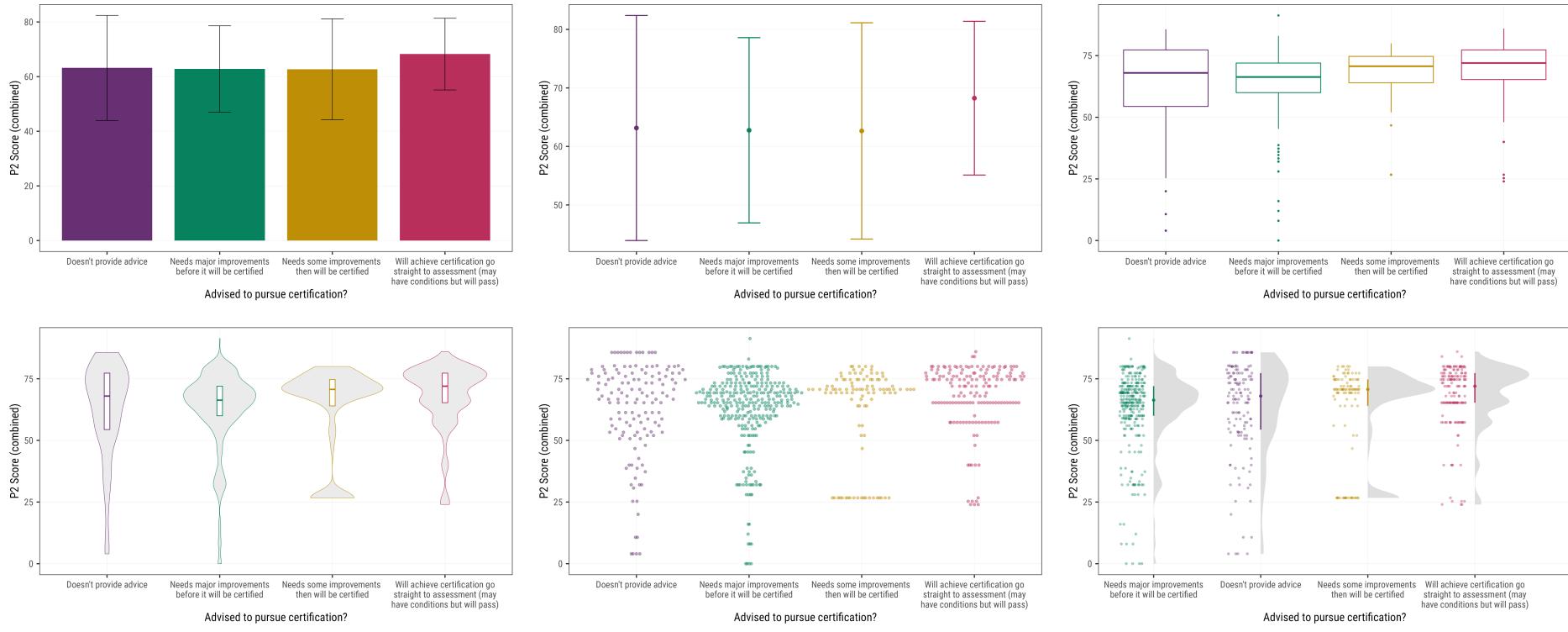












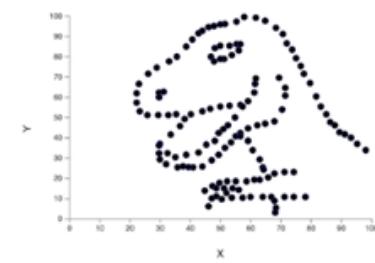
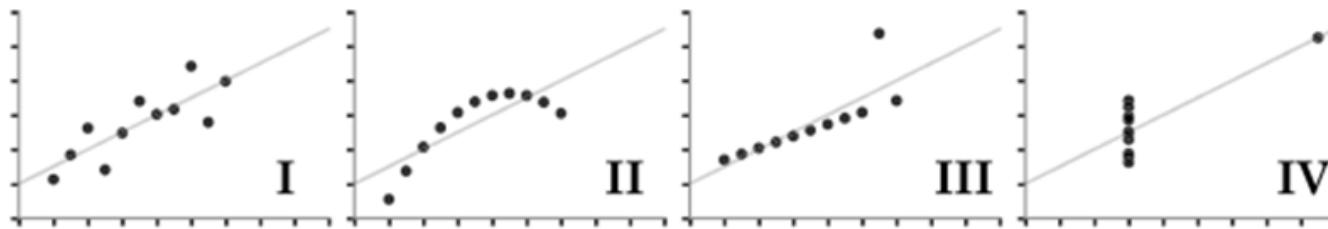
- Always check raw data and sample size
- Try several chart types
- Be open to combine chart types
- Choose chart type with your audience in mind

Same Stats, Different Graphs: Generating Datasets with Varied Appearance and Identical Statistics through Simulated Annealing

Justin Matejka and George Fitzmaurice
Autodesk Research, Toronto Ontario Canada

"The Datasaurus Dozen"

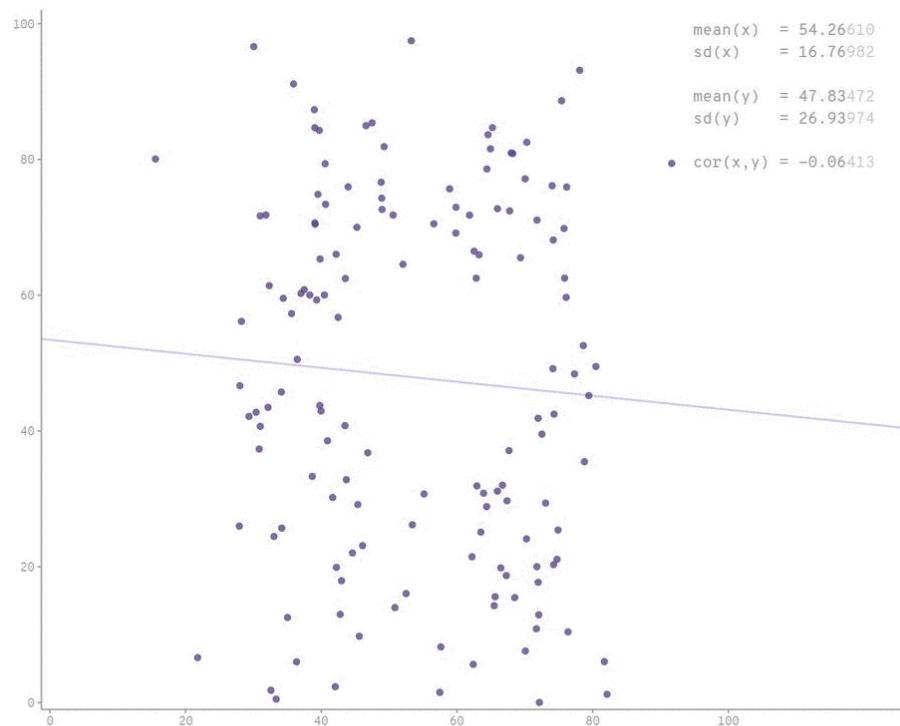
based on Anscombe's Quarter and Alberto Cairo's "Datasaurus" (or "Anscombosaurus")



Same Stats. Different Graphs.

The Famous Datasaurus (Anscombusaurus spec.) Dozen

is a set of 13 different datasets with high-identical summary statistics, which could lead one to believe the datasets are quite similar. After visualizing the data, it becomes clear that the datasets are markedly different. It is based on [Anscombe's Quartet](#) which was developed by F.J. Anscombe in 1973 to demonstrate the importance of data visualization. In 2016, Alberto Cairo created the Datasaurus dataset which urges people to never trust summary statistics alone; always visualize your data. This dataset was published together with a dozen other datasets with almost the same summary statistics by Justin Matejka & George Fitzmaurice in 2017.



Idea by Francis Anscombe, Alberto Cairo, Justin Matejka & George Fitzmaurice
Visualization by Cédric Scherer based on code by Tom Westlake

PERSPECTIVE

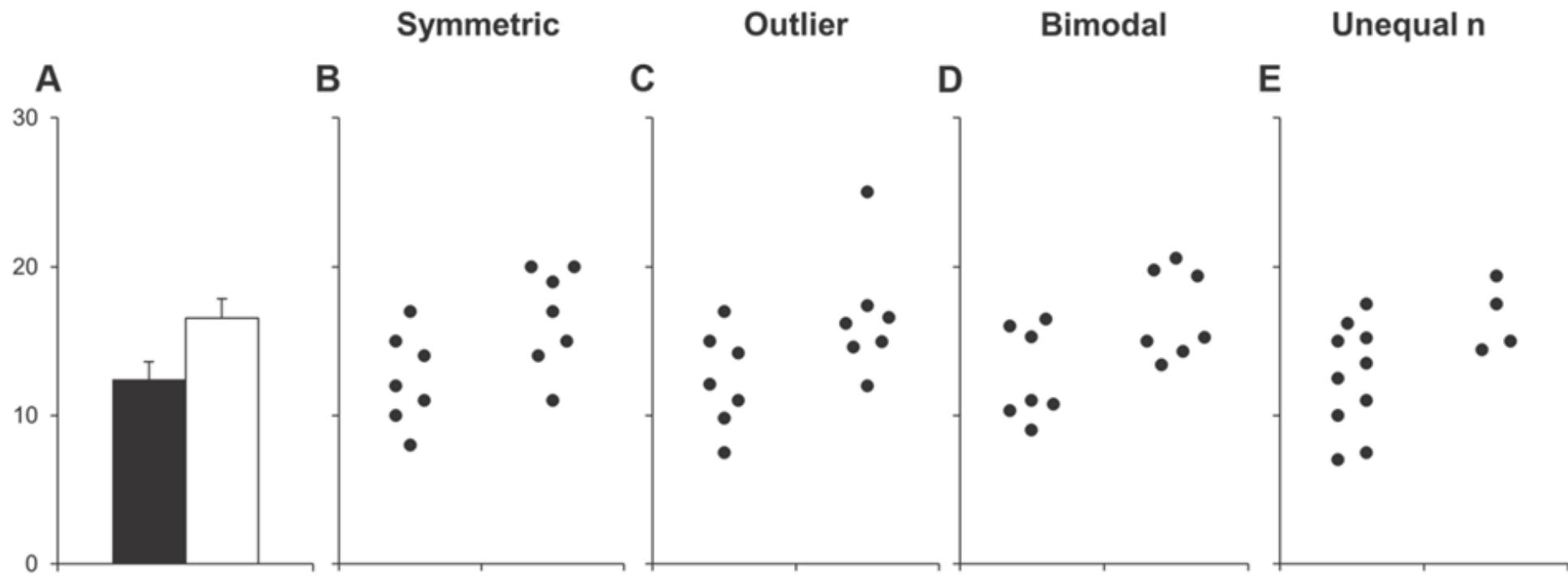
Beyond Bar and Line Graphs: Time for a New Data Presentation Paradigm

Tracey L. Weissgerber^{1*}, Nataša M. Milic^{1,2}, Stacey J. Winham³, Vesna D. Garovic¹

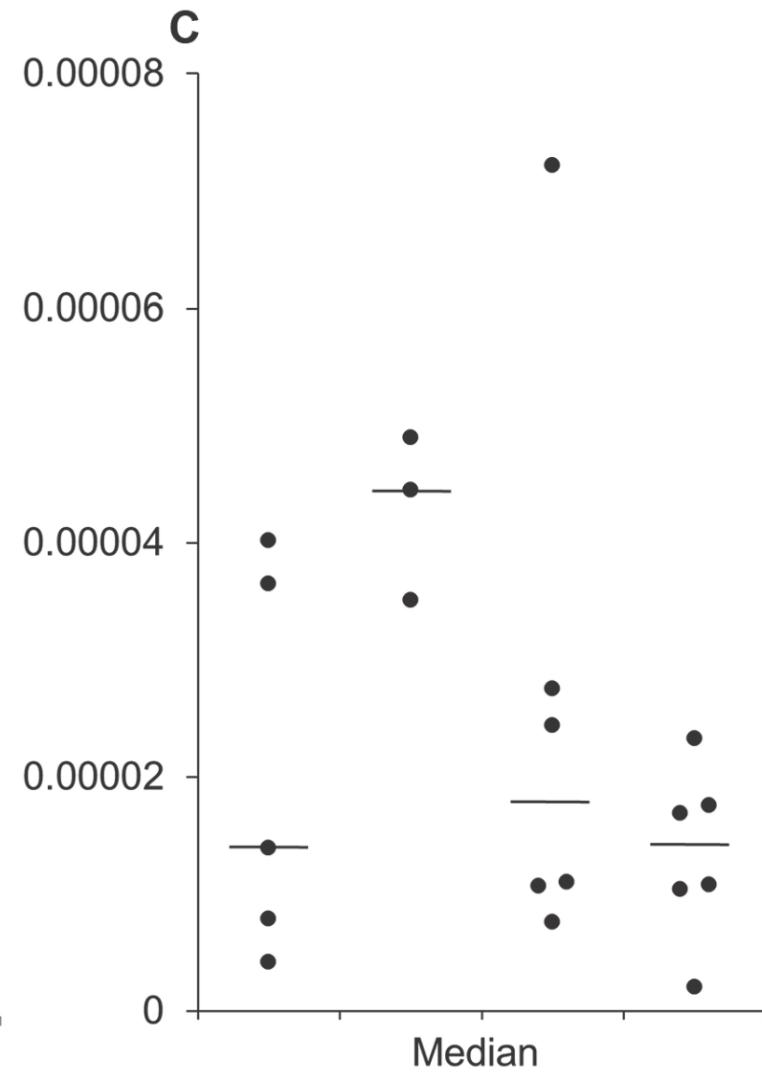
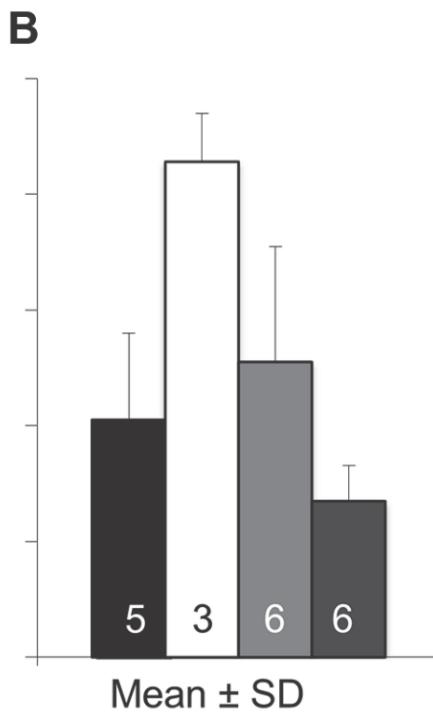
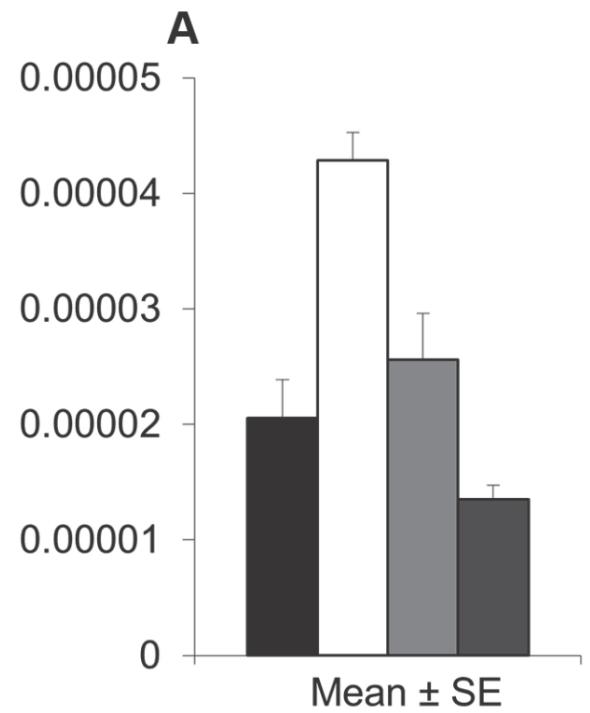
1 Division of Nephrology & Hypertension, Mayo Clinic, Rochester, Minnesota, United States of America,

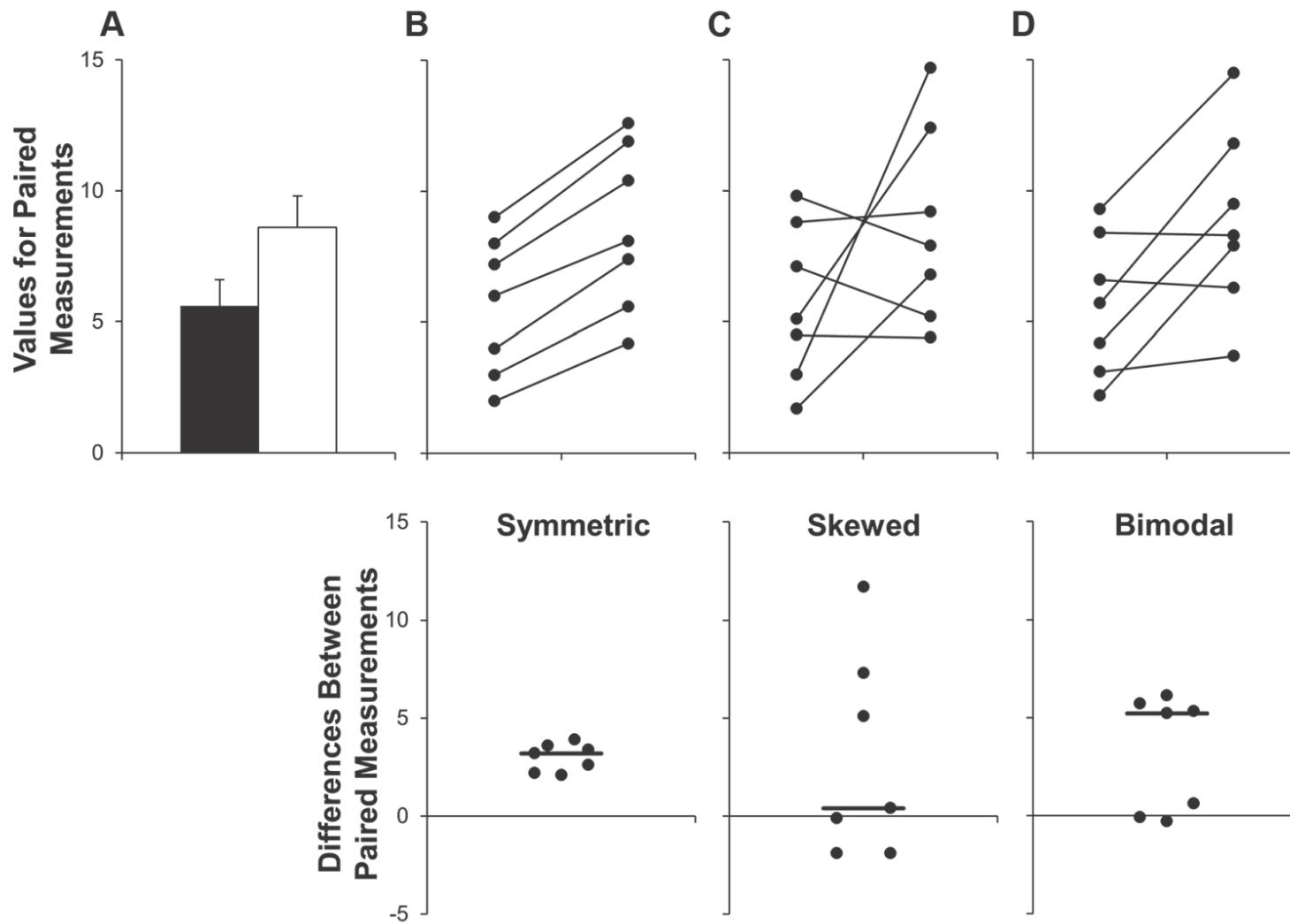
2 Department of Biostatistics, Medical Faculty, University of Belgrade, Belgrade, Serbia, **3** Division of Biomedical Statistics and Informatics, Mayo Clinic, Rochester, Minnesota, United States of America

* weissgerber.tracey@mayo.edu



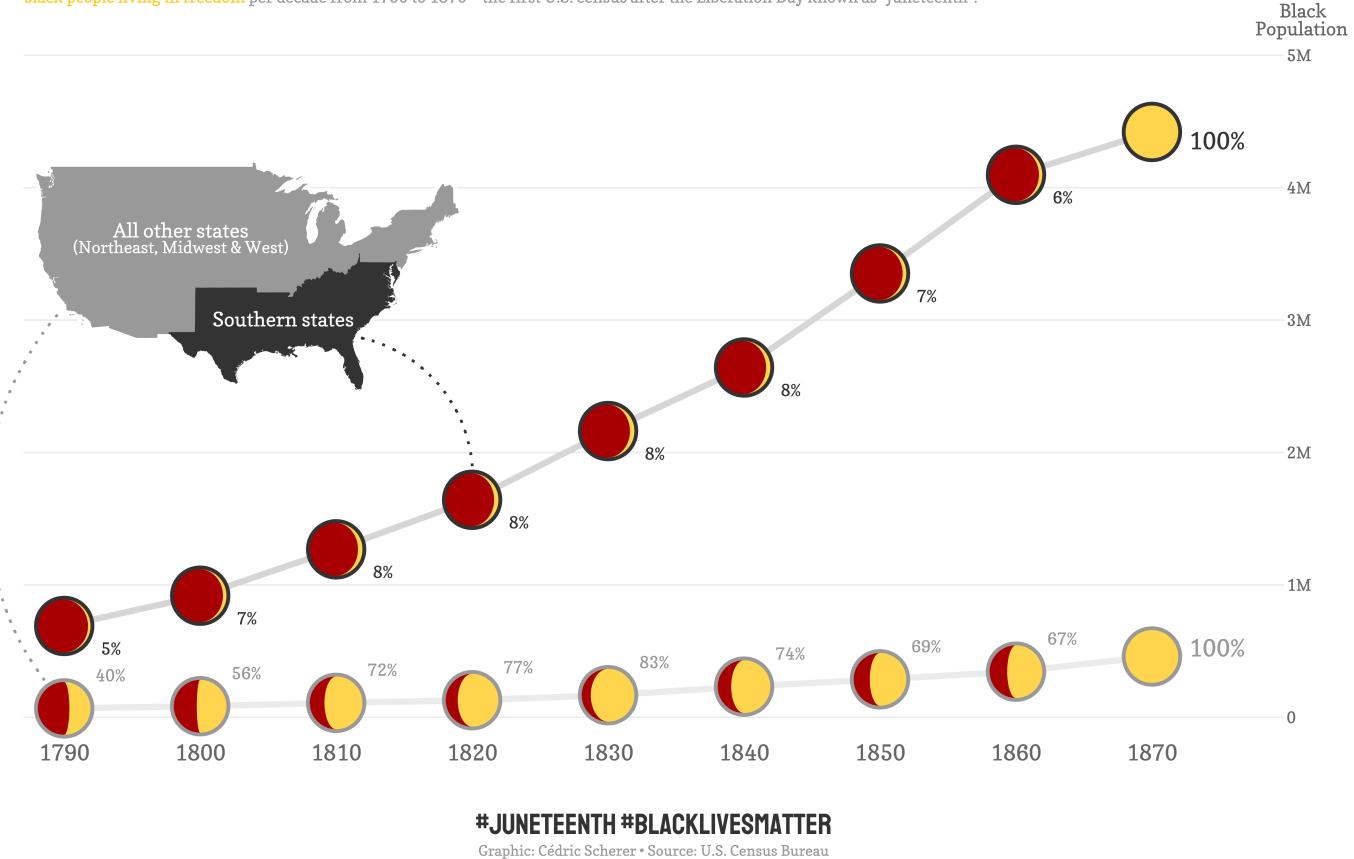
Test	p value			
T-test: Equal var.	0.035	0.050	0.026	0.063
T-test: Unequal var.	0.035	0.050	0.026	0.035
Wilcoxon	0.054	0.073	0.128	0.103





AN ECONOMY BUILT ON SLAVERY—A FUTURE BUILD ON FREEDOM?

By 1680, property owners in the south of North America began establishing plantation farms for cash crops like tobacco, cotton, and sugar cane—enterprises that required increasing amounts of labor. To meet the need, wealthy planters became slave traders and imported ever more individuals to the colonies, the vast majority from West Africa. While the "Emancipation Proclamation" was made law as of 1863, slave owners in the South, namely Texas, still maintained slavery until June 19th 1865 when Union soldiers were able to enforce the law abolishing slavery in the region. The graphic below shows the share of **black people in slavery**, most of them enslaved in the Southern states, and **black people living in freedom** per decade from 1790 to 1870—the first U.S. census after the Liberation Day known as "Juneteenth".



Not my cup of coffee...

Each dot depicts one coffee bean rated by Coffee Quality Institute's trained reviewers. In addition, the multiple interval stripes show where 25%, 50%, 95%, and 100% of the beans fall along the rating gradient from 0 to 100 points. The rated coffee beans range from 59.8 points (Guatemala) to 89.1 points (Ethiopia). Only countries of origin with 25 or more tested beans are shown. The red empty triangle marks the minimum rating, the black filled triangle indicates each country's median score.

Visualization by Cédric Scherer

60 POINTS

GUATEMALA
△59.8 POINTS

The coffee bean with the lowest rating has its origin in Guatemala.



One bean from Nicaragua got a bad rating, too.

NICARAGUA
△63.1 POINTS

70 POINTS

COSTA RICA
△71.8 POINTS

HAWAII
△73.7 POINTS

BRAZIL
△73.2 POINTS

TANZANIA
△80.3 POINTS

TAIWAN
△77.7 POINTS

HONDURAS
△69.2 POINTS

MEXICO
△68.3 POINTS

ETHIOPIA
△80.3 POINTS

KENYA
△79.8 POINTS

COLOMBIA
△72.8 POINTS

JIGANDA
△80.5 POINTS

EGYPT
△83.2 POINTS

EGYPT
△83.2 POINTS

EGYPT
△82.8 POINTS

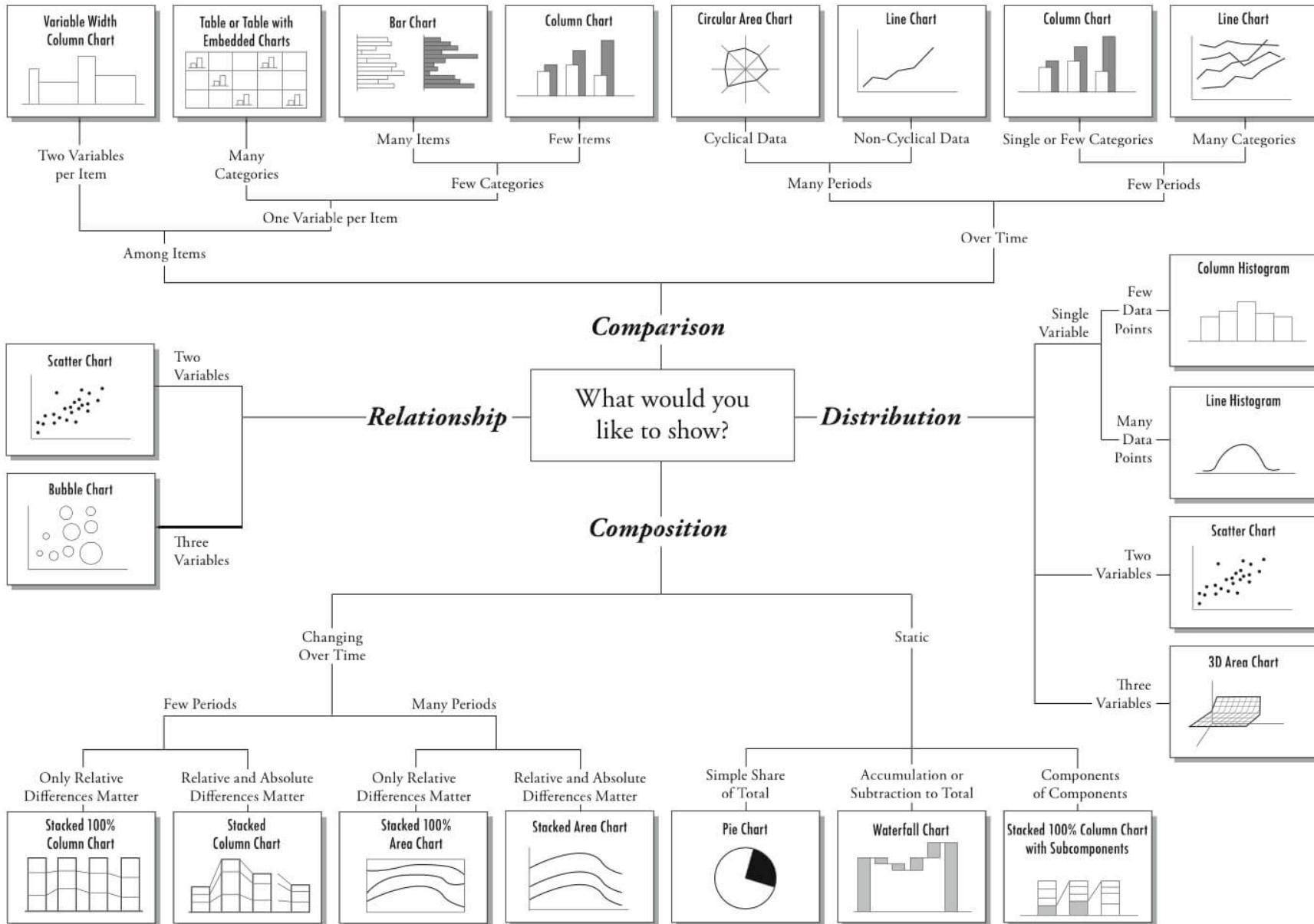
EGYPT
△82.5 POINTS

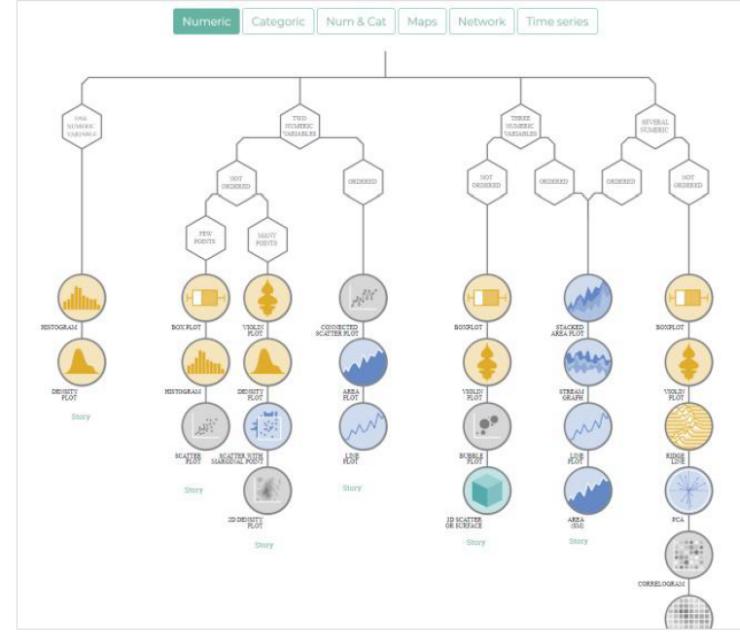
EGYPT
△82.4 POINTS

EGYPT
△82.2 POINTS

EGYPT
△85.1 POINTS

Chart Suggestions—A Thought-Starter

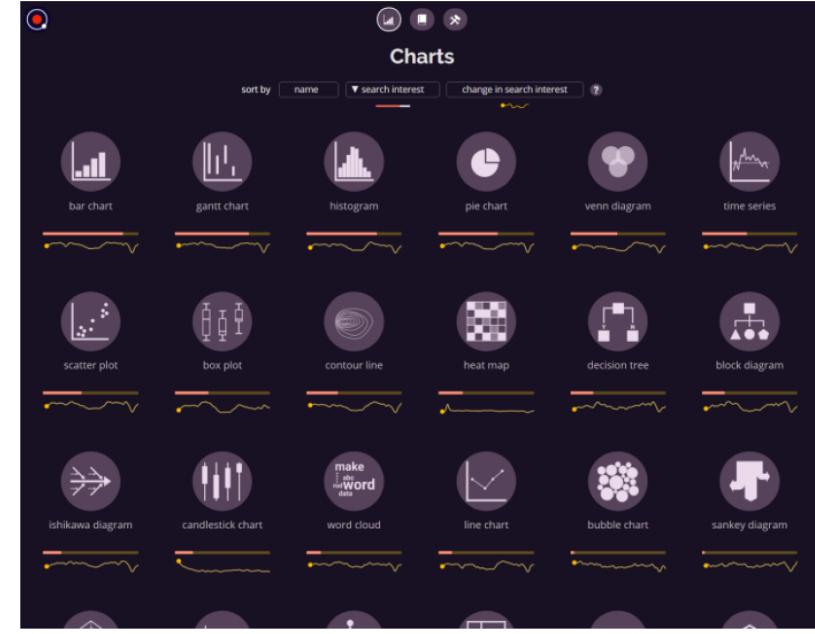




data-to-viz.com



datavizproject.com



visualizationuniverse.com/charts



from Data to Viz

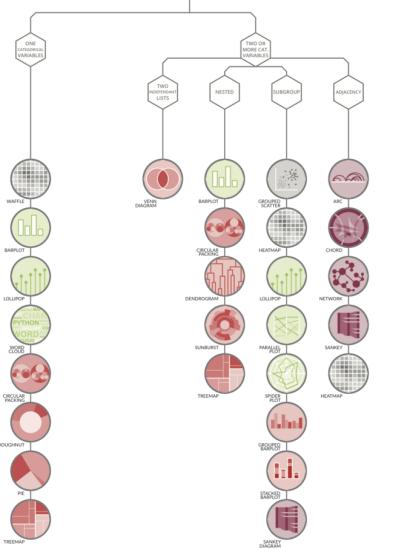
'From Data to Viz' is a classification of chart types based on input data format. It will help you find the perfect chart in three simple steps :

- 1** Identify what type of data you have.
- 2** Go to the corresponding decision tree and follow it down to a set of possible charts.
- 3** Choose the chart from the set that will suit your data and your needs best.

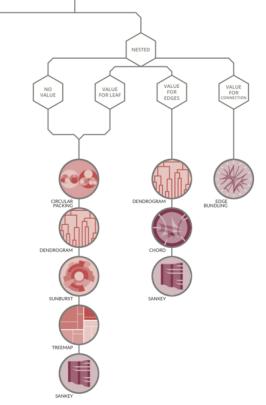
DataViz is a world with endless possibilities and this project does not claim to be exhaustive. However it should provide you with a good starting point. For an interactive version and much more, visit:

data-to-viz.com

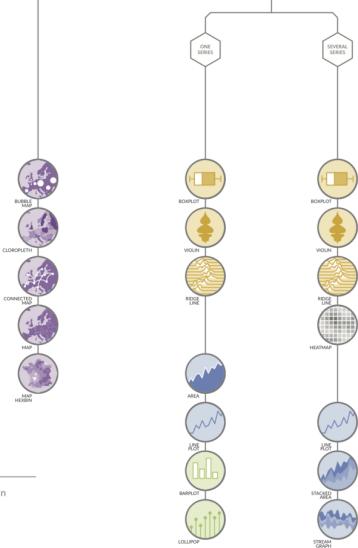
CATEGORIC



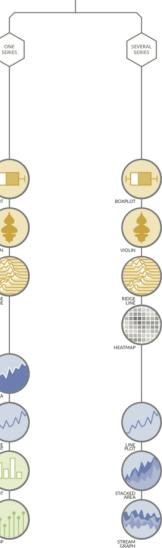
RELATIONAL



MAP



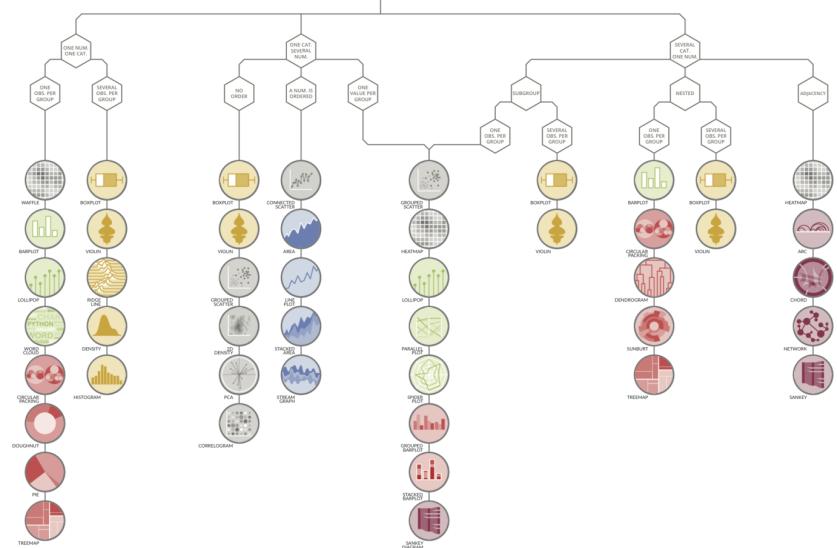
TIME SERIES



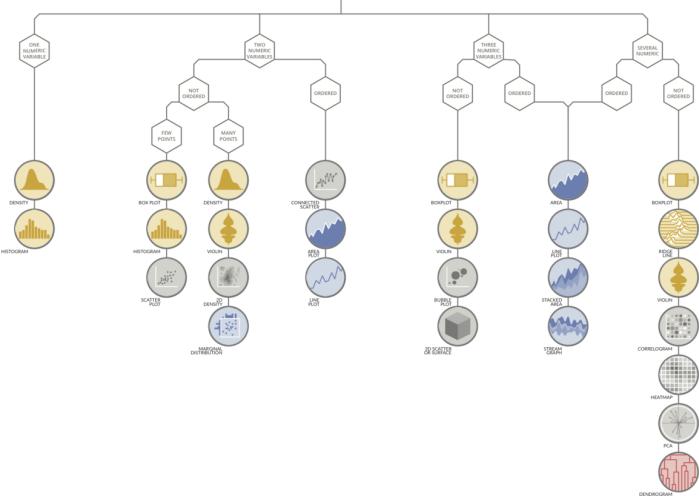
WHAT DO YOU WANT TO SHOW ?

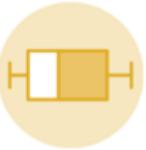
- | | |
|---|---|
| ● Distribution | ● Evolution |
| ● Correlation | ● Maps |
| ● Ranking | ● Flow |

CATEGORIC AND NUMERIC



NUMERIC





BOXPLOT

Summarize the distribution of numeric variables

[About](#)

A boxplot gives a nice summary of one or several numeric variables. The line that divides the box into 2 parts represents the median of the data. The end of the box shows the upper and lower quartiles. The extreme lines show the highest and lowest value excluding outliers.

[Common Mistakes](#)

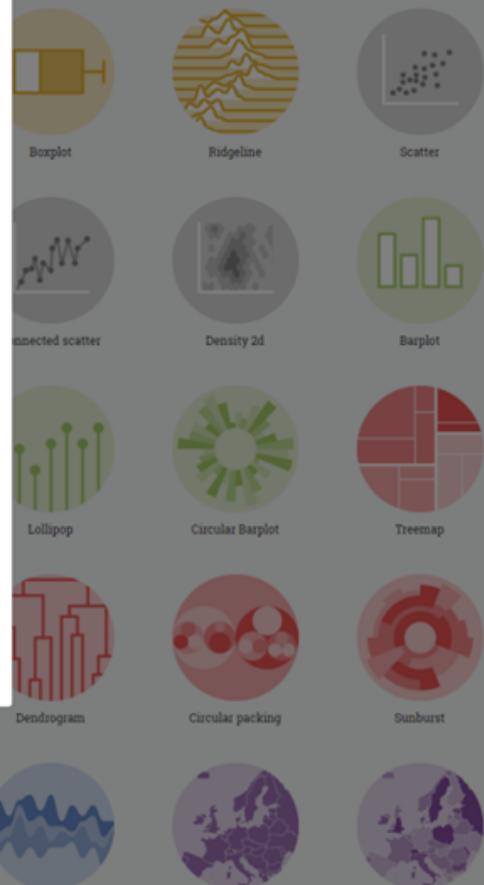
- Boxplot hides the sample size of each group, show it with annotation or box width.
- Boxplot hides the underlying distribution. Use jitter if low number of data points, or use violin with bigger data.
- Order your boxplot by median can make it more insightful.

[Code](#)

[R graph gallery](#) [Python gallery](#) [D3.js gallery](#) [Flourish](#)

[Read More](#)

See the [dedicated page](#).

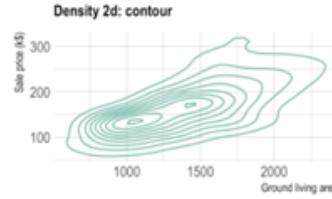
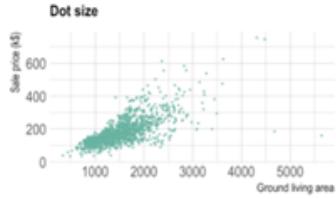


VISIBILITIES
presented in this website.

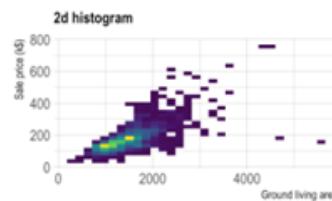
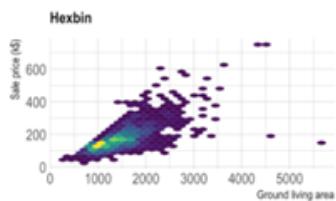
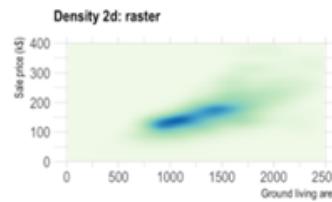
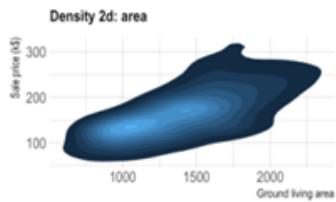
[Part of a whole](#) [Evolution](#) [Map](#) [Flow](#)

Overplotting

The most common pitfall with scatterplot is overplotting: when the sample size gets big, dots are plotted on top of each other what makes the chart unreadable. There are several work around to avoid this issue as describe in this [specific post](#). Here is a summary of the different offered techniques:



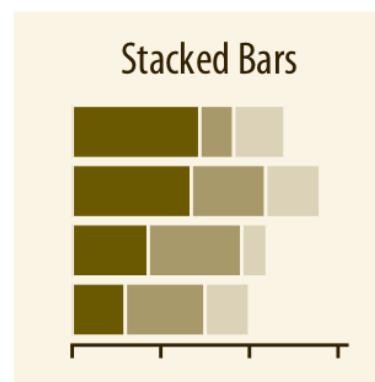
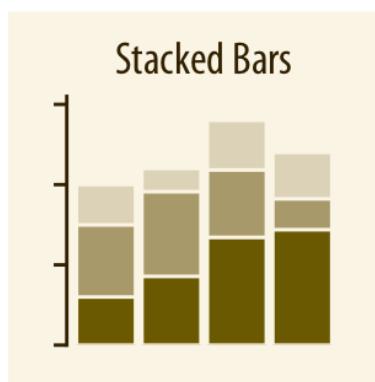
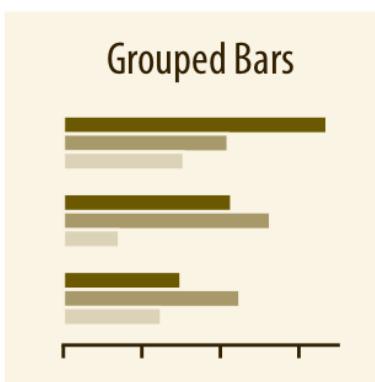
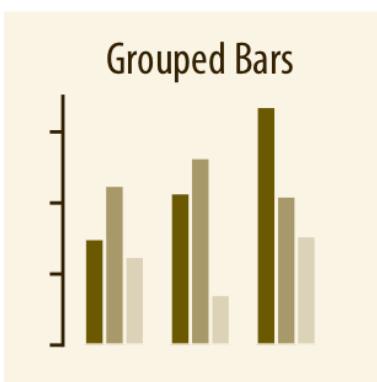
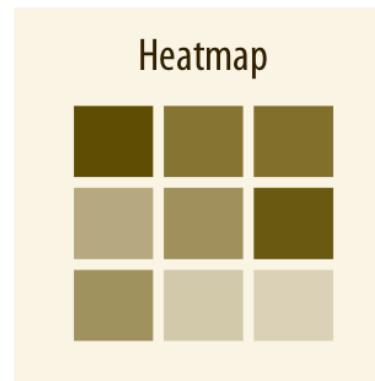
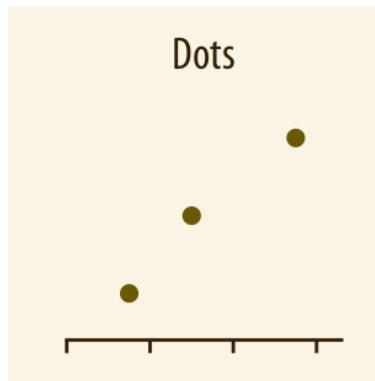
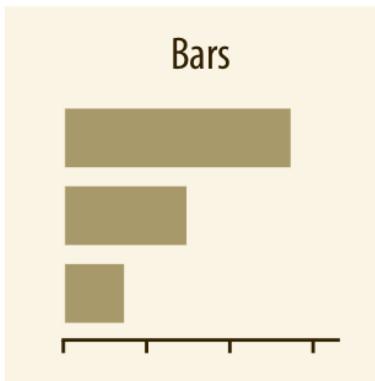
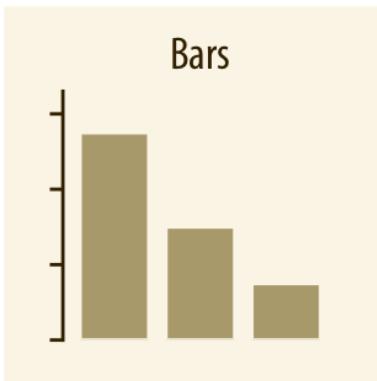
CODE



Going further

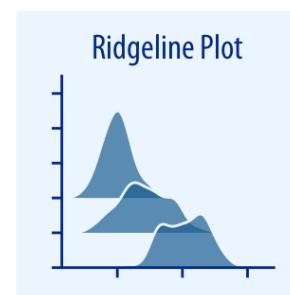
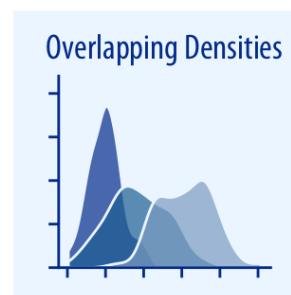
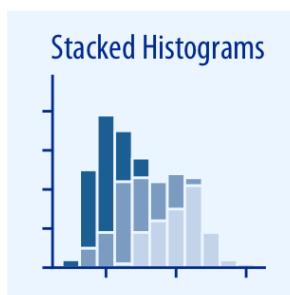
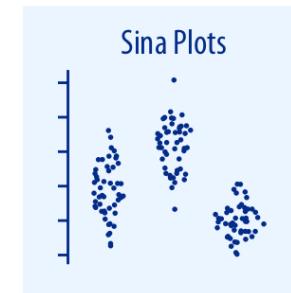
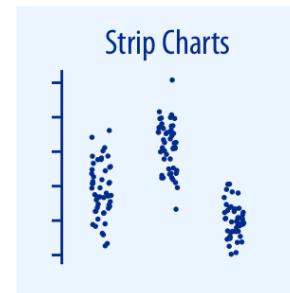
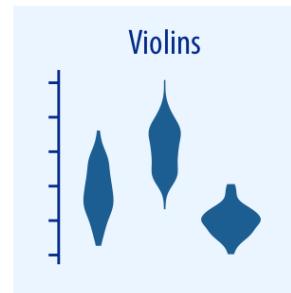
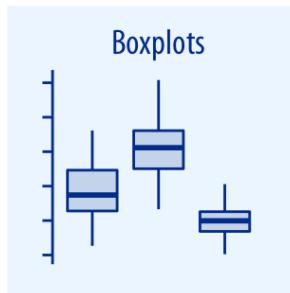
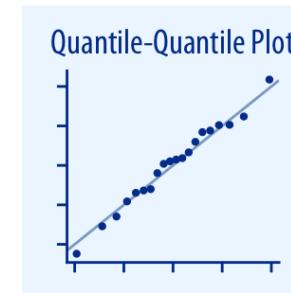
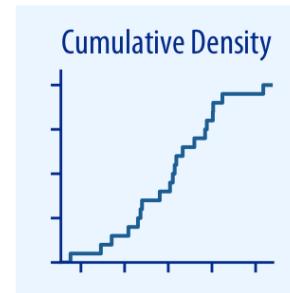
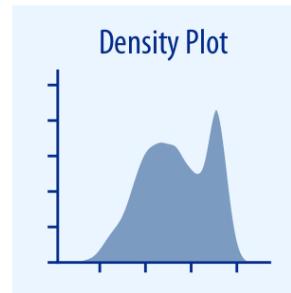
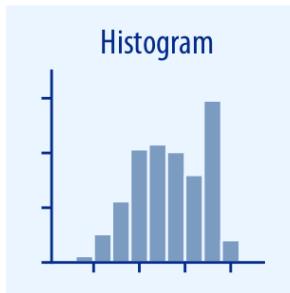
You can learn more about each type of graphic presented in this story in the dedicated

Charts to Visualize Amounts



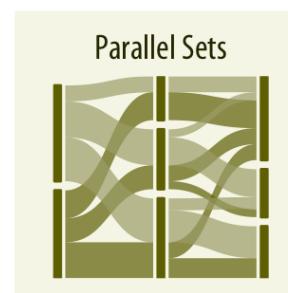
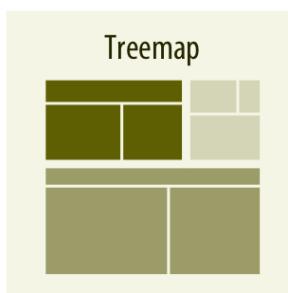
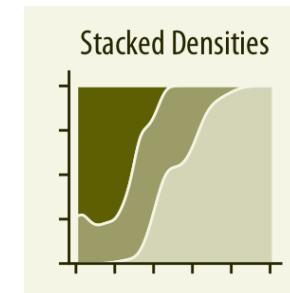
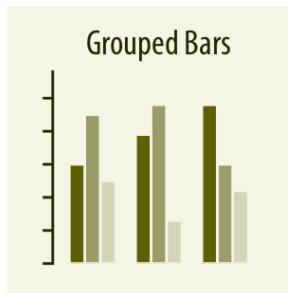
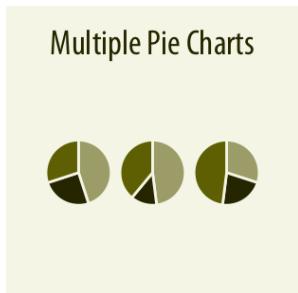
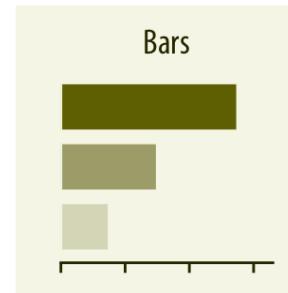
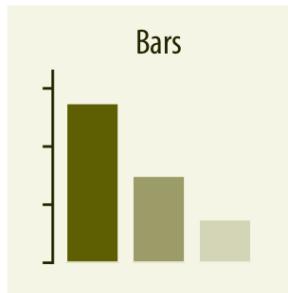
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Charts to Visualize Distributions

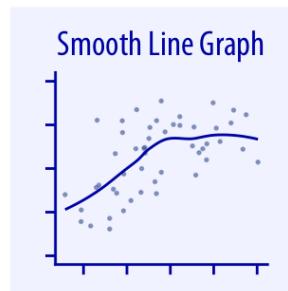
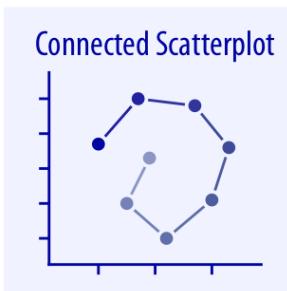
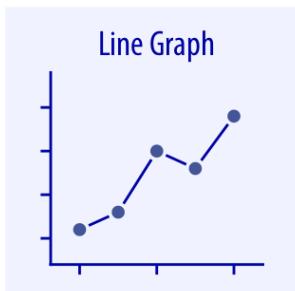
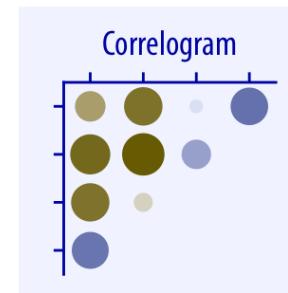
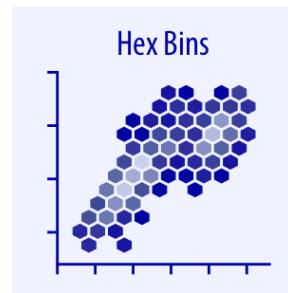
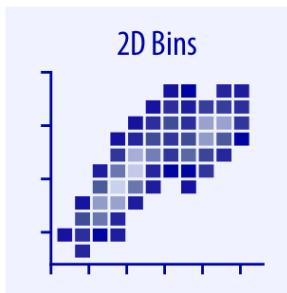
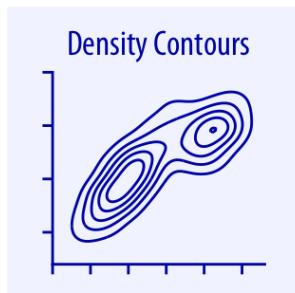
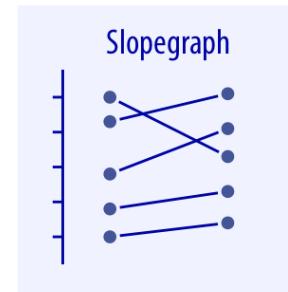
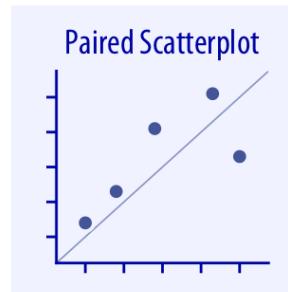
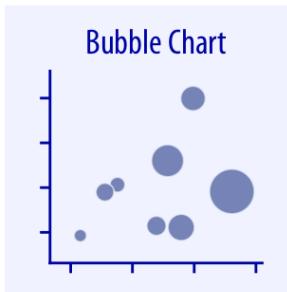
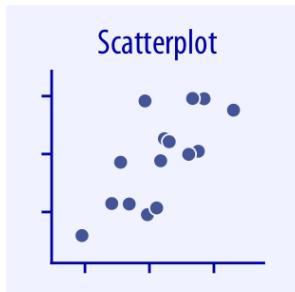


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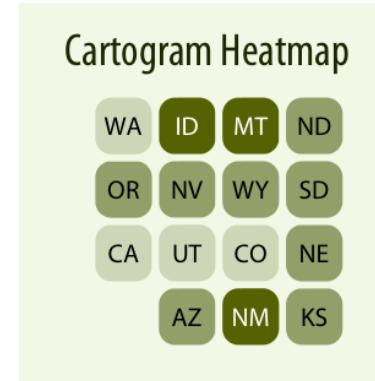
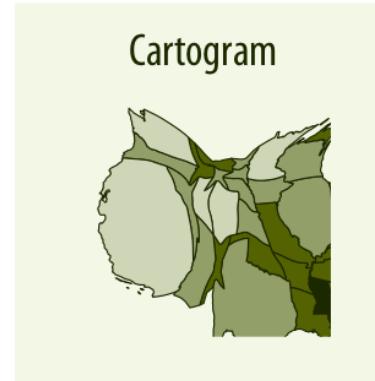
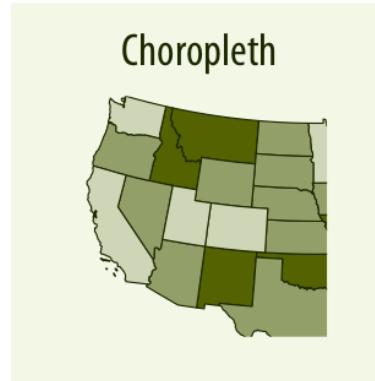
Charts to Visualize Proportions



Charts to Visualize x-y Relationships

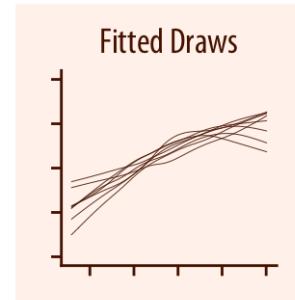
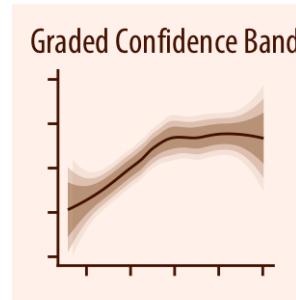
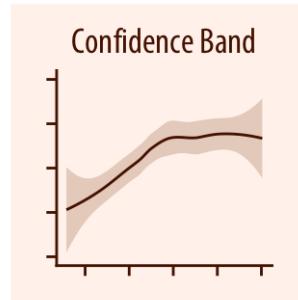
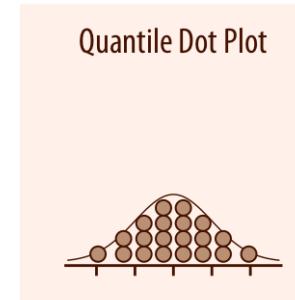
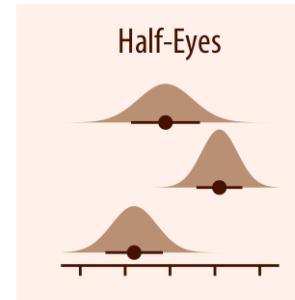
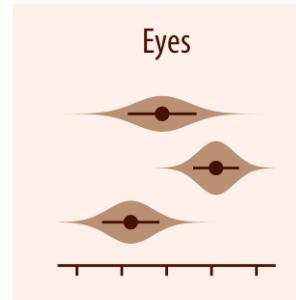
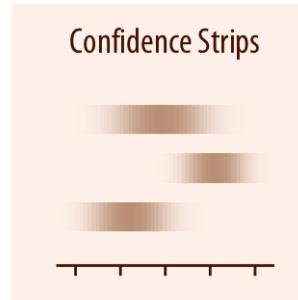
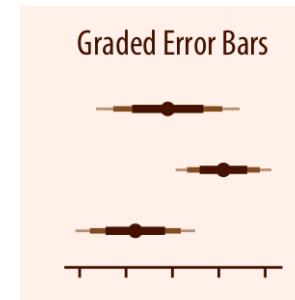
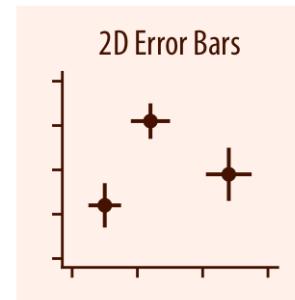
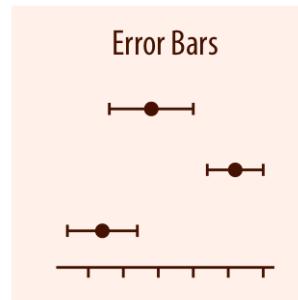


Charts to Visualize Geospatial Data



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Charts to Visualize Uncertainty



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VISUAL FORM

Follow design rules and data visualization principles