Welcome (Again!) to
MATH 4100/COMP 5360 – Introduction to Data Science

(Some) Principles of Data Visualization + Project Overview

February 11, 2025

Based on prior lectures from Alex Lex and Bei Wang Phillips

+ others where noted

…let’s talk about the Project first

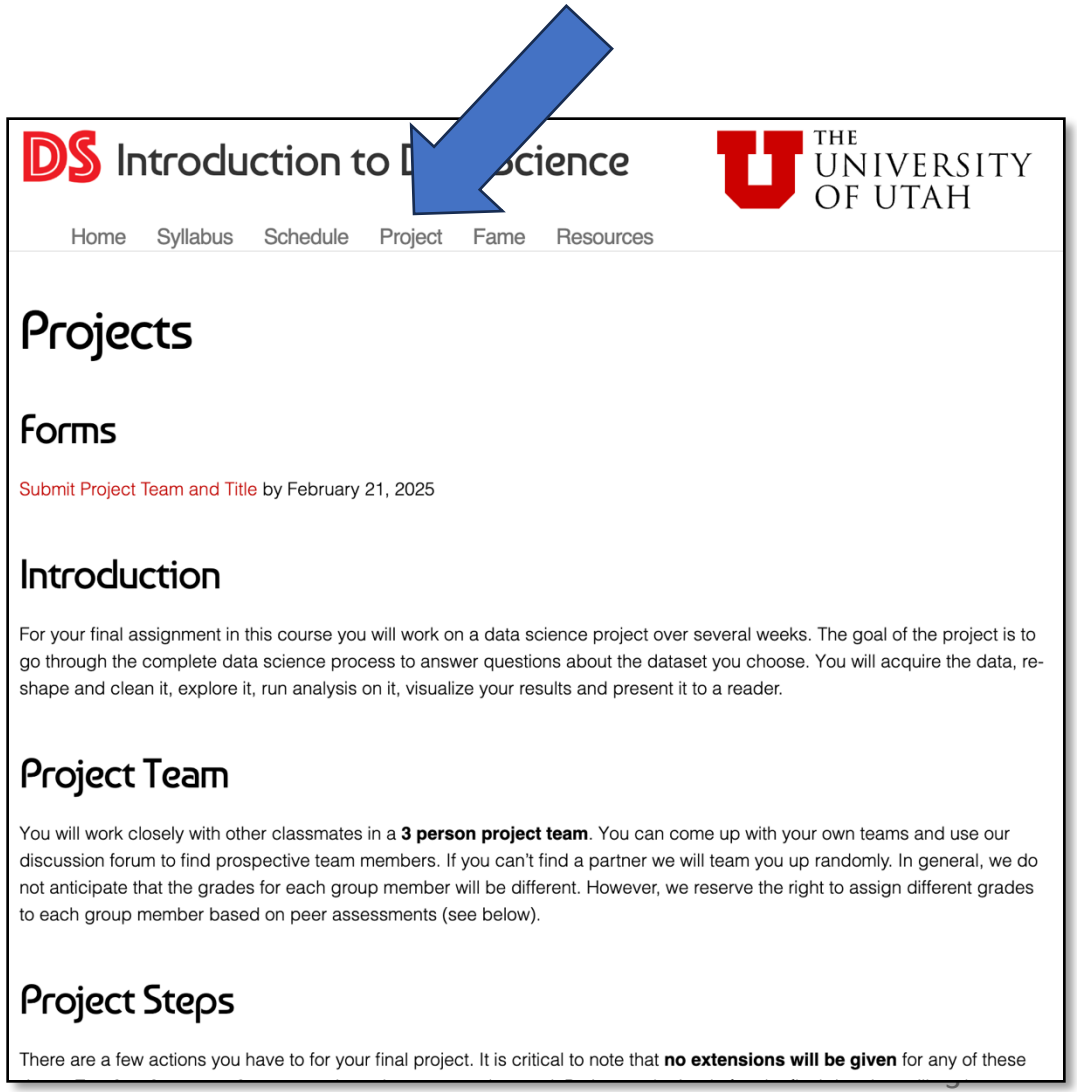
Project

https://datasciencecourse.net/2025/project/

Website has more details about milestones

What you need to get started:

- *A team of 3*
- *An idea*
- *A dataset (or multiple)*
  - *…that you can actually get!*



Project Phases

- **Feb 16 (optional):** Request random team
- **Feb 21:** Submit your team & title
- **Mar 7:** Project Proposal due
- **Mar 20 (in-class):** peer feedback (required)
- **Mar 28:** Project Milestone due
- **Mar 31 (week of):** Staff feedback
- **Apr 18:** Final Report due
- **Apr 22:** Project Awards


DS Project Teams and Titles 2025

* Indicates required question

Project Title *

Your answer

Team member information *

Put one team member on each line:

[Name], [Email], [UID]. [Programming Experience on a Scale of 1 - 5, 1 being less comfortable, 5 being very comfortable]

Projects phases must be done on time, assignment late policy does not apply – needed for feedback

Project Requirements

Scope as agreed upon with Staff

Project should include:

- Data acquisition (e.g., scraping, using an API)
- Data cleaning
- Exploratory analysis including visualization
- Two different analysis methods (e.g., classification, regression, clustering, dimensionality reduction, NLP)
  - Evaluation of alternative approaches for each one (e.g., comparing classification methods)
- Ethical considerations

With the exception of ethical considerations, one inclusion may be minimal if made up for in other areas. For example, if your acquisition is a simple download, the analysis may need to be more sophisticated.

Ethical considerations

We will discuss ethics next week, but some things to consider now:

- Where in your process are/were ethical decisions made? What were they?
- Who are the stakeholders of this project?
- If the project is successful and were to be released widely, who would be affected? Will some be more affected than others?
- Is your data biased in someway? If so, how?

"There are no ethical considerations" must be **strongly** defended. If the staff can identify any ethical considerations, you will get zero credit for that part of the project.

Don’ts

Don’t use a standard machine learning data (e.g., MNIST, common datasets from UCI ML Repository, many on Kaggle…)

- These are often pre-processed for specific analyses, and don’t require other parts of the DS process like cleaning and exploratory analysis
- If you use from these repositories, must demonstrate in proposal how data is appropriate for the entire project process

Don’t choose a dataset where it is too hard to extract structured data:

- e.g., requires advanced NLP, extracting from PDF, etc.
- …or, if you do go this route, proposal should demonstrate you are prepared to extract this data. You must state specifically how you will do so, perhaps even giving an example.

Proposal

Sections lists on website

Submit as Jupyter notebook

Group submits one together

Individual feedback forms allow you to tell staff about the division of work

Proposal

You start your project by forming your groups and letting us know what topic you are interested in exploring by submitting a project data form. **Please submit only one form per team!**. In addition to the form, you will create a proposal document in the form of a Jupyter Notebook, addressing the following points. Use these points as headers in your document.

- **Basic Info.** The project title, your names, e-mail addresses, UIDs.
- **Background and Motivation.** Discuss your motivations and reasons for choosing this project, especially any background or research interests that may have influenced your decision.
- **Project Objectives.** Provide the primary questions you are trying to answer in your project. What would you like to learn and accomplish? List the benefits.
    - This should include both questions about the data and any learning objectives you would like to fulfill. In other words, there are two kinds of benefits to address.
- **Data Description and Acquisition.** What format is your data in? How many items are there? What attributes do those items have? Are there special structures in it (e.g., networks, geographical)? From where and how are you collecting your data? If appropriate, provide a link to your data sources.
    - This part should be specific enough that the instructional staff is assured you have or will be able to obtain data.
        - If it's online through direct download, link to the specific page from which you will download it.
        - If you will scrape it from the web, link to the page from which you will scrape it and a statement regarding how you have confirmed you are permitted to scrape it.
        - If you will use an API to access it, link to the documentation of the API and explain how you have access to that API
            - If it requires an account, state you have one.
            - If it doesn't require an account, state that it does not require one.
        - If it is data you have access to through other means, describe in detail what the data is, how you have access to it, and why you have permission to use it.
- **Ethical Considerations.** Complete a stakeholder analysis for your project.
    - Who may be affected by your project and its outcomes? How could you project be used for harm?
        - "There are no ethical considerations" must be *strongly* defended. No one successfully done this before in this class.
- **Data Cleaning and Processing.** Do you expect to do substantial data cleanup or data extraction? What quantities do you plan to derive from your data? How will data processing be implemented?
- **Exploratory Analysis.** Which methods and visualizations are you planning to use to look at your dataset?
- **Analysis Methodology.** How are you planning to analyze your data?
    - What specific questions do you hope to calculate?
    - What methods (from class or otherwise) do you think you will use?
- **Project Schedule.** Make sure that you plan your work so that you can avoid a big rush right before the final project deadline, and delegate different modules and responsibilities among your team members. Write this in terms of weekly deadlines.

As a ballpark number: your proposal should be about 2-3 pages of text and figures. You can also include some preliminary data acquisition / analysis steps.

Project Milestone

For your milestone, we expect you to have acquired, cleaned, and explored your dataset. You should also explain in more detail what will go into your final analysis. Explain deviations from your initial project plan. In other words, we expect an elaborated data description, acquisition, cleaning, exploratory analysis, and an updated project schedule that discusses changes in plans from your project proposal. The acquisition, cleaning, and exploratory analysis should include the code to accomplish these tasks. Please revise any other sections as necessary.

If you are uncertain about the scope, please contact the staff member responsible for your project.

The milestone should be submitted as a zip file containing a Jupyter notebook and any supporting documents. the Jupyter notebook should contain all the narrative and code. Do no submit a separate document with the write up from the Jupyter notebook. Note this zip file should also include your in-class feedback as a separate file with the name `feedback_exercise`.

Like with the assignments, submit the Jupyter notebook with the output. Make a large note at the top if you are not able to include your data due to size.

Needs to contain narrative and code that demonstrates acquisition, cleaning, and exploratory analysis of your dataset.

Submission still single Jupyter notebook + individual feedback forms

Final Project Submission

For your final project you must complete the analysis in your notebook and present your results in a compelling way. We recommend you include revised versions of all the sections from your proposal (except for the Project Schedule) *along with* the results of your analysis, the limitations of your analysis, and your conclusions from your data analysis.

Like the previous milestones, you should submit as a zip file containing a Jupyter notebook and any supporting documents. the Jupyter notebook should contain all the narrative and code. Do no submit a separate document with the write up from the Jupyter notebook.

Like with the assignments, submit the Jupyter notebook with the output. Make a large note at the top if you are not able to include your data due to size.

Project Screen-Cast

You must include a **three minute video including audio walking us through your project**. Each team will create a **three minute screen-cast with narration** showing a demo of your project and/or some slides. You can use any screencast tool of your choice. Please make sure that the sound quality of your video is good. Upload the video to an online video-platform such as YouTube or Vimeo and link to it from your notebook.

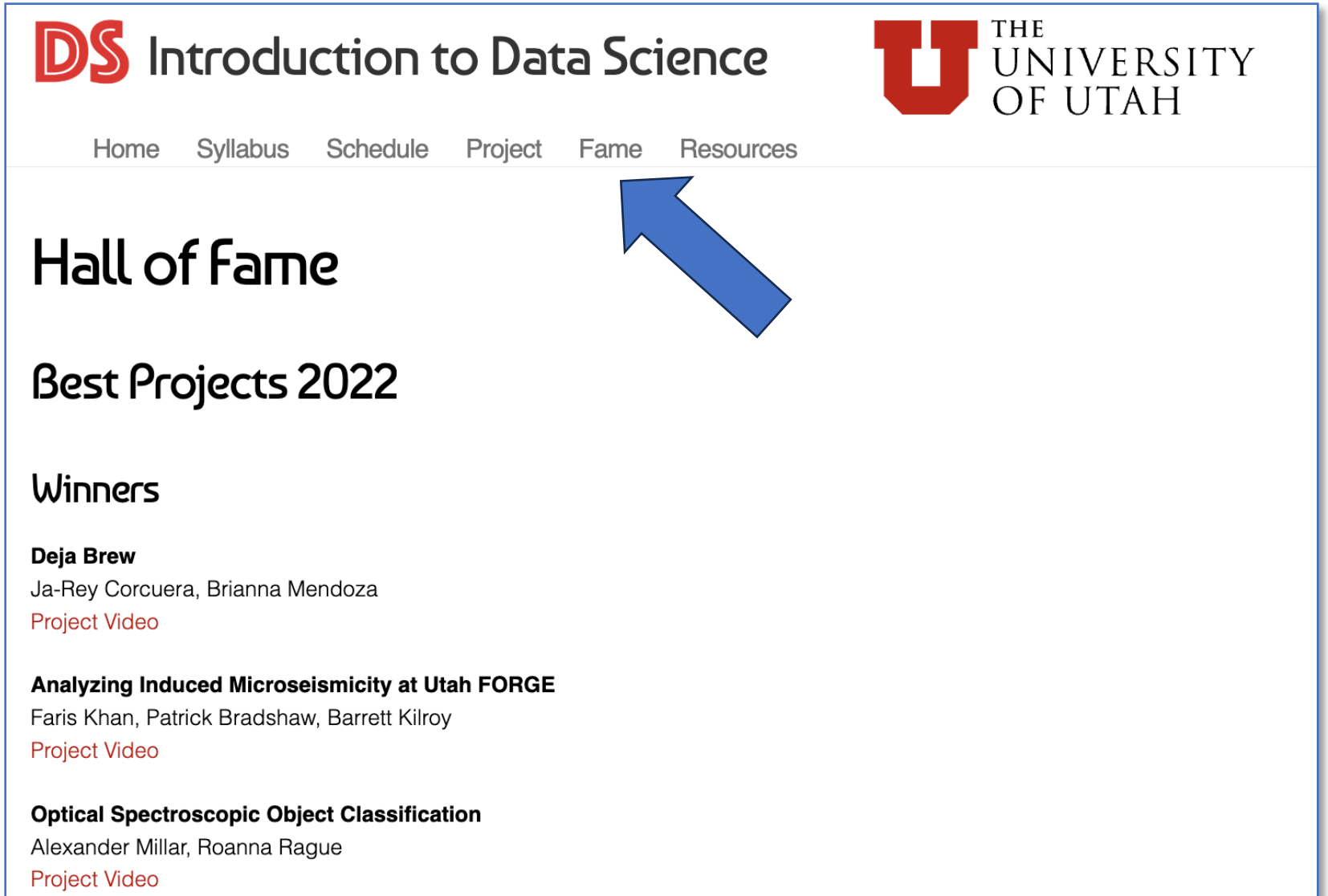
Present your analysis questions and your main contributions, but also explain your methods and justify your choices. What do you feel is the best part of your project? What insights did you gain? What is the single most important thing you would like your audience to take away?

We will strictly enforce the three minute time limit for the video, so please make sure you are not running longer. Use principles of good storytelling and presentations to get your key points across. Focus the majority of your screencast on your main contributions rather than on technical details. What do you feel is the best part of your project? What insights did you gain? What is the single most important thing you would like your audience to take away? Make sure it is front and center rather than at the end.

Full narrative of the project, including your analyses, your conclusions, and a narrative of the whole project (within the notebook & the movie)

Submission is the Jupyter notebook, individual feedback, + a video & screencast

Example Projects on Course Website



**Some groups smaller than three because we had more Staff back then.*

Please scale up your project accordingly.

Group Work Expectations

Be responsive to your teammates

- Communicate regularly, status updates help:
  - “I can’t make it today, but I have done X, Y, and Z and put it in the shared Drive.”
  - “I have work at that time, but I’ll get you A and B before the meeting.”
  - “Sorry I’m behind but I will have it to you by DATETIME.”
    - …and if that doesn’t work for your team, they can move on without you.
- If a teammate has not responded in 48 hours, you may move on without them. Please let the course staff know.

Recognize that “glue work” takes time

- Your teammates can’t add your work at the last minute. It takes time to integrate it. If they don’t have time to integrate it, you can’t get credit for it.
- Glue work is work. It is a contribution to the project.

Handling Group Work Issues

If problems arise, let the course staff know early.

- We can't go back in time and change assignment grades
- We don't always adjust grades when something is reported
- If someone didn't contribute at all, they will get a zero
- We can't share with you any individual student's grade but your own

Worried about hard feelings? Communicate directly rather than staff.

- "I don't feel work was evenly distributed in the proposal. [Details]. How can we divide it better in the next milestone?"
- "I scrambled to integrate your work at the last minute but I can't do that in the next milestone."

Worried your work isn't recognized? Use version control (git, etc)

- Version control through git or other platforms can keep a history of the work you did. We will review if there are discrepancies.

…back to Visualization

The purpose of computing is insight, not numbers.

- Richard Wesley Hamming

The purpose of visualization is insight, not pictures.

- Card, Mackinley, & Shneiderman

What is visualization?

One definition:

Visualization is the process that ***transforms*** *(abstract)* ***data*** *into* ***interactive graphical representations*** *for the purpose of* ***exploration***, ***confirmation***, *or* ***presentation***.

Good Data Visualization…

…makes data accessible

…combines the strengths of humans and computers

…enables insight

…communicates

Why Visualization?

To inform humans about complex situations:

Communication

What is the state of the election polls?

Why Visualization?

To inform humans about complex situations:

Communication

What is the state of the election polls?

When questions are not well defined:

Exploration

What is the structure of the scammer network?

Which drug can help my patient?

Is this data even right?

Why Visualization?

To inform humans about complex situations:

Communication

(when you know the data and want to share with others)

What is the state of the election polls?

When questions are not well defined:

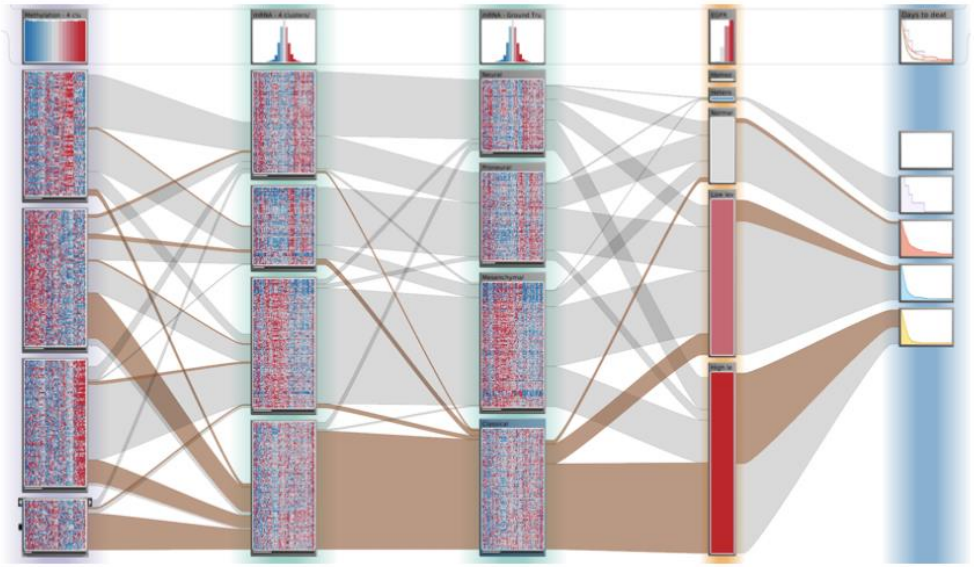
Exploration

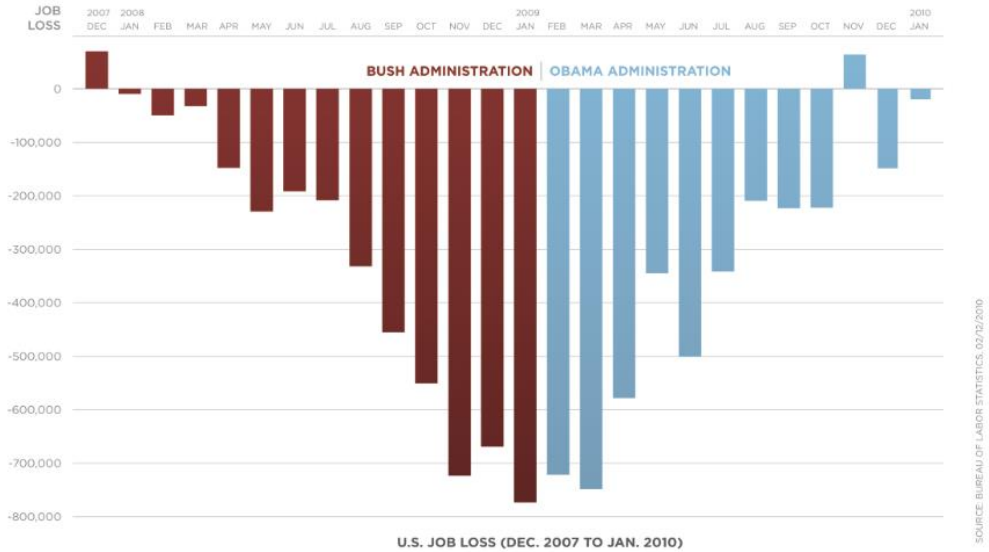
(when results and questions are unknown)

What is the structure of the scammer network?

Which drug can help my patient?

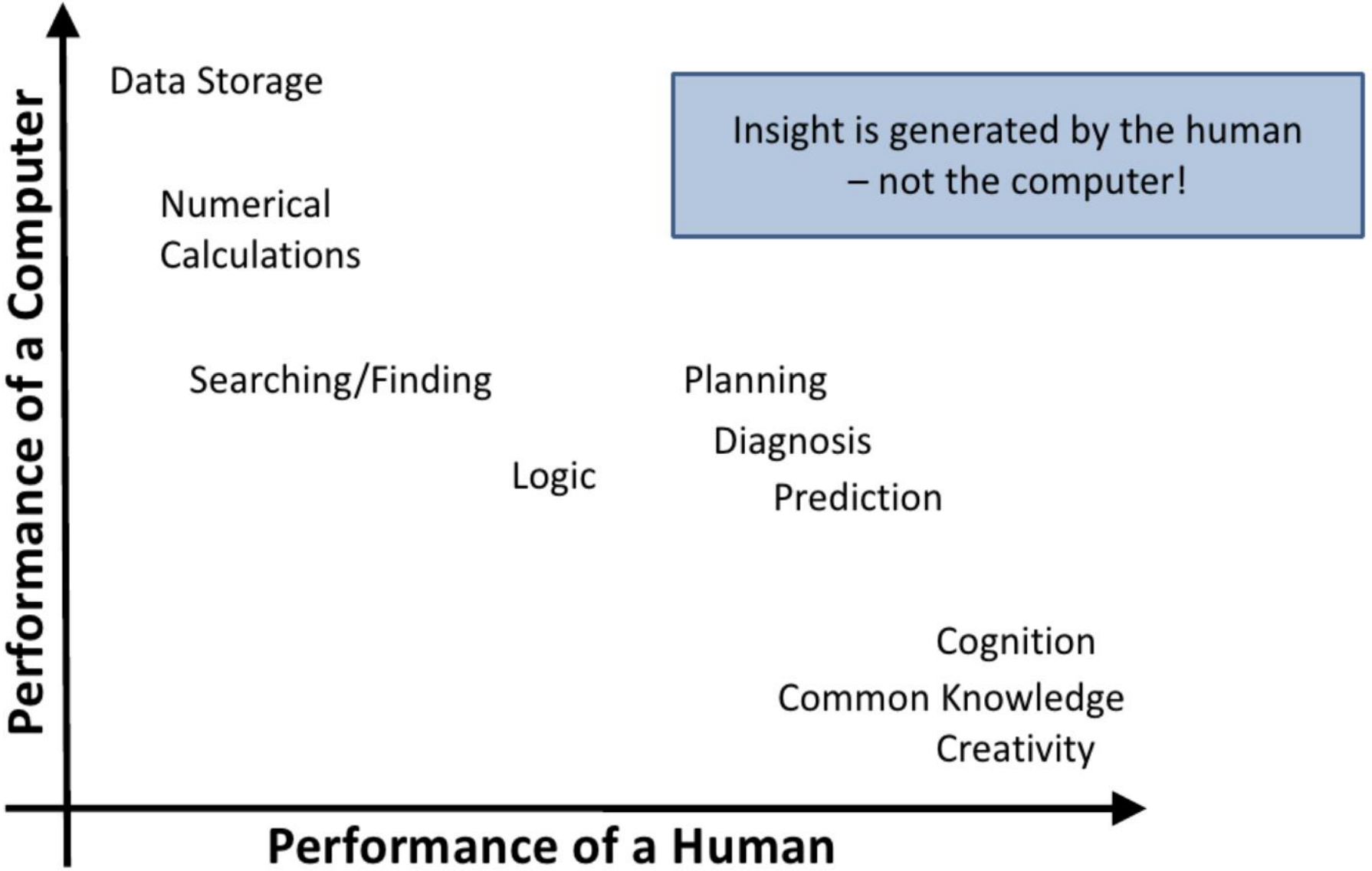
Is this data even right?



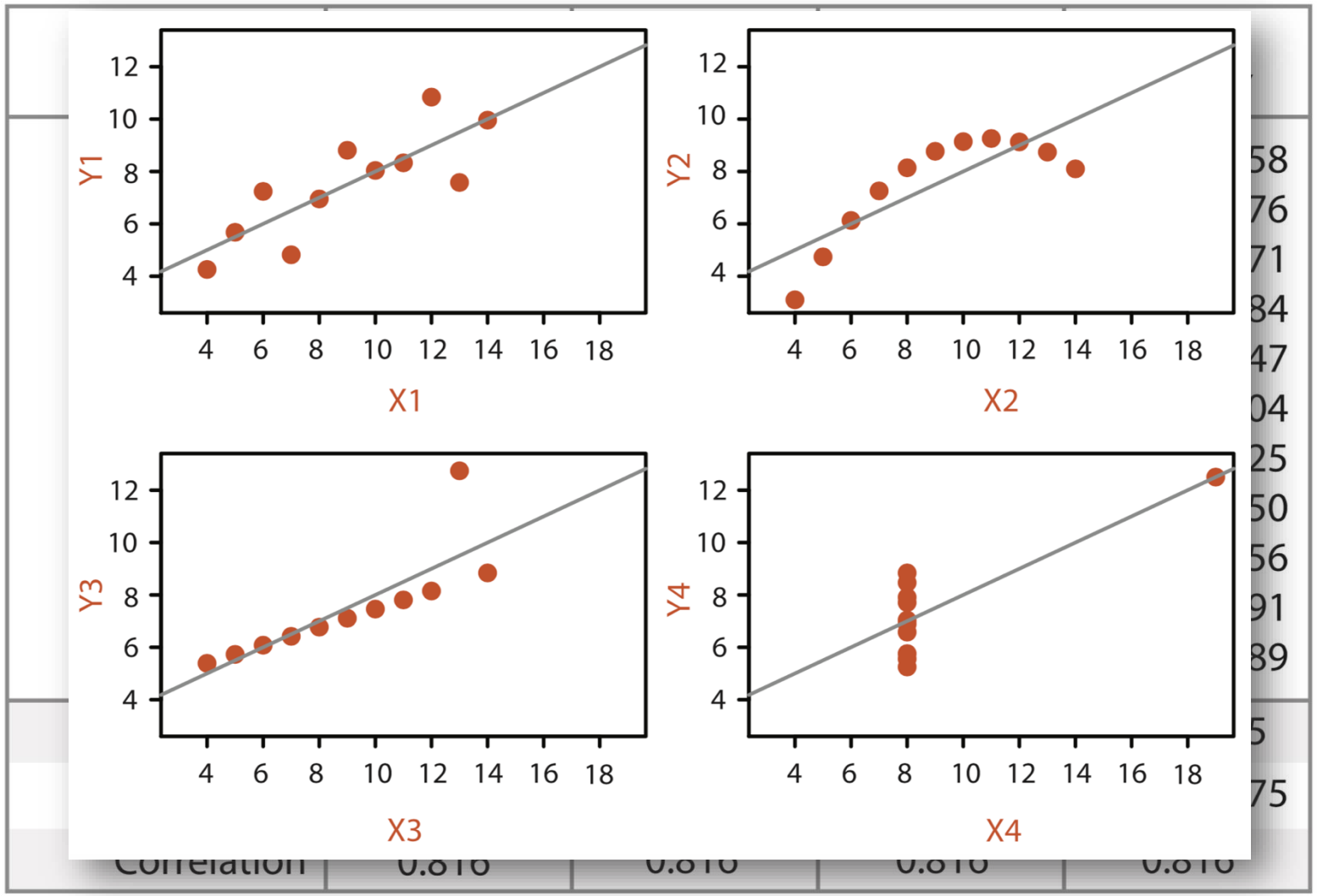


Open Exploration — Confirmation — Communication

Ability Matrix



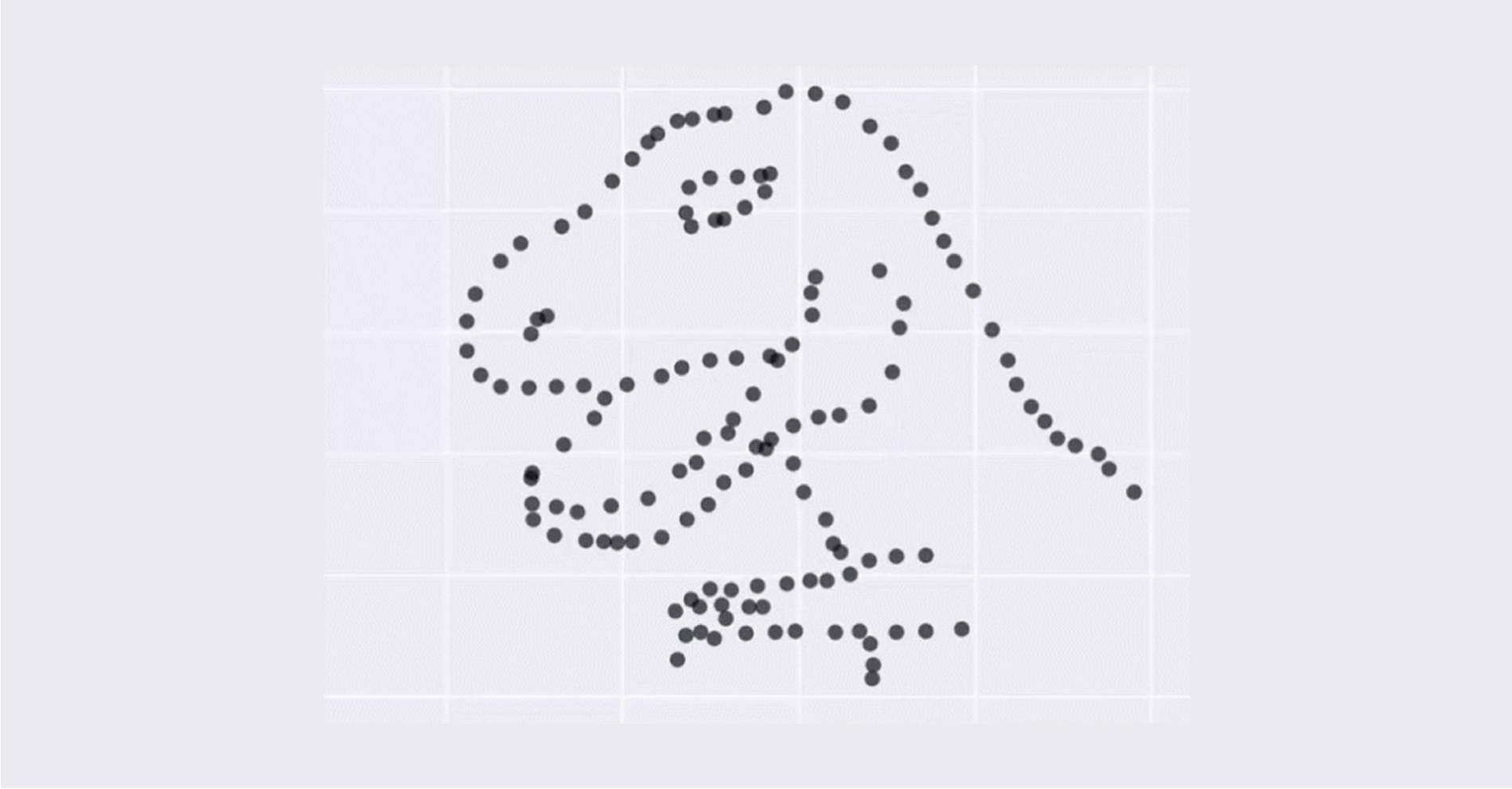
Why Visualization?



Sometimes summary statistics don't tell the full story.

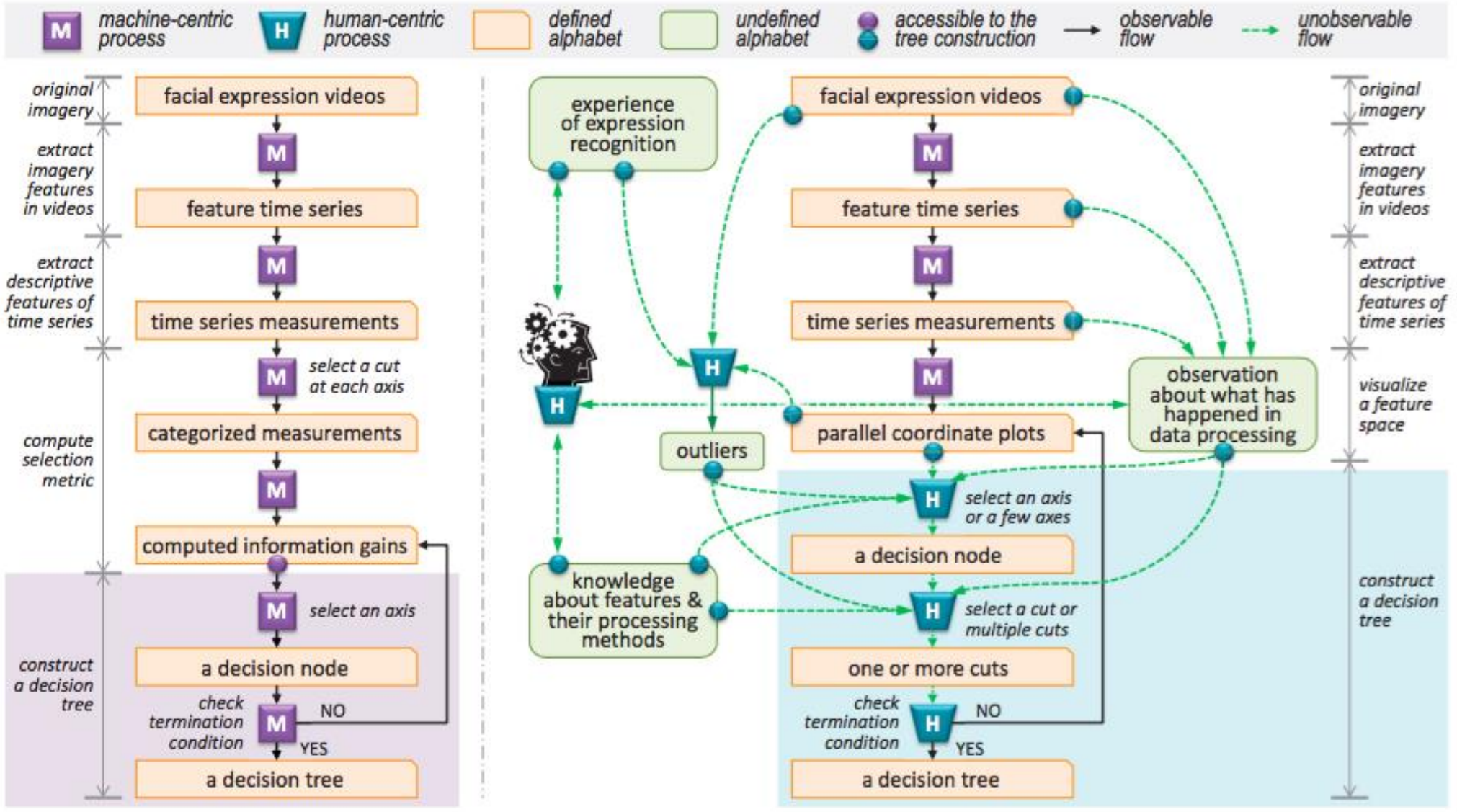
Anscombe's Quartet figure from ***Visualization Analysis and Design***, Tamara Munzner

Why Visualization?



The Datasaurus Dozen of "**Same Stats, Different Graphs: Generating Datasets with Varied Appearance and Identical Statistics through Simulated Annealing**", Justin Matejka, George Fitzmaurice

Why Visualization?



Humans have access to information and context that pure automated methods don't.

From ***An Analysis of Machine- and Human-Analytics in Classification***, Lam et al. 2017

What can visualization do?

- Answer vague questions
- Answer multiple questions simultaneously
- Help generate new questions
- Help generate hypotheses
- Help find patterns
- Act as external memory
- Communicate to others
- Help “debug” your data
- Explain to others
- Please and delight

Visualization is…

Human Data Interaction

Visualization in the Data Science Process

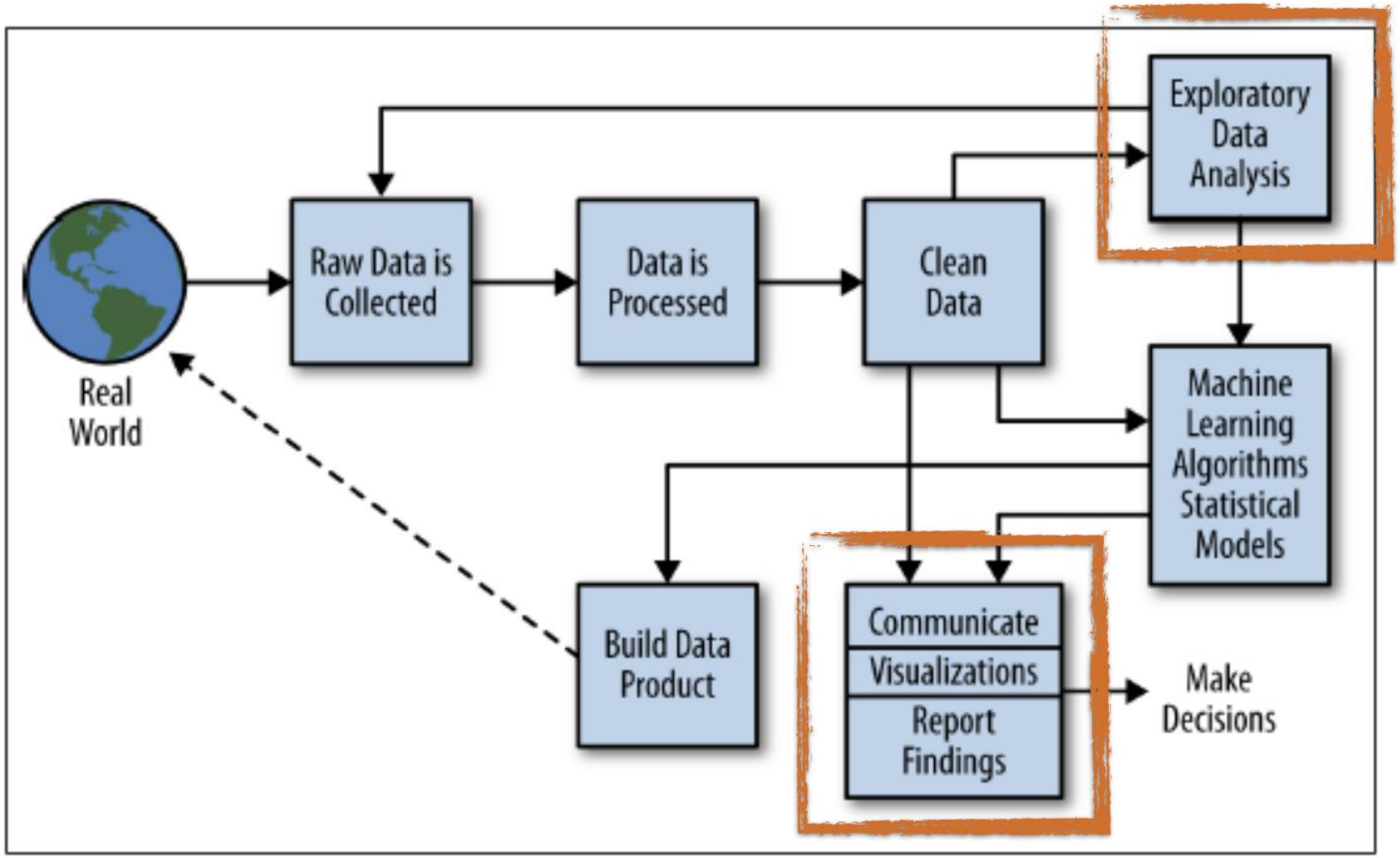
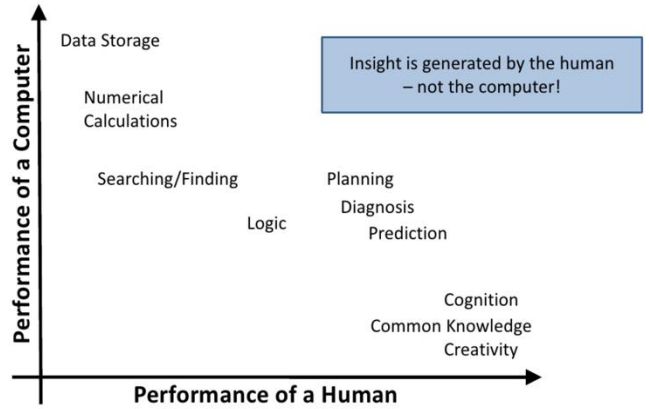


Figure 2-2. The data science process

Why Humans?



Leverage human capabilities:

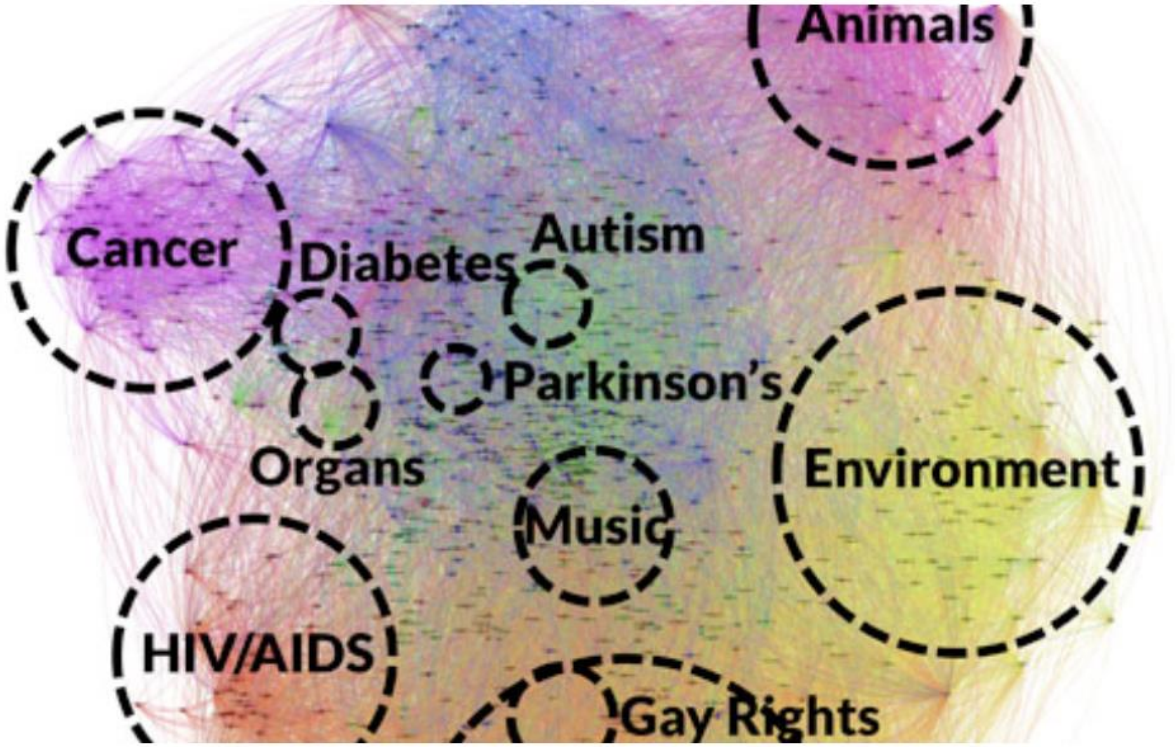
Pattern discovery: clusters, outliers

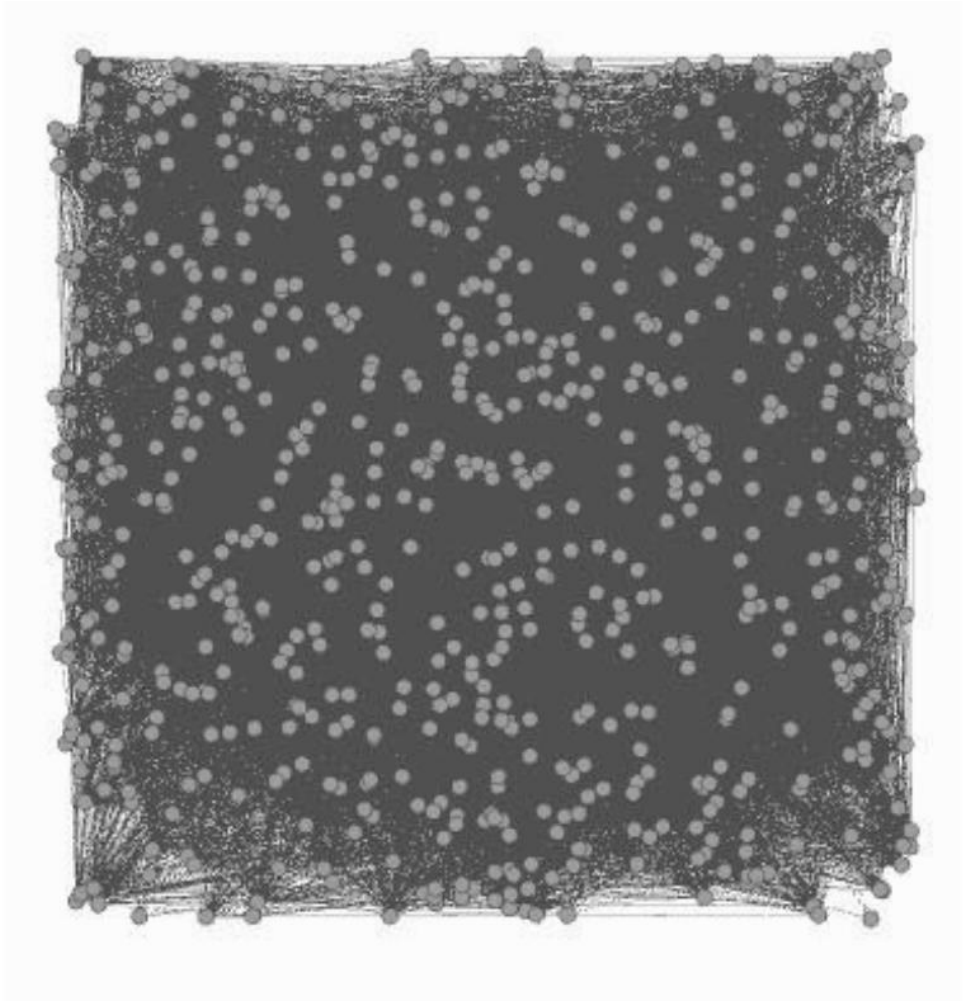
Contextual knowledge: expectations, explanations of patterns

Action: humans learn and take action

Because humans, we also have to ***design for humans their limitations***.

Just because we can draw it doesn't mean a human can read it.





What insight do we get from these?

Describing Visualizations

Marks & Channels

Marks, Channels, & Encoding

Encoding: Map data to visual structure

Marks: Graphical primitives that encode items / entities

Channels: Properties of mark appearance, often used to encode attributes or other information

Marks, Channels, & Encoding

Seem familiar?

Encoding: Map data to visual structu

Marks: Graphical primitives that enc

Channels: Properties of mark appea
attributes or other information

```
# Create a visualization
sns.relplot(
    data=tips,
    x="total_bill", y="tip",
    hue="smoker", size="size",
)
```

```
alt.Chart(movies_genre).mark_tick().encode(
  x='AvgRating'
)
```

Encodings

The next step is to add *visual encoding channels* (or *encodings* for short) to the chart. An encoding channel specifies how a given data column should be mapped onto the visual properties of the visualization. Some of the more frequently used visual encodings are listed here:

- `x` : x-axis value
- `y` : y-axis value
- `color` : color of the mark
- `opacity` : transparency/opacity of the mark
- `shape` : shape of the mark
- `size` : size of the mark
- `row` : row within a grid of facet plots
- `column` : column within a grid of facet plots

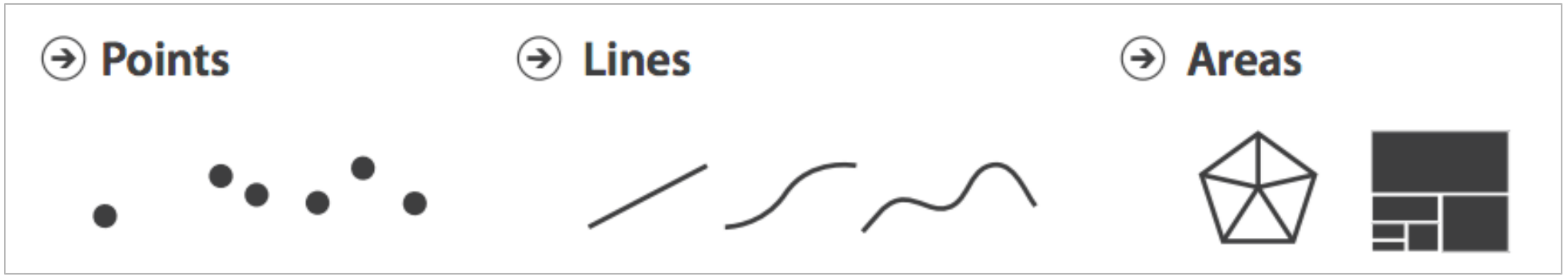
For a complete list of these encodings, see the Encodings section of the documentation.

Visual encodings can be created with the `encode()` method of the `Chart` object.

```
alt.Chart(movies_genre).mark_point().encode(
  y='AvgRating', size="Watches"
```

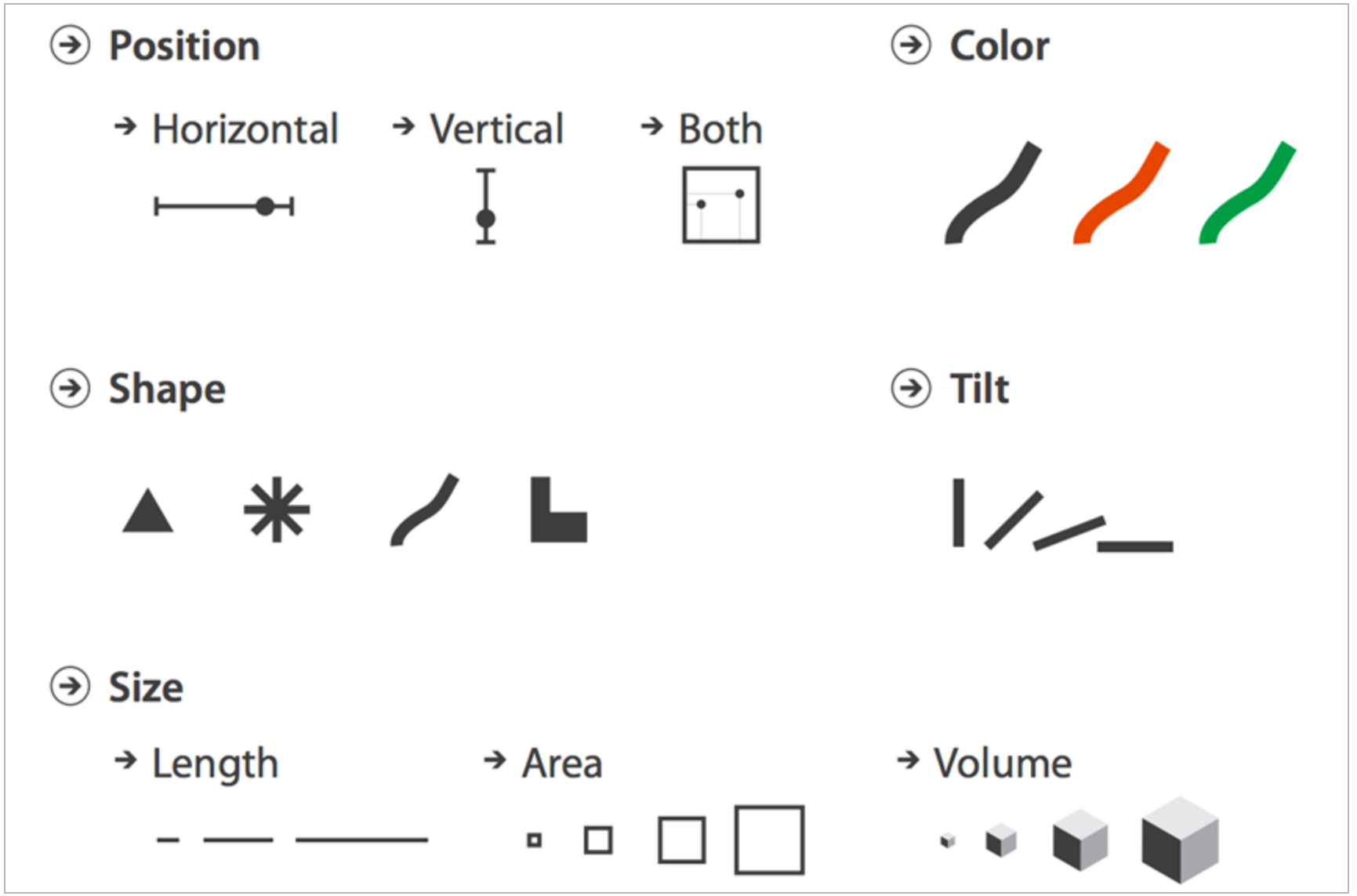
Marks, Channels, & Encoding

Marks: Graphical primitives that encode items / entities



Images from Munzner, Visualization Analysis and Design

Channels: Properties of mark appearance, often used to encode attributes or other information

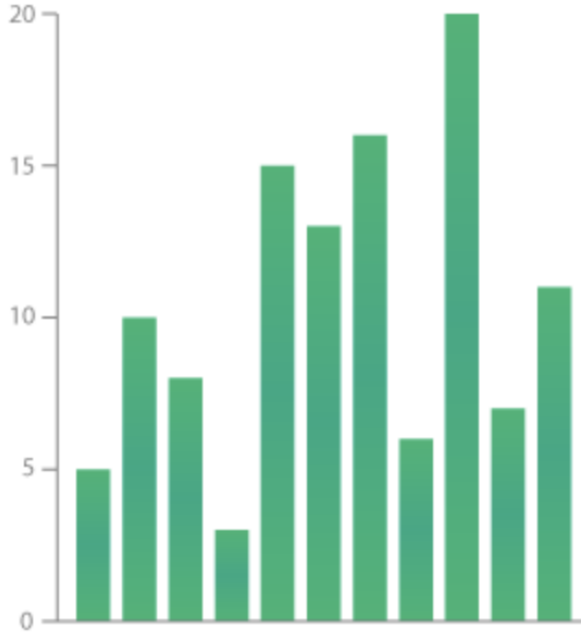


Images from Munzner, Visualization Analysis and Design

What are the marks & channels of…

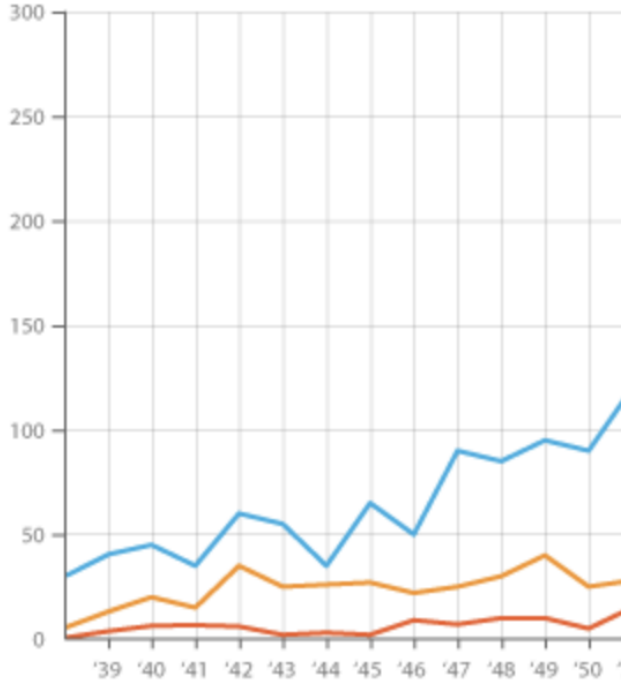
Pie Chart

Marks: Wedge
Channels: Color, Angle (not Area, not Size!)



Bar Chart

Marks: Rectangle
Channels: x-position, Length



Line Chart

Marks: Line (Path)
Channels: x,y-positions, Color

Images from datavizcatalogue.com

Expressiveness & Effectiveness

Expressiveness Principle: Encoding should express all of, and only, the information in the data

- Example: Don't imply order where this is not but imply order where there is

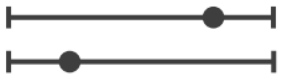
Effectiveness Principle: The more important the data/attribute, the more **salient** the encoding should be

- Important things should be noticeable

From Munzner, Visualization Analysis and Design

Magnitude Channels: Ordered Attributes

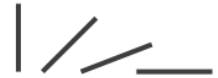
Position on common scale



Position on unaligned scale

Length (1D size)

Tilt/angle



Area (2D size)

Depth (3D position)

Color luminance

Color saturation

Curvature

Volume (3D size)

Identity Channels: Categorical Attributes

Spatial region

Color hue

Motion

Shape

Choosing channels…

Images from Munzner, Visualization Analysis and Design

Loved & Dangerous – The Color Channel

Magnitude Channels: Ordered Attributes

Position on common scale

Position on unaligned scale

Length (1D size)

Tilt/angle

Area (2D size)

Depth (3D position)

Color luminance

Color saturation

Same

Effectiveness

Most

Identity Channels: Categorical Attributes

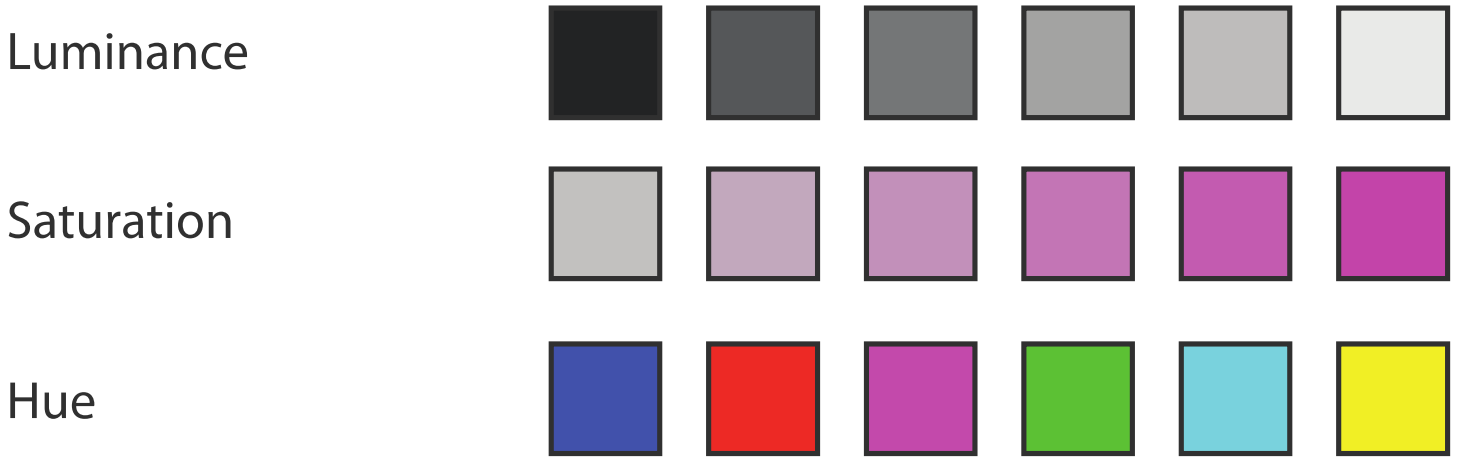
Spatial region

Color hue

Motion

Shape

Which has order? Which doesn't?



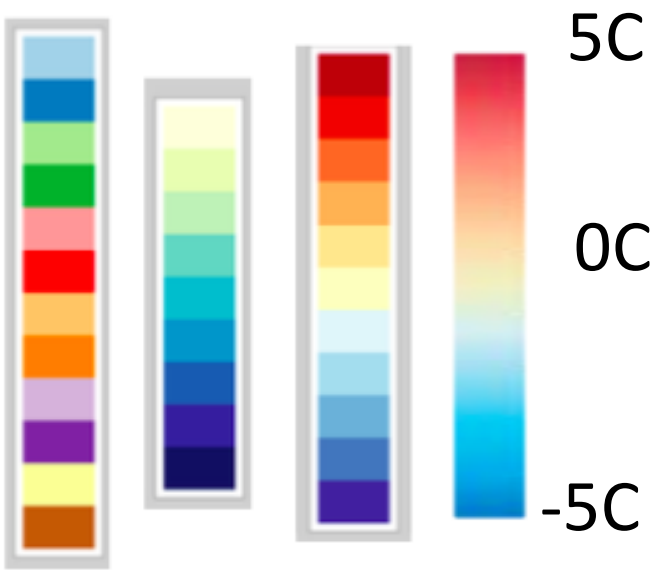
Vary the appropriate dimension depending on your data type

Ramps from Munzner, Visual Analysis and Design

Color maps specify a mapping between color and value

If you are using color to encode a value, you should include a representation of the color map.

Don’t forget to label their meaning!



Images from Josh Levine

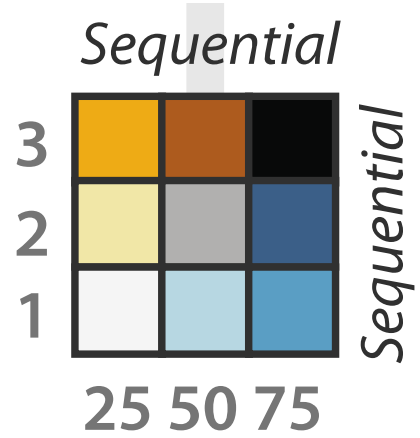
Color map axes: Design color map to match the attribute(s) you are encoding

Categorical vs. Ordered

Diverging vs. Sequential

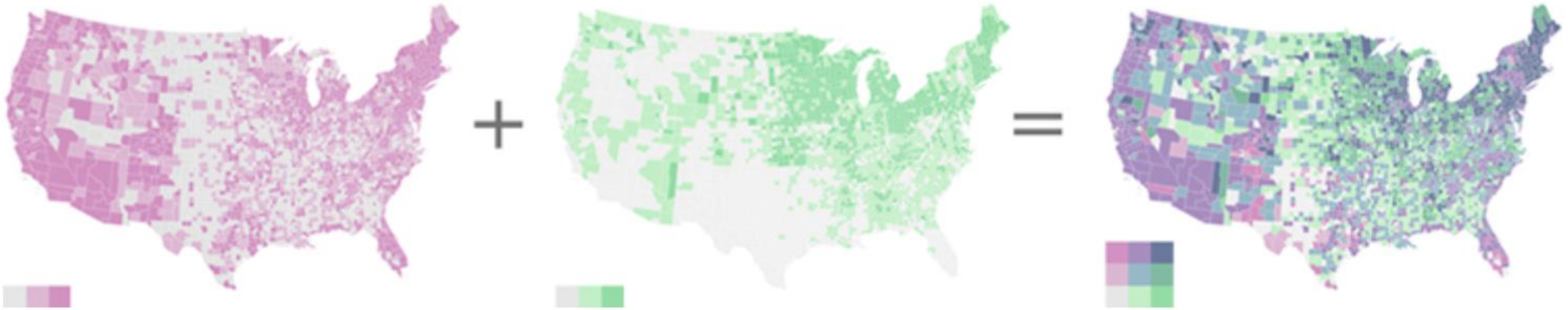
Segmented vs. Continuous

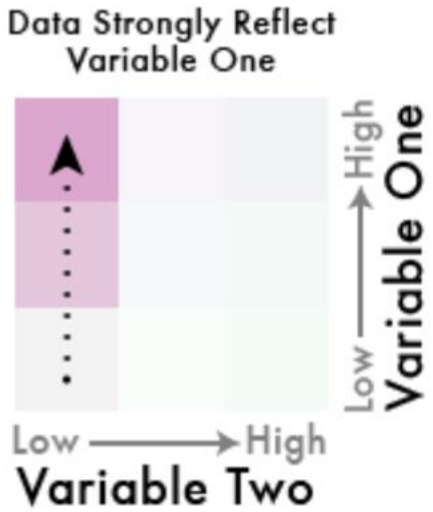
Univariate vs. Bivariate

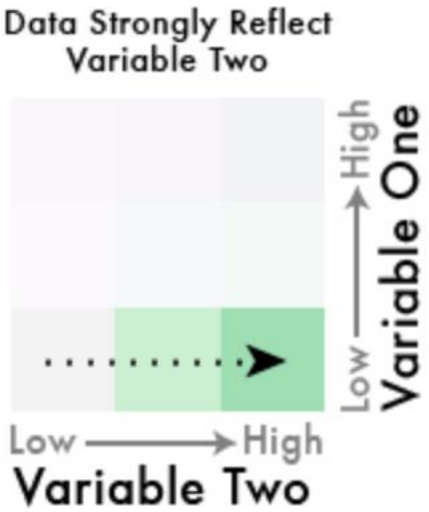


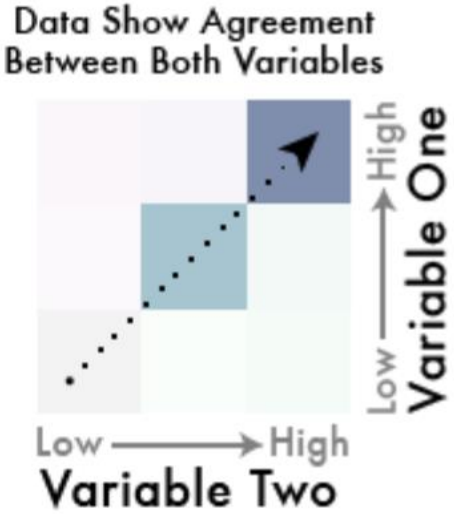
Adapted from Josh Levine

Bivariate Example





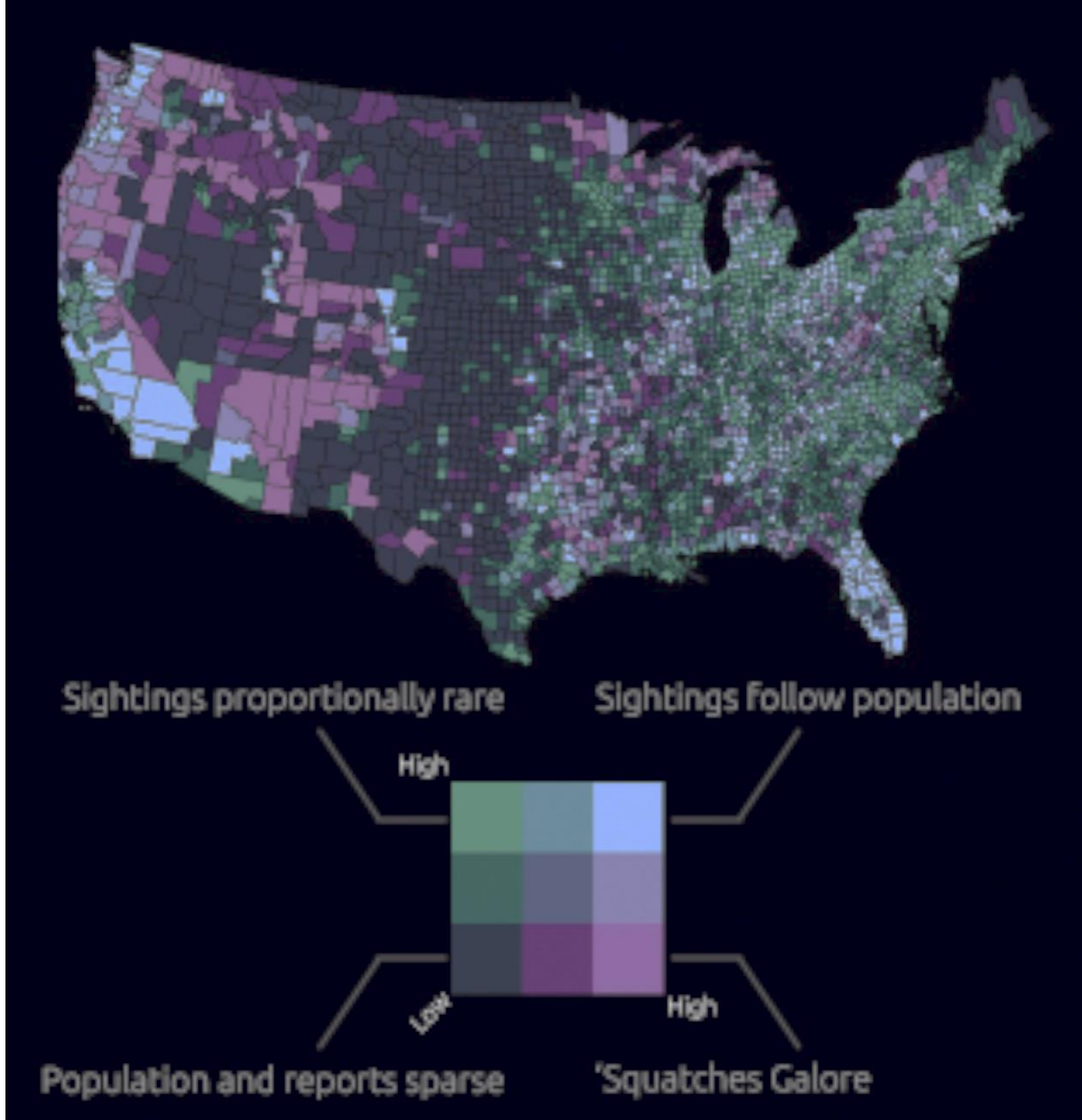




From josuhuastevens.net

Bivariate Example

Population
&
Sasquatch (BigFoot) Sightings



…not so easy to read.

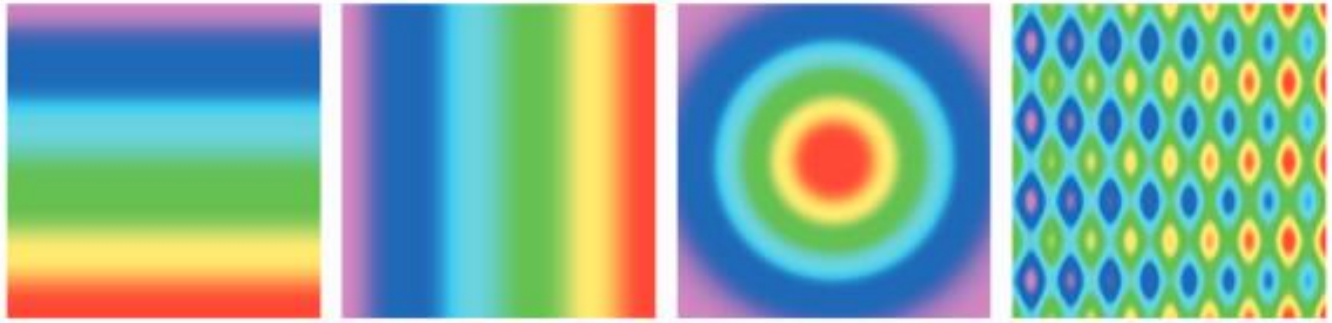
Consider also using
hue/lightness,
hue/thickness of border,
hue + mark&channel…

From josuhuastevens.net & Ware, Information Visualization

The Dangers of Rainbows

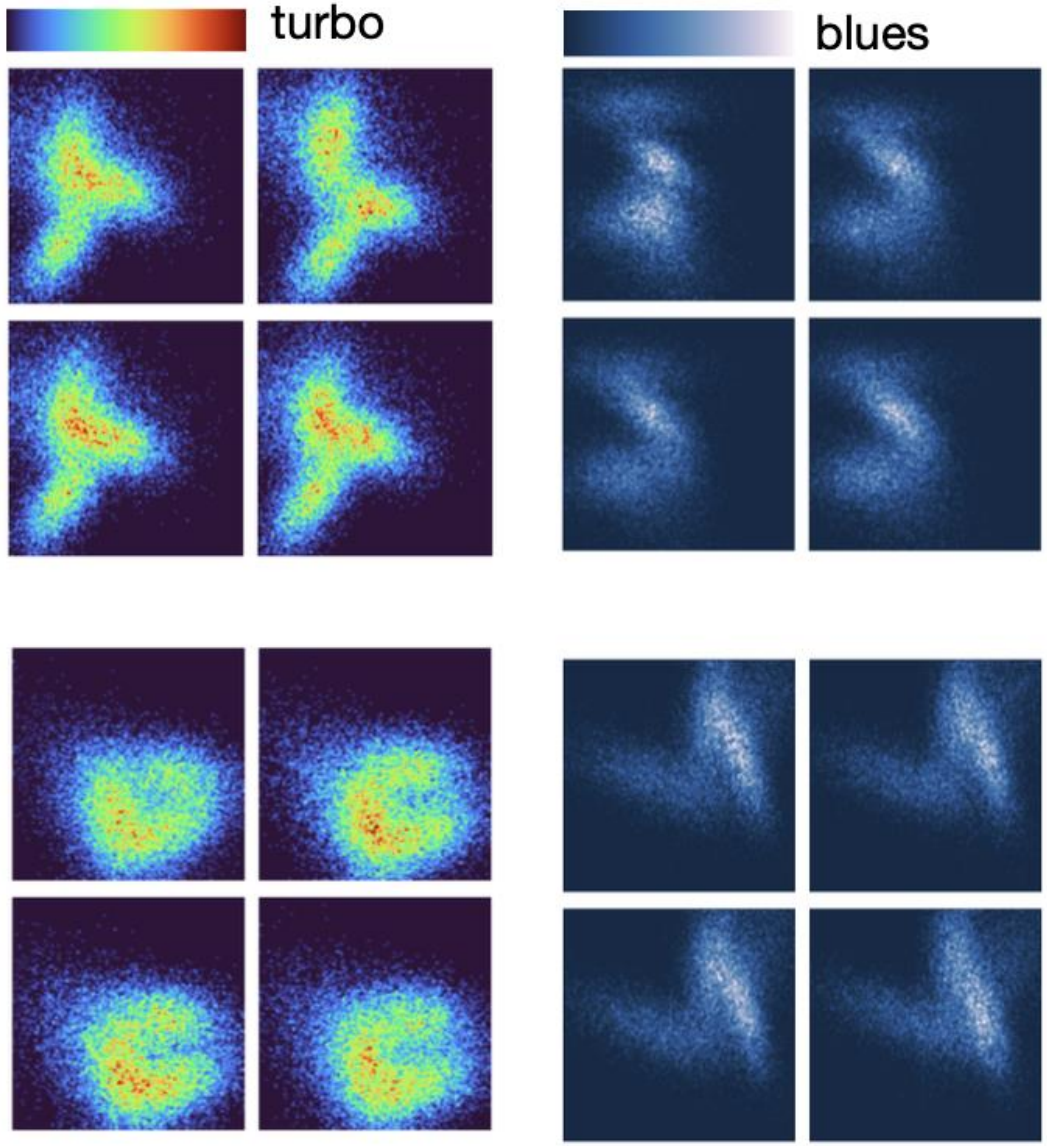
The common rainbow color map is often a poor choice due to:

- Lack of perceptual linearity
- Using hue for ordering
- Using hue for fine-grained detail



Munzner, Visualization Analysis and Design, with images from slides of Josh Levine (left) from "Rainbow Color Map (Still) Considered Harmful" (right)

The Dangers of Dismissing Rainbows



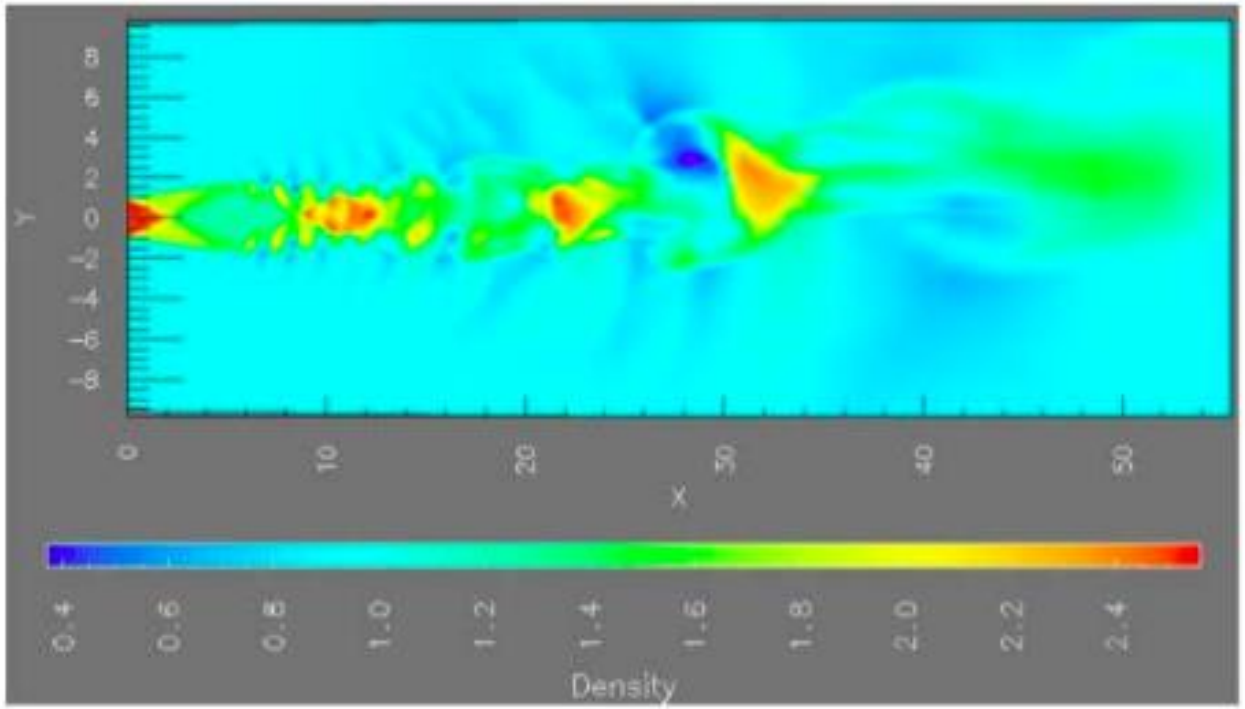
Some rainbow color maps may be helpful even in continuous tasks.

- Some tasks may benefit from the ability to name colors

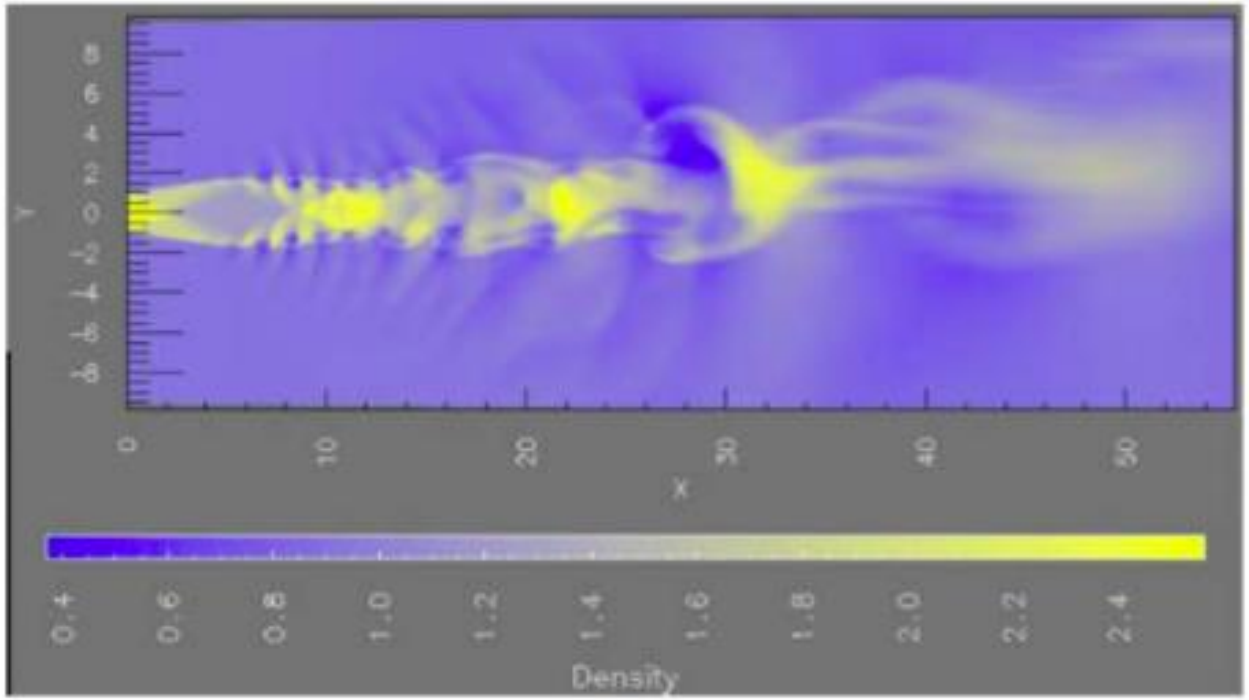
- Detection of false features may not be as pervasive as we thought

From “Rainbows Revisited: Modeling Effective Colormap Design for Graphical Inference” Reda and Szafir, 2021

Different color maps are good for different insights



(a)



(b)

Figure 10.11. Rainbow versus two-hue continuous colormap. (a) Using many hues, as in this rainbow colormap, emphasizes mid-scale structure. (b) Using only two hues, the blue–yellow colormap emphasizes large-scale structure. From [Bergman et al. 95, Figures 1 and 2].

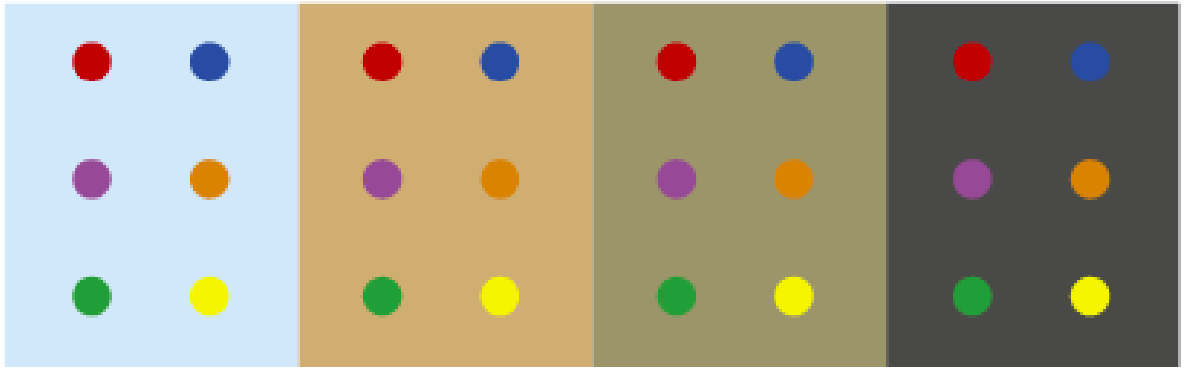
Figure/caption from Munzner, Visualization Analysis and Design

Categorical Data: Color Categories & Naming

- We can only quickly differentiate 5-10 colors. Limit categorical use of color.
  - With work we can do more, but best not to rely on it
  - May assign colors hierarchically
- Pick colors we can differentiate by name, especially in collaborative contexts
  - e.g., dark blue & light blue, dark red & light red, etc.

Ware, Information Visualization: Perception for Design

Color Perception is Relative

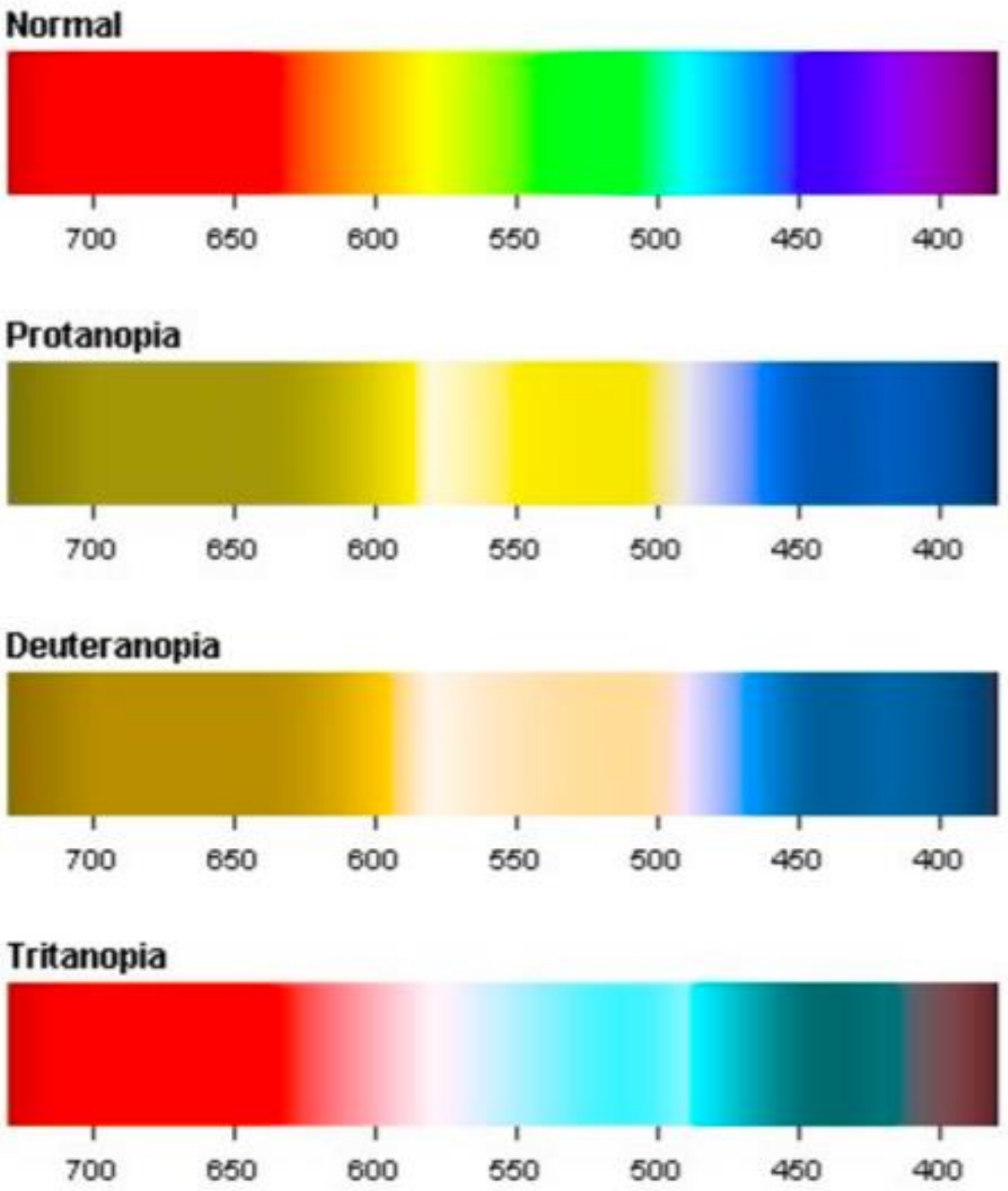


What happens when you take off tinted goggles?

- To avoid contrast issues with background, surround points with white or black lines.
- Make sure colors do not have same luminance as background

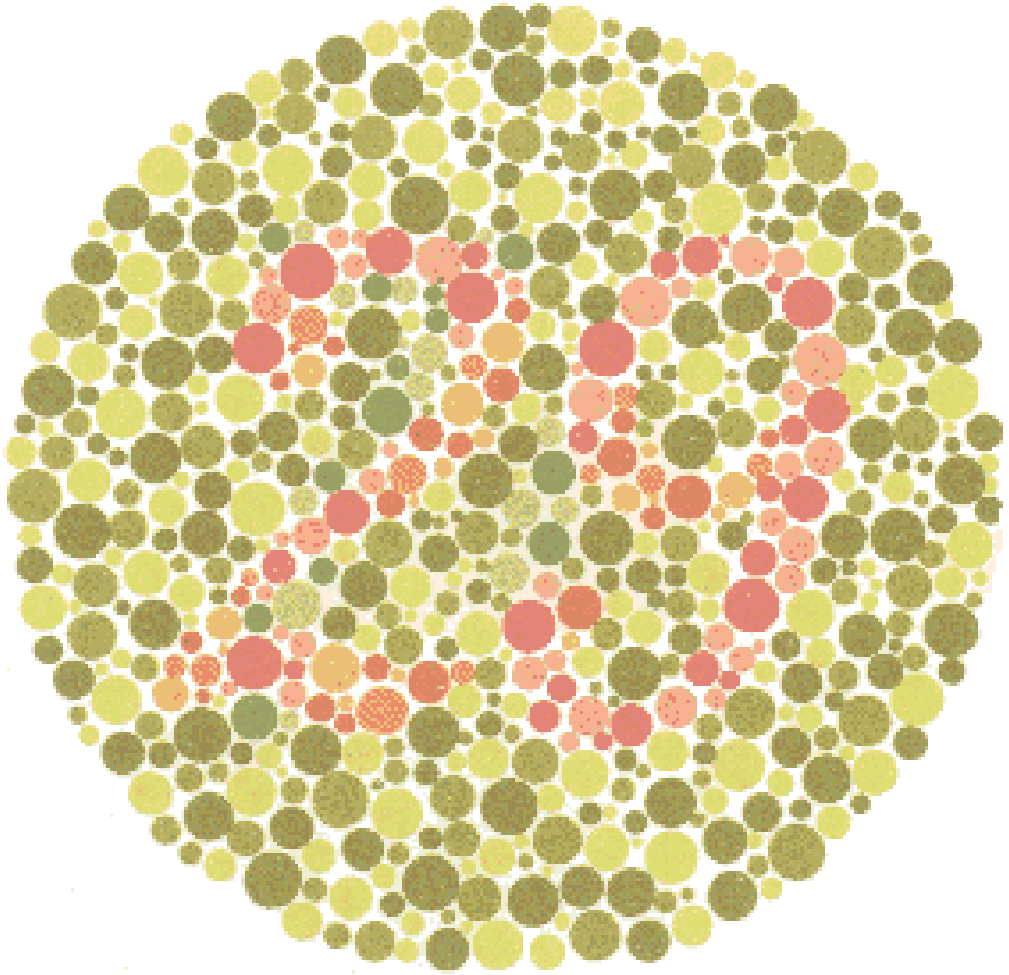
Ware, Information Visualization: Perception for Design

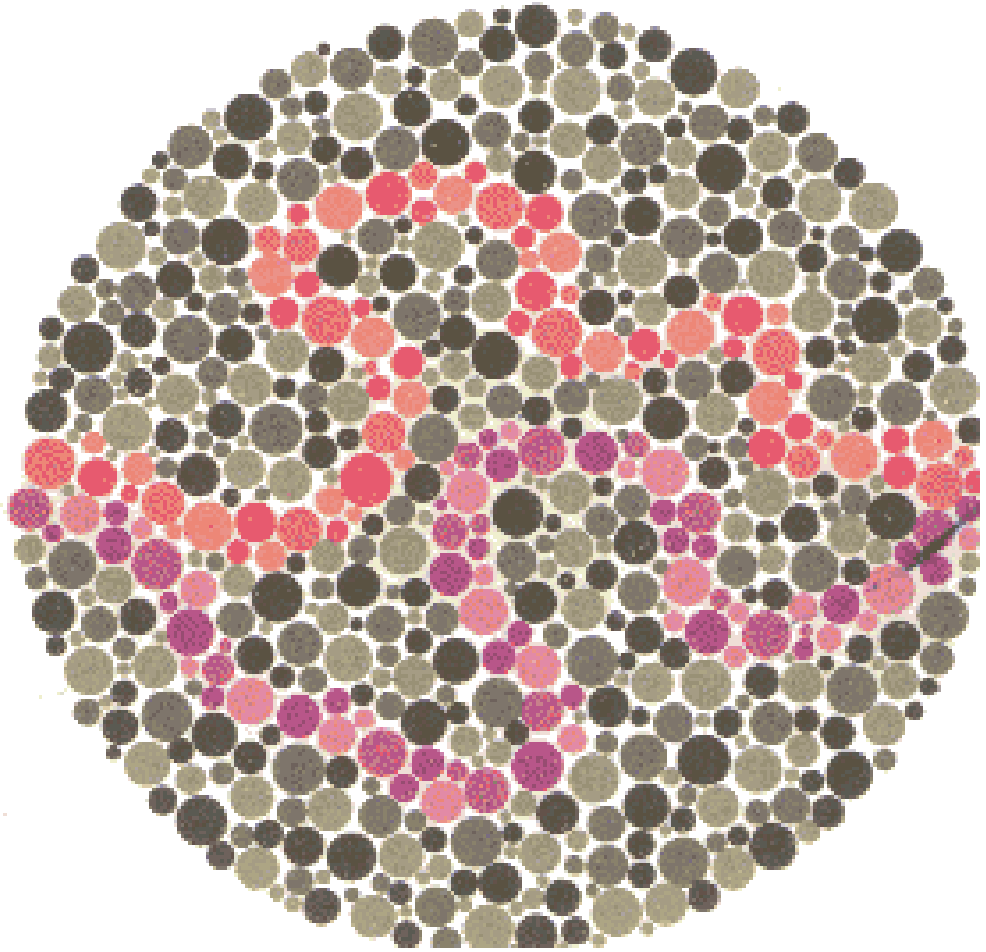
Color Vision Deficiencies affect ~7% of the population



Slide adapted from Carlos Scheidegger

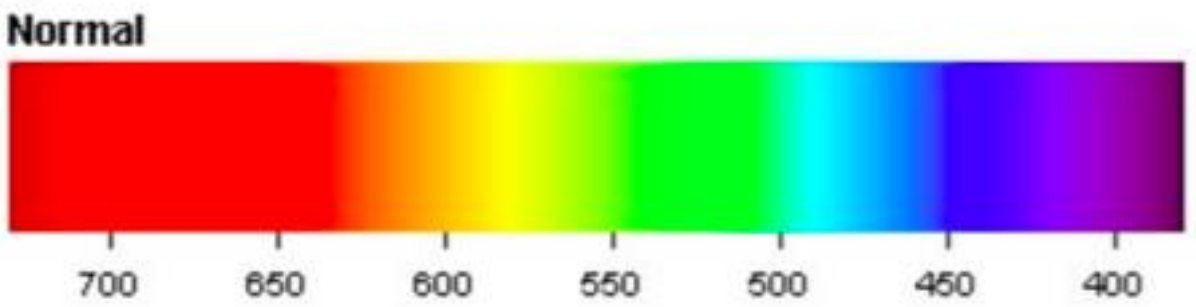
Ishihara Plates are used to test for Color Vision Deficiencies

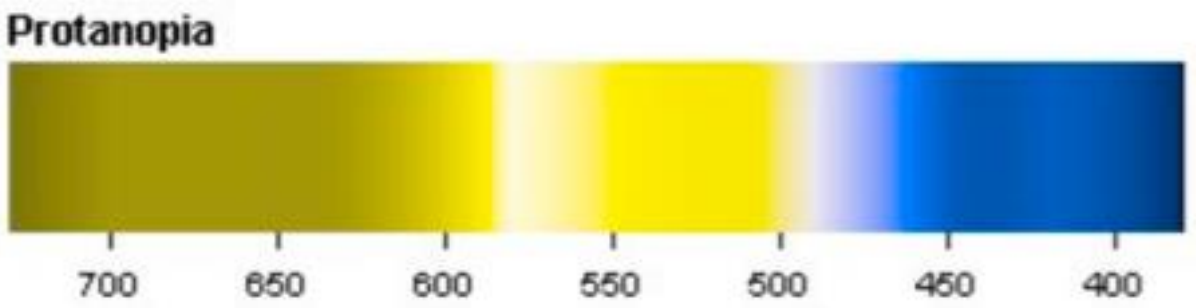


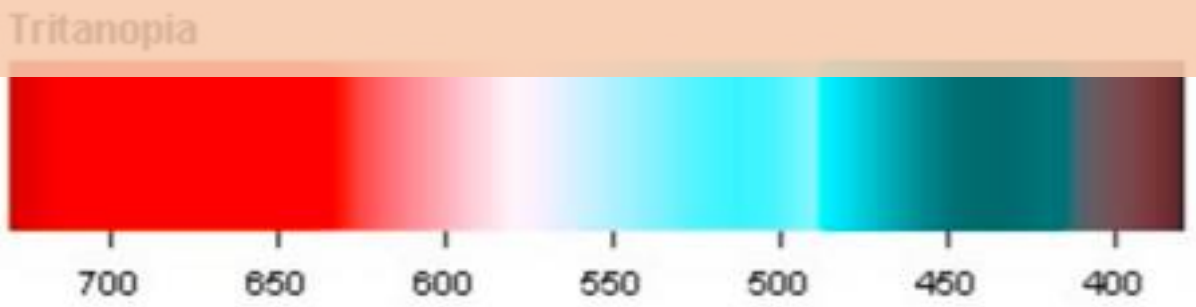


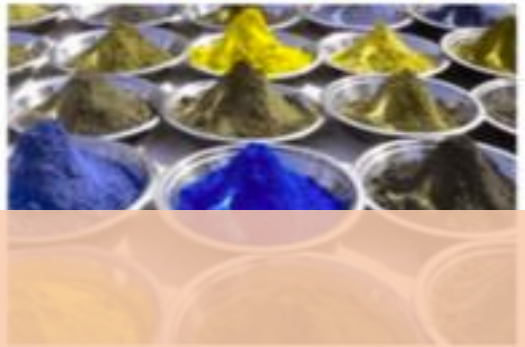
Slide adapted from Carlos Scheidegger

Color Vision Deficiencies affect ~7% of the population





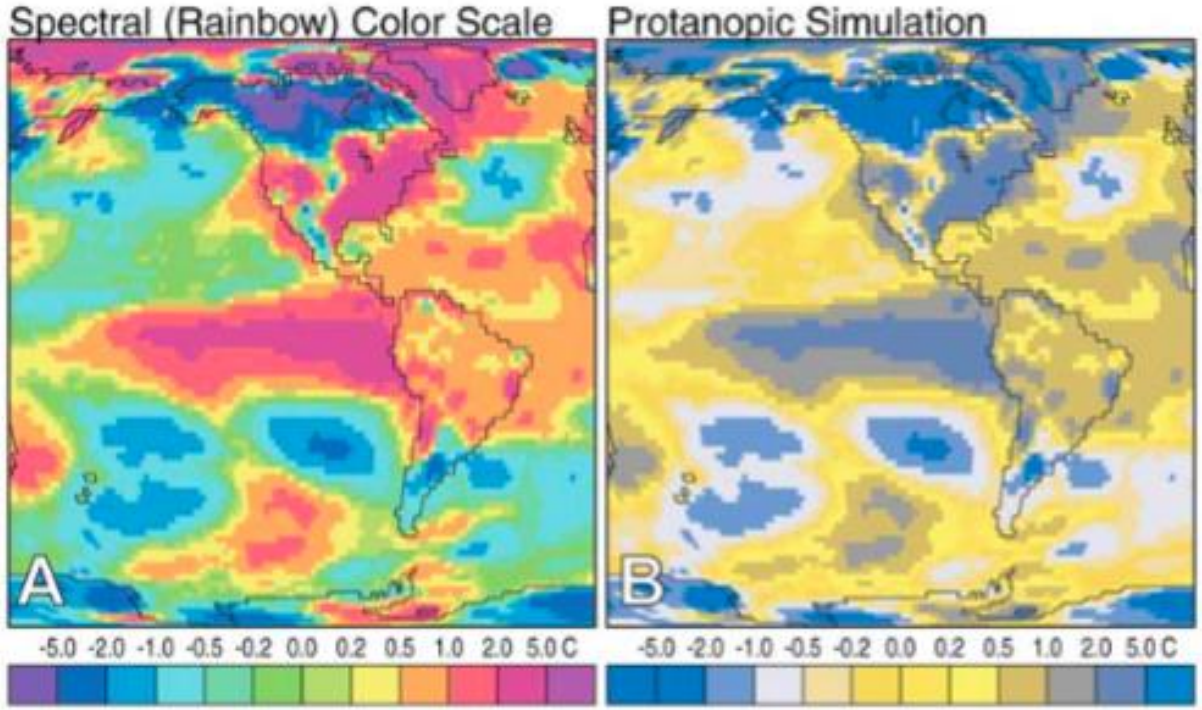




…but which 7%?

Slide adapted from Carlos Scheidegger

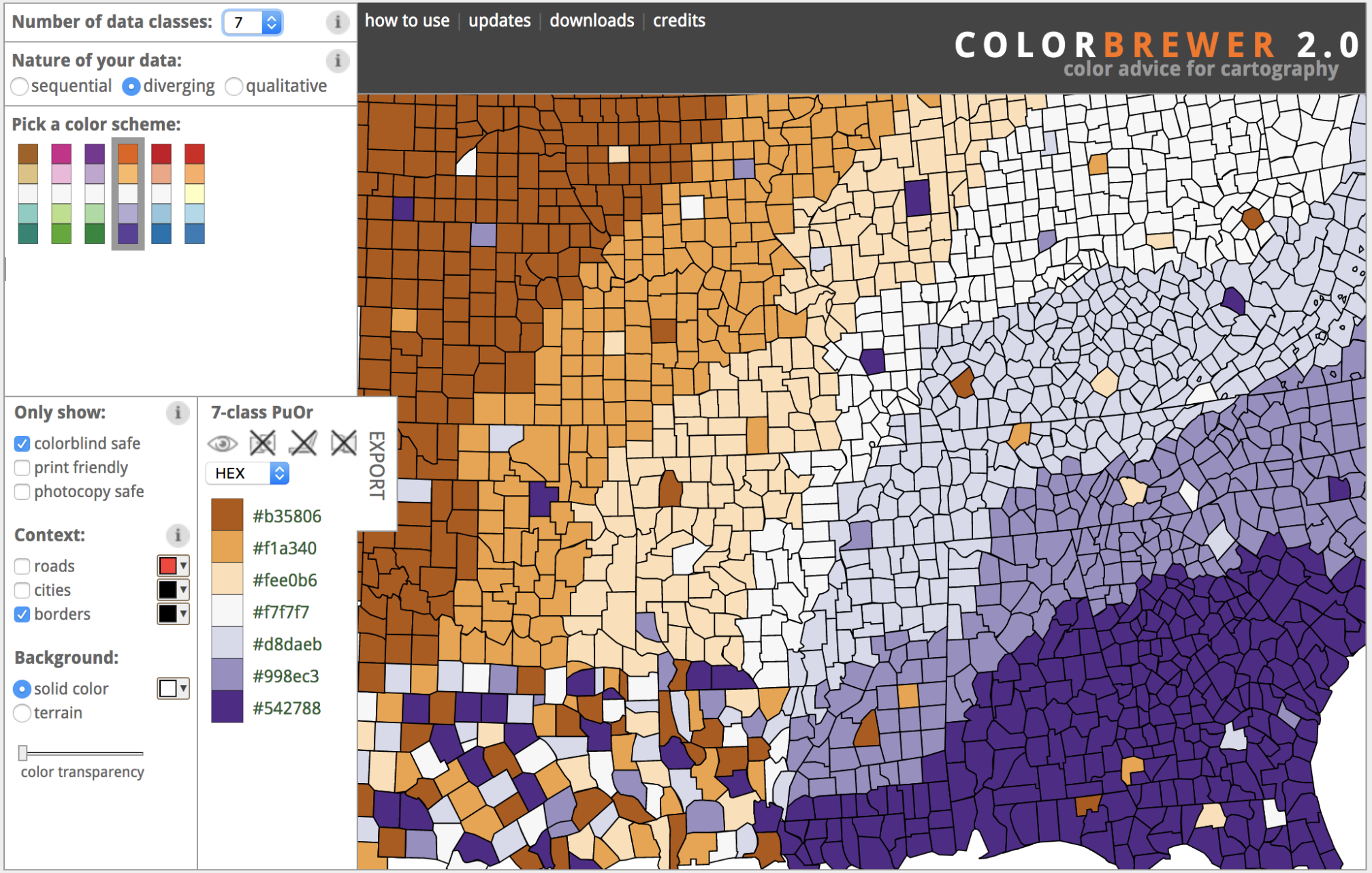
Rainbow Colormap & Color Vision Deficiency



Guideline: "Get it right in black and white"

Adapted from Josh Levine, from Light & Bartlein 2004

Many online resources for CVD-friendly color maps



Source code and feedback
Back to Flash version
Back to ColorBrewer 1.0

axismaps

Guideline: Use color deliberately & sparingly

Magnitude Channels: Ordered Attributes

- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation

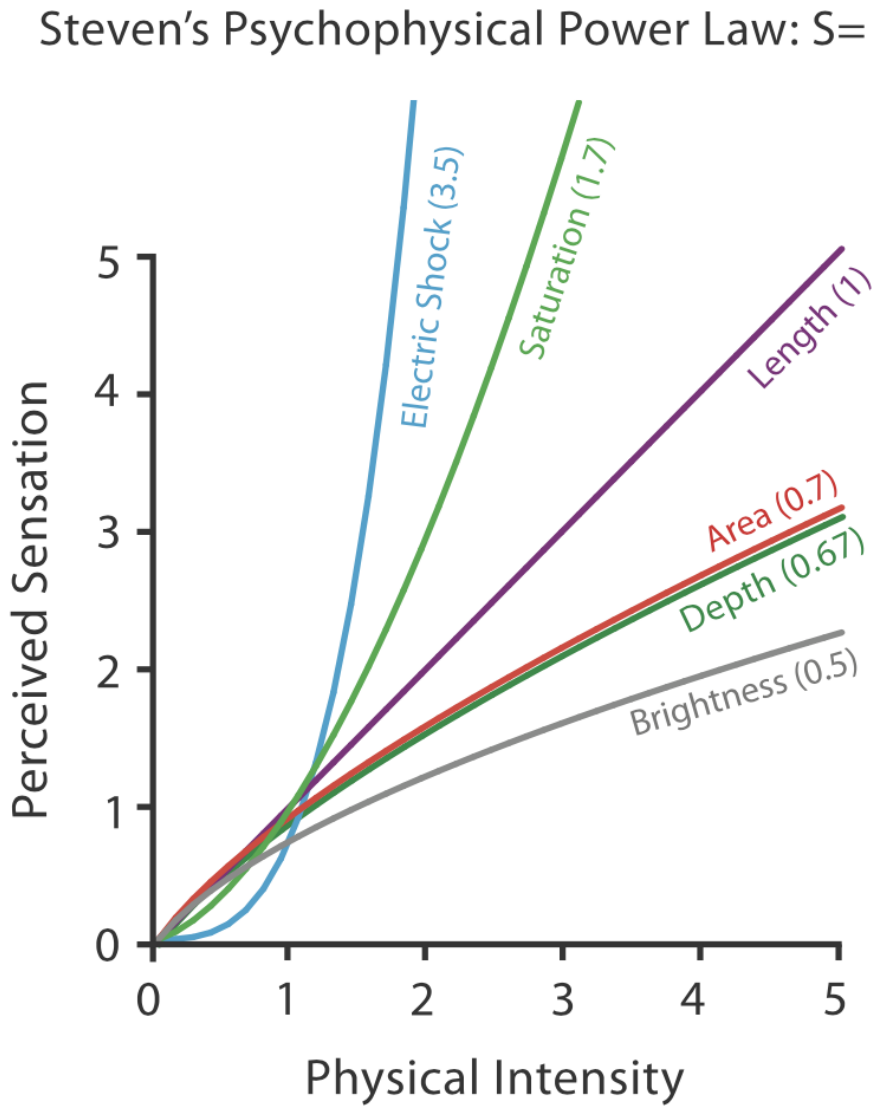
Same

Effectiveness: Most

Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape

Where do these rankings come from?



S = sensation
I = intensity

Psychological intensity ("Sensation") increases as the nth power of stimulus intensity

The general form of the law is

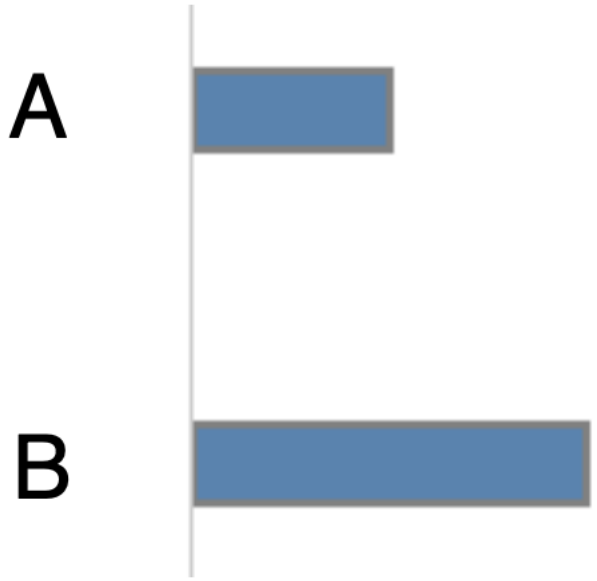
$$\psi(I) = kI^a,$$

where *I* is the intensity or strength of the stimulus in physical units (energy, weight, pressure, mixture proportions, etc.), ψ(*I*) is the magnitude of the sensation evoked by the stimulus, *a* is an exponent that depends on the type of stimulation or sensory modality, and *k* is a proportionality constant that depends on the units used.

https://en.wikipedia.org/wiki/Stevens%27s_power_law

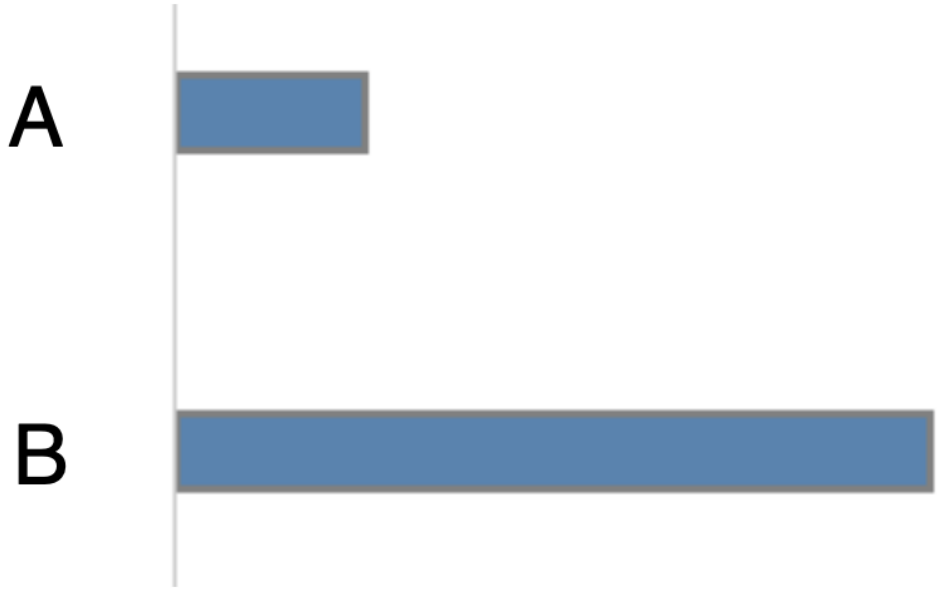
***In part**

How Much Longer?



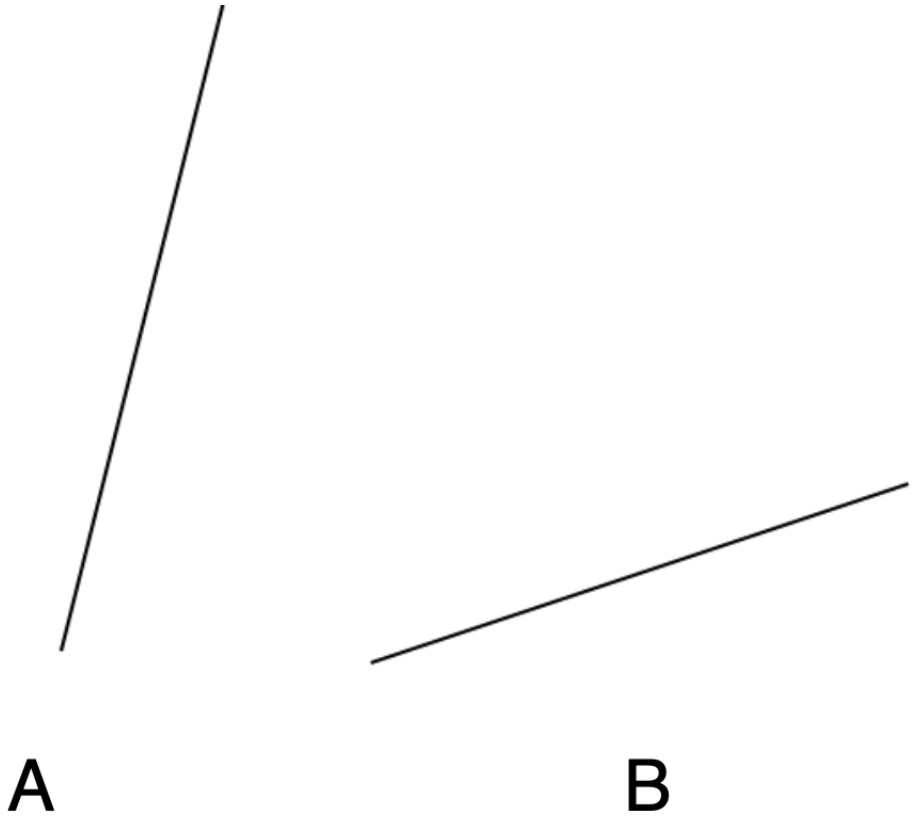
2x

How Much Longer?



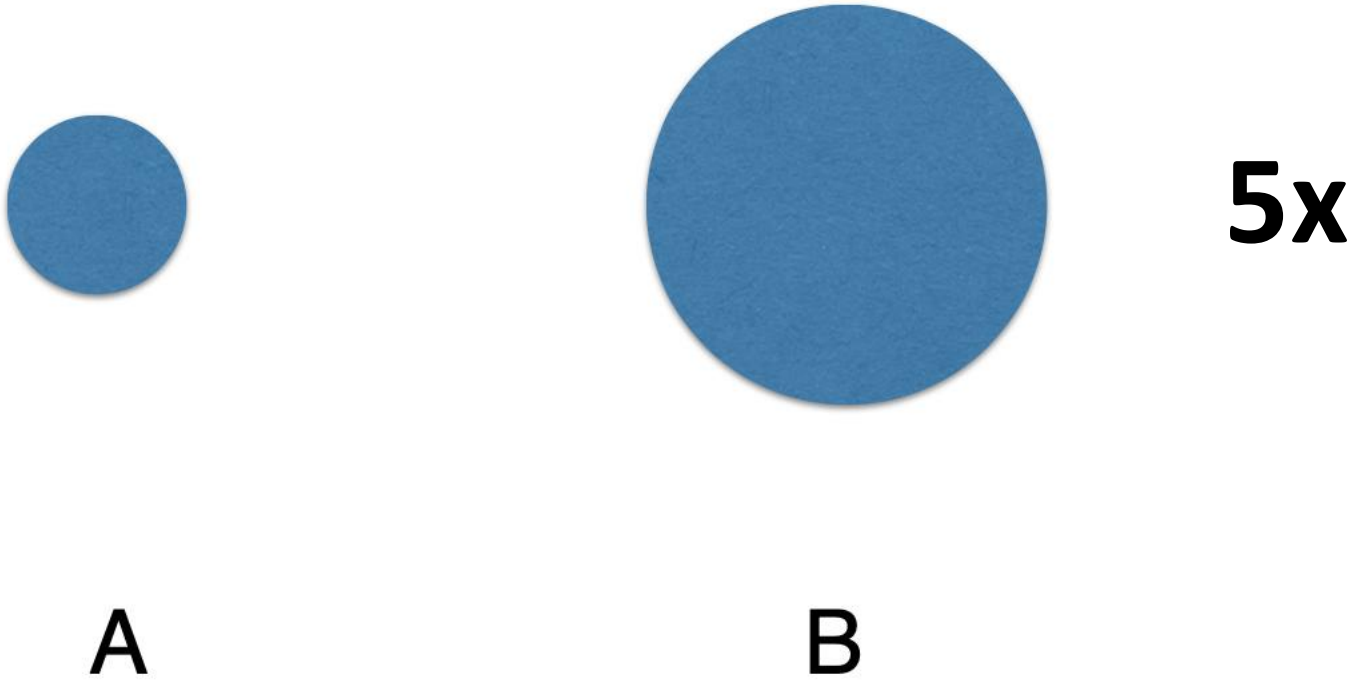
4x

How Much Steeper?



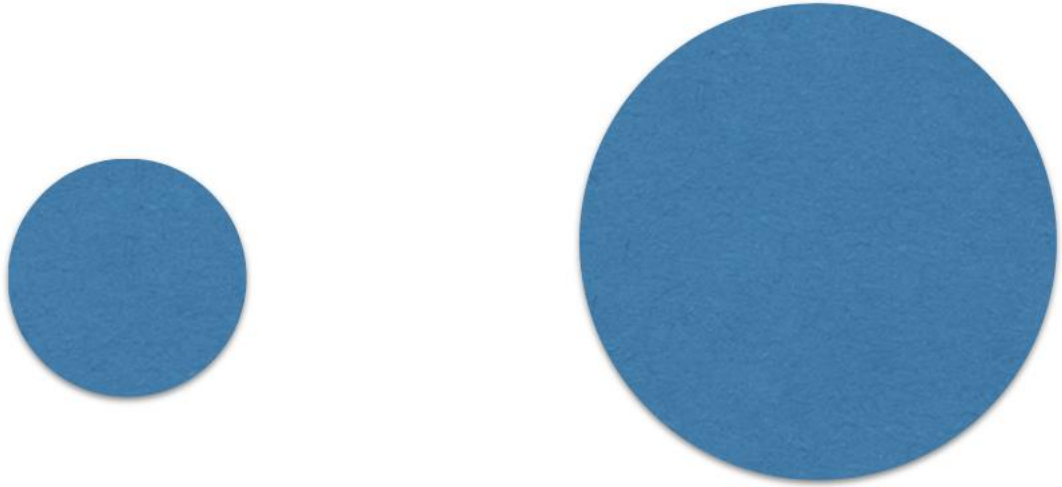
~4x

How Much Larger?



5x

How Much Larger?



A

B

4x area
2x diameter

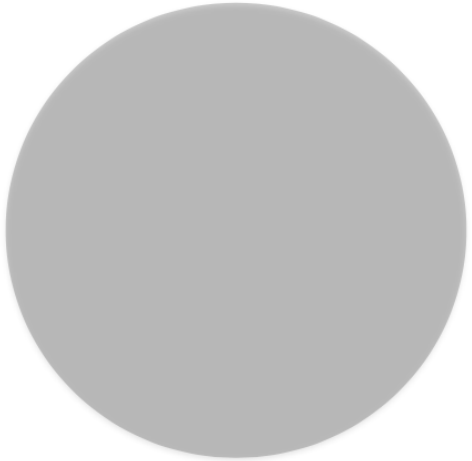
How Much Larger (by area)?

3x

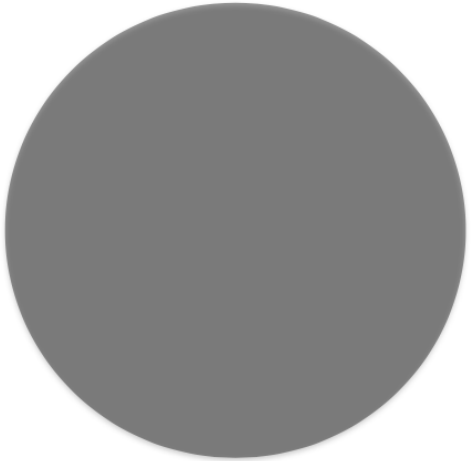
A

B

How Much Darker?



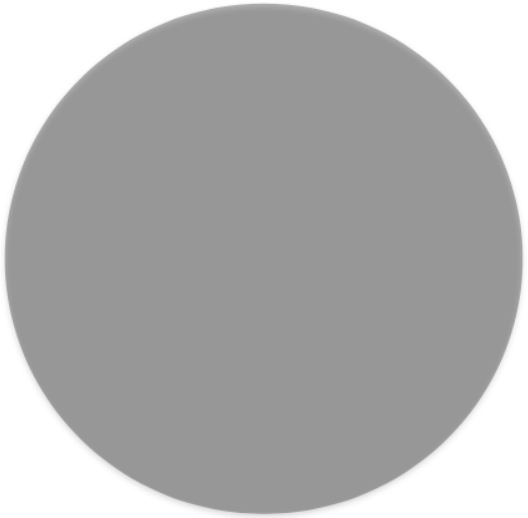
A



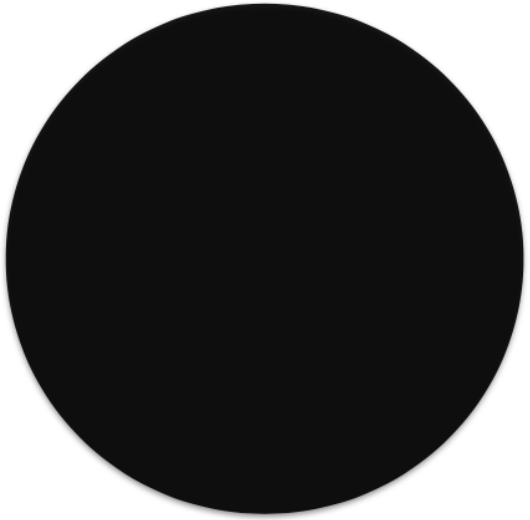
B

2x

How Much Darker?



A



B

3x

Other factors affect accuracy too…

Alignment

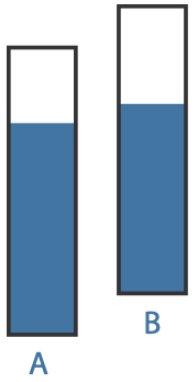
Distractors

Distance

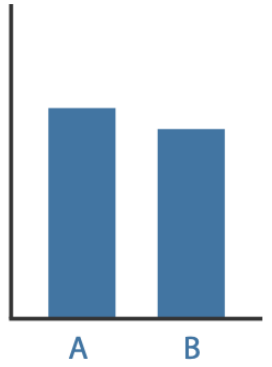
Common scale

…

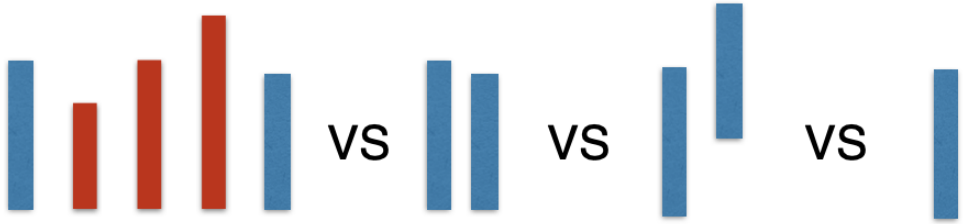
Unframed
Unaligned



Framed
Unaligned



Unframed
Aligned



Some more guidelines…

Expressiveness & Effectiveness

Expressiveness Principle: Encoding should express all of, and only, the information in the data

- Example: Don't imply order where this is not but imply order where there is

Effectiveness Principle: The more important the data/attribute, the more **salient** the encoding should be

- Important things should be noticeable

From Munzner, Visualization Analysis and Design

Guideline: Use color deliberately & sparingly

Magnitude Channels: Ordered Attributes

- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation

Same

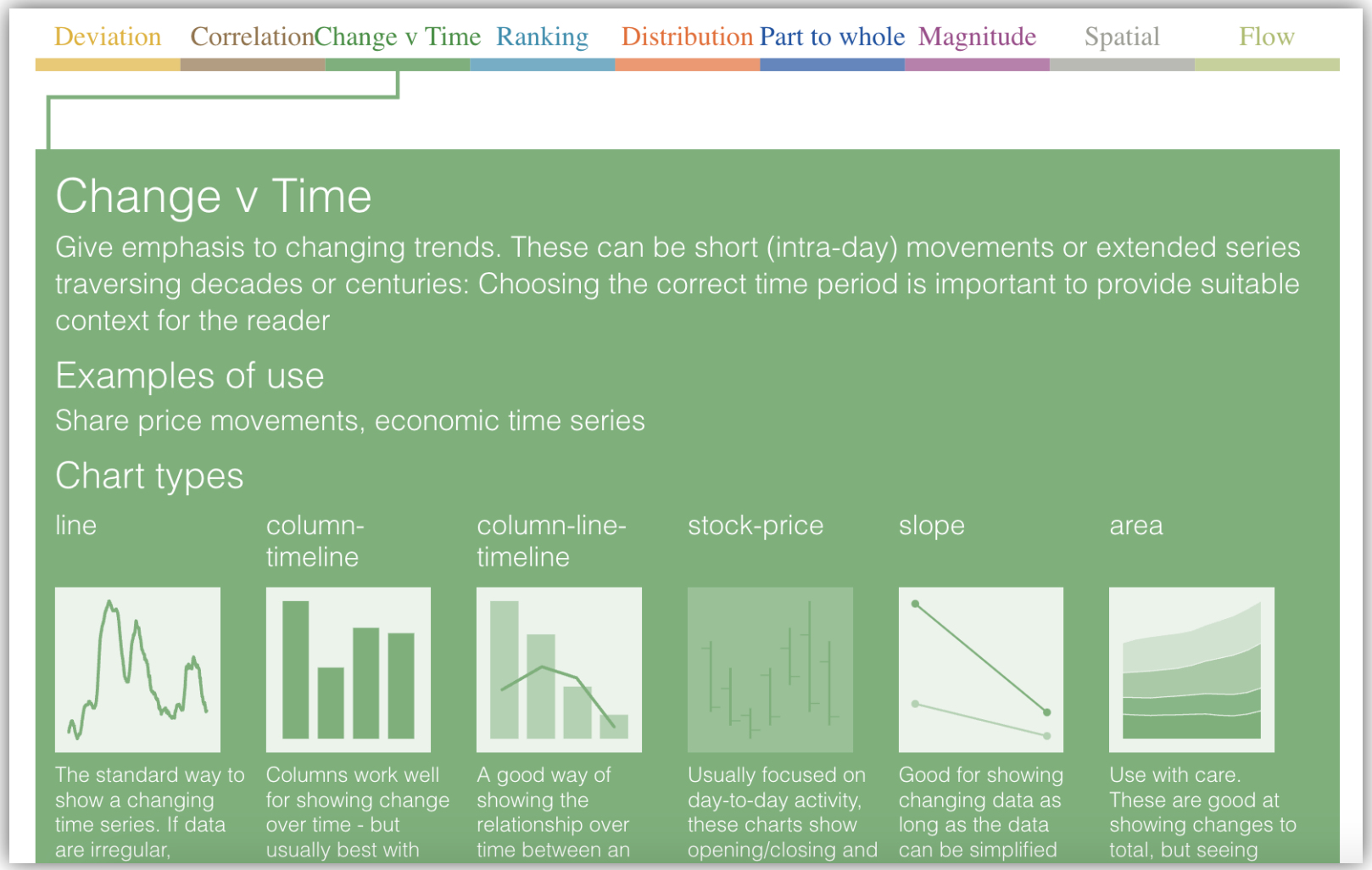
Effectiveness: Most

Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape

What chart should I use? …it depends on what you are trying to show! Visualization vocabularies can help!

Financial Times Visualization Vocabulary



https://ft-interactive.github.io/visual-vocabulary/

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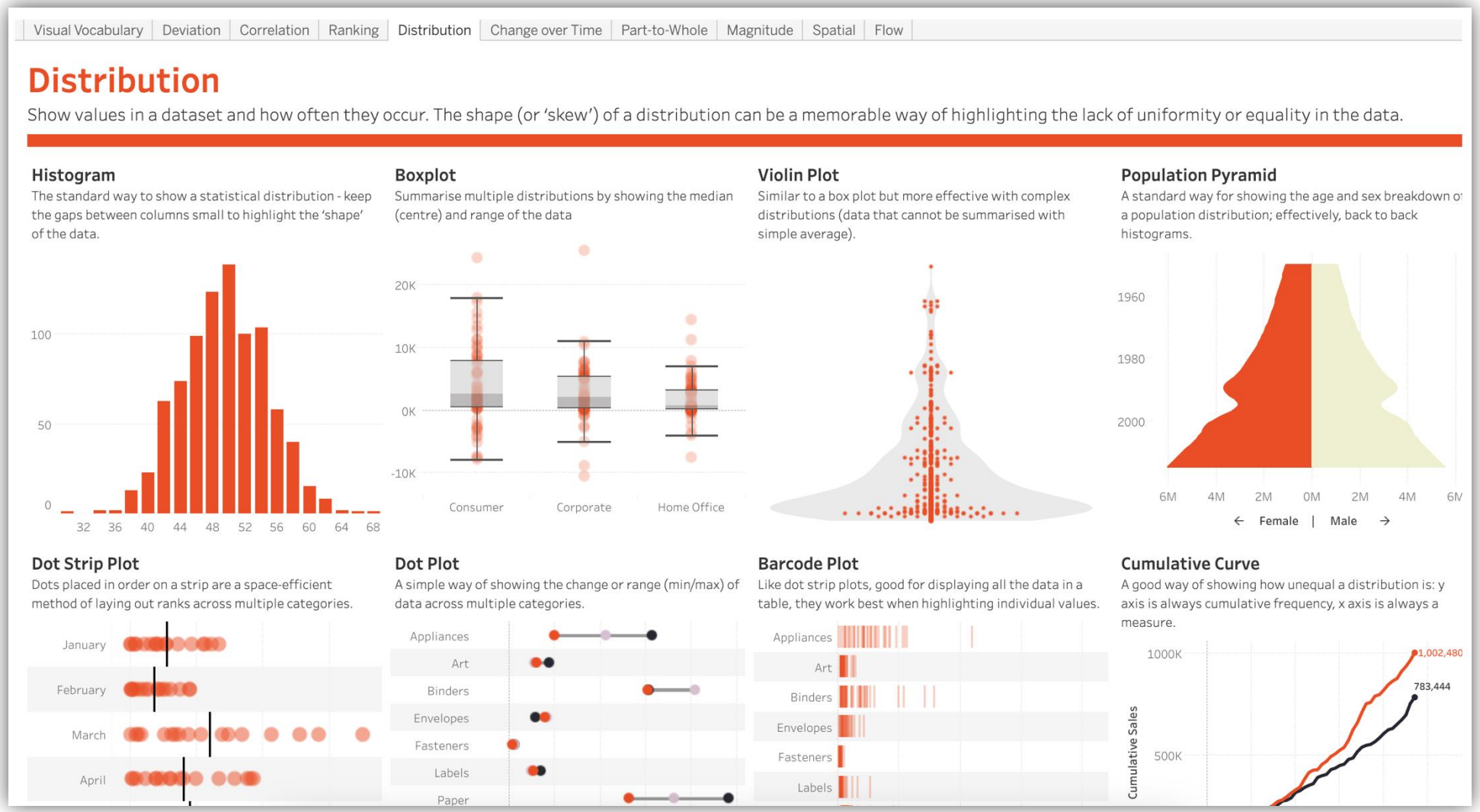


Tableau Visualization Vocabulary

https://www.tableau.com/solutions/gallery/visual-vocabulary

Tufte’s Integrity Principles

Show **data variation**, not design variation

Clear, detailed, and thorough **labeling** and **appropriate scales.**

Lie Factor: Size of the **graphic effect** should be **directly proportional to the numerical quantities.**

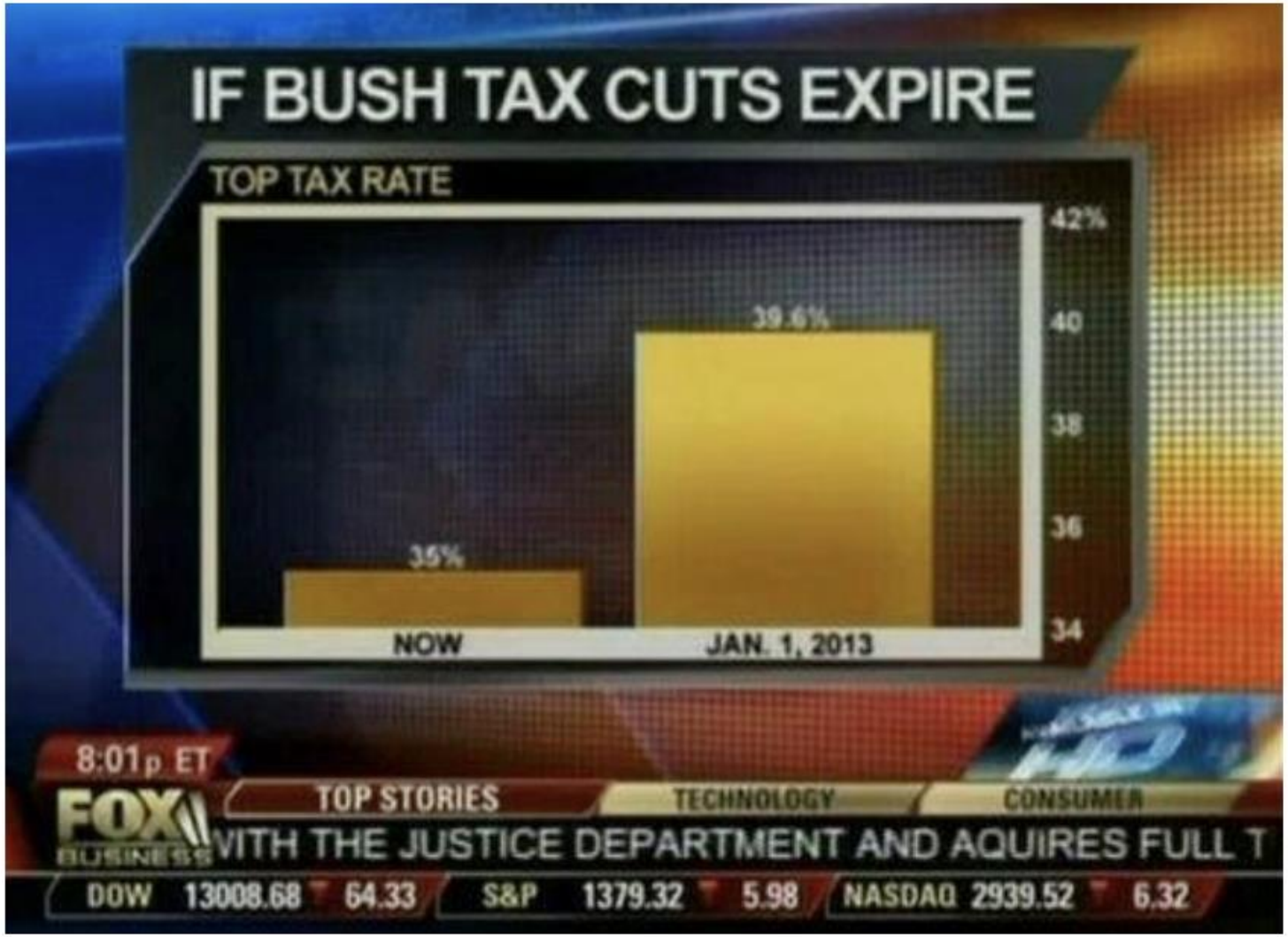
The Lie Factor

$$\frac{\text{Size of the effect shown in graphic}}{\text{Size of the effect in data}}$$

The Lie Factor – Graphical Integrity

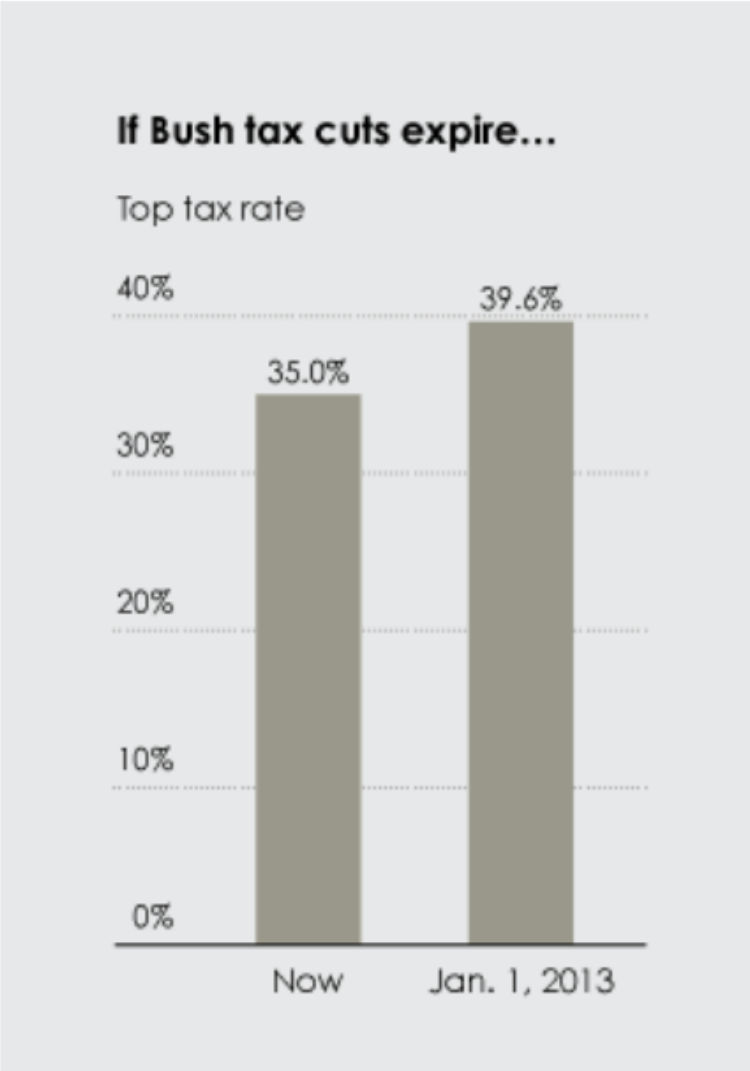
Magnitude in data must correspond to magnitude of mark

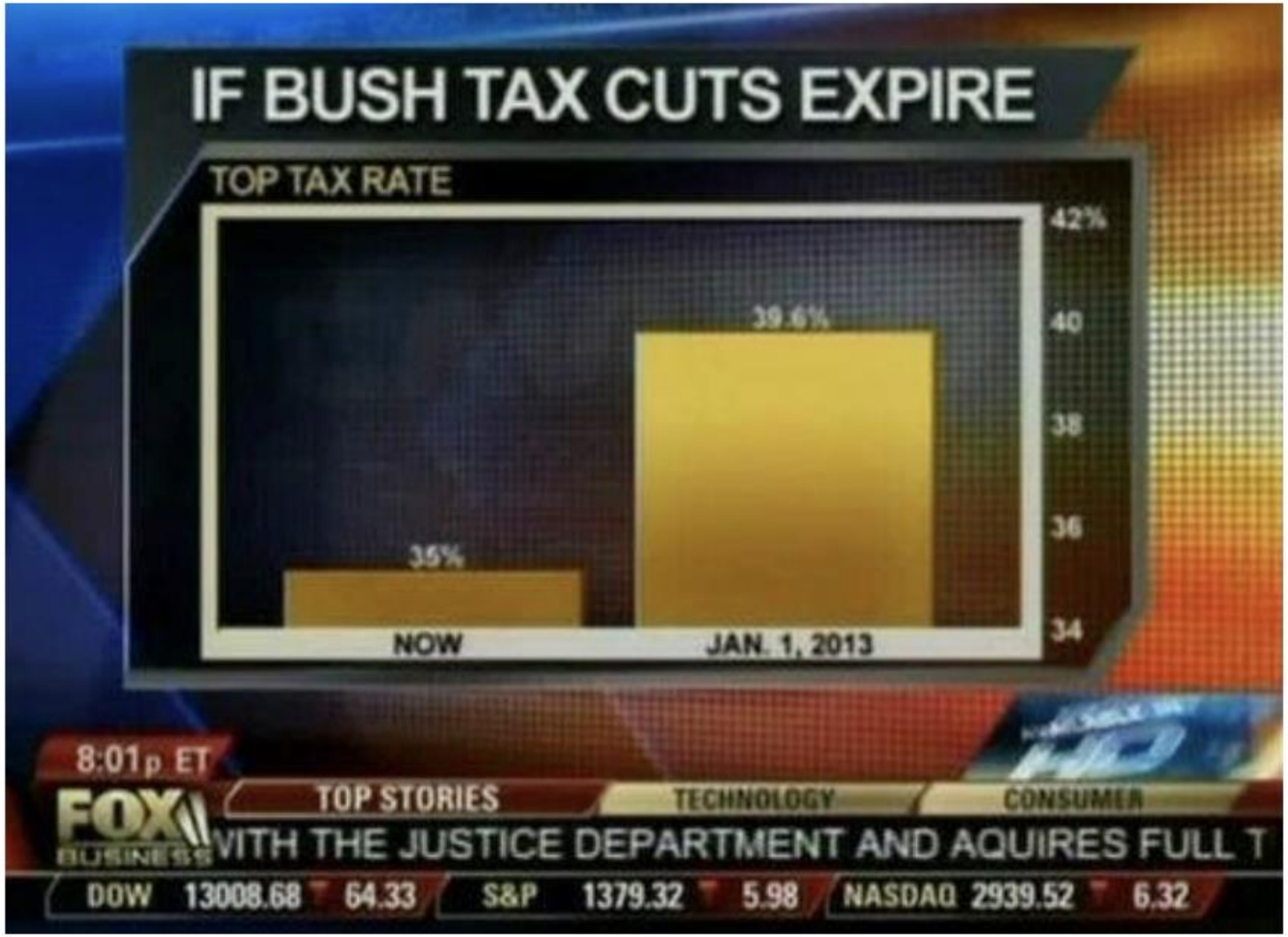
Effect in data: 1.14
Effect in graphic: 5
Lie factor: 5/1.14 = 4.38



From Flowing Data

The Lie Factor – Graphical Integrity





From Flowing Data

How much has Dickey's knuckleball slowed?

Images https://www.huffingtonpost.com/raviparikh/lie-with-data-visualization_b_5169715.html

What’s wrong?

Viele Bezieher mit "ungeklärter Staatsbürgerschaft"

Die größte Gruppe in der Liste der Mindestsicherungsbezieher ist aber jene der "ungeklärten Staatsbürgerschaft". Dass es sich bei den 16.712 Personen um

What’s wrong?

Viele Bezieher mit "ungeklärter Staatsbürgerschaft"

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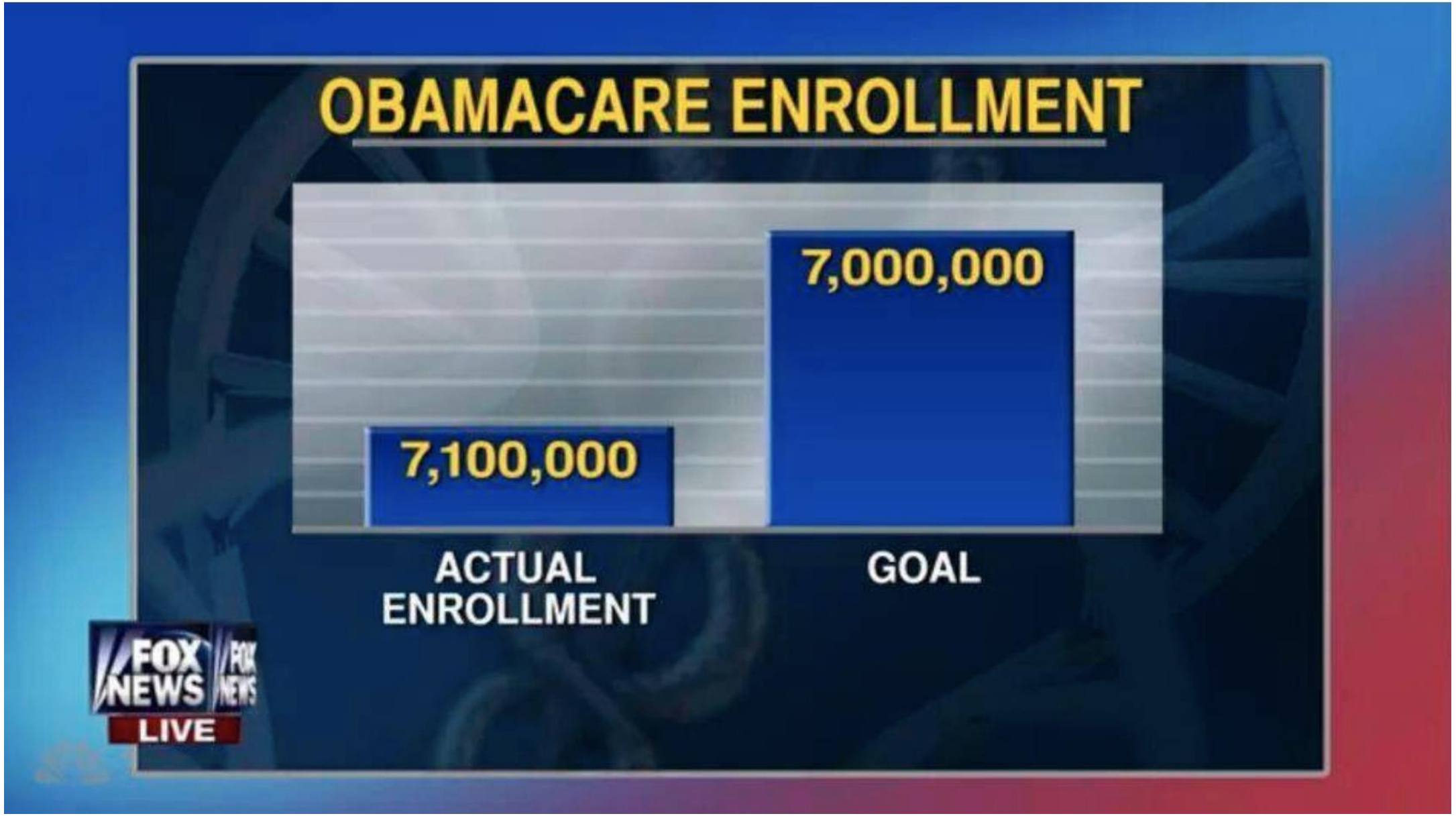
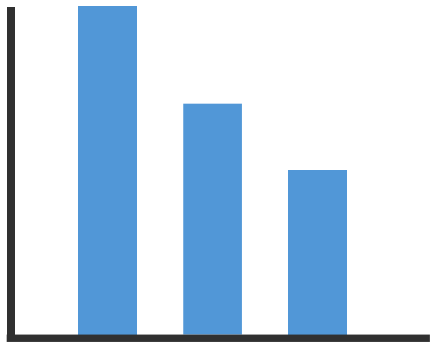

OBAMACARE ENROLLMENT
7,100,000
7,000,000
ACTUAL ENROLLMENT
GOAL
FOX NEWS
LIVE

Where should the y-axis start?



Length
(aligned)

In bar charts, bar length is being compared. Therefore, starting the y-axis at an arbitrary position will work against the visualization task… often tricking the viewer.

This is referred to as "*truncating the y-axis*." Be careful when you start at something other than zero.

Images from Munzner, Visual Analysis and Design

What's happening here?

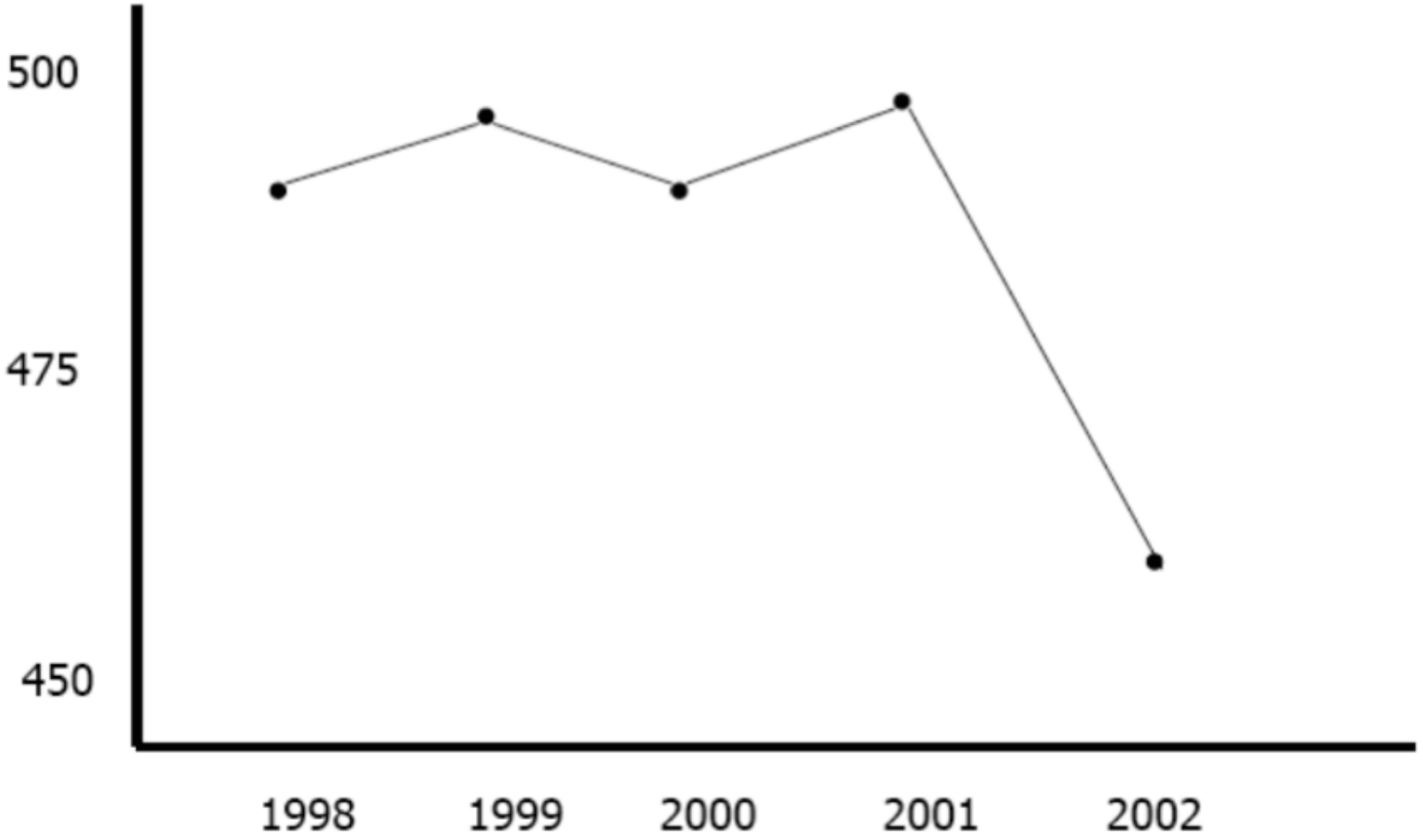


Image from slides of Josh Levine, adapted from John Stasko

What's happening here?

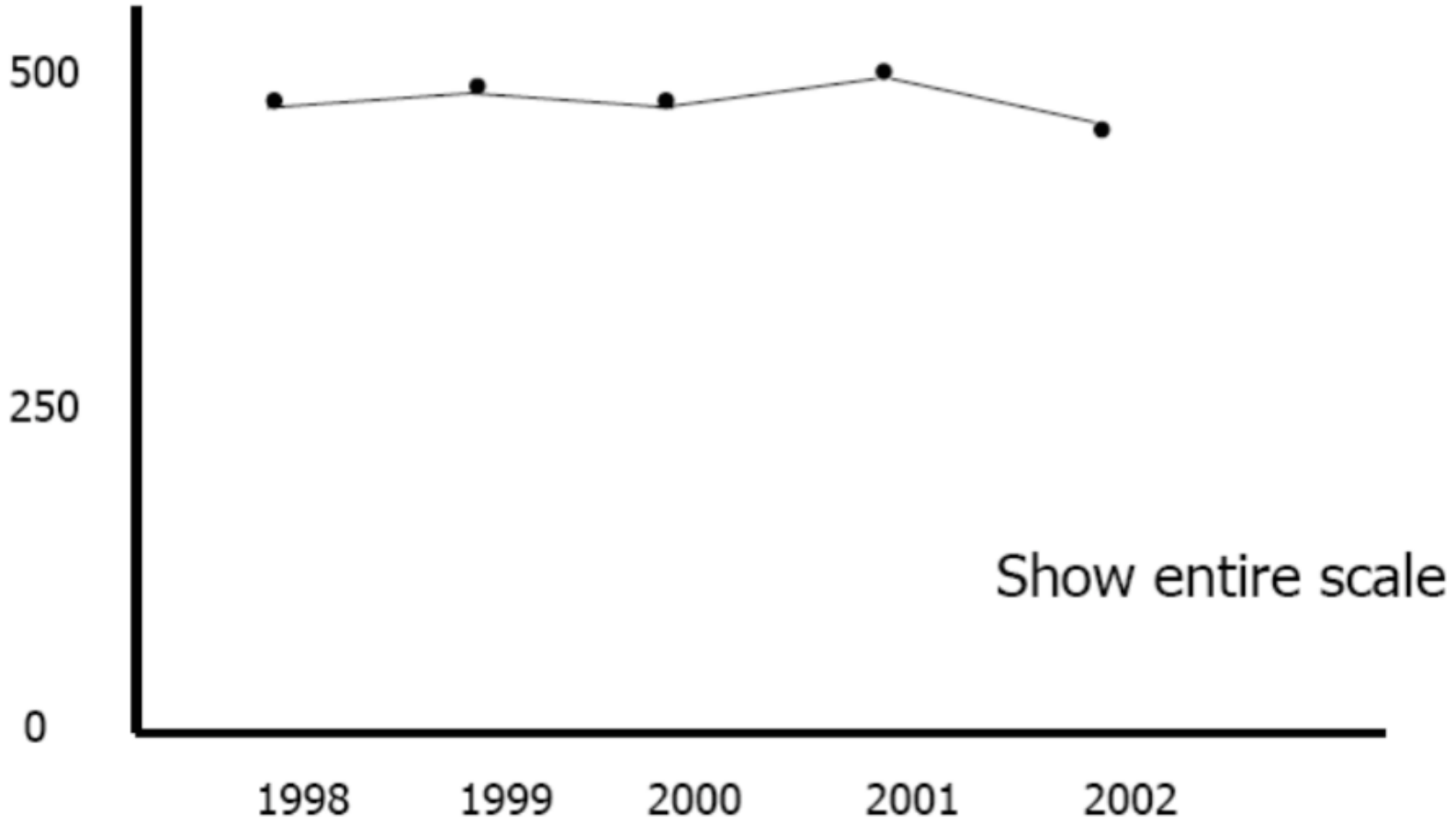


Image from slides of Josh Levine, adapted from John Stasko

What's happening here?

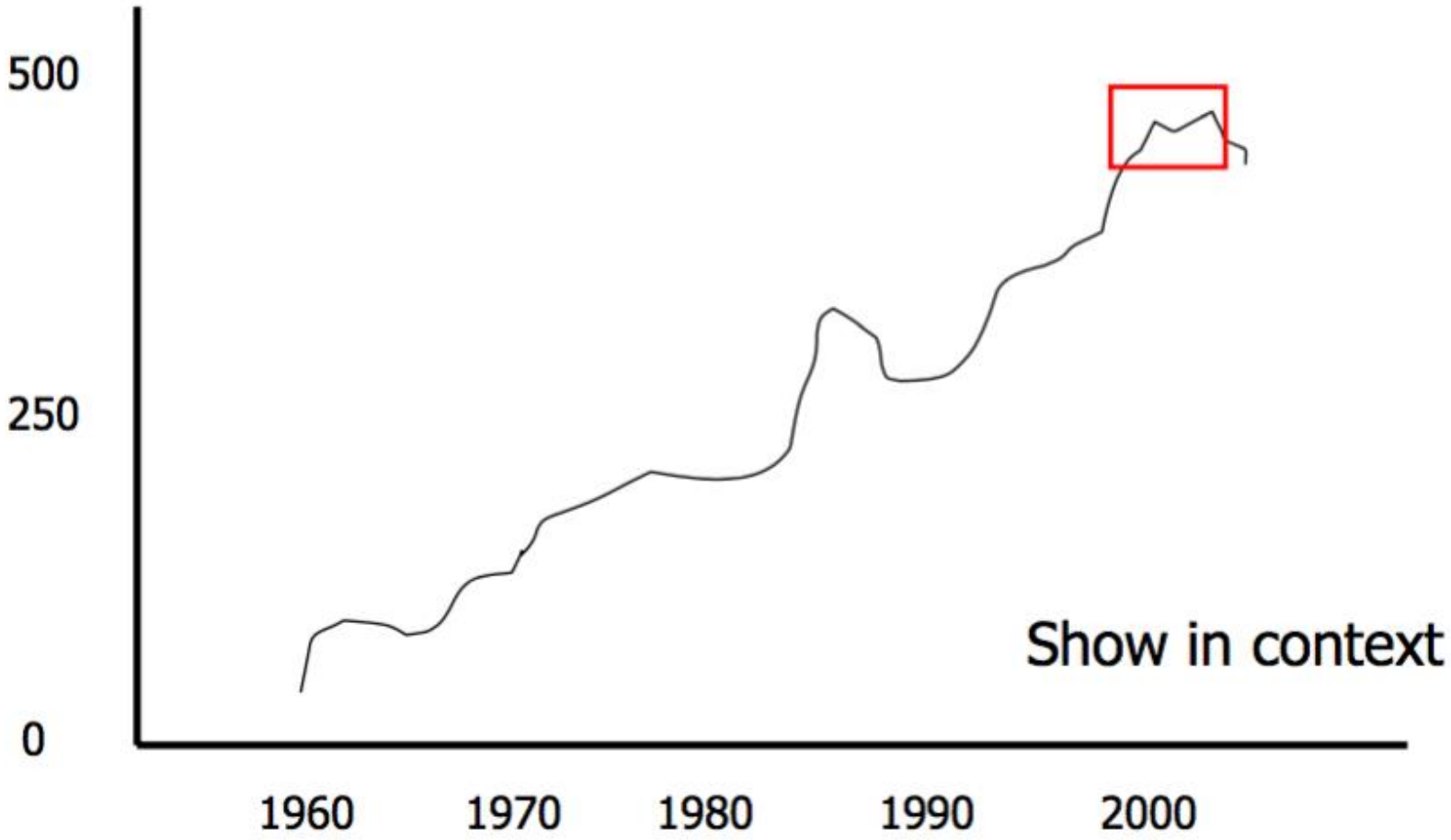
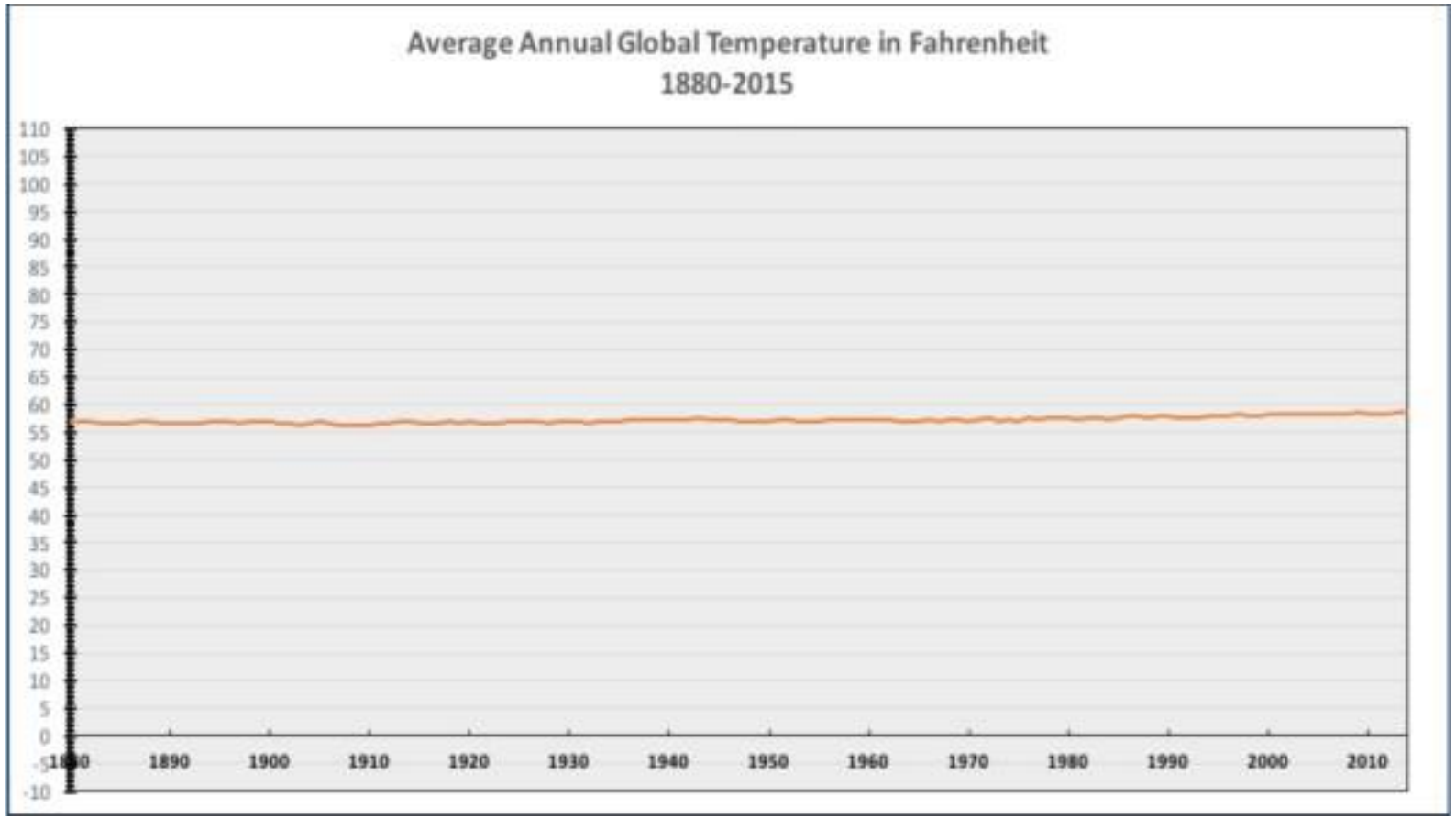


Image from slides of Josh Levine, adapted from John Stasko

Where should the y-axis start?



There are several possible "zero" points. Which one is the most natural?

Line graphs are generally used to analyze *change* in a range rather than absolute. The analysis task matters!

Image from the National Review

Meta-Psychology, 2019, vol 3, MP.2018.895,
https://doi.org/10.5626/MP.2018.895
Article type: Original Article

Open data: Yes
Open materials: Yes
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Graph Construction: An Empirical Investigation on Setting the Range of the Y-Axis

Jessica K. Witt
Colorado State University

Graphs are an effective and compelling way to present scientific results. With few rigid guidelines, researchers have many degrees-of-freedom regarding graph construction. One such choice is the range of the y-axis. A range set just beyond the data will bias readers to see all effects as big. Conversely, a range set to the full range of options will bias readers to see all effects as small. Researchers should maximize congruence between visual size of an effect and the actual size of the effect. In the experiments presented here, participants viewed graphs with the y-axis set to the minimum range required for all the data to be visible, the full range from 0 to 100, and a range of approximately 1.5 standard deviations. The results showed that participants' sensitivity to the effect depicted in the graph was better when the y-axis range was between one to two standard deviations than with either the minimum range or the full range. In addition, bias was also smaller with the standardized axis range than the minimum or full axis ranges. To achieve congruency in scientific fields for which effects are standardized, the y-axis range should be no less than 1 standard deviations, and aim to be at least 1.5 standard deviations.

Keywords: Graph Design, Effect size, Sensitivity, Bias

One way to lie with statistics is to set the range of the y-axis to form a misleading impression of the data. A range set too narrow will exaggerate a small effect and can even make a non-significant trend appear to be a substantial effect (Pandey, Rall, Satterthwaite, Nov, & Bertini, 2015). Yet the default setting of many statistical and graphing software package range set too wide also creates a misleading impression of the data by making effects seem smaller than they are. Here, I argue that for scientific fields that use standardized effect sizes and adopt Cohen's convention that an effect of $d = 0.8$ is big, the range of the y-axis should be approximately 1.5 standard deviations (SDs).

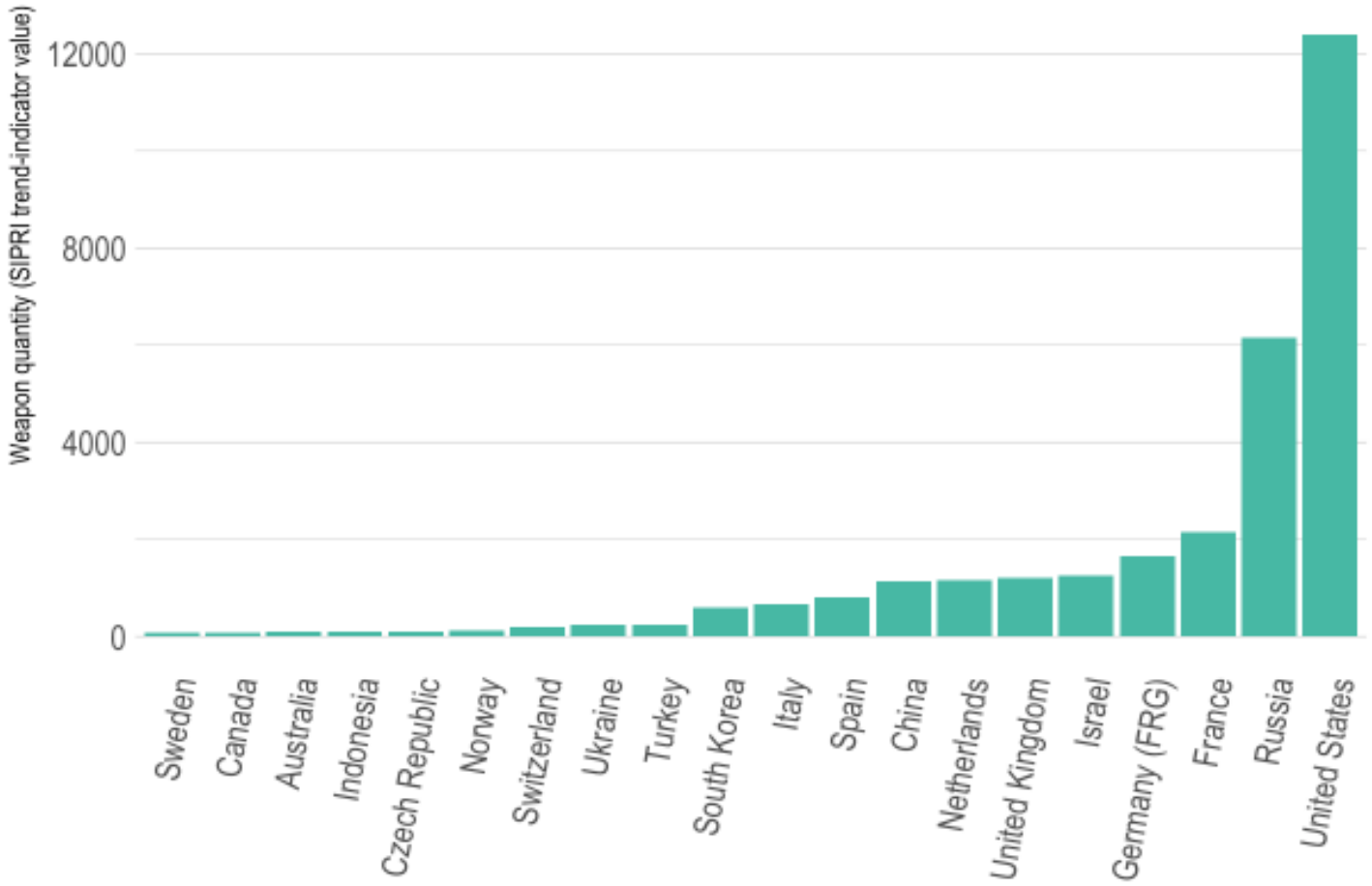
What range should I use?

Data range?
Start from zero?

Like all things, depends on the task.

Guideline: Rotate for Readability

Be Aware of Text Angle

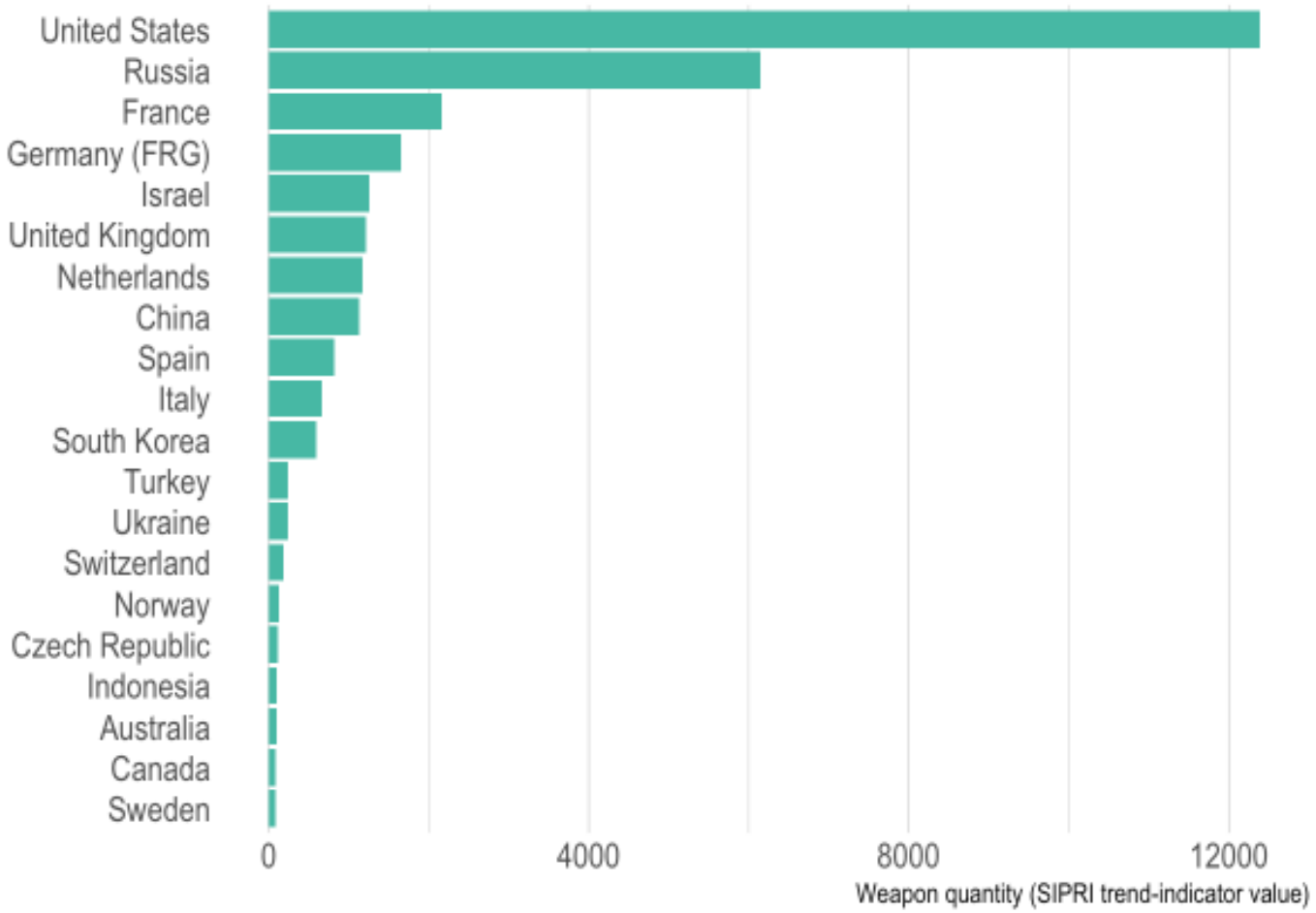


Users shouldn't feel the need to tilt their head to read labels.

Furthermore, while we can rotate fonts at any angle, they distort and become jagged.

Image from https://www.data-to-viz.com/caveat/hard_label.html

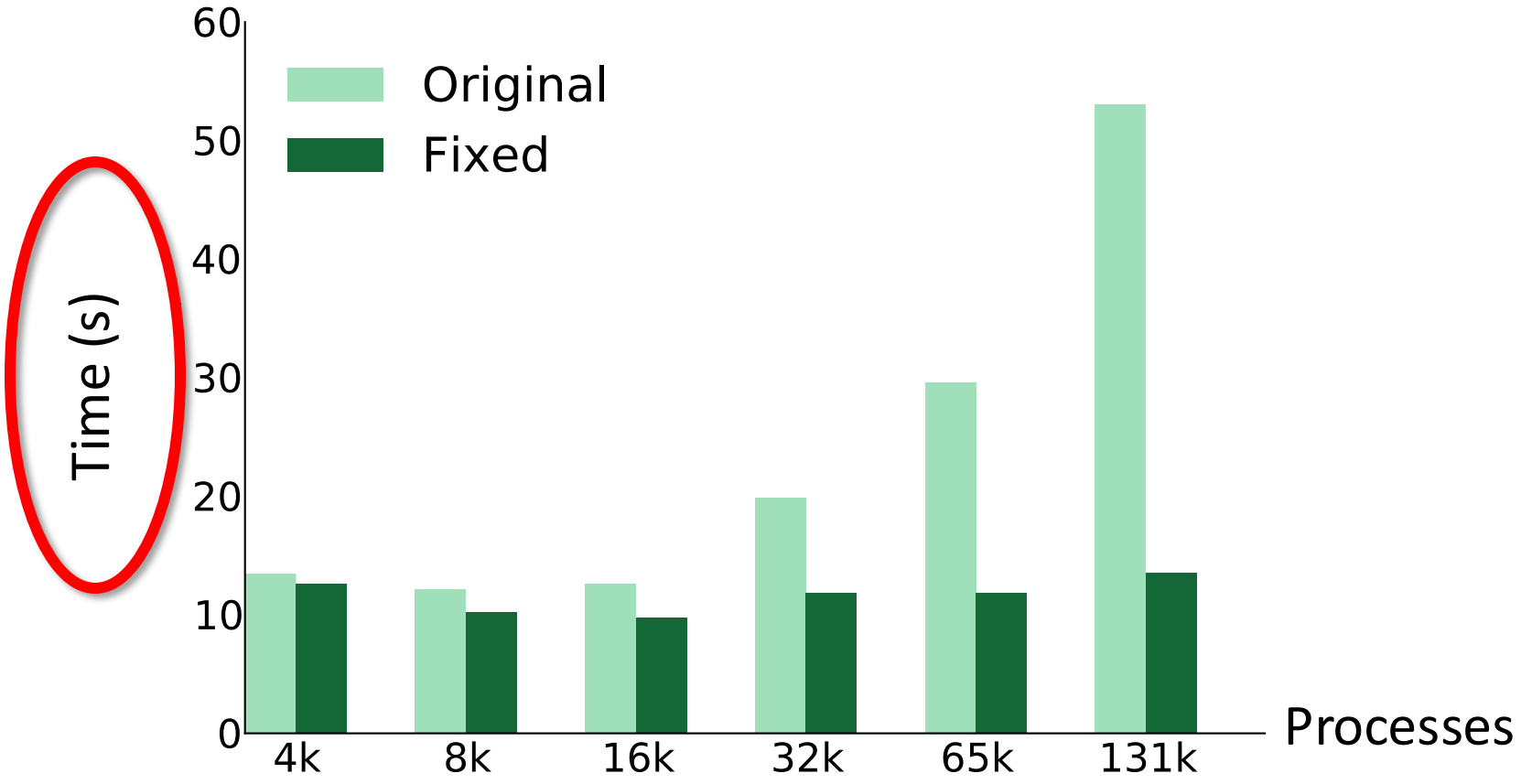
Consider rotating a bar chart



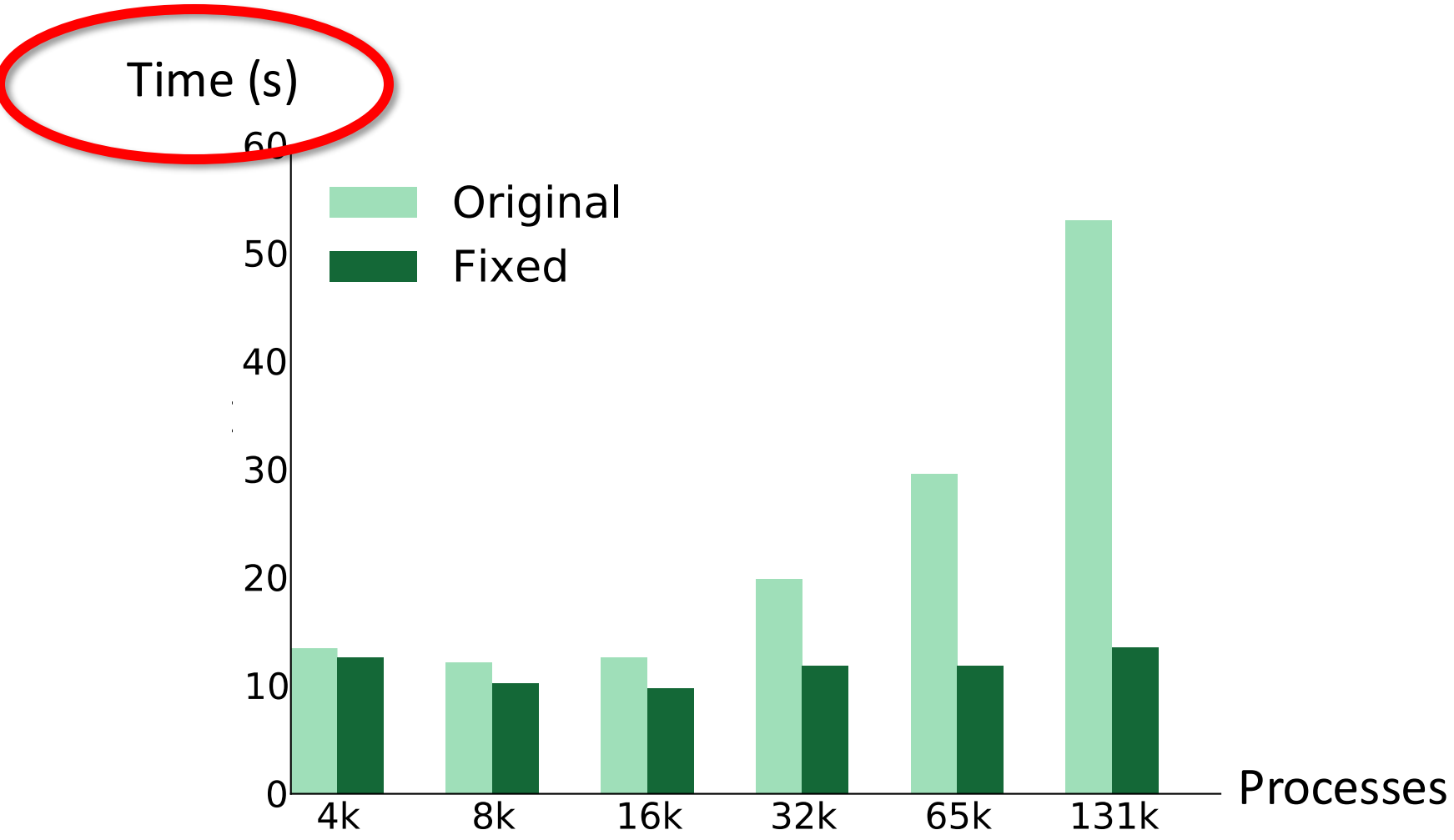
*Note however that some axes have a strong association with the x-axis (e.g., time). In that case, the design trade off may leave tilted text.

Image from https://www.data-to-viz.com/caveat/hard_label.html

Labels on the y-axis need not be vertical



Labels on the y-axis need not be vertical



When the rotation bucks convention, it may be misinterpreted

What is your initial reaction?

The designer's desire was to evoke blood running down a wall.

Takeaway: any design counter to well known conventions must be strongly justified.

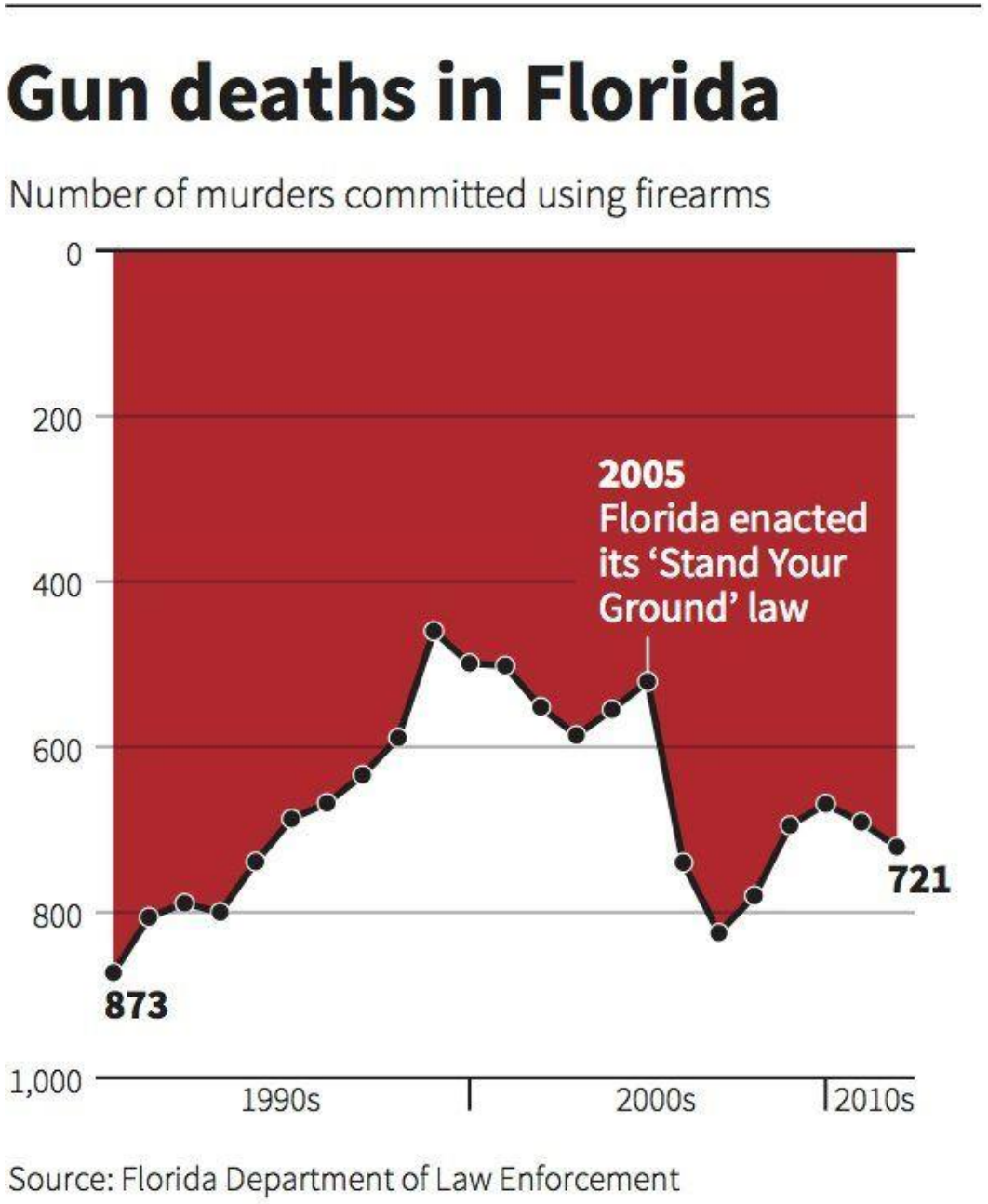
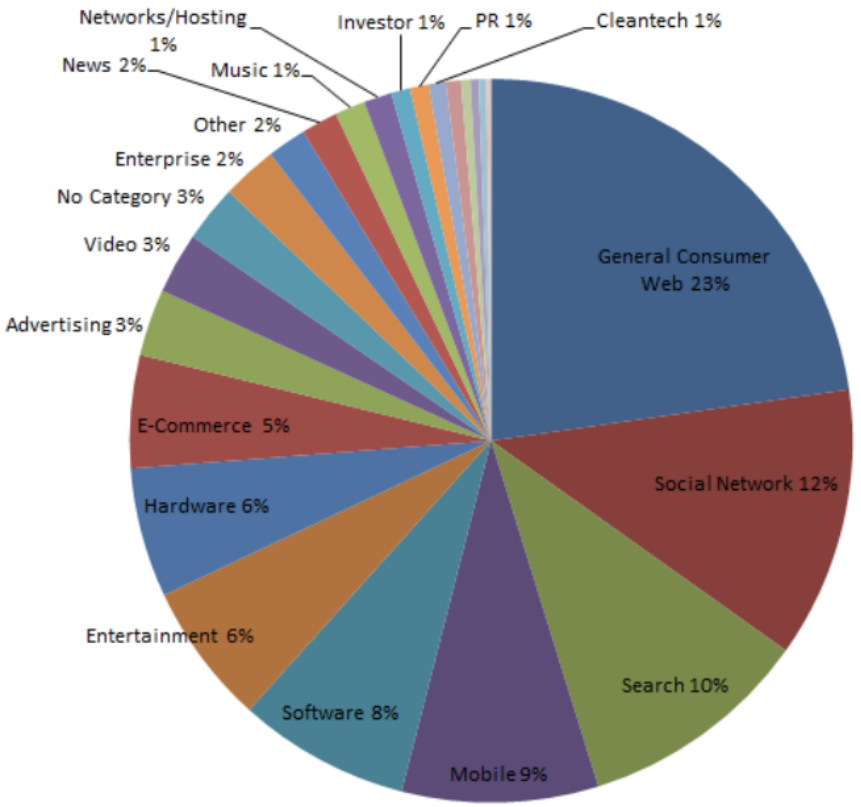


Image retrieved from https://www.livescience.com/45083-misleading-gun-death-chart.html

Guideline: Pie with Care

Pie Charts… easy to get wrong

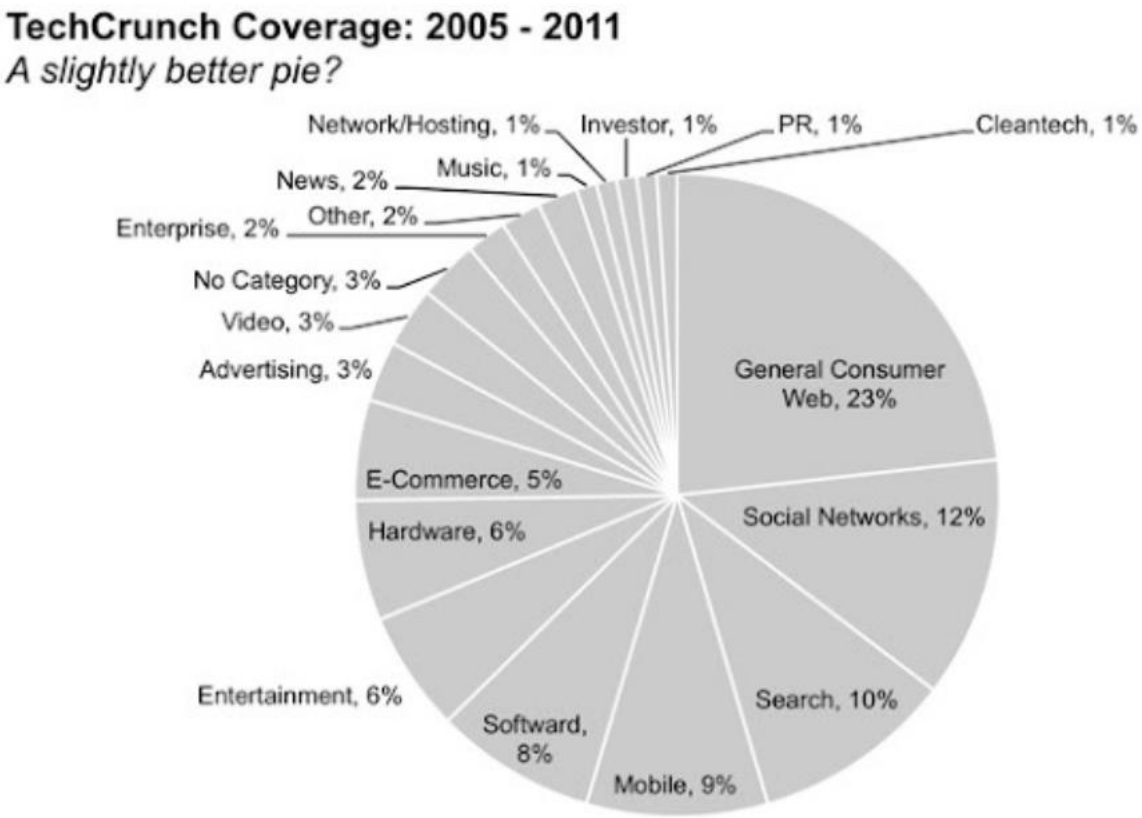


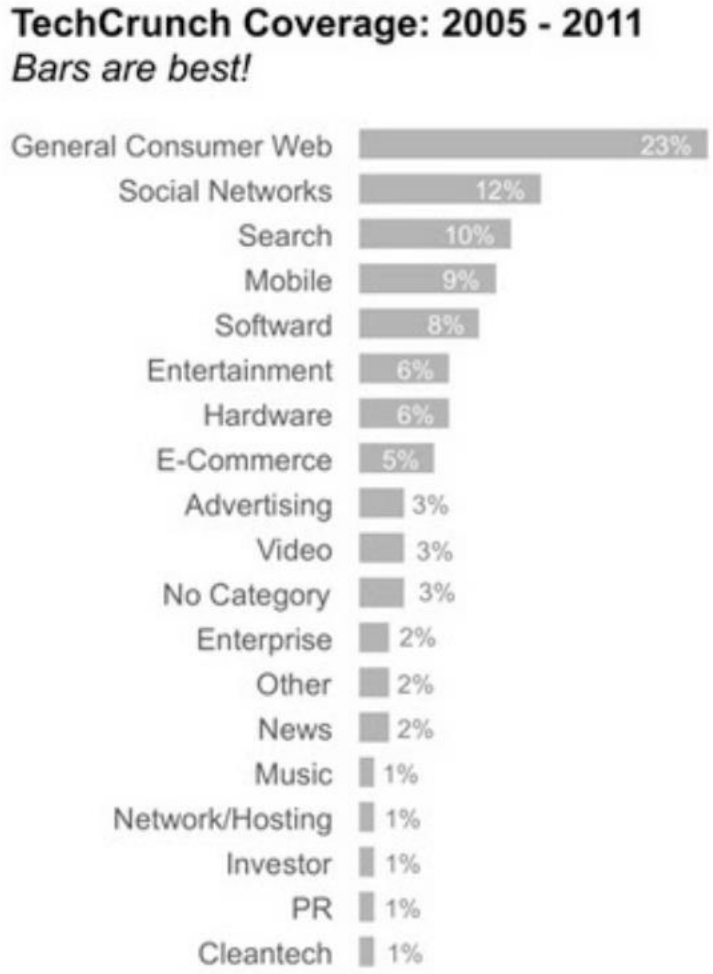
Share of coverage on TechCrunch

"I hate pie charts.
I mean, really hate them."

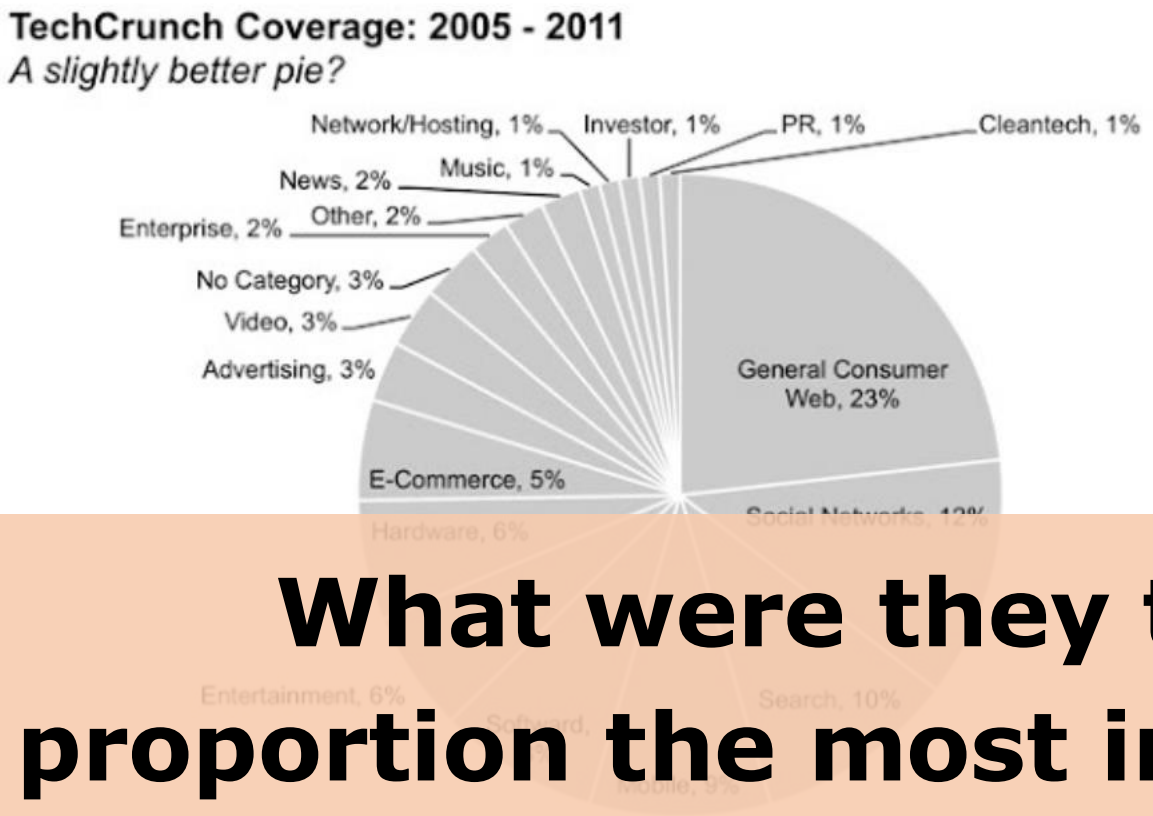
www.storytellingwithdata.com/2011/07/death-to-pie-charts.html

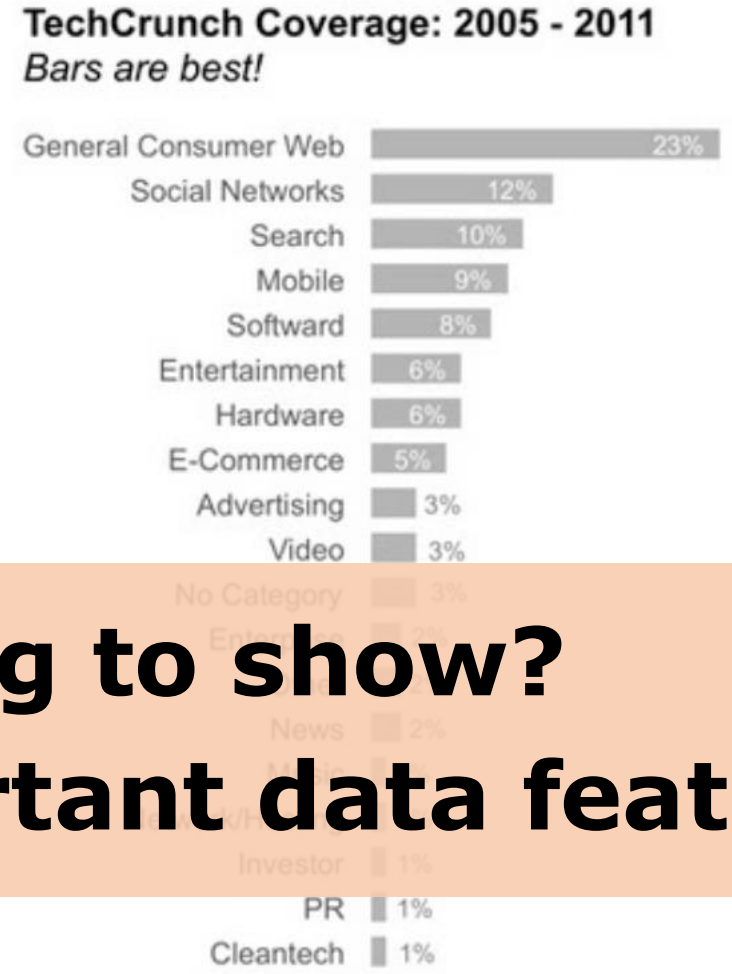
Redesign


TechCrunch Coverage: 2005 - 2011
A slightly better pie?
Network/Hosting, 1%
Investor, 1%
PR, 1%
Cleantech, 1%
Music, 1%
News, 2%
Other, 2%
Enterprise, 2%
No Category, 3%
Video, 3%
Advertising, 3%
General Consumer Web, 23%
E-Commerce, 5%
Social Networks, 12%
Hardware, 6%
Search, 10%
Entertainment, 6%
Softward, 8%
Mobile, 9%


TechCrunch Coverage: 2005 - 2011
Bars are best!
General Consumer Web 23%
Social Networks 12%
Search 10%
Mobile 9%
Softward 8%
Entertainment 6%
Hardware 6%
E-Commerce 5%
Advertising 3%
Video 3%
No Category 3%
Enterprise 2%
Other 2%
News 2%
Music 1%
Network/Hosting 1%
Investor 1%
PR 1%
Cleantech 1%

Redesign

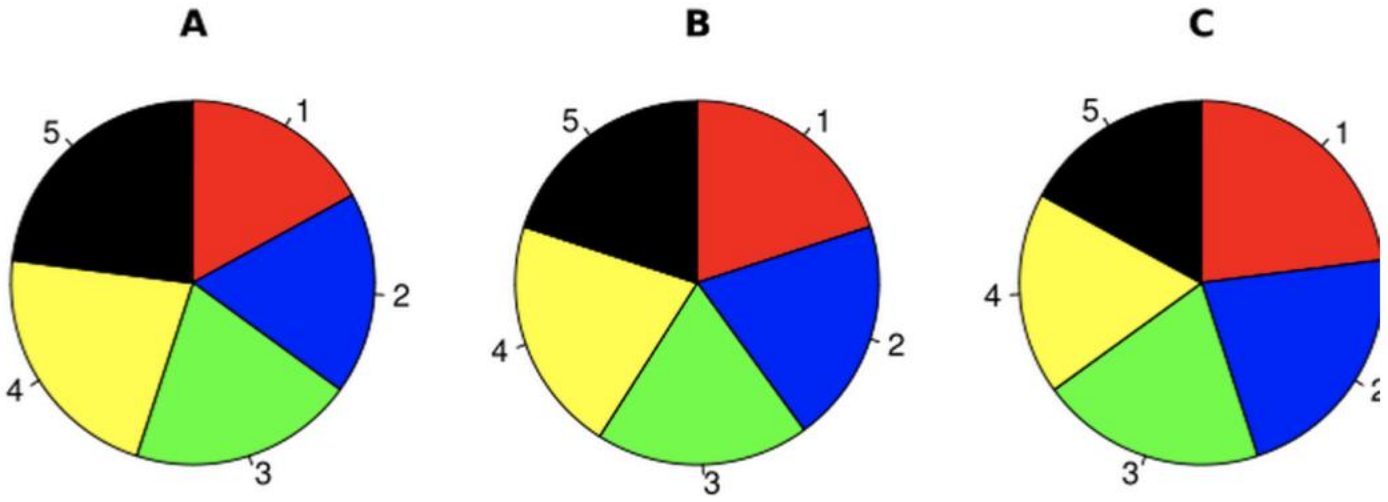




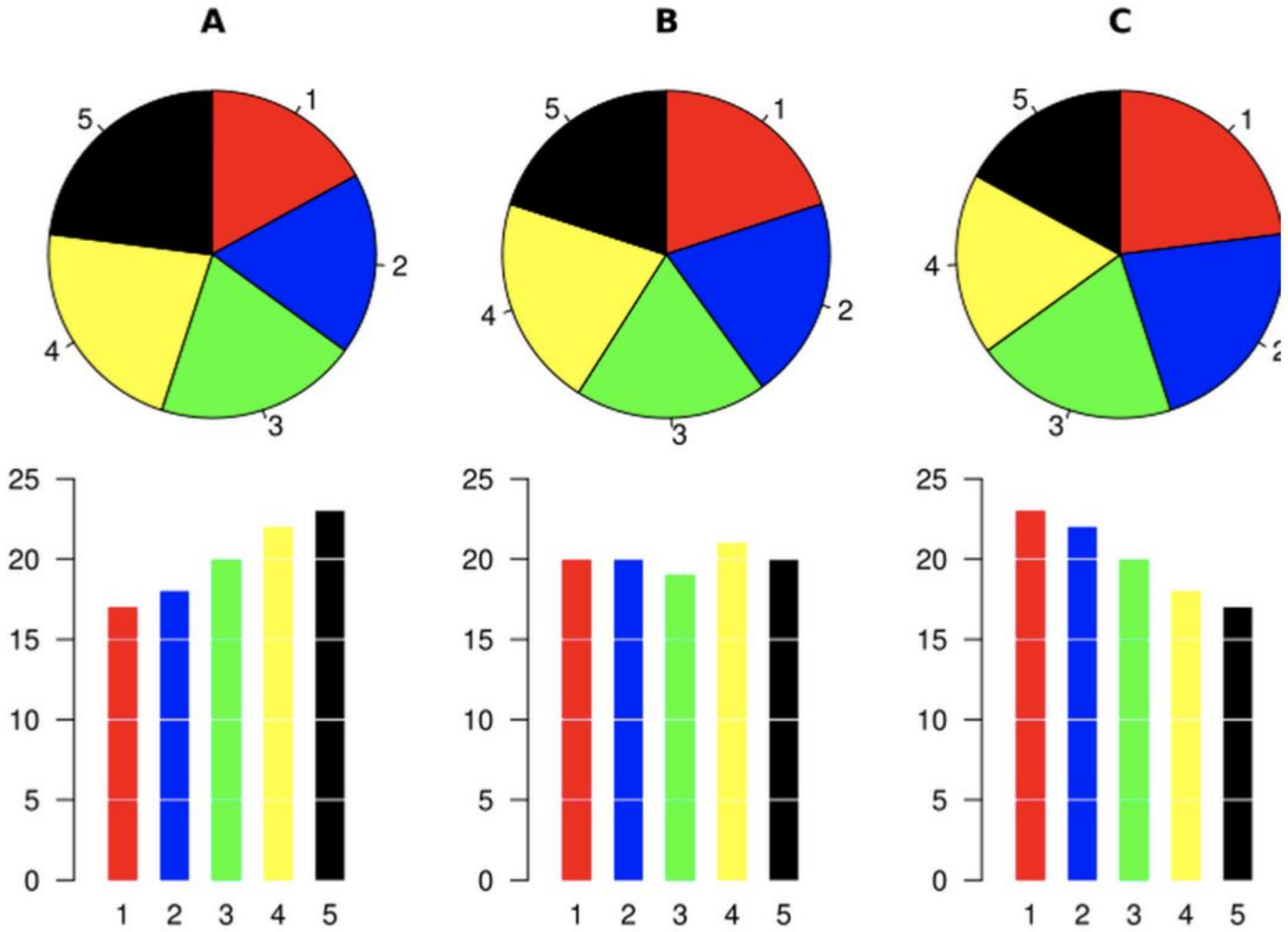
What were they trying to show?

Is proportion the most important data feature?

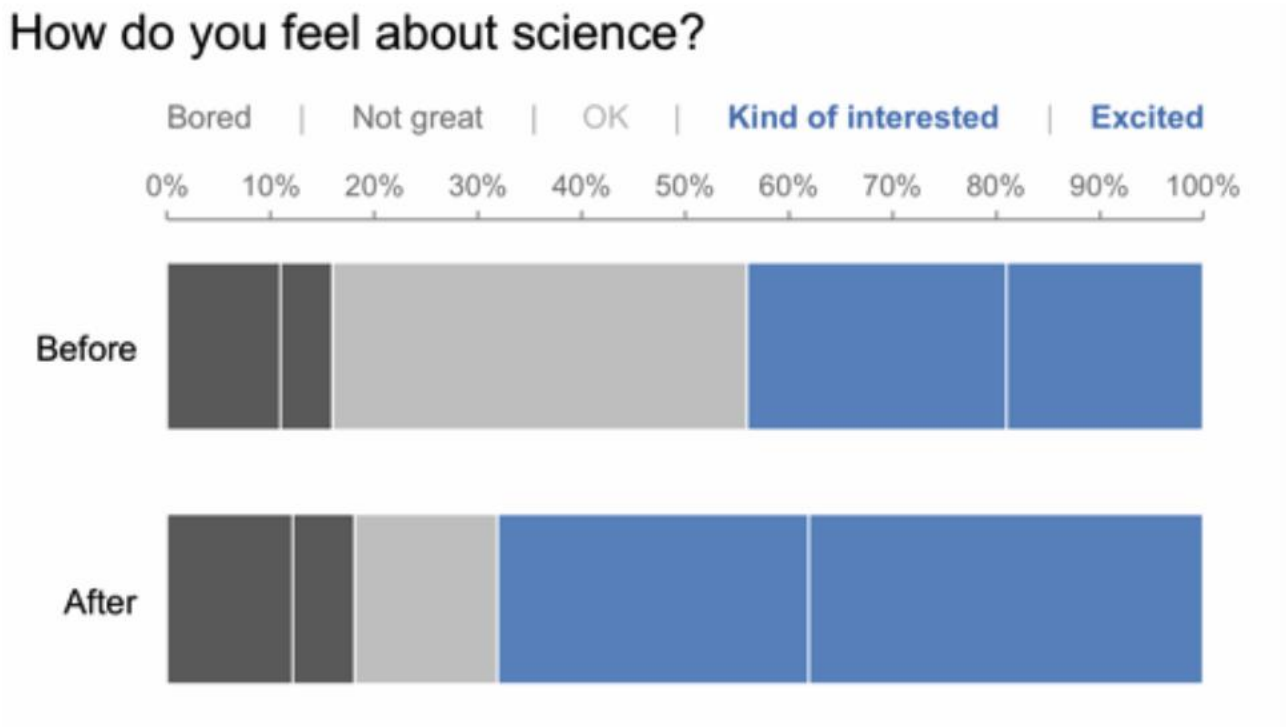
Can you spot the differences?



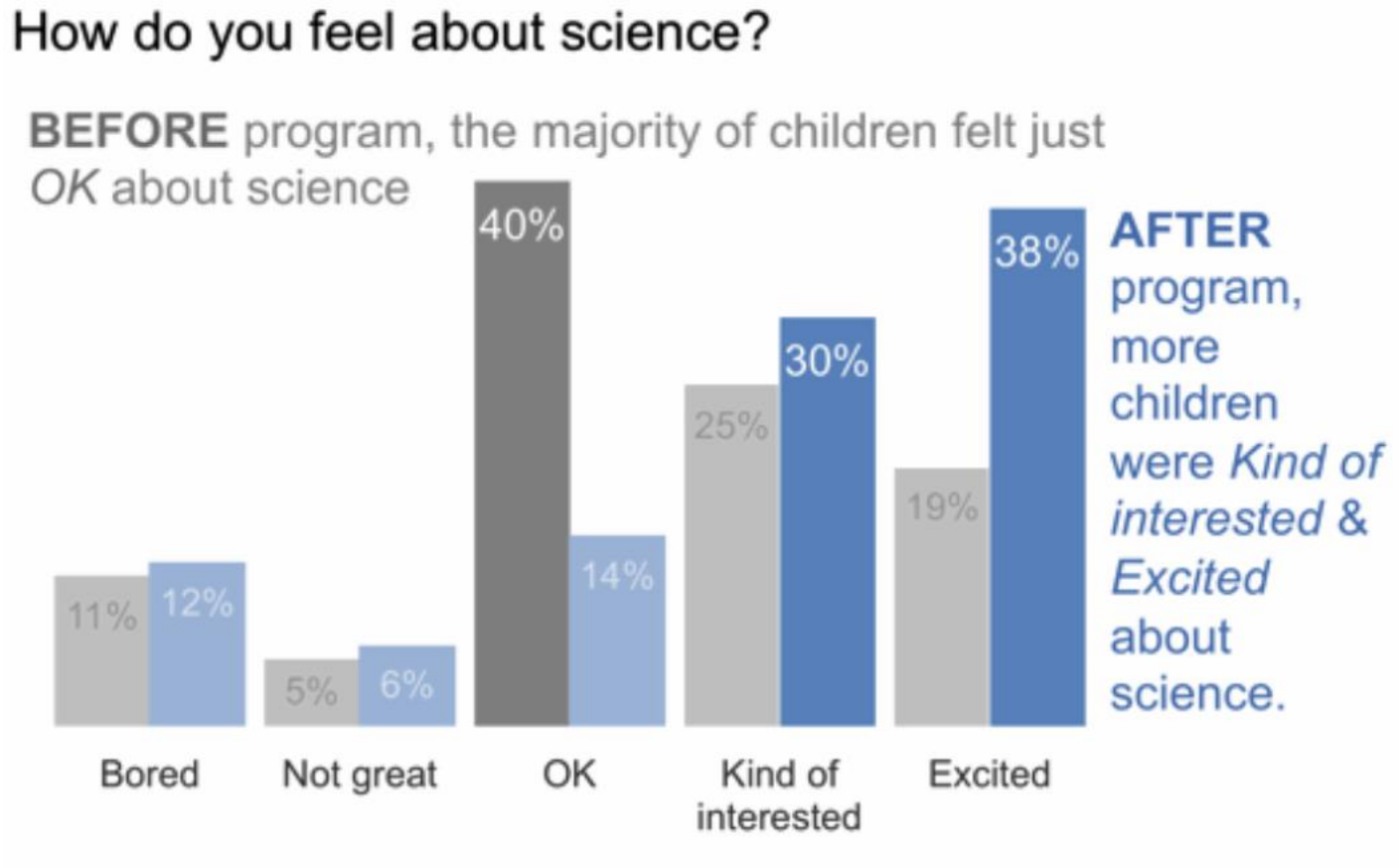
Can you spot the differences?



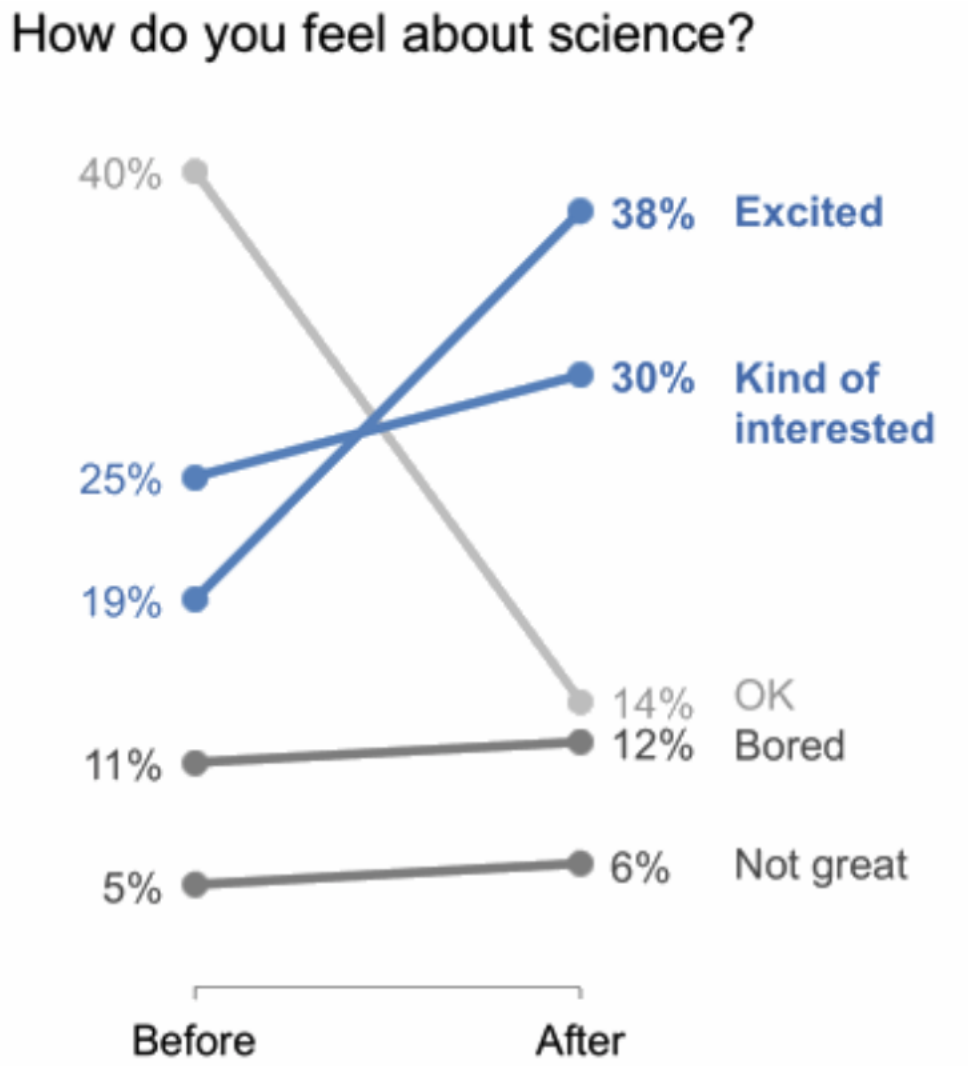
Pie Alternatives: Stacked Bar Charts



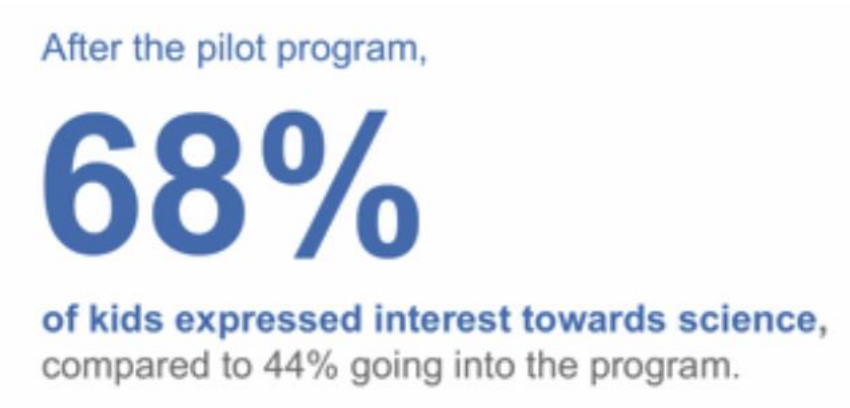
Pie Alternatives: Bar charts



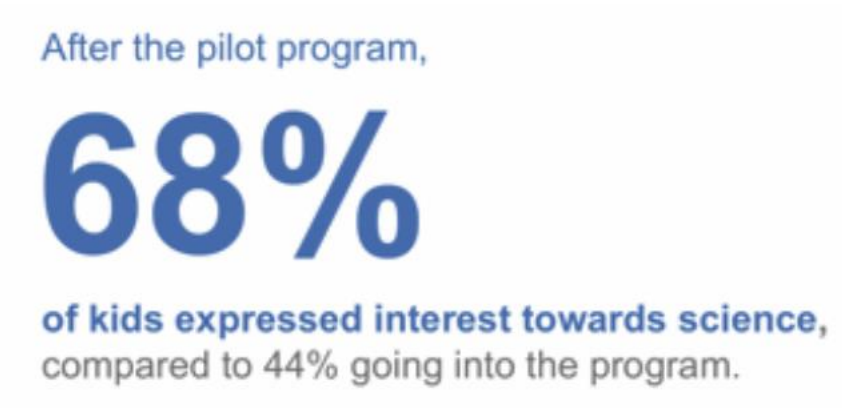
Pie Alternatives: Slope graphs



Pie Alternatives: Just show the numbers

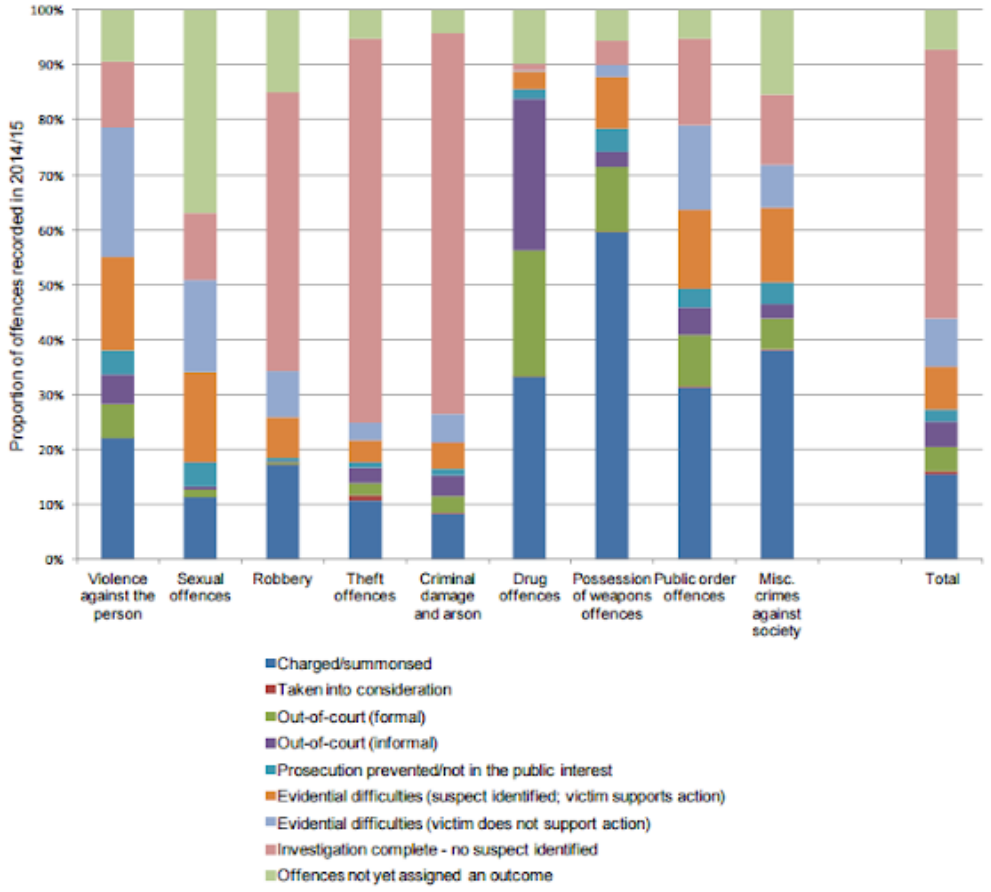


Pie Alternatives: Just show the numbers

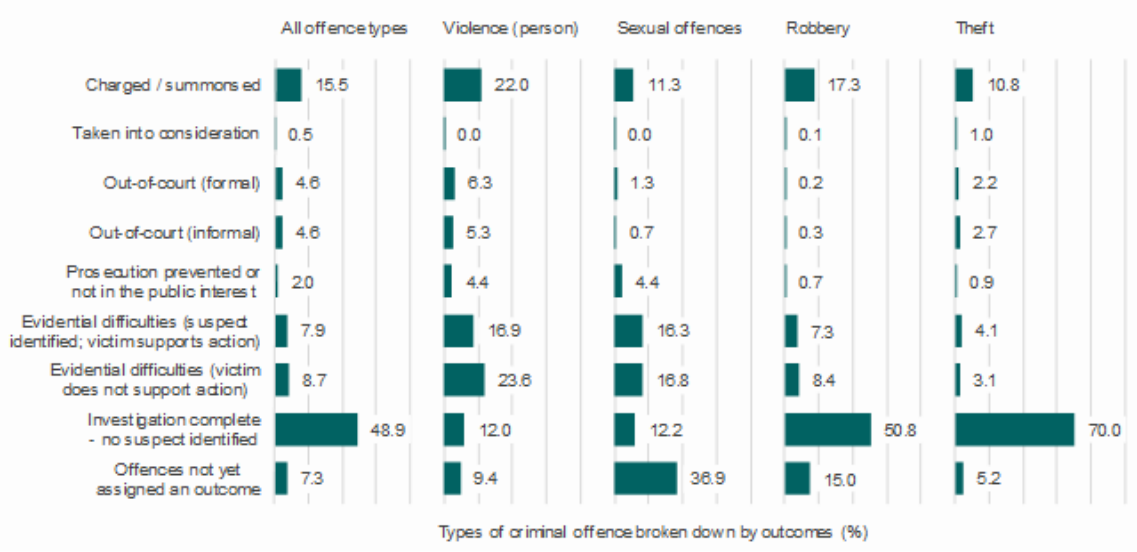


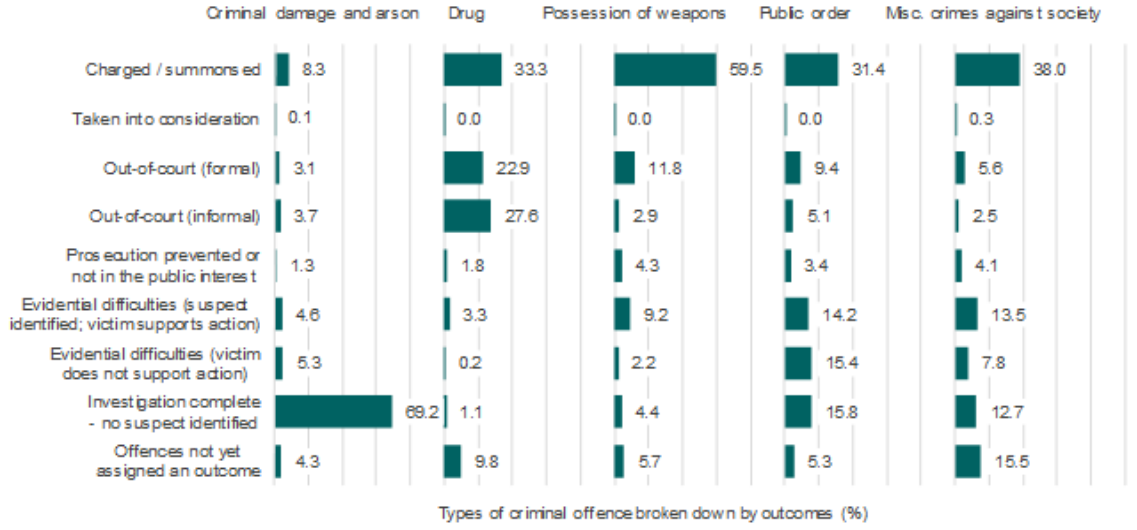
Stacked Bar Charts vs. Small Multiples

Figure 2.1: Outcomes assigned to offences recorded in 2014/15, by outcome group and offence group



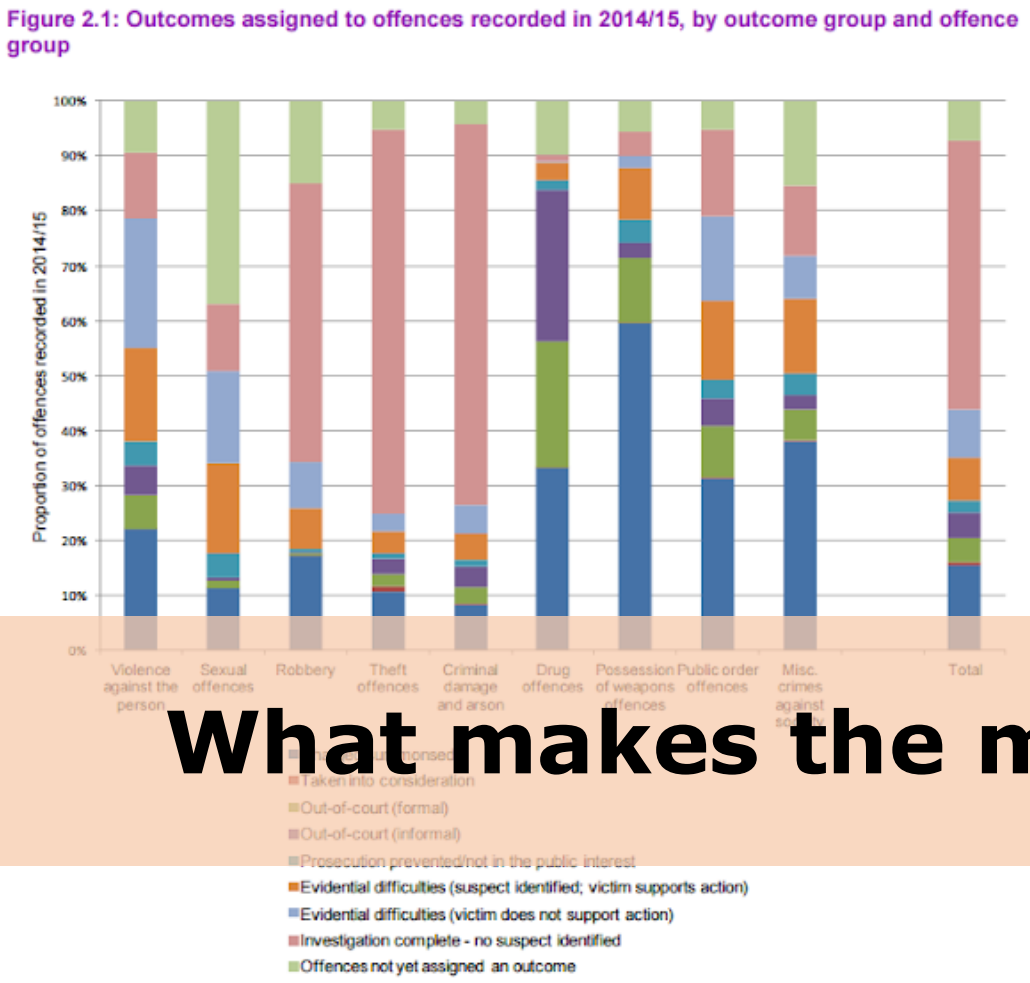
Source: Home Office Data Hub and voluntary spreadsheet return
1. Based on 38 forces that supplied data as referenced in Table 2.1.
2. The numbers behind this chart are in Table 2.3

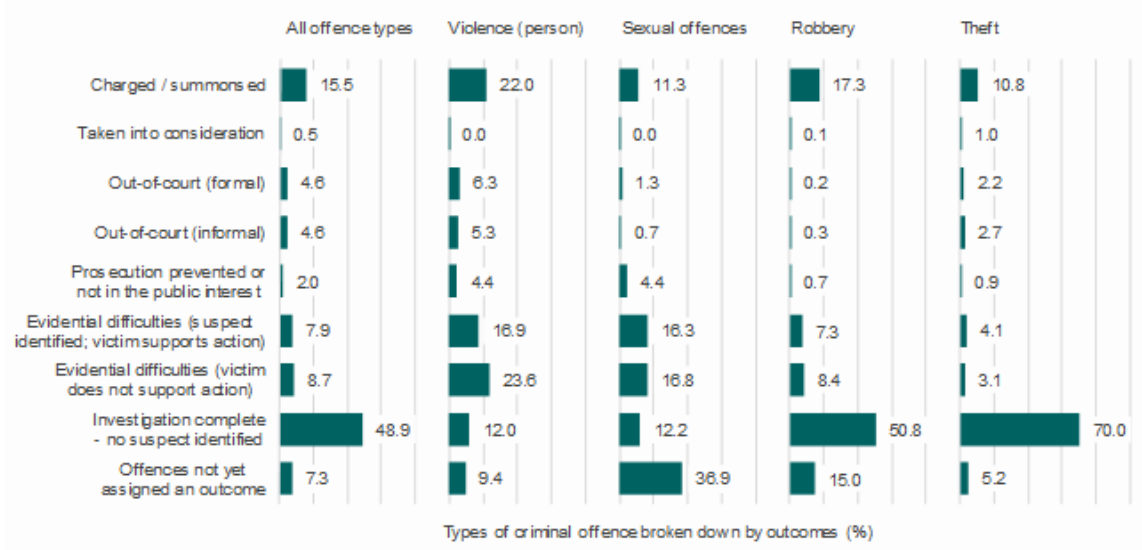


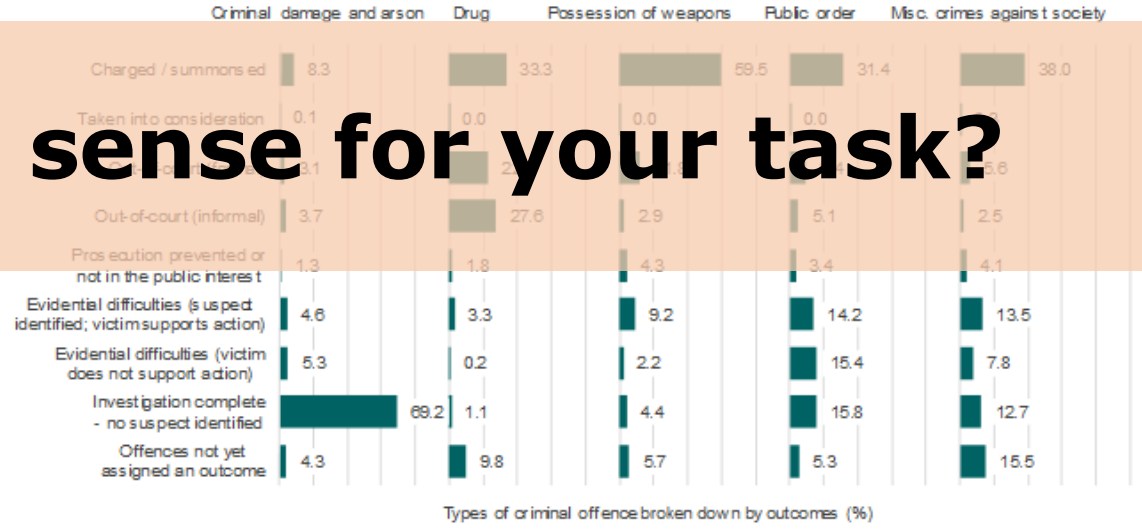


Images from http://chartartistry.blogspot.com/2016/02/small-multiples-when-stack-bars-just.html

Stacked Bar Charts vs. Small Multiples







What makes the most sense for your task?

Images from http://chartartistry.blogspot.com/2016/02/small-multiples-when-stack-bars-just.html

Pie charts not inherently bad. Maybe the biggest problem with pie charts is that they have been so often done poorly…

Google

bad pie charts

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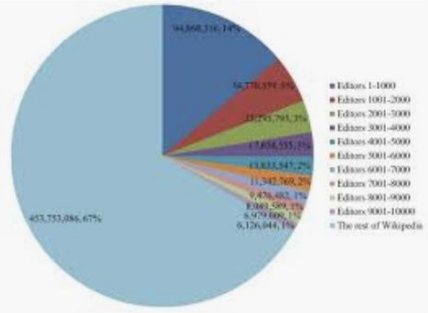
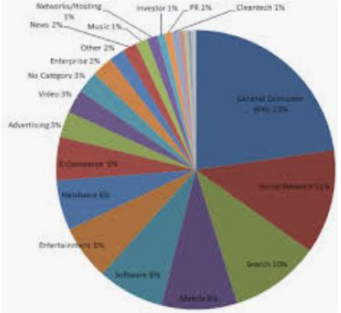
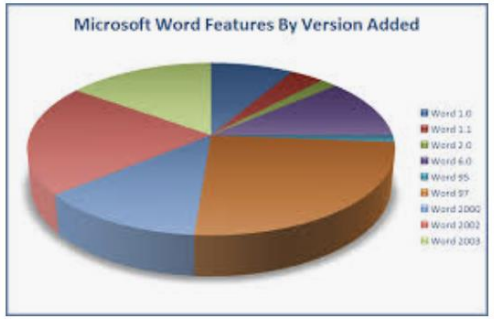
wrong | media | example | data visualization | male female | economy florida | 2016 presidential election | attractive | advanced | 2



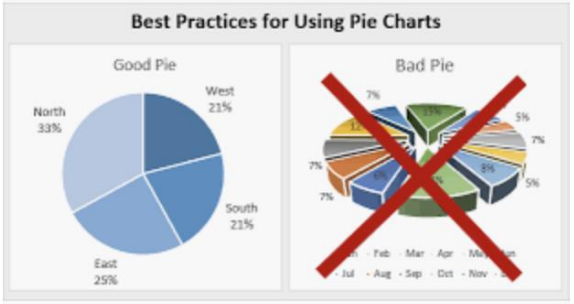
Yet another bad pie chart : dataisugly
reddit.com



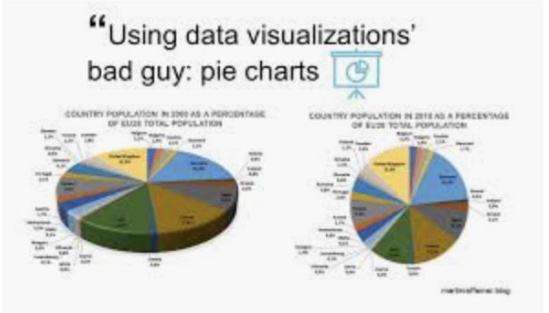
death to pie charts — storytelli…
storytellingwithdata.com



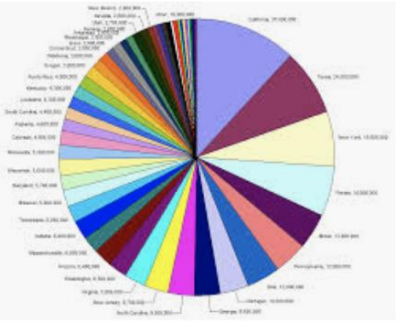
Pie charts: the bad, the worst and the ...
visuanalyze.wordpress.com



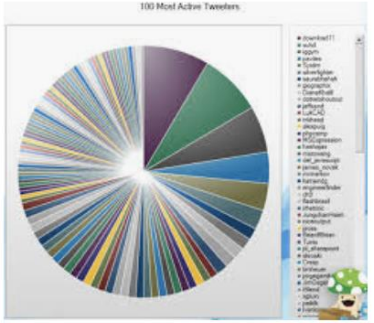
When to use Pie Charts in Dashboards ...
excelcampus.com



Using data visualizations' bad guy: pie ...
martinraffeiner.blog



Understanding Pie Charts
eagereyes.org



Pie charts: the bad, the worst an…
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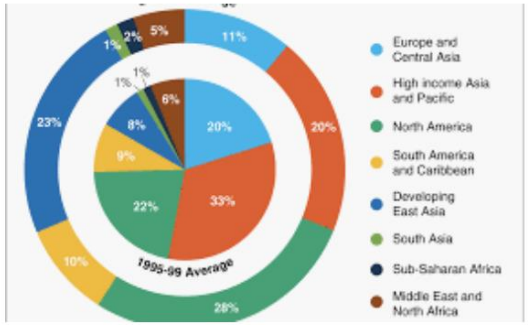
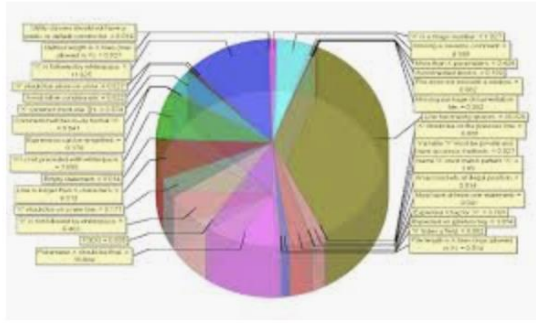


Remake: Pie-in-a-Donut Chart - Policy Viz
policyviz.com



Pin on Chartjunk Data Visualization
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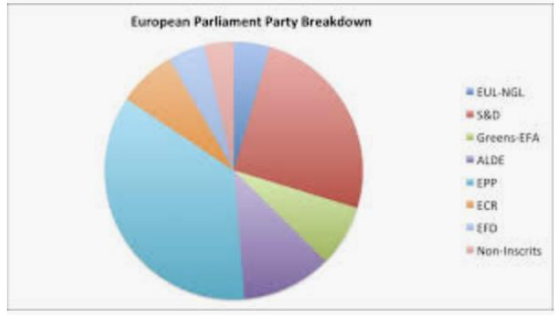


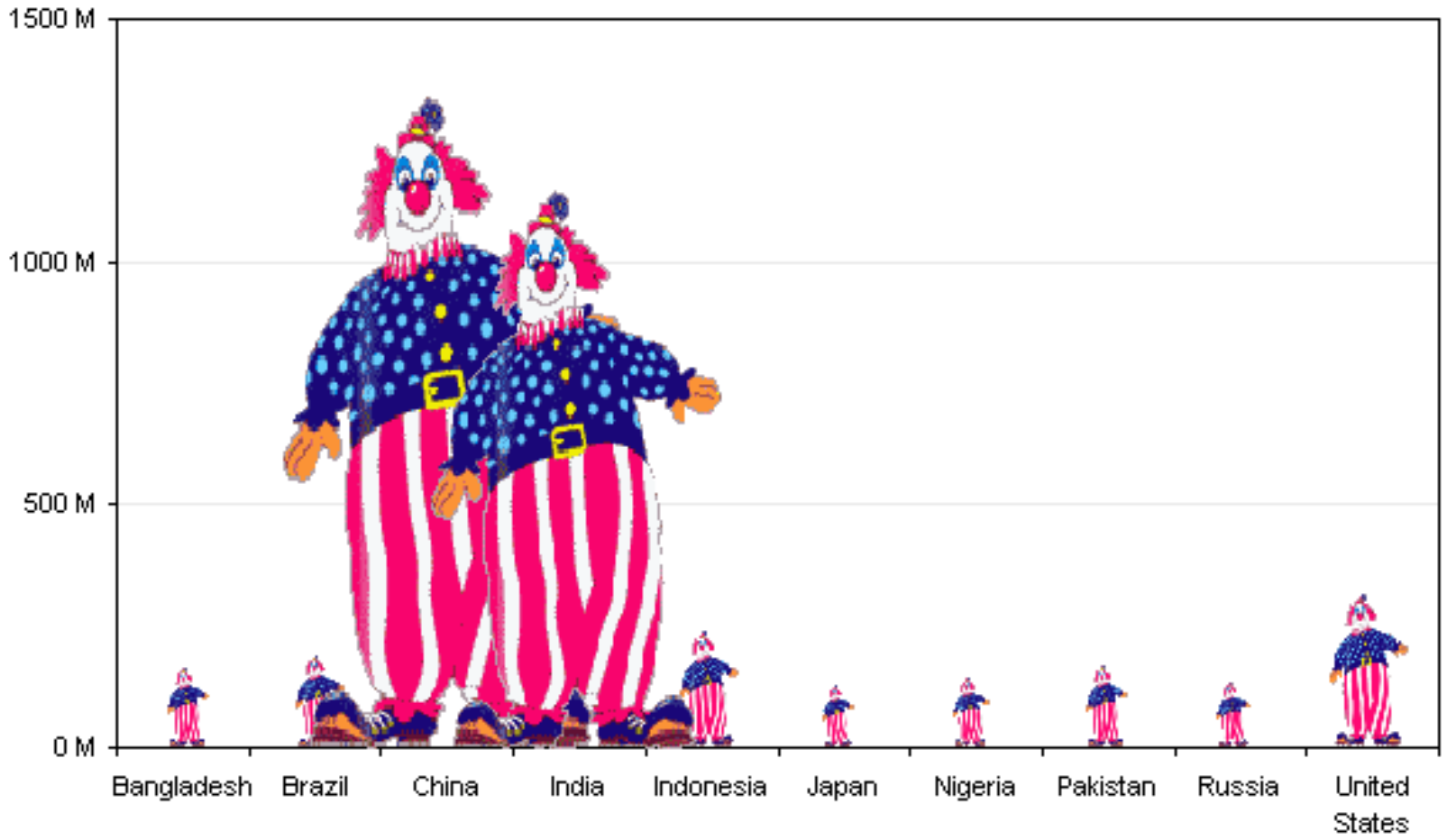
Pie Charts Are The Worst - Business Insider
businessinsider.com

Guideline: Area-as-Quantity with Care

How many streams are there in November compared to December?

7.5 times as many streams!

Be careful of length vs. area for other marks



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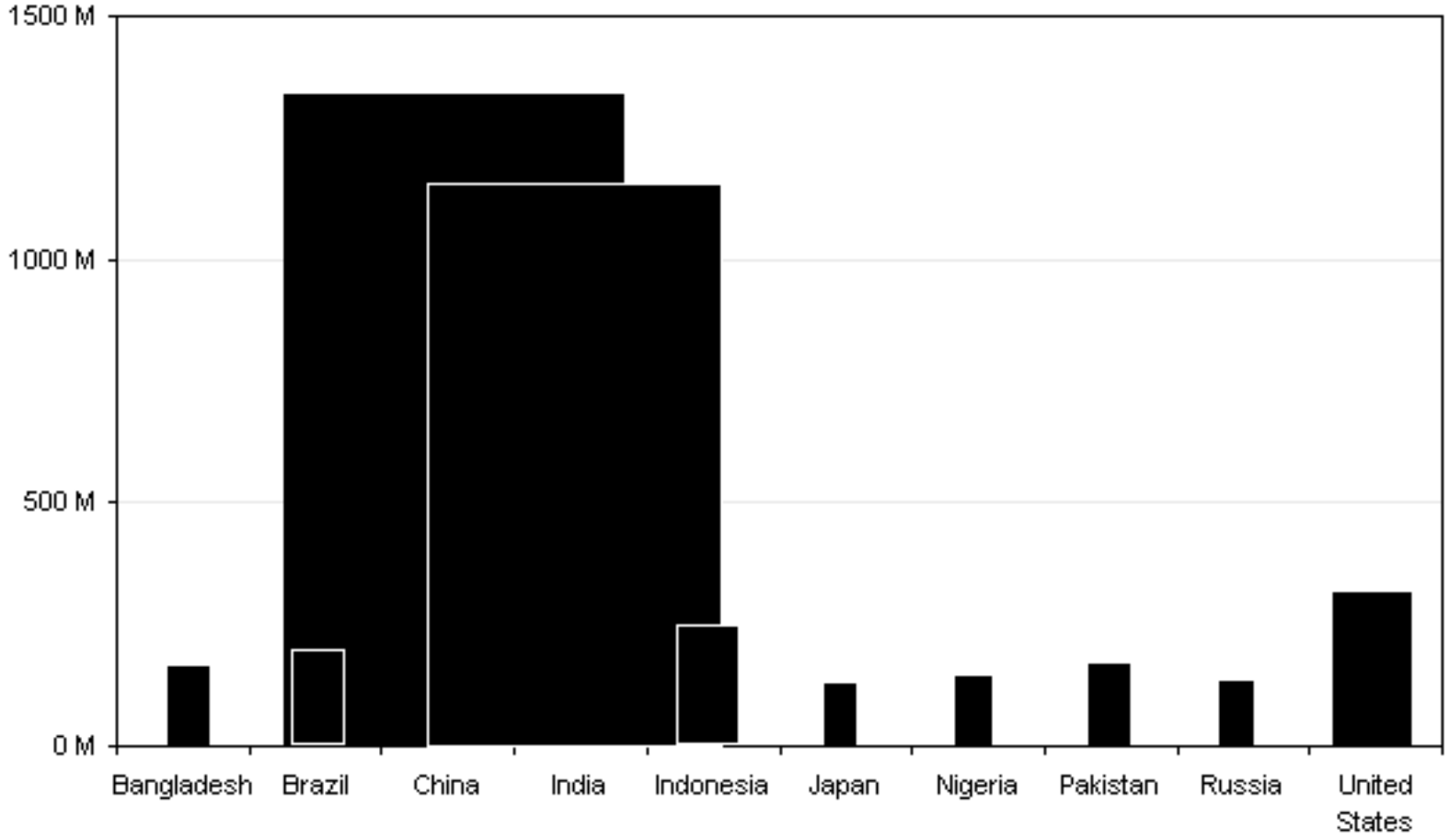
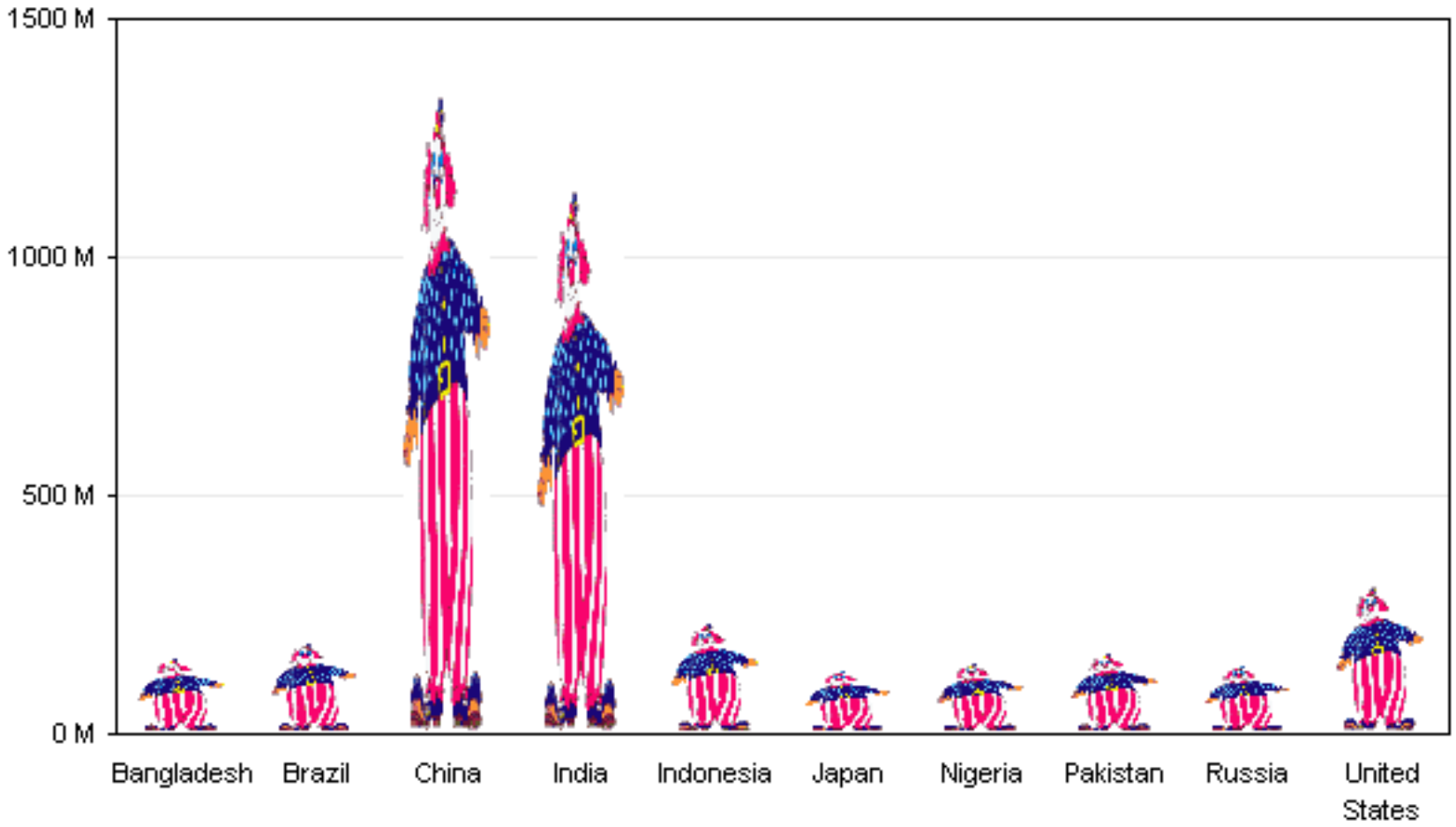
What is being perceived?



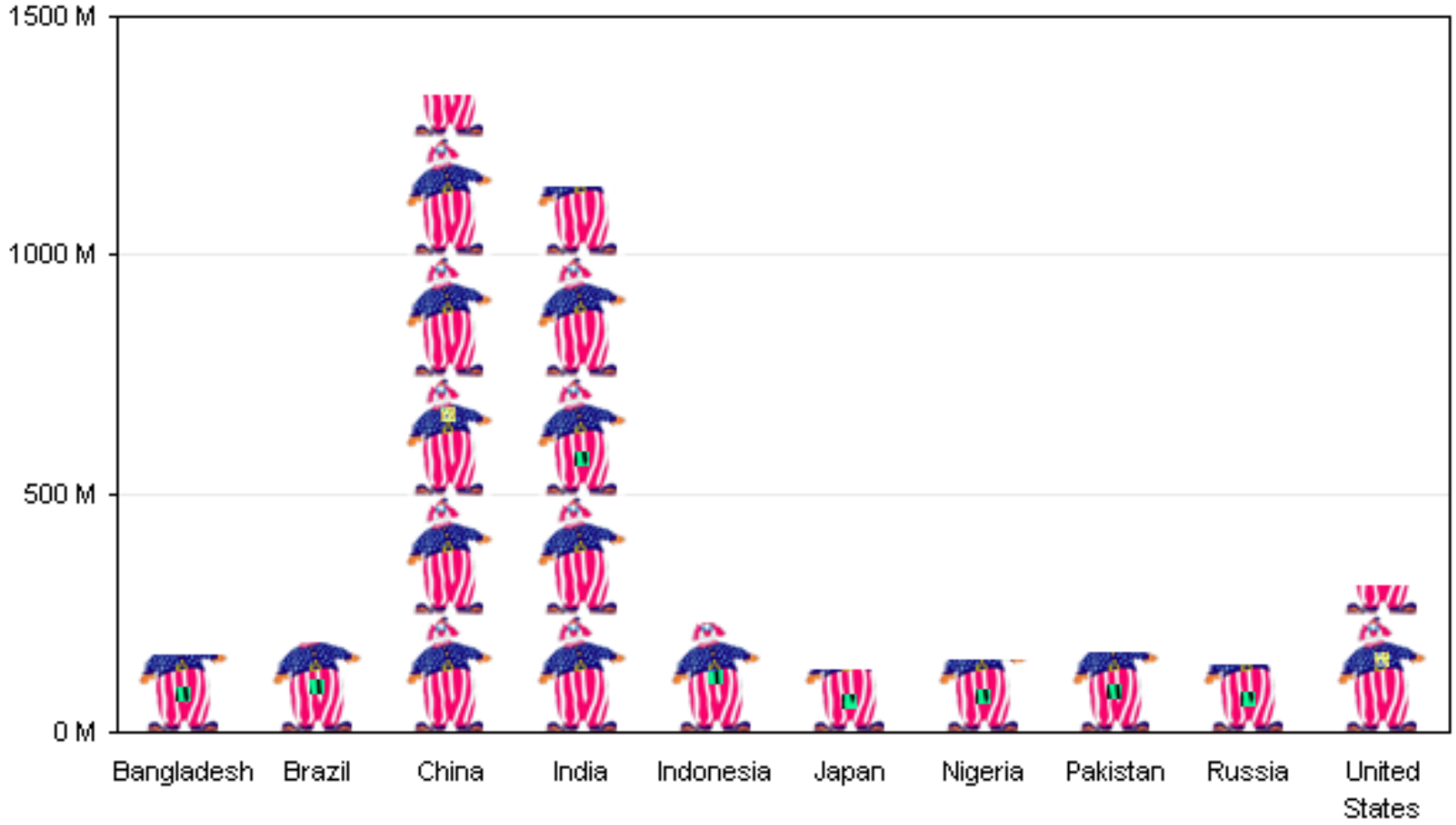
https://peltiertech.com/bad-bar-chart-practices-or-send-in-the-clowns/

Fixing the width



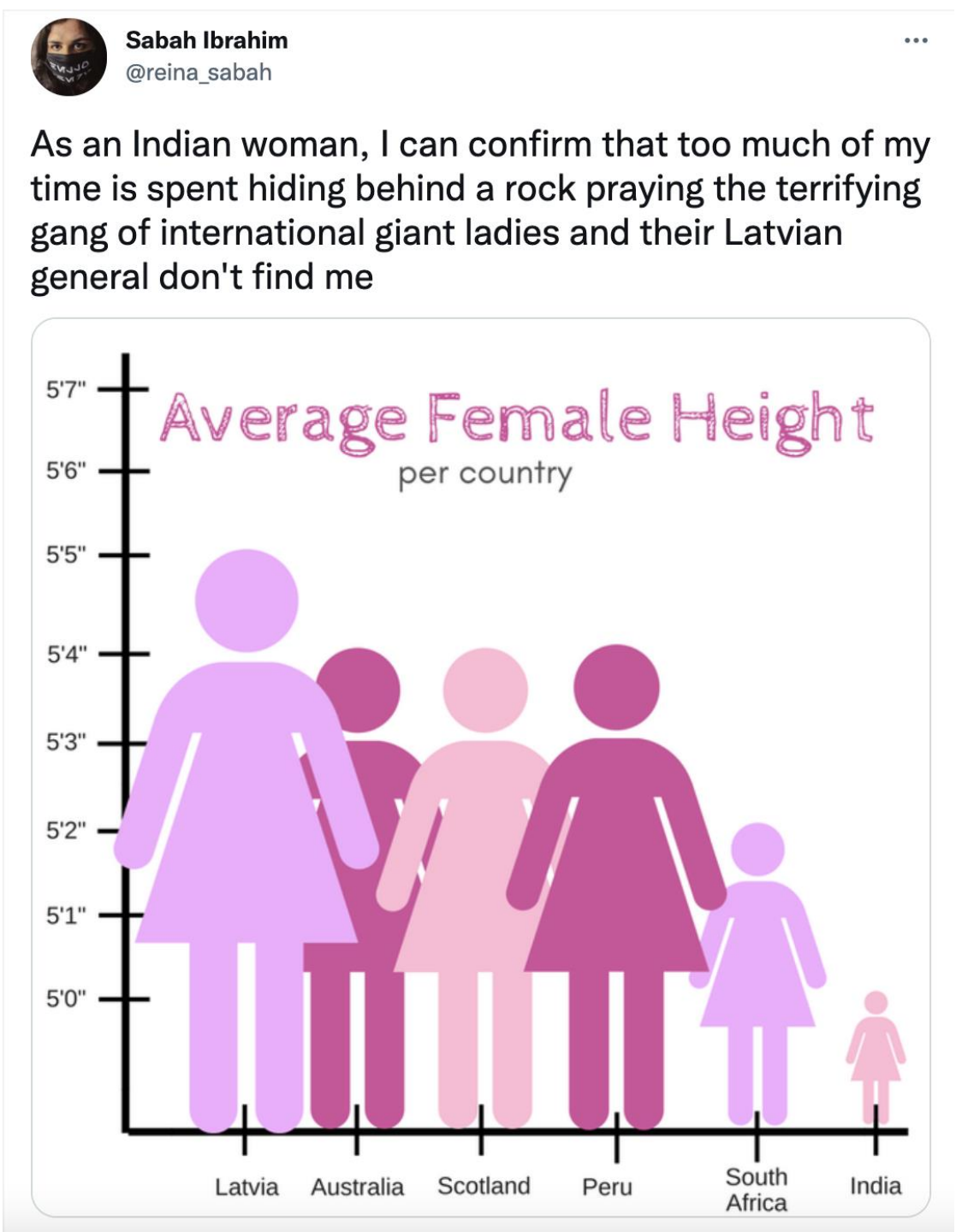
https://peltiertech.com/bad-bar-chart-practices-or-send-in-the-clowns/

Consider using an Isotope Chart

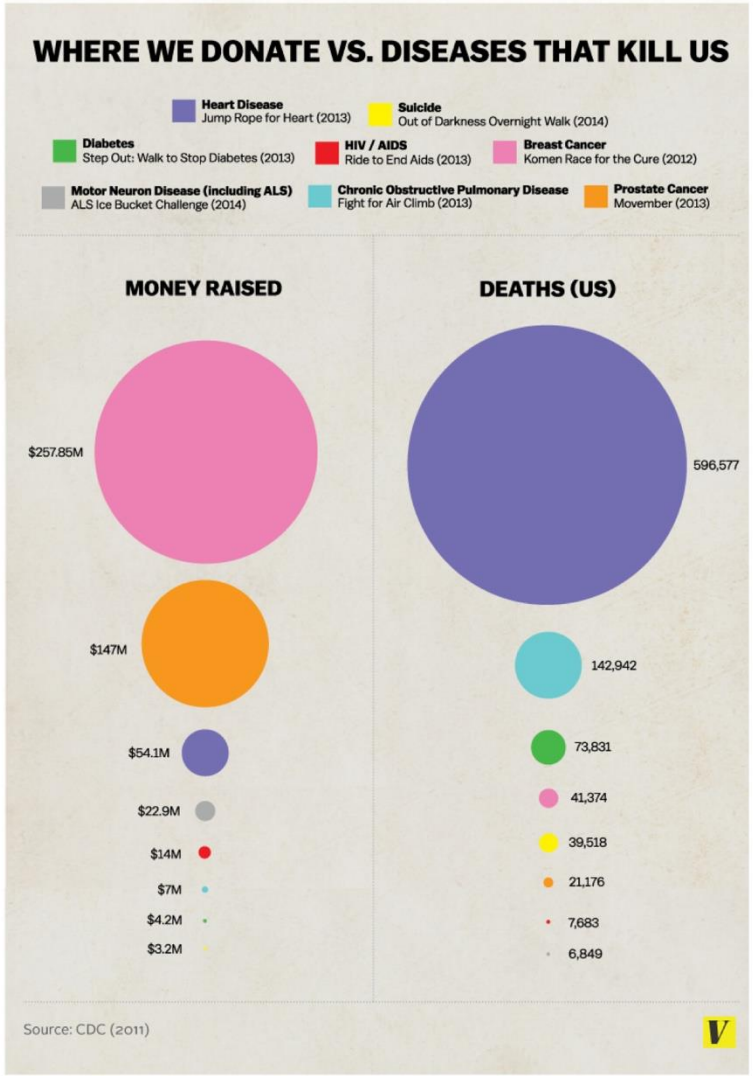


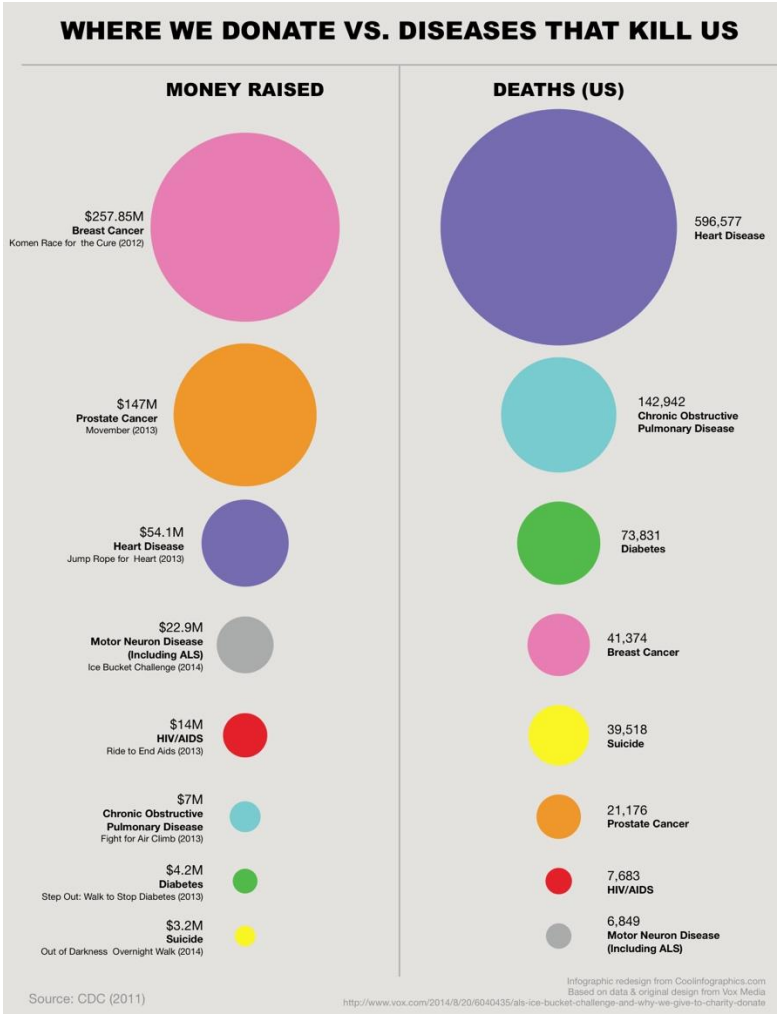
https://peltiertech.com/bad-bar-chart-practices-or-send-in-the-clowns/

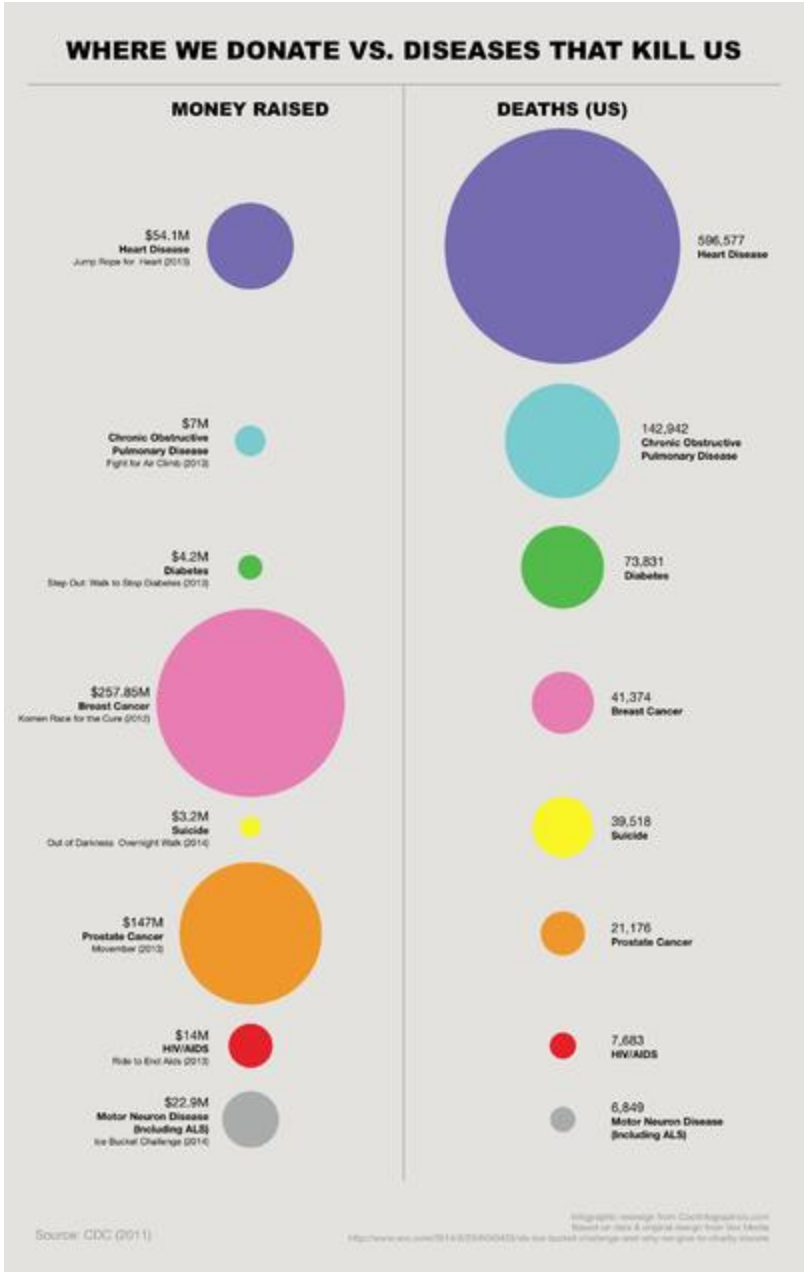
Now we're just breaking multiple guidelines at once



Circles: Encode by Area not Radius

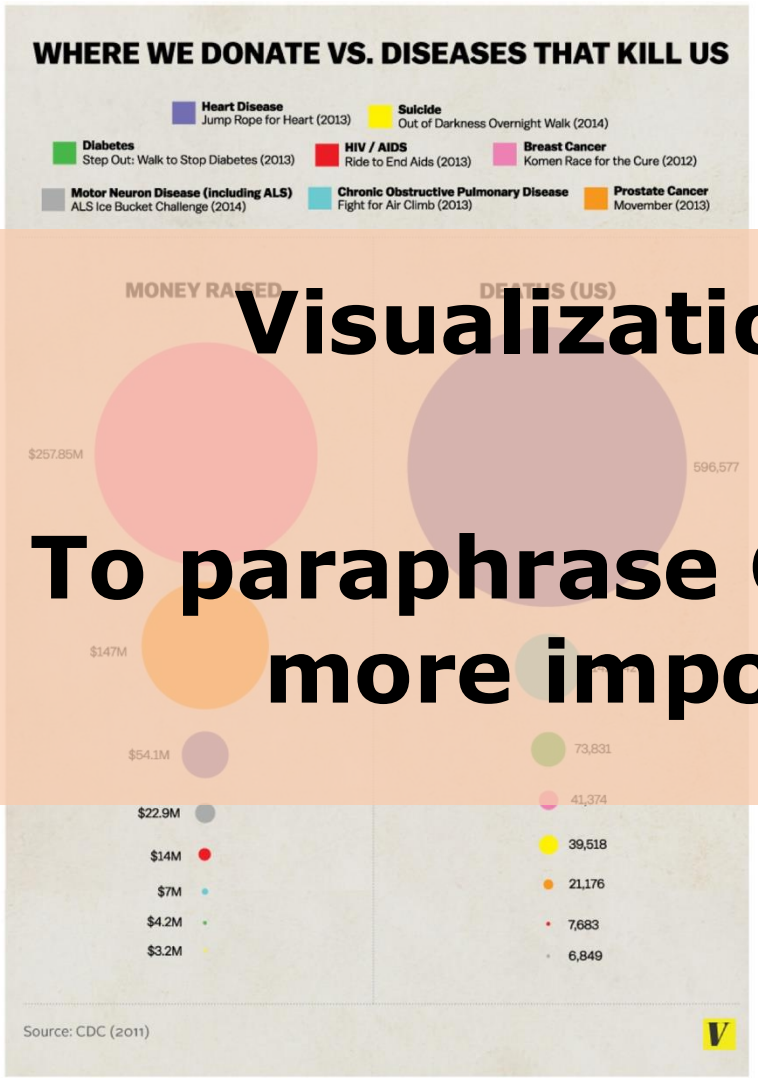


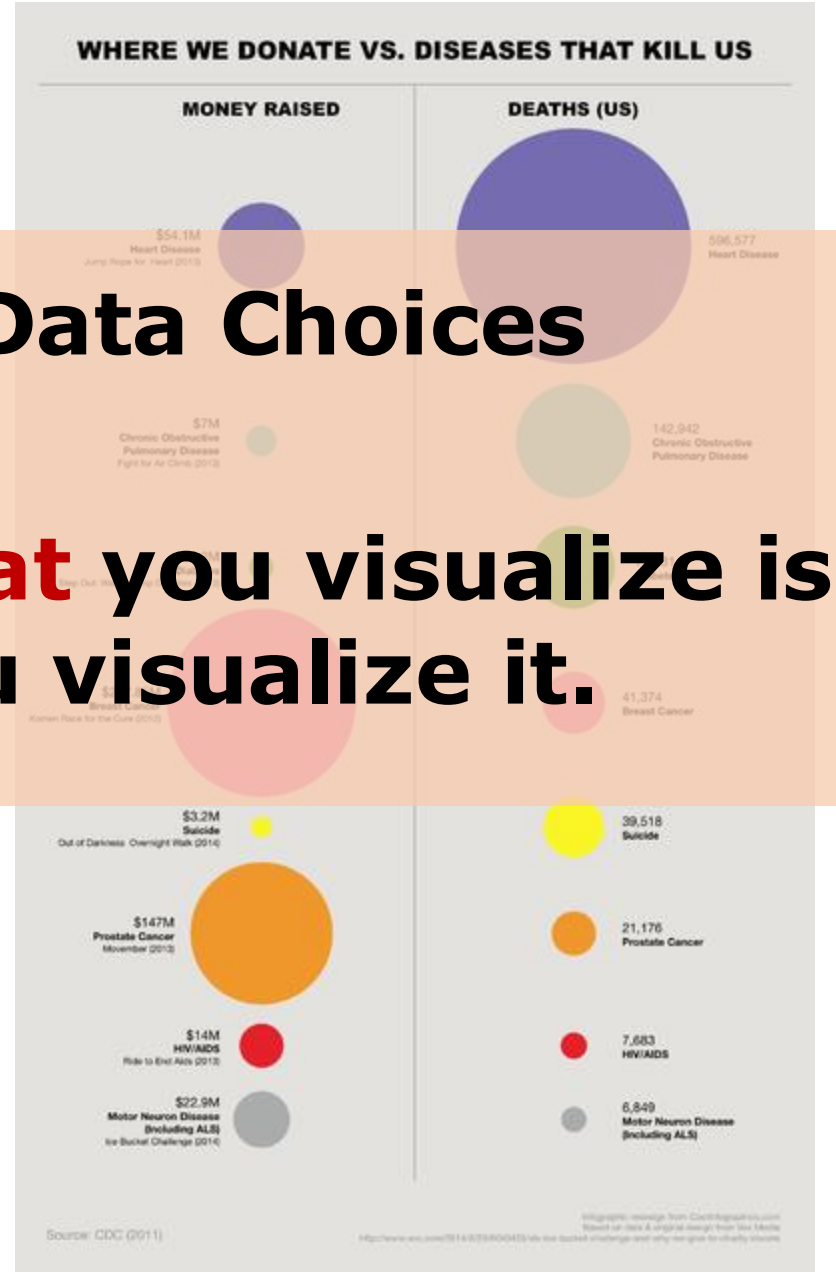




Images from Vox and http://coolinfographics.com/blog/2014/8/29/false-visualizations-sizing-circles-in-infographics.html

Circles: Encode by Area not Radius





Visualization can't overcome Data Choices

To paraphrase George Furnas, what you visualize is more important than how you visualize it.

Images from Vox and http://coolinfographics.com/blog/2014/8/29/false-visualizations-sizing-circles-in-infographics.html