

Visualizing Data

Some might argue that there is confusion over the interpretation and usage of *p*-values. More likely, its' value is misplaced and subsequently misused. The *p*-value is the probability of an effect or association (hereafter collectively referred to as ‘effect’), and is most often computed through testing a (null) hypothesis like “the mean values from two samples have been obtained by random sampling from the same normal populations”. The *p*-value is the probability of this hypothesis. Full-stop. *P*-values cannot reveal the plau-

Recap

- Goal is to get you to stop and think about your plots *before* you make them. What are the kinds of things you should be considering?

What is Data Viz?

Data visualization is both an art *and* a science

Art:

- Aesthetically pleasing
- The story you're trying to tell

Science:

- Graphical representation of specific types of data
- The story you're trying to tell

Warning

Making figures for academic purposes \neq making figures for pure data viz purposes

If you go into data science (and aren't constrained by academia), you'll want to check out R shiny (for interactive plots), web design, typography, etc.

If your PI asks you build a dashboard, think long and hard before committing.

Today

- What kinds of things should you be thinking about when it comes to data viz *for academic papers?*
- What **not** to do (I'm gonna rant a bit)
- Hopefully helpful resources (no memorizing!)

What should we be thinking about?

1. Telling your story
2. Contrast
3. Accessibility

Telling your story

- Raw data are not intuitive. For the most part, you can't look at a spreadsheet of numbers and decipher any patterns. Especially with really big spreadsheets!
- We need a way to graphically show the data so that our human eyes can try to make sense of the data.
- It is so easy to **LIE** with data! Balancing act of conveying your message and not lying.
- As our datasets become more complex and high dimensional, data visualization can become more challenging.
- The goal is NOT to show every bit of data you have collected. It's to show the relationship you care about in an honest manner.

What makes a good figure?

- Clear, descriptive title
- Axes are clearly labeled with variables and units of measurement
 - **Label. Your. Damn. Axes.**
- Scale is:
 - consistent across axis
 - easily interpreted
 - chosen so that data are evenly distributed
- Data points are represented clearly, with a good key/legend
- Graph is the *appropriate* type for your data (nominal, ordinal, interval, ratio etc.)

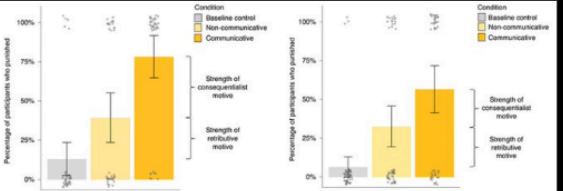
Appropriateness

There are no 100% right answers, but there are wrong ones...

- **3D pie charts are the worst of the worse**
 - Instead, try stacked bar plot or even better, stacked dot plot
- **3D bar plots are never the answer**
- Typically, you should show either the raw data or at least a distribution
 - Shelly is anti bar plot, generally
 - Shelly is anti box plots on their own (nice when combined)
 - Shelly is skeptical of lines -- need to be careful

 **Stephanie Spielman, PhD** @stephsspiel · Nov 27, 2020 ...
This visualization perfectly displays why barplots with error bars are often egregiously misleading. #dataviz

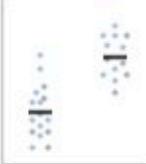
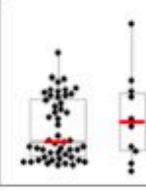
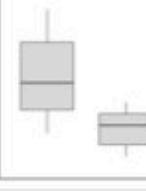
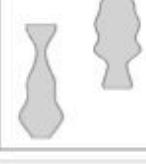
 **Nature Research** @nresearchnews · Nov 27, 2020
Many children are willing to make personal sacrifices to punish wrongdoers and even more so if they believe punishment will teach the transgressor a lesson, according to a study in @NatureHumBehav. go.nature.com/3nUWtma



nature human behaviour

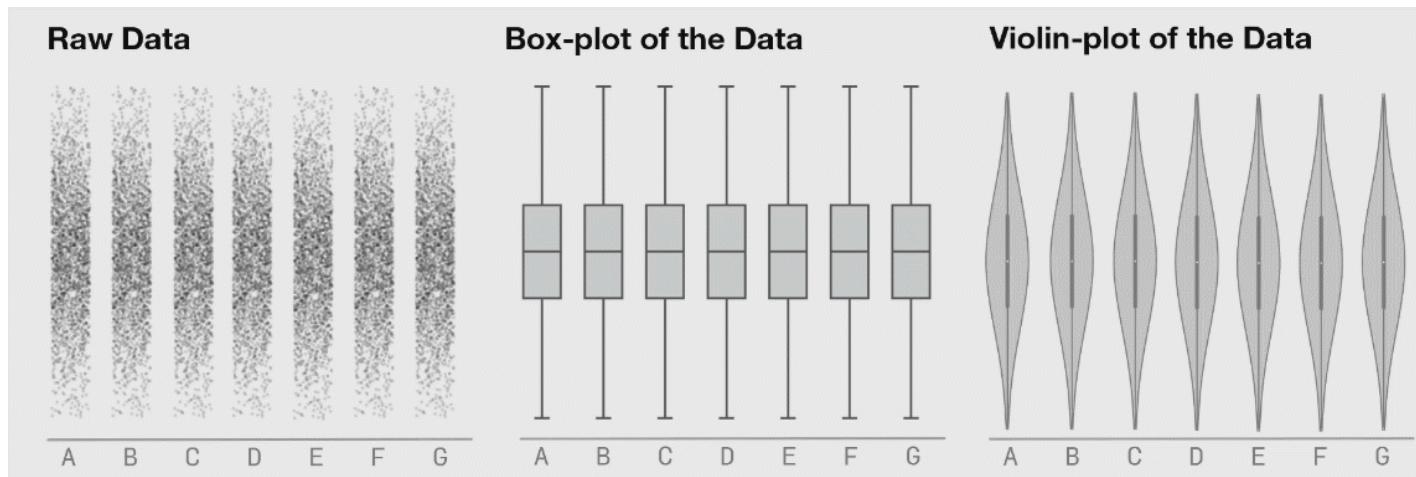
 **Stephanie Spielman, PhD** @stephspiel · Nov 27, 2020 ...
I must also add: Big props to authors for overlaying the jitter plot here. The combined visualization does make the actual underlying data distribution extremely clear (while also revealing the flaws of barplots as standalone viz).

- Different alternatives exist, with dotplots being the best option probably
- Bars are more appropriate when you have proportions or counts; but even still -- dotplots
- **Excellent thread** with many resources on how to maximize the utility of dotplots

Figure Types	Example	Type of Variable	What the Plot Shows	Sample Size	Data Distribution	Best Practices
Dot plot		Continuous	Individual data points & mean or median line Other summary statistics (i.e. error bars) can be added for larger samples	Very small OR small; can also be useful with medium samples	Sample size is too small to determine data distribution OR Any data distribution	<ul style="list-style-type: none"> Make all data points visible - use symmetric jittering Many groups: Increase white space between groups, emphasize summary statistics & de-emphasize points Only add error bars if the sample size is large enough to avoid creating a false sense of certainty Avoid "histograms with dots"
Dot plot with box plot or violin plot		Continuous	Combination of dot plot & box plot or violin plot (see descriptions above and below)	Medium	Any	<ul style="list-style-type: none"> Make all data points visible (symmetric jittering) Smaller n: Emphasize data points and de-emphasize box plot, delete box plot and show only median line for groups with very small n Larger n: Emphasize box plot and de-emphasize points
Box plot		Continuous	Horizontal lines on box: 75 th , 50 th (median) and 25 th percentile Whiskers: varies; often most extreme data points that are not outliers Dots above or below whiskers: outliers	Large	Do not use for bimodal data	<ul style="list-style-type: none"> List sample size below group name on x-axis Specify what whiskers represent in legend
Violin plot		Continuous	Gives an estimated outline of the data distribution. The precision of the outline increases with increasing sample size.	Large	Any	<ul style="list-style-type: none"> List sample size below group name on x-axis The violin plot should not include biologically impossible values
Bar graph		Counts or proportions	Bar height shows the value of the count or proportion	Any	Any	<ul style="list-style-type: none"> Do not use for continuous data

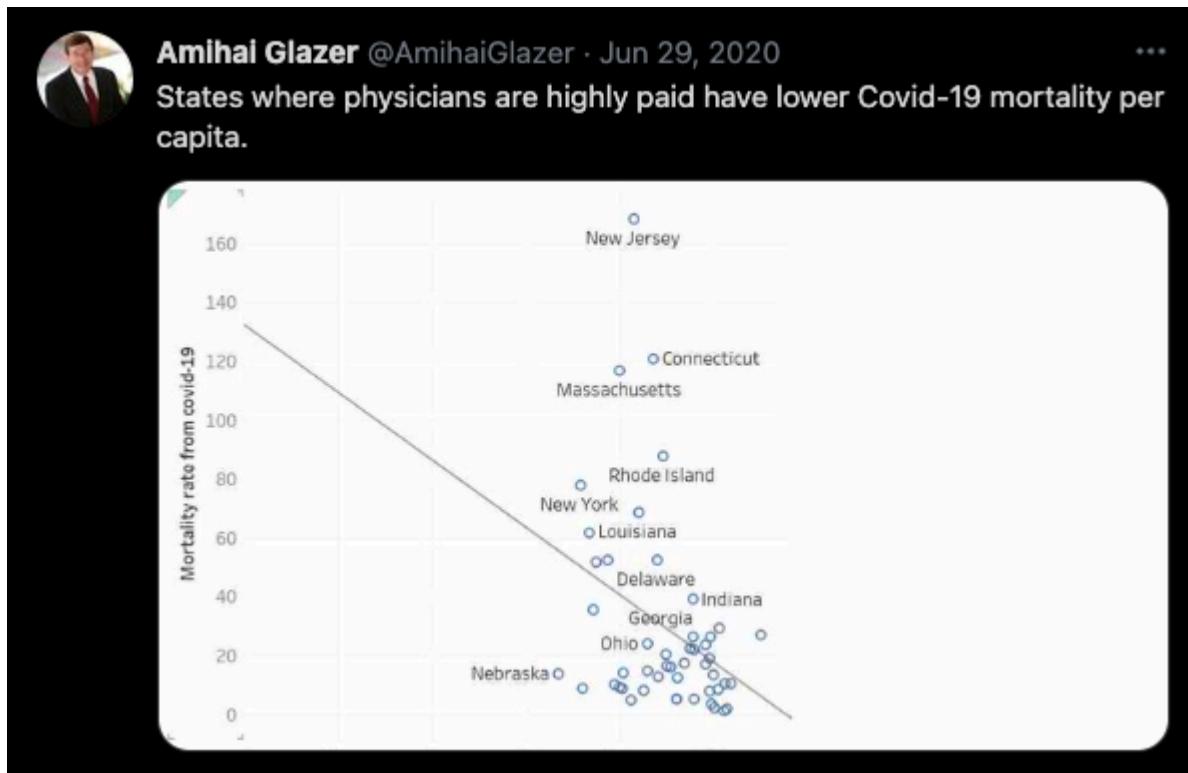
Source: @T_Weissgerber

Why box plots on their own can suck



<https://www.autodesk.com/research/publications/same-stats-different-graphs>

Why adding lines can be misleading

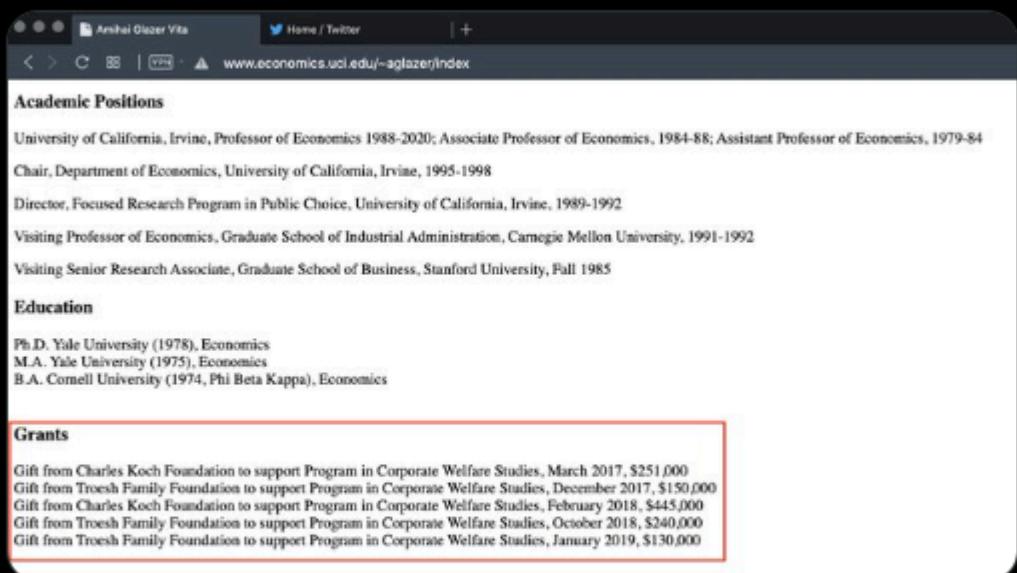


Lines Cont...

 **Бай Михал** @BajMihal · Jul 5, 2020

Replying to @AmihaiGlazer

And that explains everything:



Grants

Gift from Charles Koch Foundation to support Program in Corporate Welfare Studies, March 2017, \$251,000
Gift from Troesh Family Foundation to support Program in Corporate Welfare Studies, December 2017, \$150,000
Gift from Charles Koch Foundation to support Program in Corporate Welfare Studies, February 2018, \$445,000
Gift from Troesh Family Foundation to support Program in Corporate Welfare Studies, October 2018, \$240,000
Gift from Troesh Family Foundation to support Program in Corporate Welfare Studies, January 2019, \$130,000

3 14

 **Jack Pondit vs** @Jack_Pondit · Jul 2, 2020

Replying to @AmihaiGlazer

This is a horrible misuse and misinterpretation of statistics.

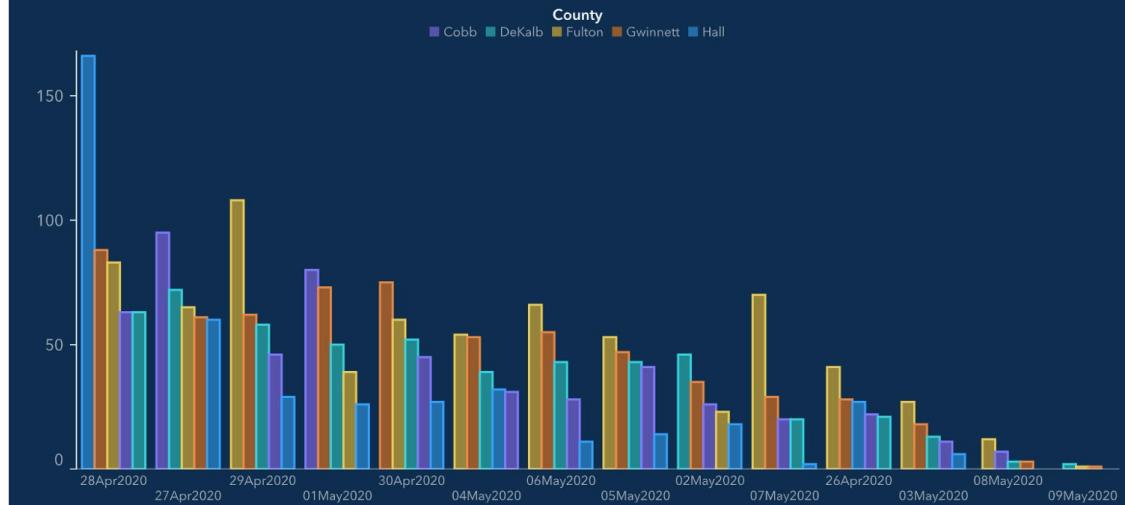
Things to avoid

- Misleading text/axes
- Inaccurate plotting
- So many COVID-19 data visualizations...

Misleading Text/Axes

Top 5 Counties with the Greatest Number of Confirmed COVID-19 Cases

The chart below represents the most impacted counties over the past 15 days and the number of cases over time. The table below also represents the number of deaths and hospitalizations in each of those impacted counties.

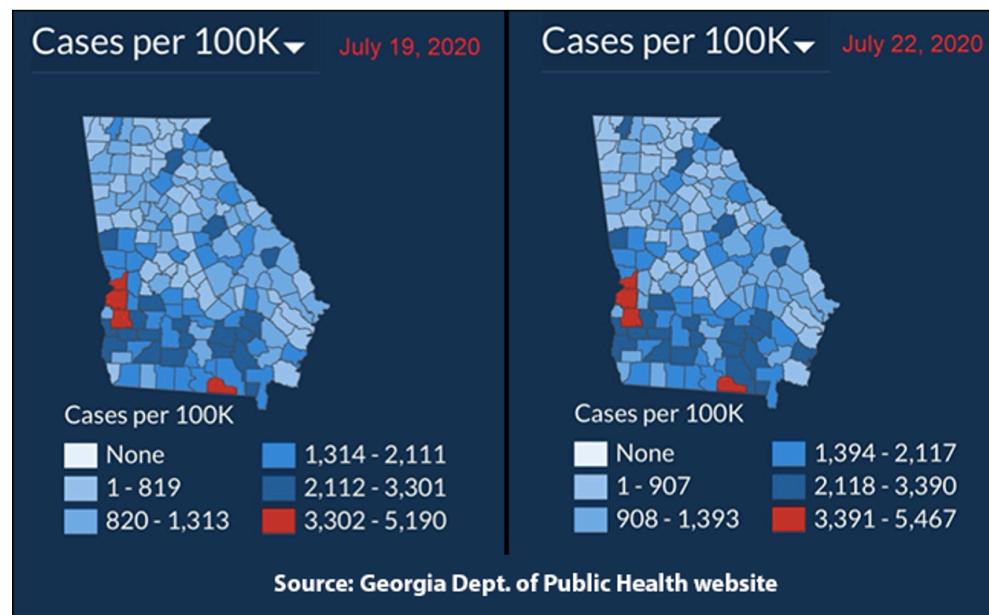


davidmcarlson
@davidmcarlson

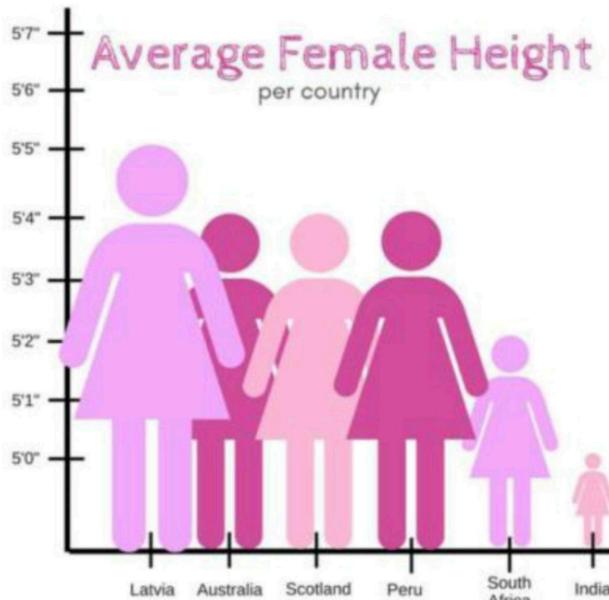
On the official Georgia COVID stats web page is this graph. Looks good, getting better, right? Look closer at the dates on the X-axis. They have arranged the dates out of order to create a declining appearance.
@GaDPH @georgiagov

Inaccurate Plotting

This strange plot was put out by Georgia's Health Department. It's trying to show that basically there haven't been any real changes in COVID-19 statewide. But look at the values in the legend...They've changed them to basically keep the same graph. WUT?!



Misleading Shapes



Scrimphony Warchestra · 8h

Replies to @reina_sabah

DATA VISUALIZATION IS MY
PASSION



1



7



494



Sabah Ibrahim @reina_sa... · 8h

STOP YELLING YOU WILL ALERT
THE LATVIANS



12



7



940



Accessibility is IMPORTANT

- Colorblindness sucks. ~1 in 12 men are colorblind (much lower in women)
- People have poor vision (glasses, anyone?)
- Journals scale your figure sizes down so that it fits within the article (like within a column of text)

What can we do?

- Colors
- Contrast
- Big text size (bigger/bolder you can get away with less color contrast)

Color Palettes

Also super helpful! `RColorBrewer` and `ggsci` are great. But there are millions of others.

All you need are hex codes (6 digits, alphanumeric). This is true for all color palettes (including monochromatic).

Different types of palettes (unordered, sequential, divergent etc.). Look [at this blog post](#) to learn more about these

Bad use of colors

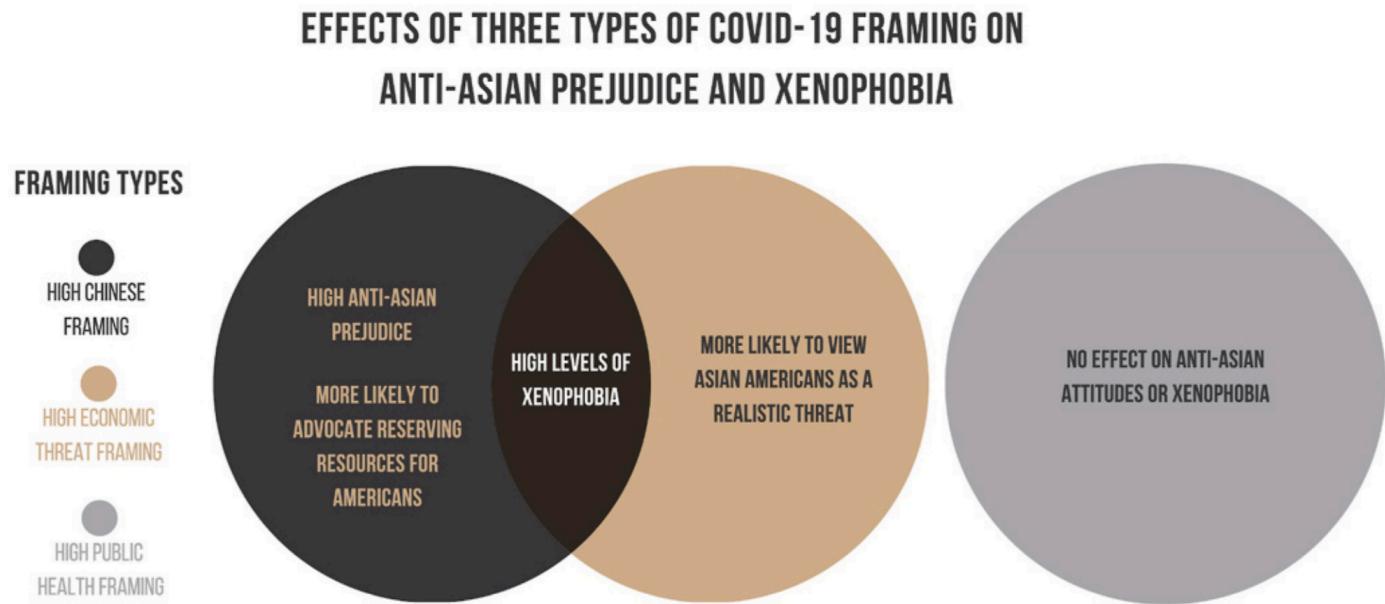
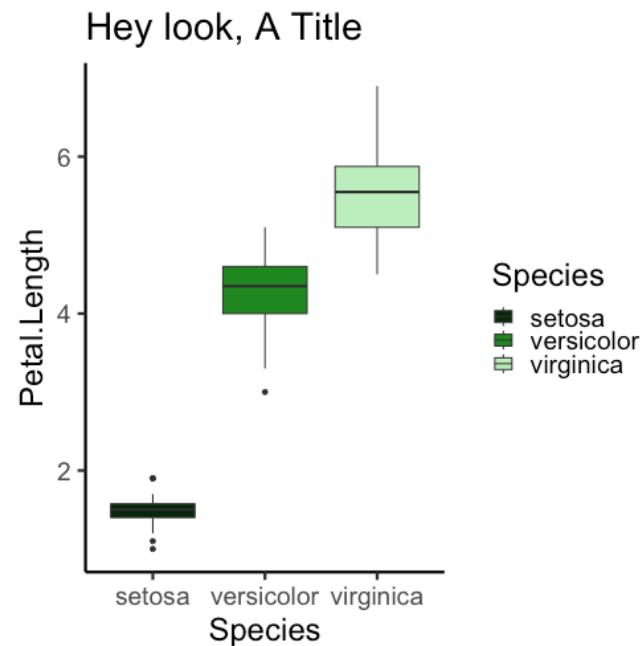


Fig. 1. Summary of primary study findings.

Contrast

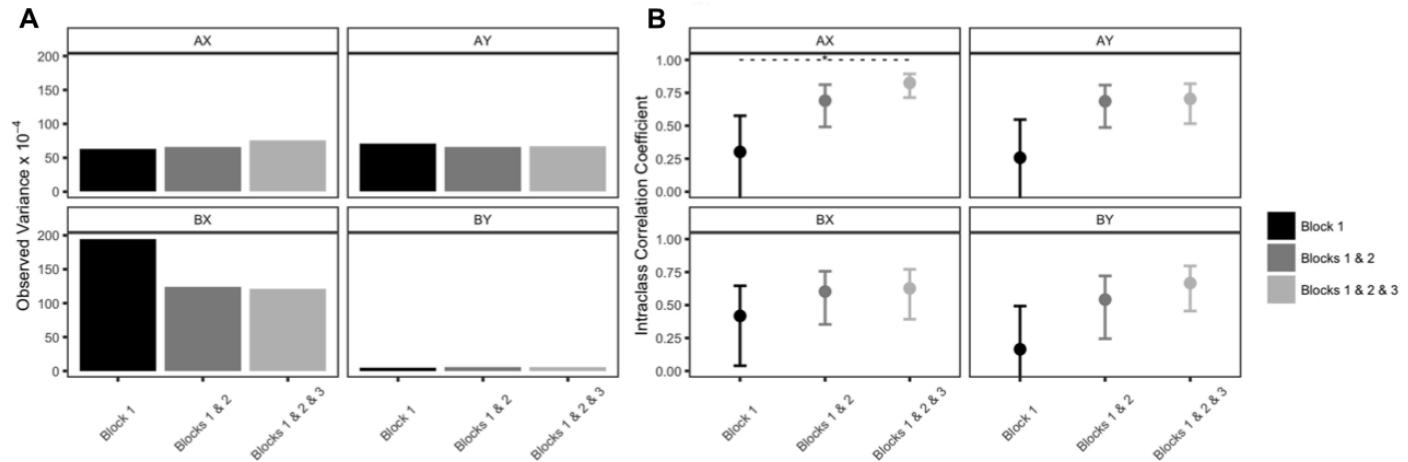
When you have something side-by-side, you can have different colors. OR you can have the same color but a different shade/tone/tint.

```
ggplot(data = iris, aes(x = Species,
                        geom_boxplot(aes(fill = Species),
                        scale_fill_manual(values = c("#00008B",
                        "#228B22",
                        "#8B4513"),
                        labs(title = "Hey look, A Title",
                        theme_classic(base_size = 24)
```



Grayscale

The most obvious of this is grayscale (technically, it's not a hue, and you're dealing with saturation, but that's completely unimportant for this intro):



Providing Contrast is Important

It lets the reader *easily* extract meaningful information.

Colors, shapes, size (as in bubble plots), sometimes transparency etc.

Need help picking different shades/tones/tints of the same color? A ton of websites can help! Ex:

<https://www.colorhexa.com/>

Text Size

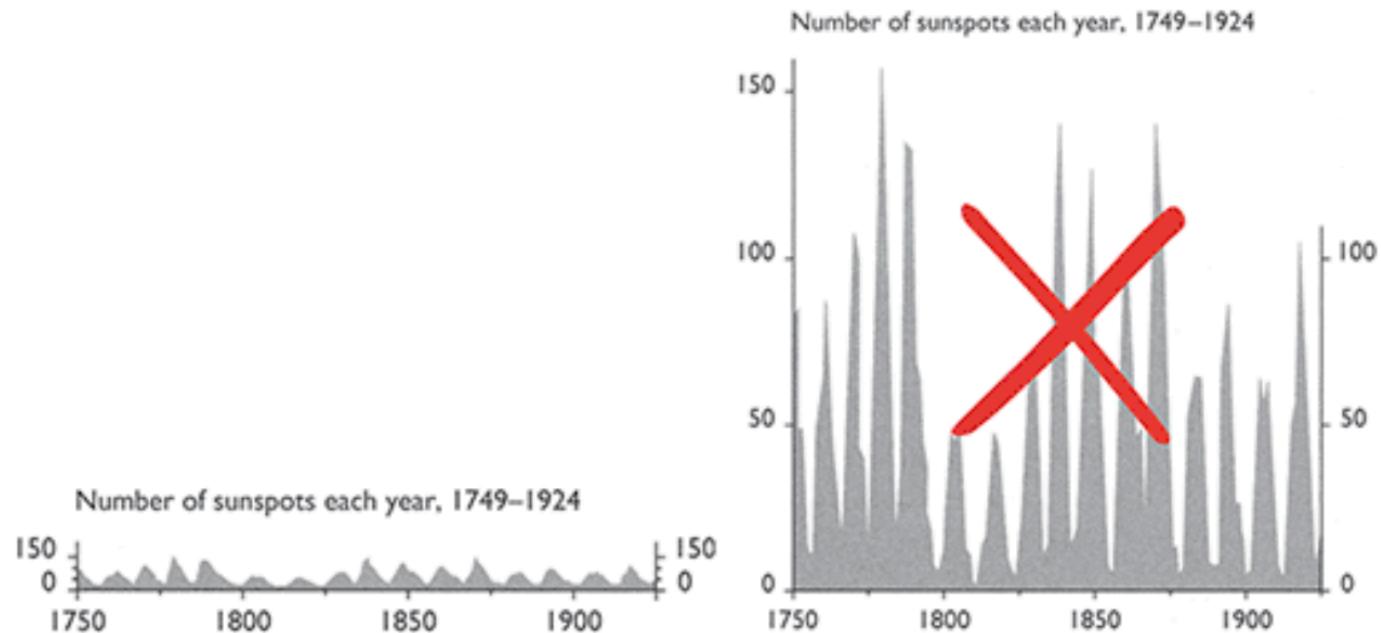
Don't make your font size super uber small!

Some of us are getting old and our eyesight is fading (*I'm not bitter...yes I am...*)

Also, academic journals scale down your figures. Better to make the text size larger so that when it gets scaled down, it's still readable.

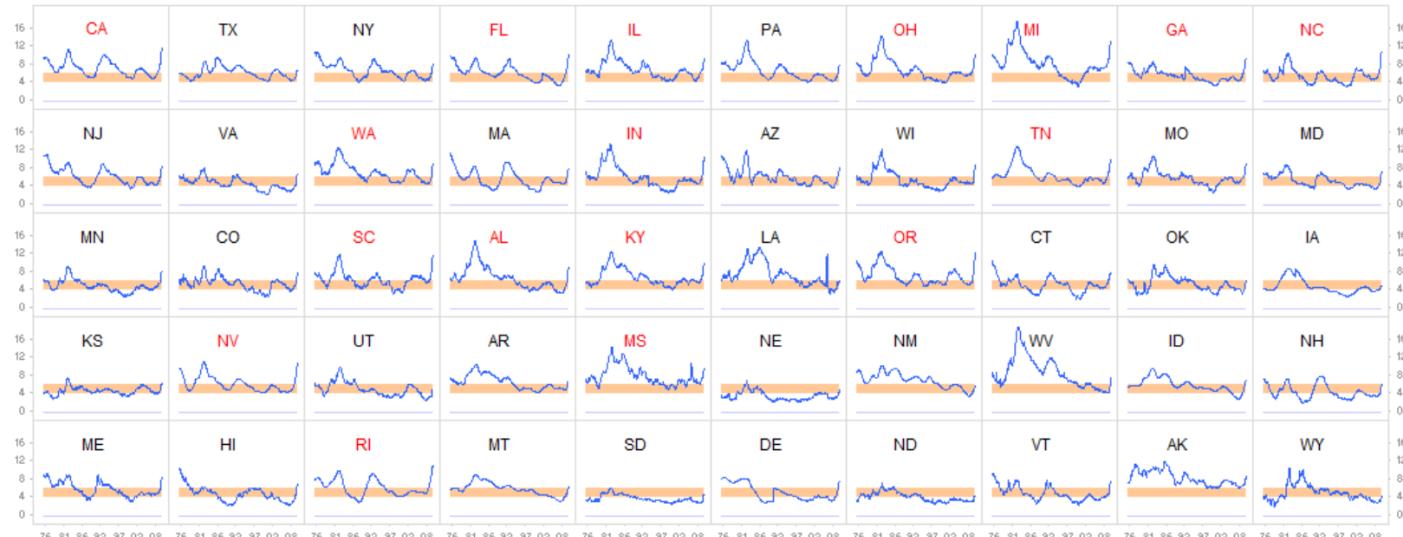
Aspect Ratios

You want to display your figures faithfully, but you don't want to take up extra space you don't need. Think about the aspect ratio of your plots!



Small Multiples

Monthly Unemployment Rates by State, Jan 1976 - Apr 2009



Source: Bureau of Labor Statistics

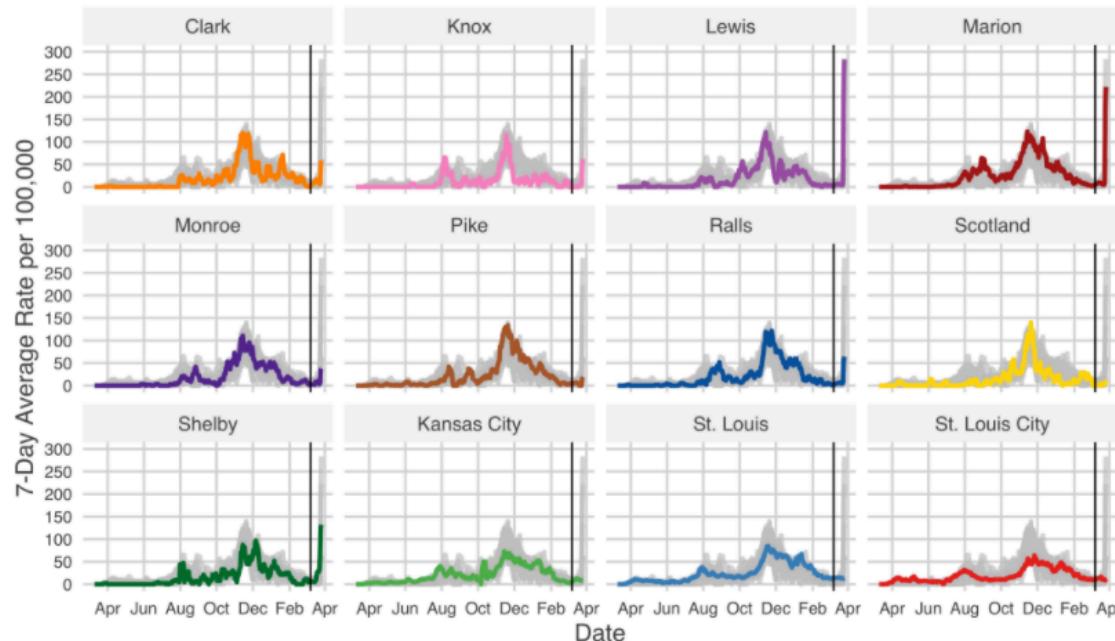
Notes: The orange band denotes a "normal" unemployment rate (4%-6%);
State code in red: unemployment rate in April 2009 is higher than the US average

<https://www.juiceanalytics.com/writing/better-know-visualization-small-multiples>

Small Multiples with COVID

Pace of New COVID-19 Cases in Select Missouri Counties

Northeastern Missouri Focus
2020-03-10 through 2021-03-26



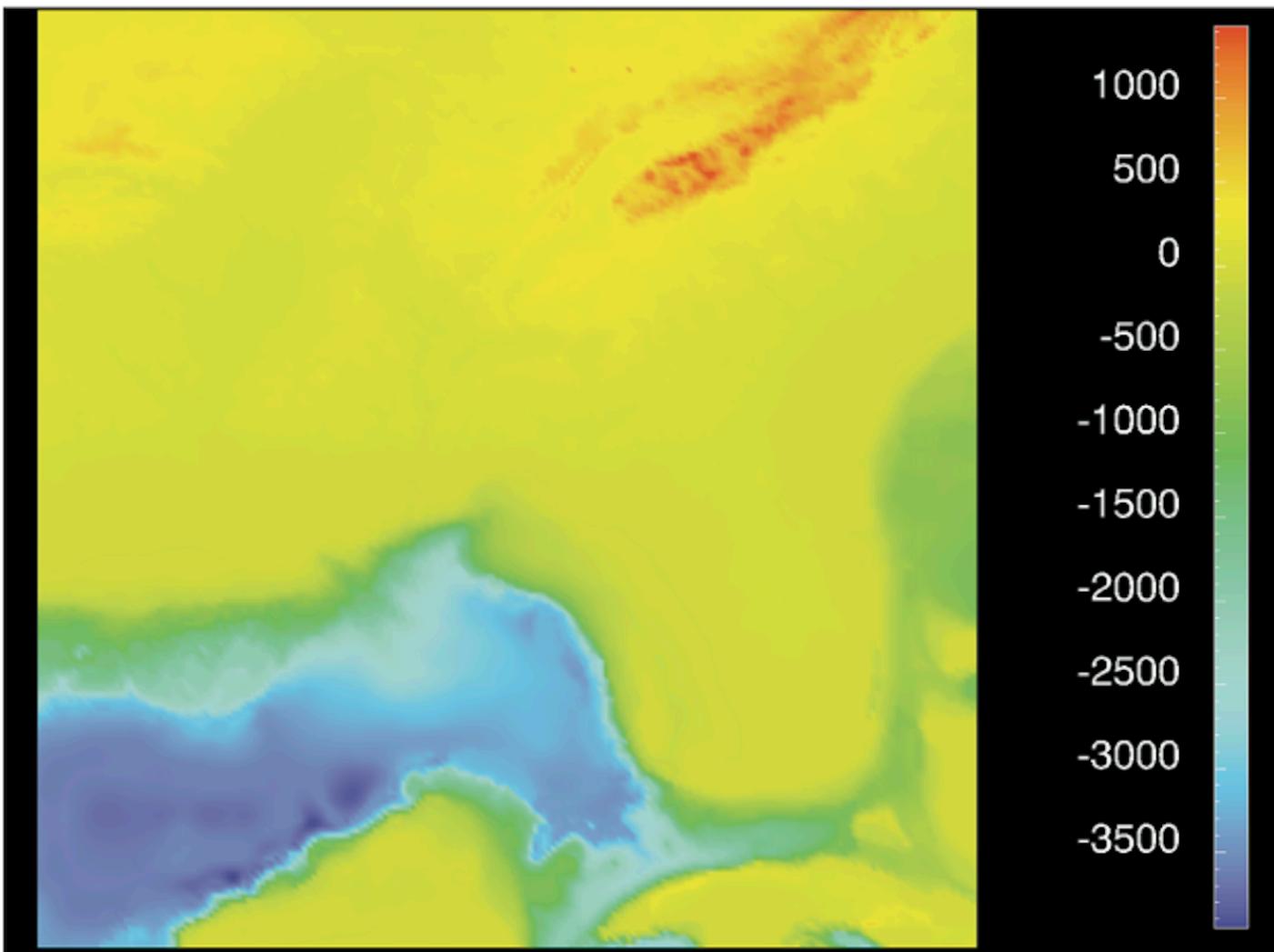
Plot by Christopher Prener, Ph.D.

Data via the New York Times COVID-19 Project and the U.S. Census Bureau

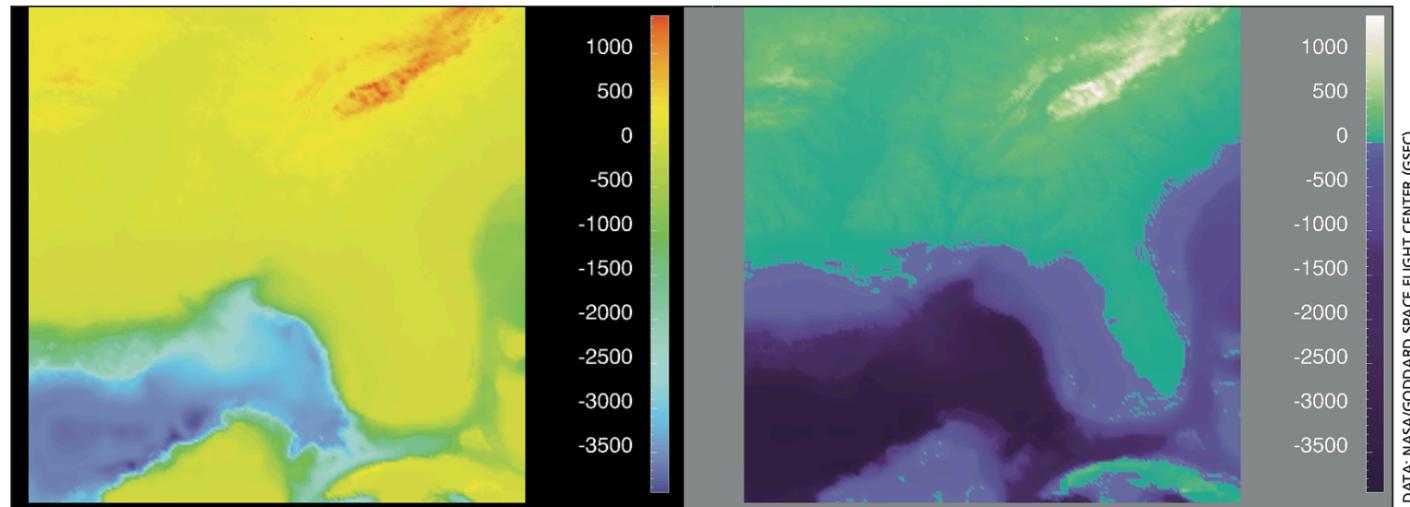
Vertical line represents addition of antigen test data for most Missouri counties on 2021-03-08

<https://twitter.com/chrisprener/status/1375937857840353280/photo/2>

Rainbow Colormaps



Don't Use Rainbow Colormaps



Rogowitz & Treinish, IEEE Spectrum, 35(12):52-59. 1998

Self-evaluation

How do you know if you've made a good figure?

- Does it **EASILY** communicate what you want?
- Do readers need to read and re-read your figure legend, or is your message clear?
- Is it accessible to people with poor eyesight or colorblindness?
- Does it ***faithfully*** reflect your data? Beauty + truth

- Don't make a plot when a table will do
- Represent data with appropriate significant figures
- Use appropriate plot types for the data types
- **Label your axes**
- Title your figures
- Whenever possible, show all the data (or at least the distribution)
- Don't rely on a legend or caption/text
- Don't rely on default plotting conventions
- If possible, show outliers rather than removing them
- Sort categorical data accordingly
- Exploit small multiples to great effect (in R, use faceting)
- Strive to maintain the same color conventions/palettes across all figures
- Start with what you want your plot to look like, then work backwards
- **SHOW. YOUR. CODE.**

Helpful Things in R

- `geom_dotplot`; better than bar plots, typically (see earlier slide)
- Raincloud plots; [blog post here](#)
- Using the same theme modifications for all plots? Make a function to store that theme and call it later.
- **Google is your friend; Google is your professor**
- Want examples of good COVID plotting with open R code? Check out [Chris Prener's Twitter account](#). If you'd like this as a weekly newsletter, check out his [River City Data](#) tracking site!
- Interested in making generative art in R? Check out the Twitter accounts of [Danielle Navarro](#) and [Ijeamaka Anyene](#); then look at their websites!