# Visualizing Complex Science

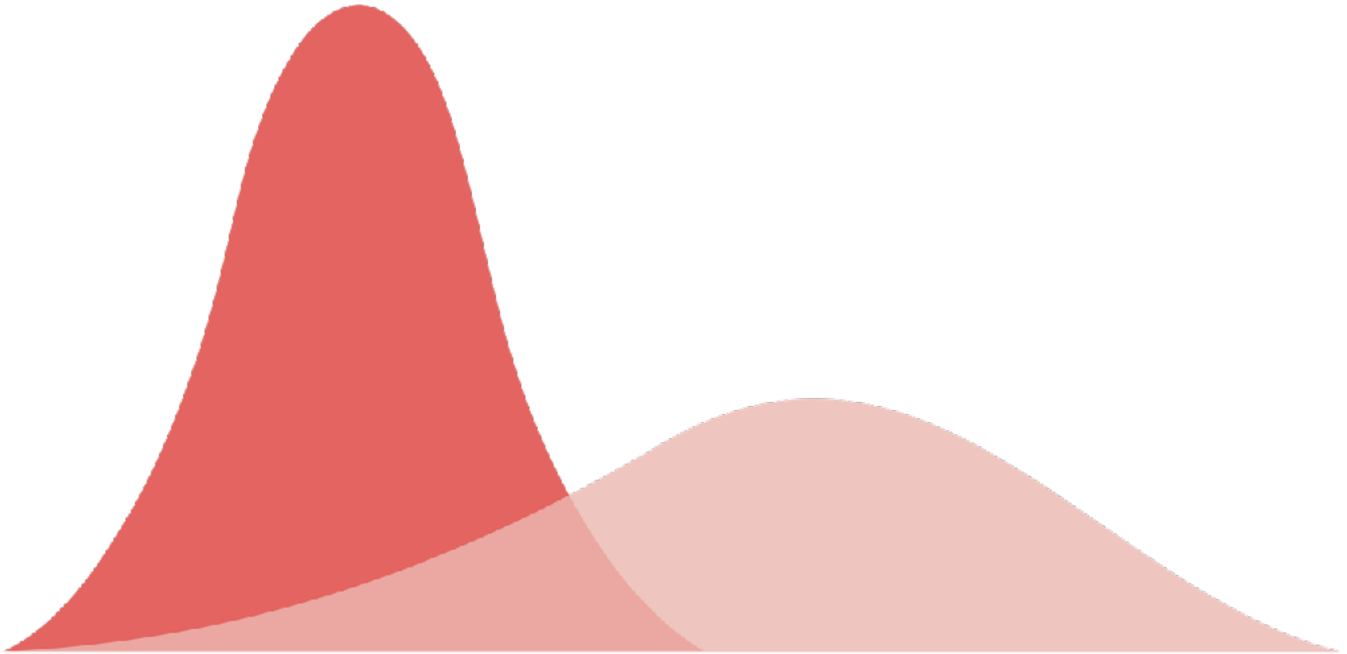

## Sam Way

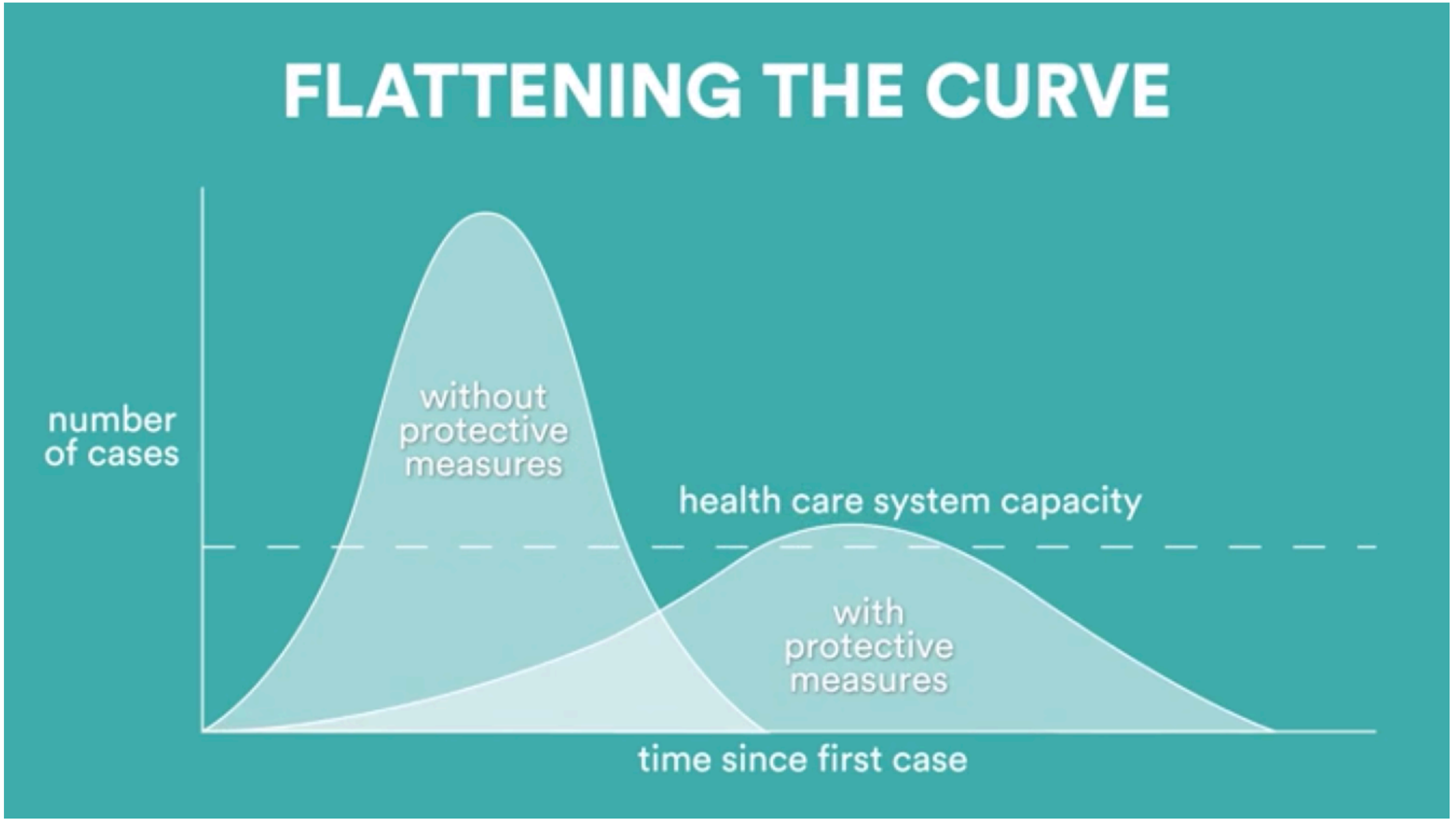
Research Scientist, Spotify

samfway@spotify.com

# Thank you, organizers.

For both of the conferences you planned for us






By Esther Kim (designer) + Carl Bergstrom (professor at UW)

Quickly:

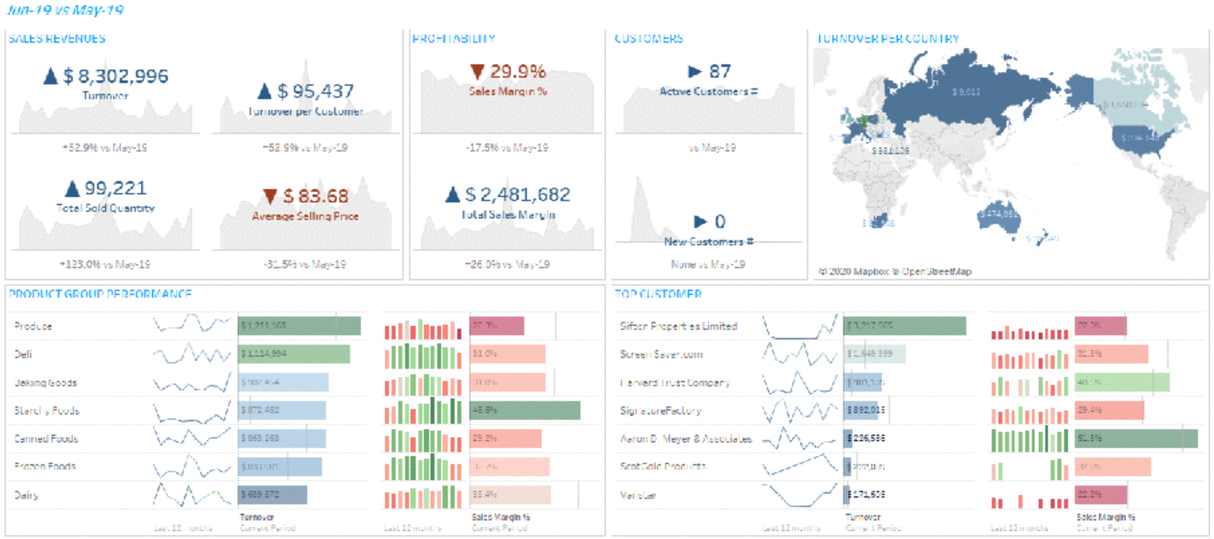
# Data Viz at Spotify

Less quickly:

# Tips for creating simple and effective visualizations

# Visual communication at an **audio** company

A short tour of (some of) our audiences

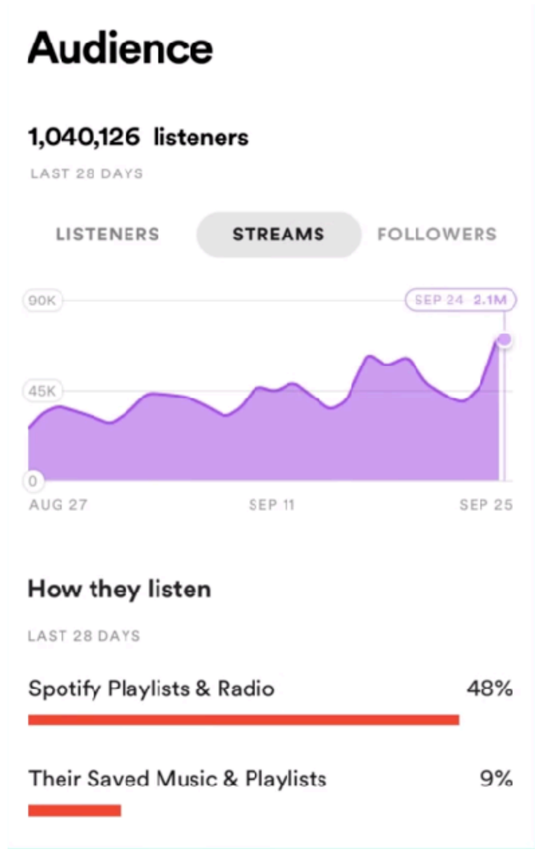



**Not** a Spotify dashboard, sorry. Credit: linpack-for-tableau.com

We create visualizations for...

# Our teams.

We build dashboards to help teams communicate and make decisions.

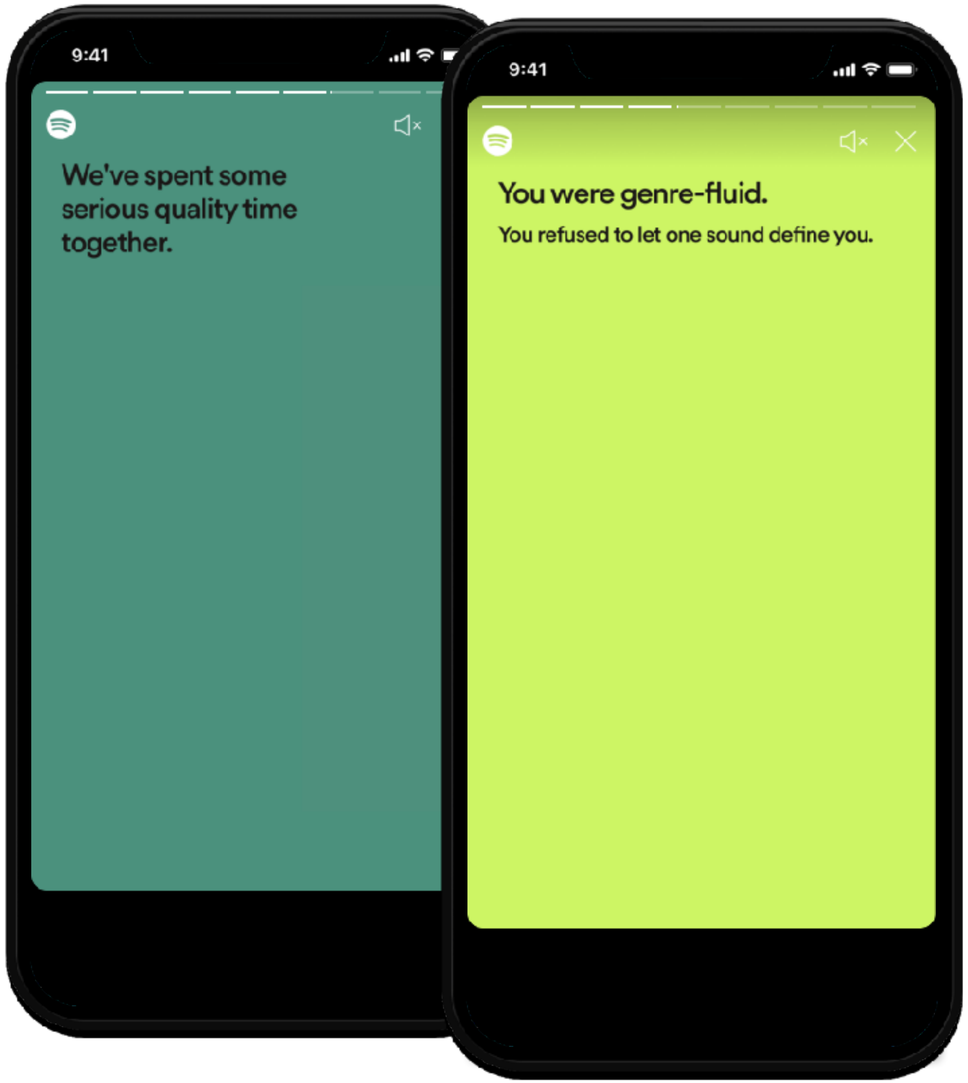



Spotify for Artists

We create visualizations for...

# Our artists.

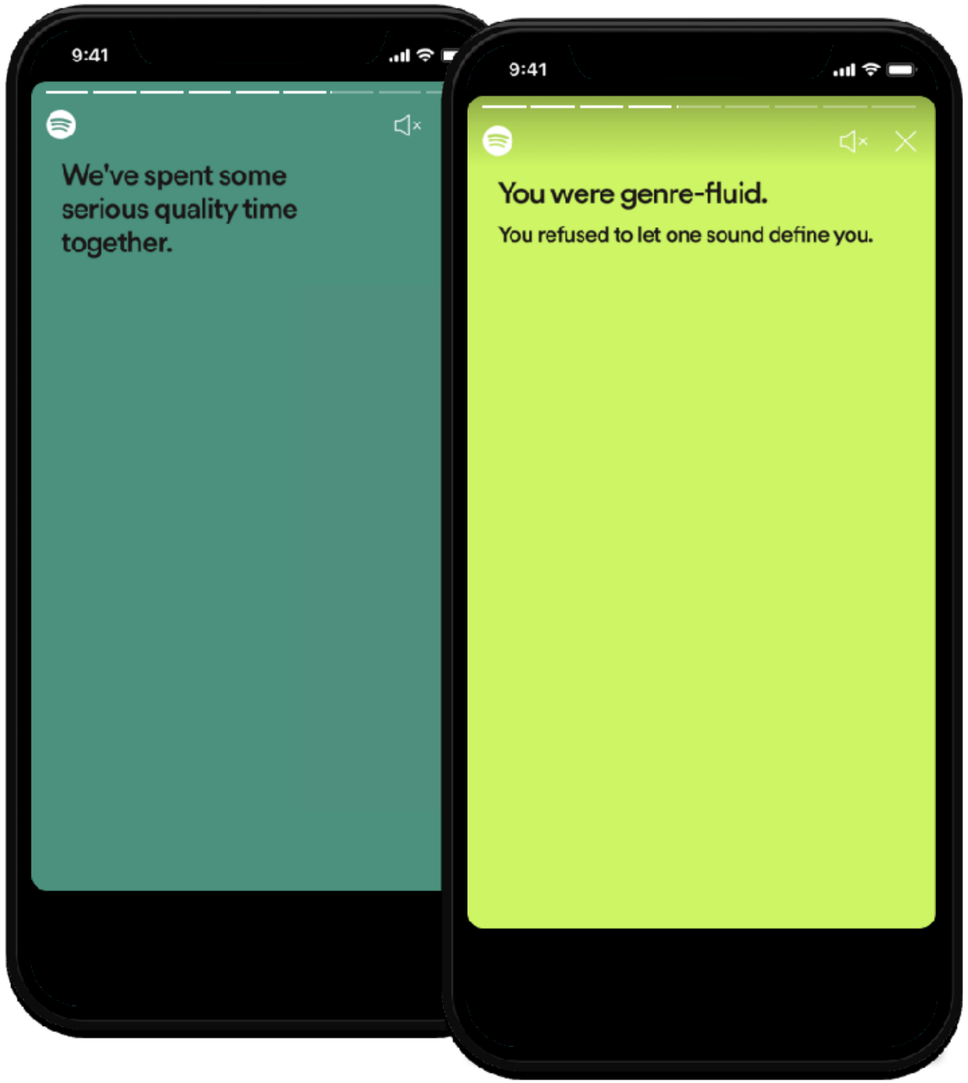
We help creators explore their data and learn more about their listeners.




We create visualizations for...

# Our listeners.

Our end-of-year Wrapped campaign lets listeners explore their data.

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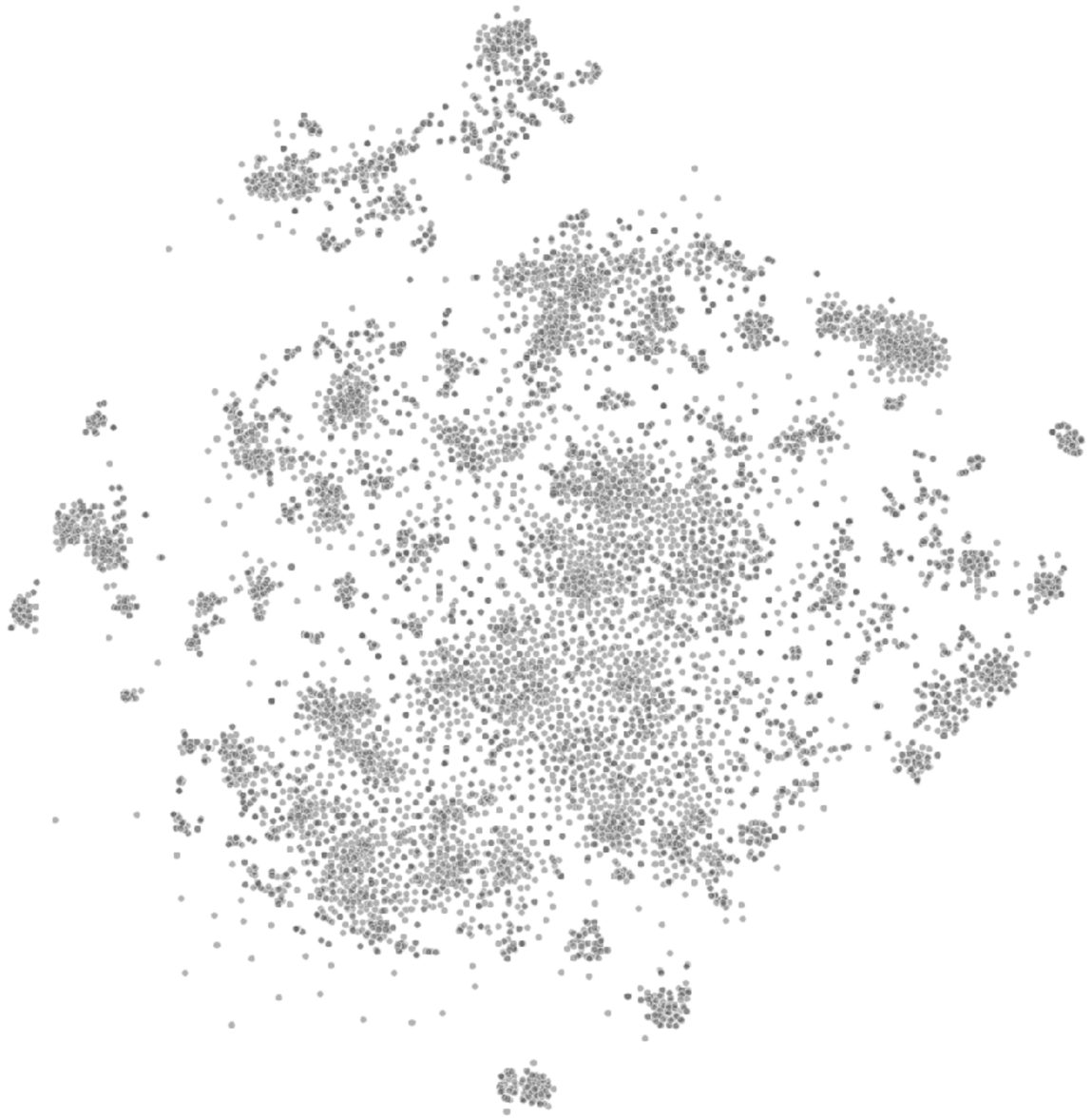
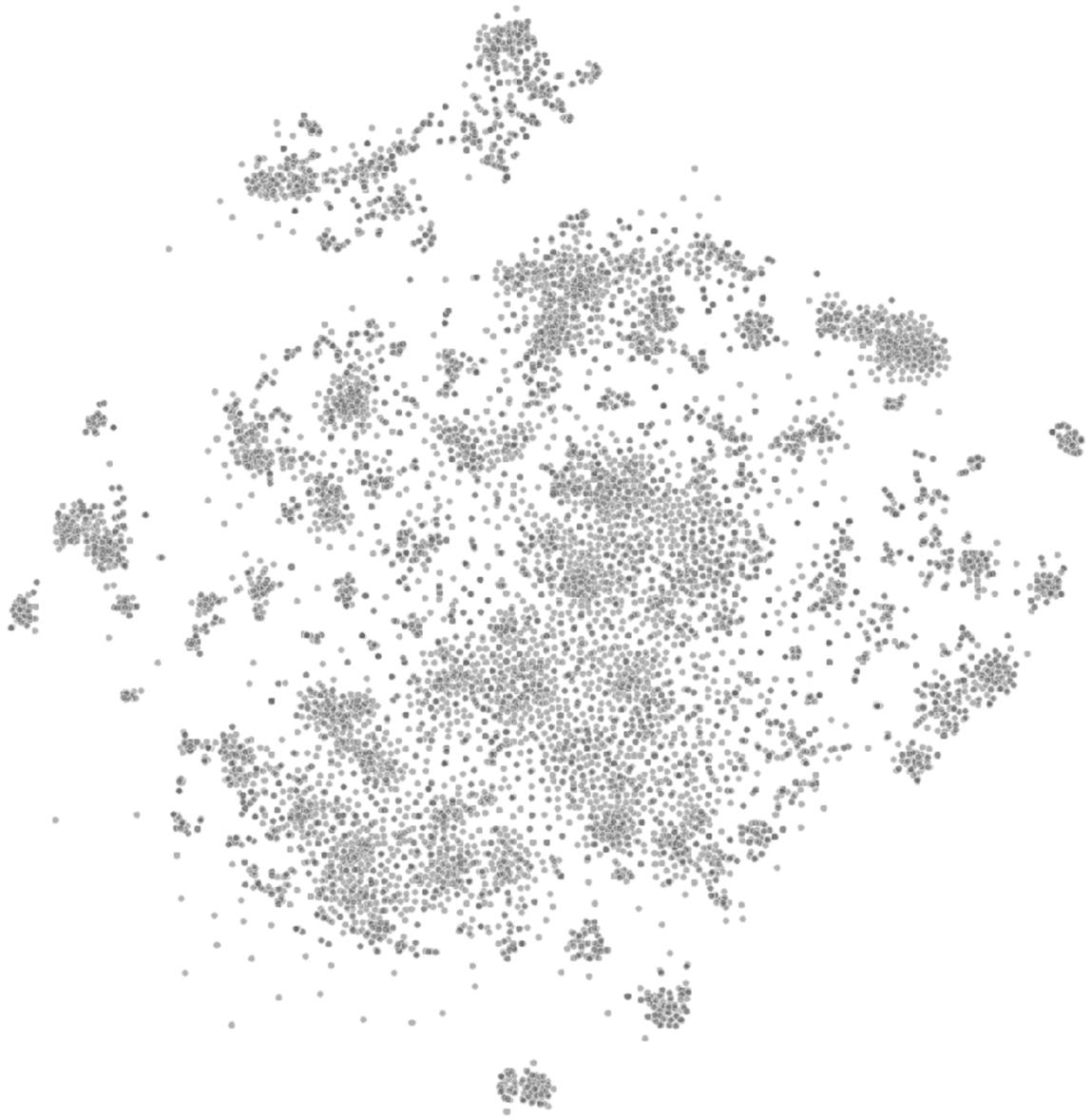


We create visualizations for...

# Our science.

We publish research that communicates what we've learned connecting listeners and artists.



We create visualizations for...

# Our science.

We publish research that communicates what we've learned connecting listeners and artists.

We create visualizations for...

# Ourselves.

That is, for fun. Playful is literally one of our company's core values.

https://newsroom.spotify.com/2018-12-28/heres-where-your-favorite-artists-toured-the-most-in-2018/

# On Tour.

Created by Skyler Johnson

January 2017 — December 2017

50 Cent

A R I Z O N A

ASAP Ferg

AJR

Alan Jackson

alt-J

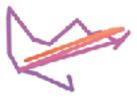
Ariana Grande

B.o.B

Banks

Bastille

Bebe Rexha



Billy Joel

Blackbear

Blake Shelton

blink-182

Bon Jovi

Bruno Mars

Cage The Elephant

Carnage

Chance The Rapper

Charlie Puth

Cheat Codes

Chief Keef

Chris Brown

Chris Stapleton

Clean Bandit

Cold War Kids

Coldplay

D.R.A.M.

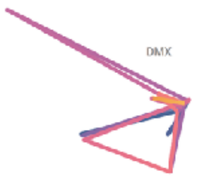
Darius Rucker

Daya

Desiigner

Dierks Bentley

DMX



DNCE

Dua Lipa

Ed Sheeran

Emily Warren

Enrique Iglesias

Eric Church

# Few scientists receive explicit training on how to make visualizations

Quickly:

# Data Viz at Spotify

Less quickly:

# Tips for creating simple and effective visualizations

# Consider the following suggestions.

- Rules of thumb that apply to many – not all – instances
- Visualizations are one of the most creative parts of being a scientist. Developing your own style is encouraged.

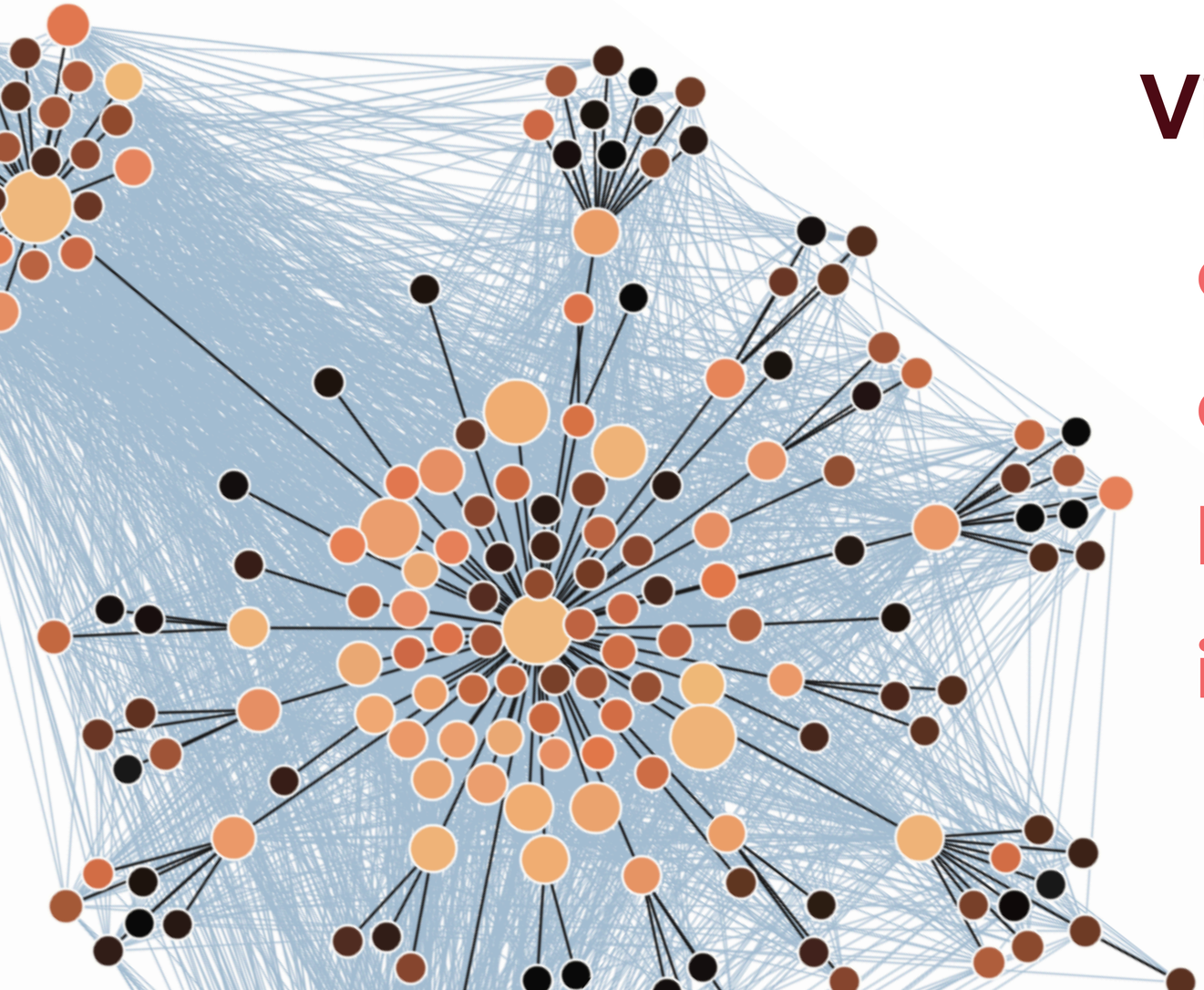
Determining your goals

Selecting appropriate visualization

Building prototypes

Gathering feedback

# First, why make visualizations?



## Visualizations can...

clarify your story,

emphasize a message,

build trust with audience,

inform their decisions.

Note: bad visualizations can do the opposite of all these things!

# Specify goals for your visualization.

Visualizations can serve several purposes.
Think about which goals you have for the viewer.

Showing people what you see
- **clarify your story,**
- **emphasize a message,**

Letting people to explore
- **build trust with audience,**
- **inform their decisions.**

Possible differentiation between information visualization and “infographics” (see: https://www.denizcemonduygu.com/2015/06/redefining-infographics/).

# Specify goals for your visualization.

Visualizations can serve several purposes.
Think about which goals you have for the viewer.

**Bottom line: Make sure your visualization has a purpose.**

Showing people what you see { carry your story, [illegible] message,

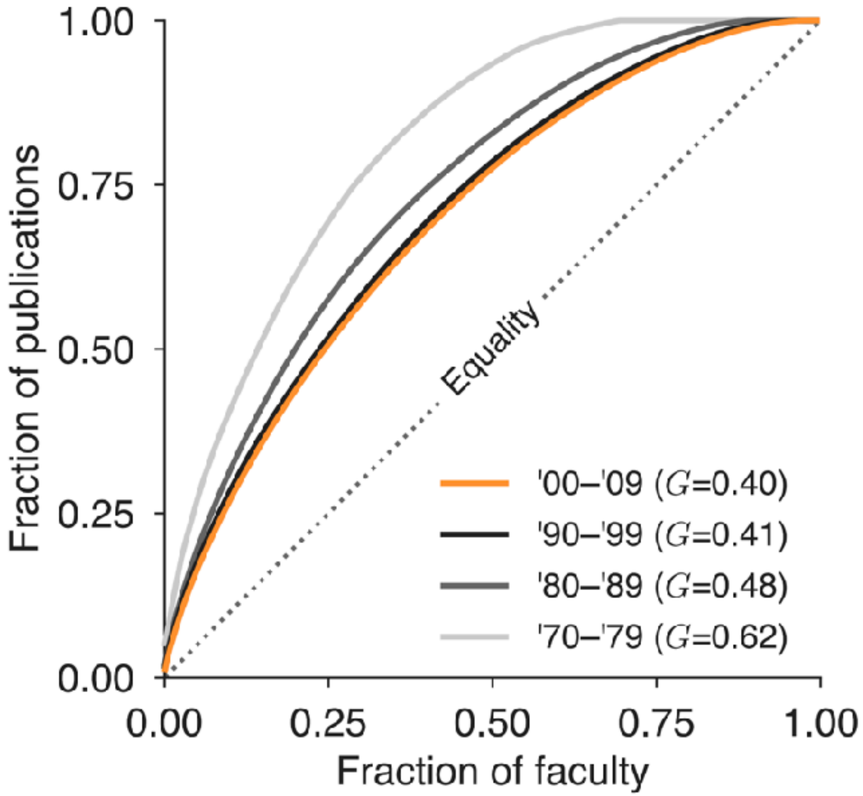
Letting people to explore { build trust with audience, inform their decisions.

# Consider your audience.

Who's going to see your visualization?

What goals do *they* have?

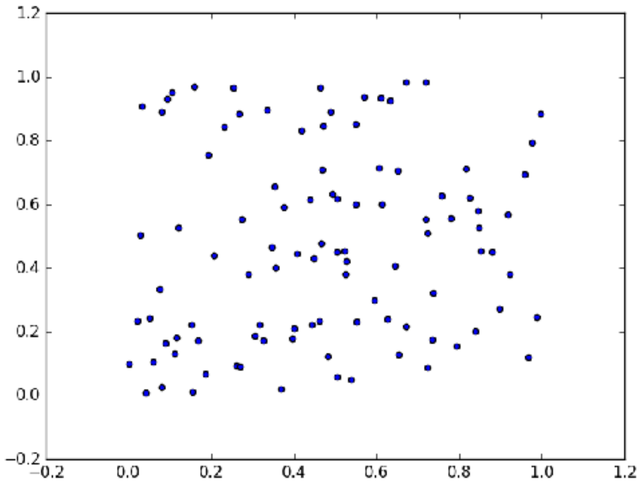
What's their background? What assumptions might they make?

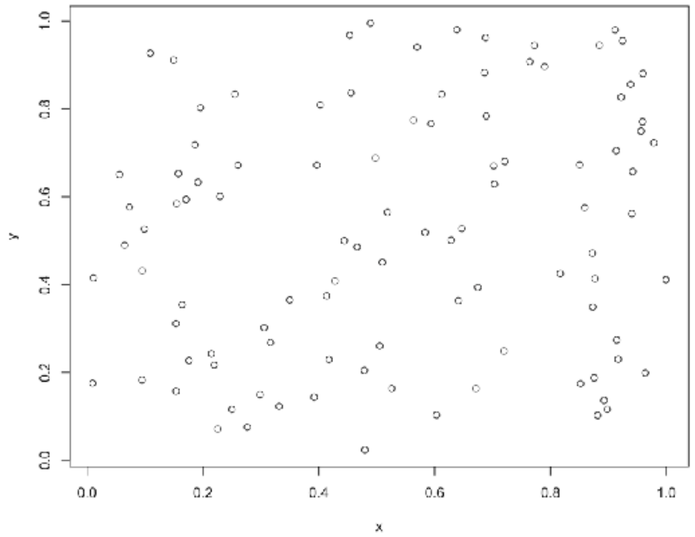


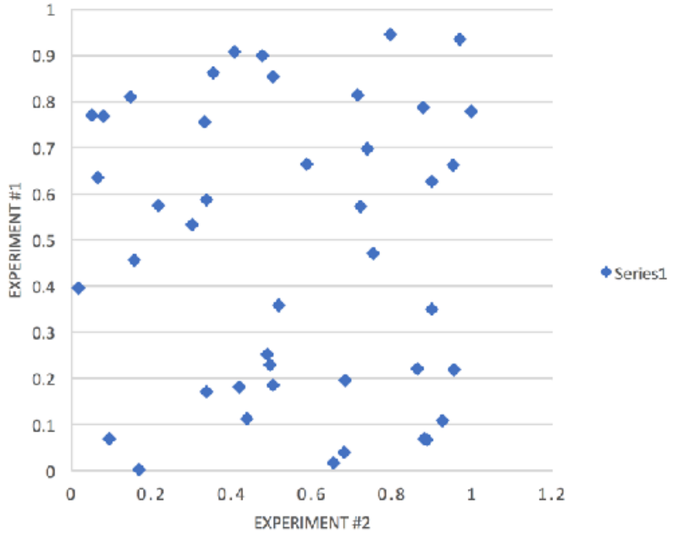

Here, will they know what a Gini coefficient is? Will they know how to read this kind of plot? If not, how can we help them?

# Be aware of unintentional messages.

What can you tell me about the person who made these figures?



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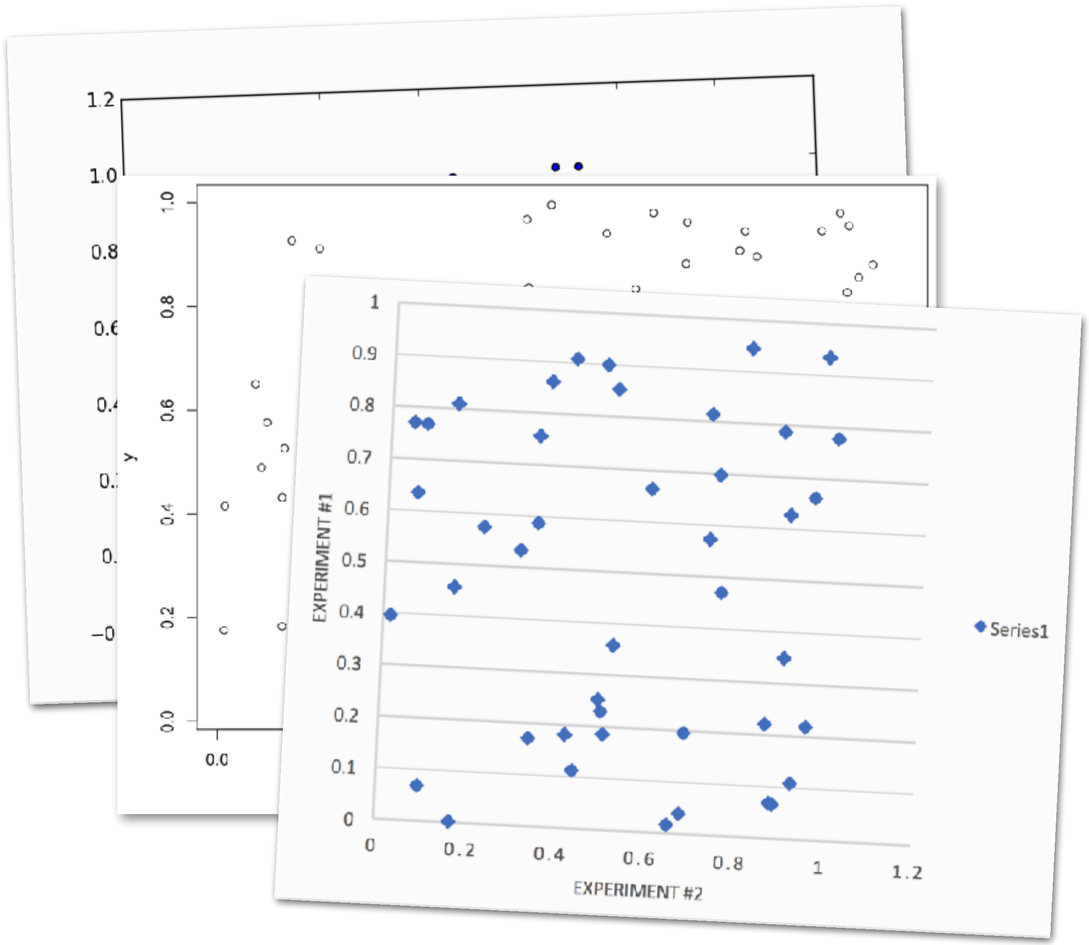


Defaults aren't necessarily bad

*But*, they could suggest you put little effort into your visualizations

Some fields might unfairly judge you/your science by the program

Put effort into your visualizations

* Great science can be and is done with all of these programs, and the value of science should be independent of the person or tool that created it. That said, be mindful of the biases that may exist in your fields.

Determining your goals

Selecting appropriate visualization

Building prototypes

Gathering feedback

# Make use of people's intuition.

What kind of graph will they expect? Start there.

"The variables are related"

"The distribution is skewed"

"The groups differ in Y"

"Popular in the Southeast"

Think about how tweaking even a very standard plot might make it more useful (e.g. https://www.nature.com/articles/d41586-018-06912-1).

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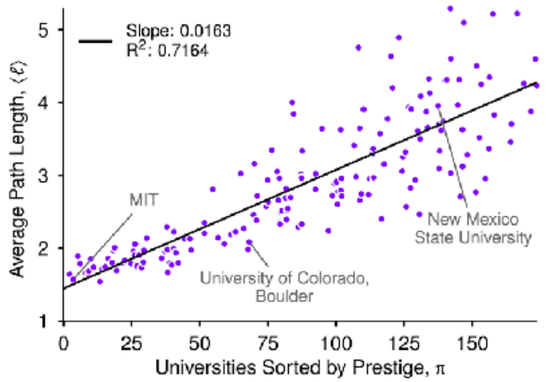


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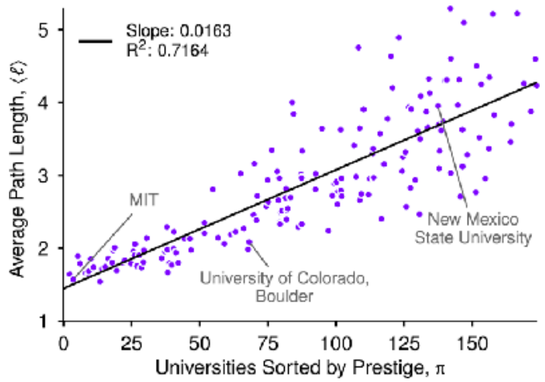


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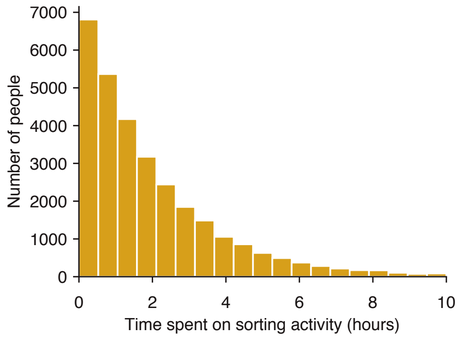


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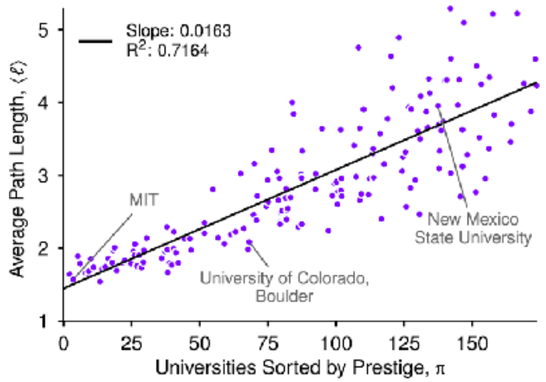


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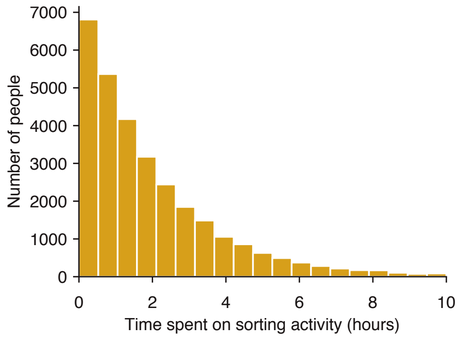


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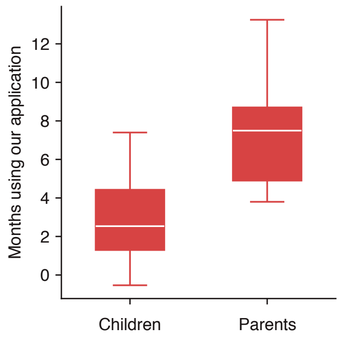


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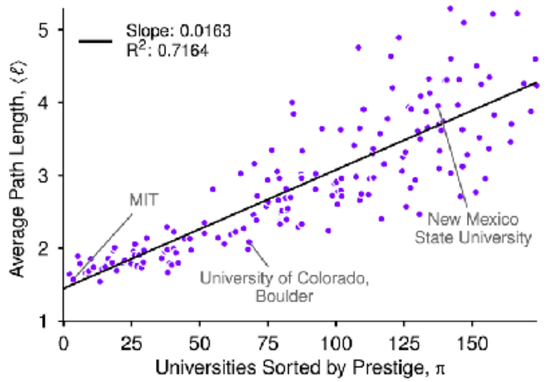


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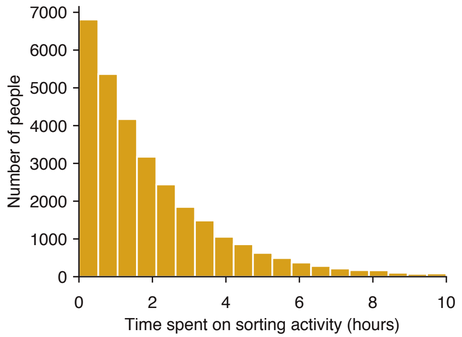


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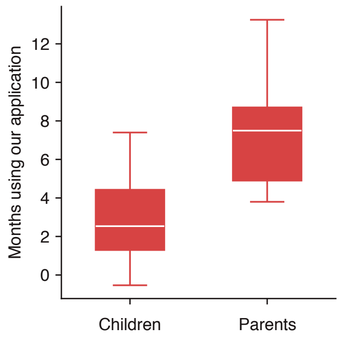


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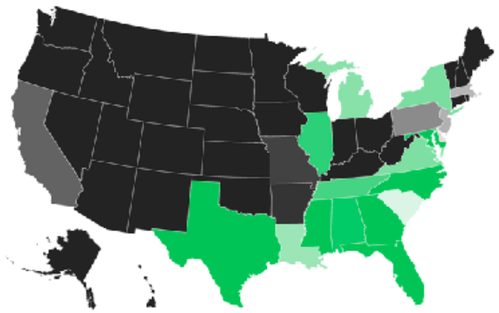
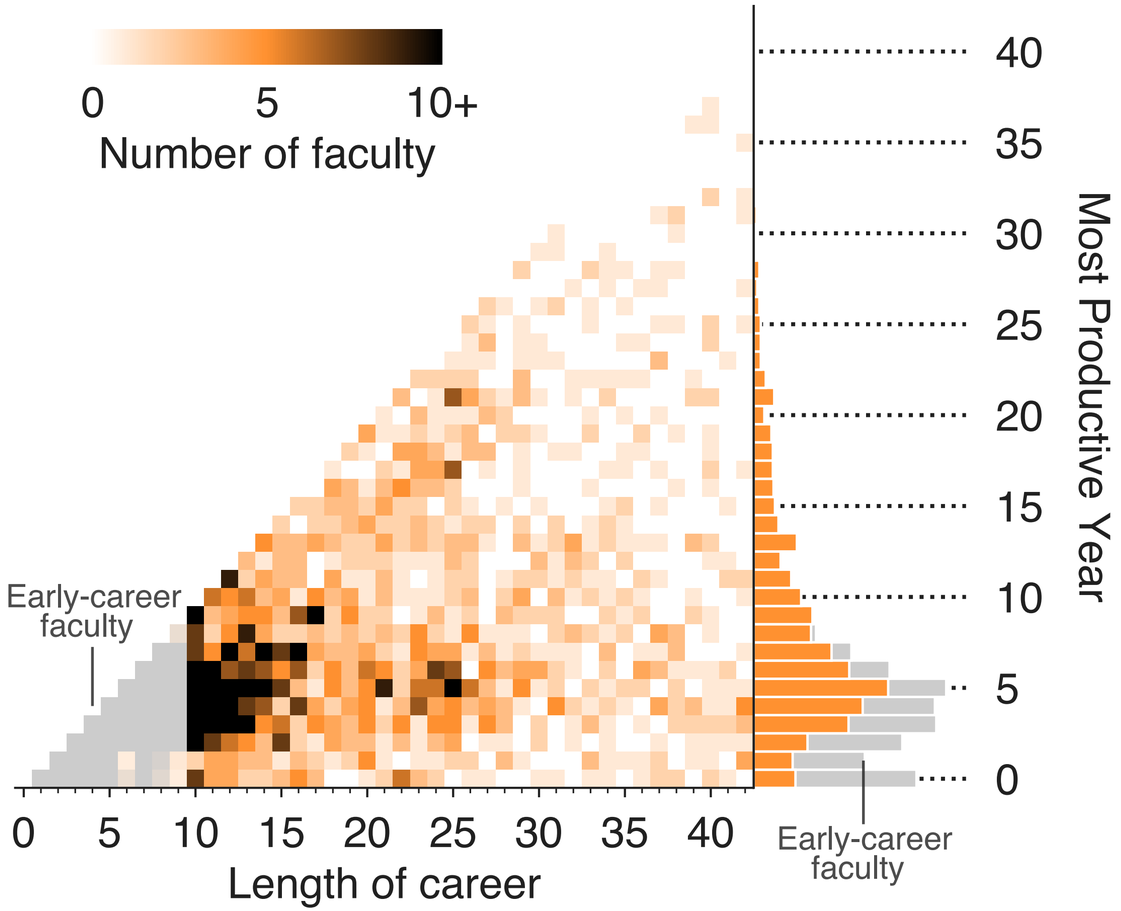


Think about how tweaking even a very standard plot might make it more useful (e.g. https://www.nature.com/articles/d41586-018-06912-1).

# Combine multiple types.

## Example: when are faculty most productive?



# Combine multiple types.

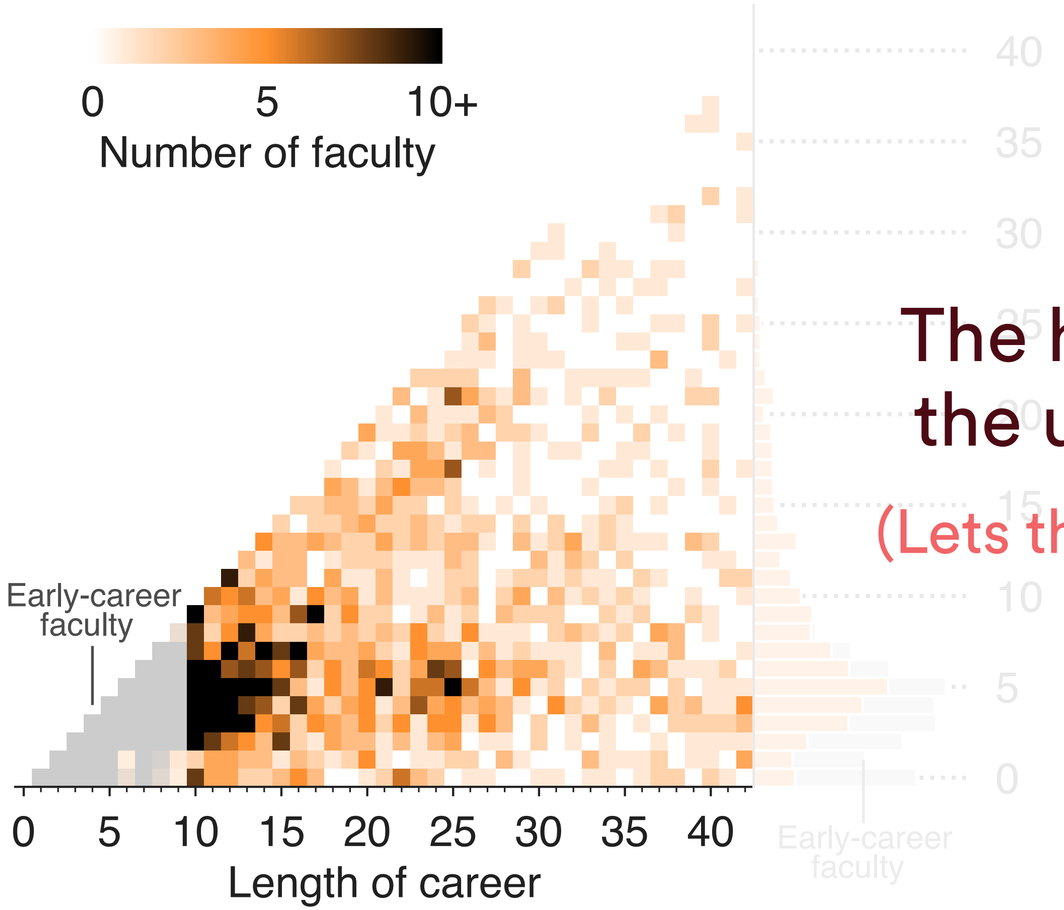
## Example: when are faculty most productive?

The histogram answers our scientific question.

(Tells a story)

# Combine multiple types.

## Example: when are faculty most productive?




The heatmap reveals the underlying data.

(Lets the audience explore)

Determining your goals

Selecting appropriate visualization

Building prototypes

Gathering feedback

# Prototype your visualizations.

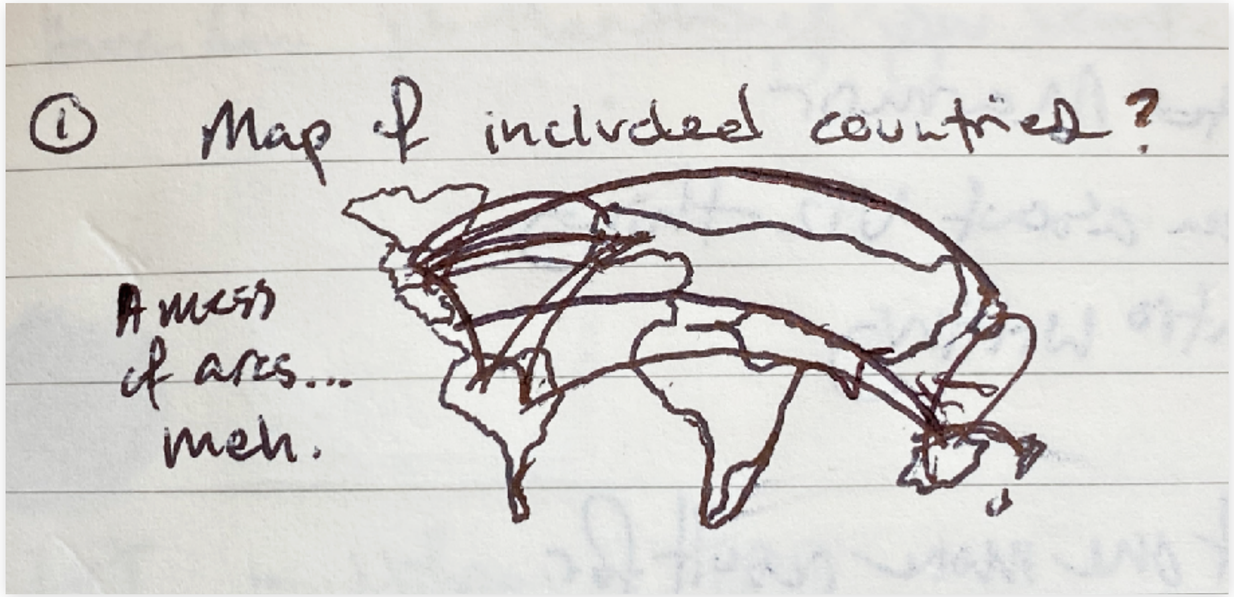
Before you code up anything, get out your colored pencils and draw.

Come up with a handful of concepts and reflect on what you like about each one of them.

Idea from Prof. Danielle Szafir (University of Colorado). Photo from Washington Oliveria.
Ok, so maybe drawing isn't your thing. Point is: get rough ideas down on paper, matplotlib, whatever. Iterate quickly before polishing, adding interactivity, etc.

# Prototype your visualizations.

Example: who listens to whose music?



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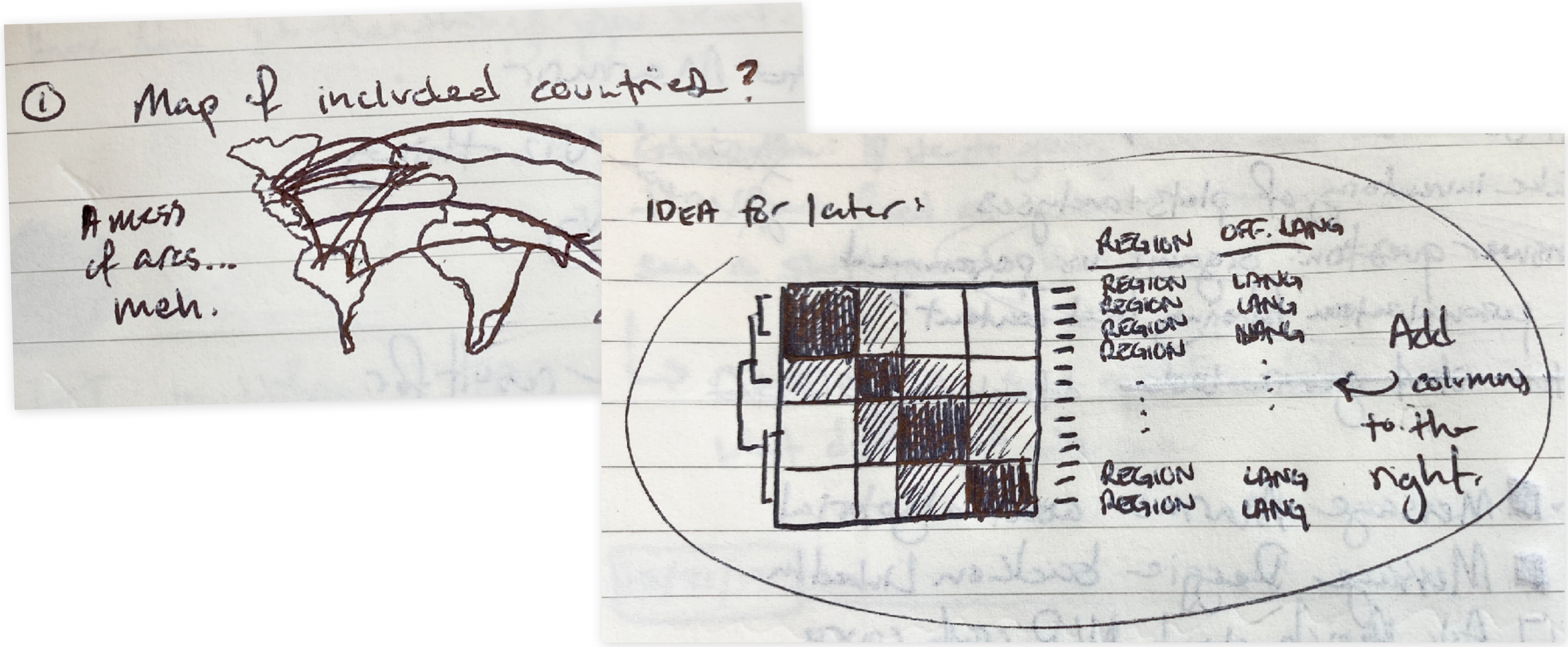

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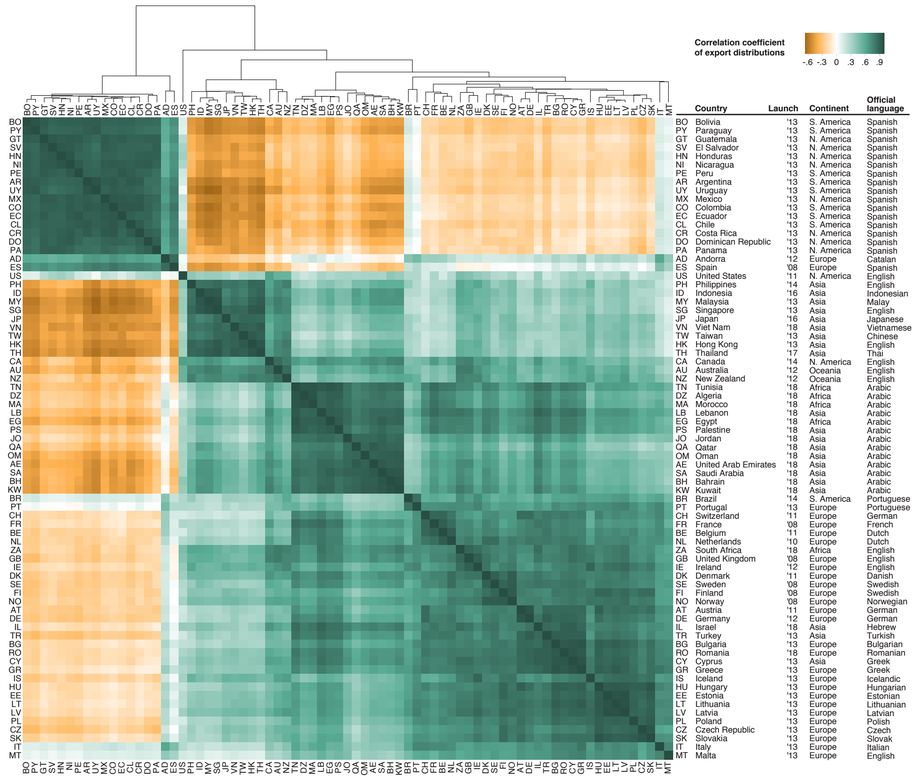


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| PY | Paraguay | '13 | S. America | Spanish |
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| SV | El Salvador | '13 | N. America | Spanish |
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| NI | Nicaragua | '13 | N. America | Spanish |
| PE | Peru | '13 | S. America | Spanish |
| AR | Argentina | '13 | S. America | Spanish |
| UY | Uruguay | '13 | S. America | Spanish |
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| EC | Ecuador | '13 | S. America | Spanish |
| CL | Chile | '13 | S. America | Spanish |
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| PA | Panama | '13 | N. America | Spanish |
| AD | Andorra | '12 | Europe | Catalan |
| ES | Spain | '08 | Europe | Spanish |
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| PH | Philippines | '14 | Asia | English |
| ID | Indonesia | '16 | Asia | Indonesian |
| MY | Malaysia | '13 | Asia | Malay |
| SG | Singapore | '13 | Asia | English |
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| VN | Viet Nam | '18 | Asia | Vietnamese |
| TW | Taiwan | '13 | Asia | Chinese |
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| TH | Thailand | '17 | Asia | Thai |
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| DZ | Algeria | '18 | Africa | Arabic |
| MA | Morocco | '18 | Africa | Arabic |
| LB | Lebanon | '18 | Asia | Arabic |
| EG | Egypt | '18 | Africa | Arabic |
| PS | Palestine | '18 | Asia | Arabic |
| JO | Jordan | '18 | Asia | Arabic |
| QA | Qatar | '18 | Asia | Arabic |
| OM | Oman | '18 | Asia | Arabic |
| AE | United Arab Emirates | '18 | Asia | Arabic |
| SA | Saudi Arabia | '18 | Asia | Arabic |
| BH | Bahrain | '18 | Asia | Arabic |
| KW | Kuwait | '18 | Asia | Arabic |
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| PT | Portugal | '13 | Europe | Portuguese |
| CH | Switzerland | '11 | Europe | German |
| FR | France | '08 | Europe | French |
| BE | Belgium | '11 | Europe | Dutch |
| NL | Netherlands | '10 | Europe | Dutch |
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| IE | Ireland | '12 | Europe | English |
| DK | Denmark | '11 | Europe | Danish |
| SE | Sweden | '08 | Europe | Swedish |
| FI | Finland | '08 | Europe | Swedish |
| NO | Norway | '08 | Europe | Norwegian |
| AT | Austria | '11 | Europe | German |
| DE | Germany | '12 | Europe | German |
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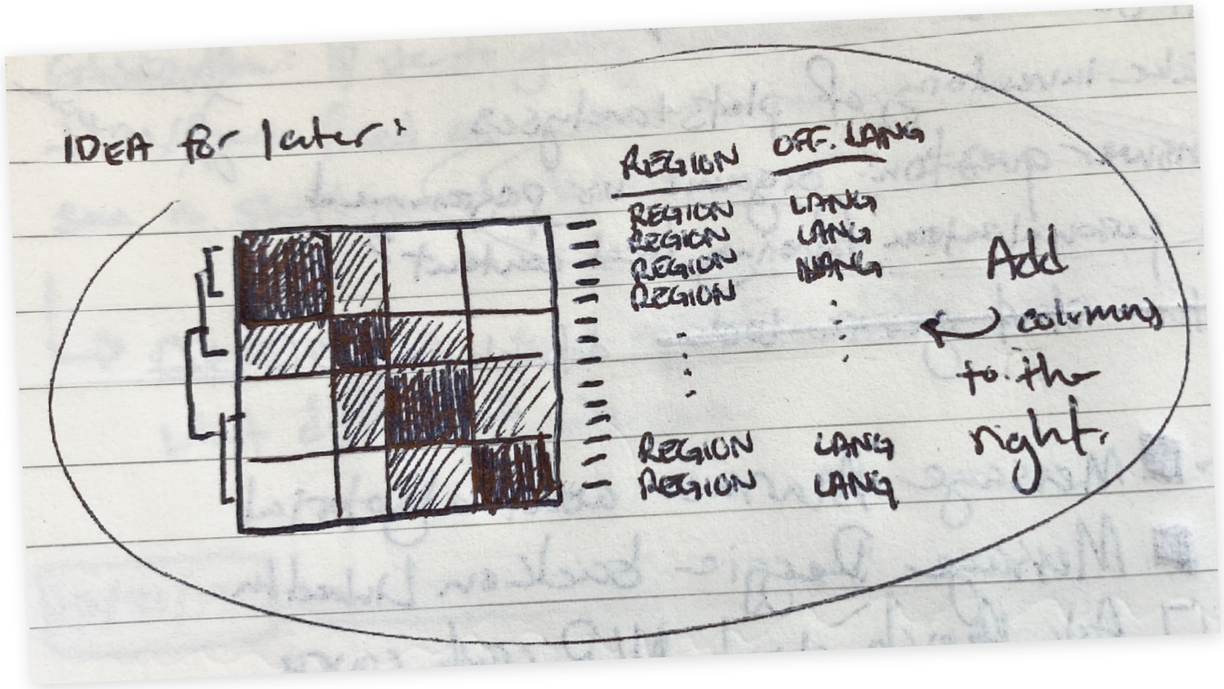

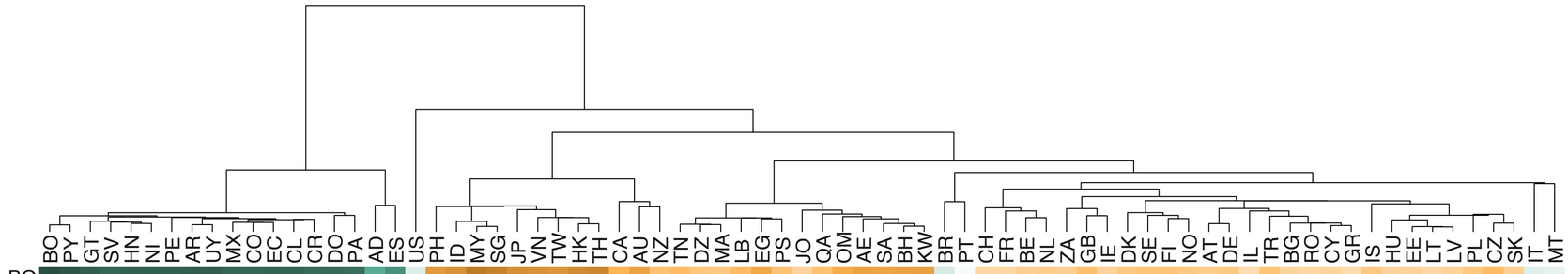


**Correlation coefficient of export distributions**

-.6 -.3 0 .3 .6 .9

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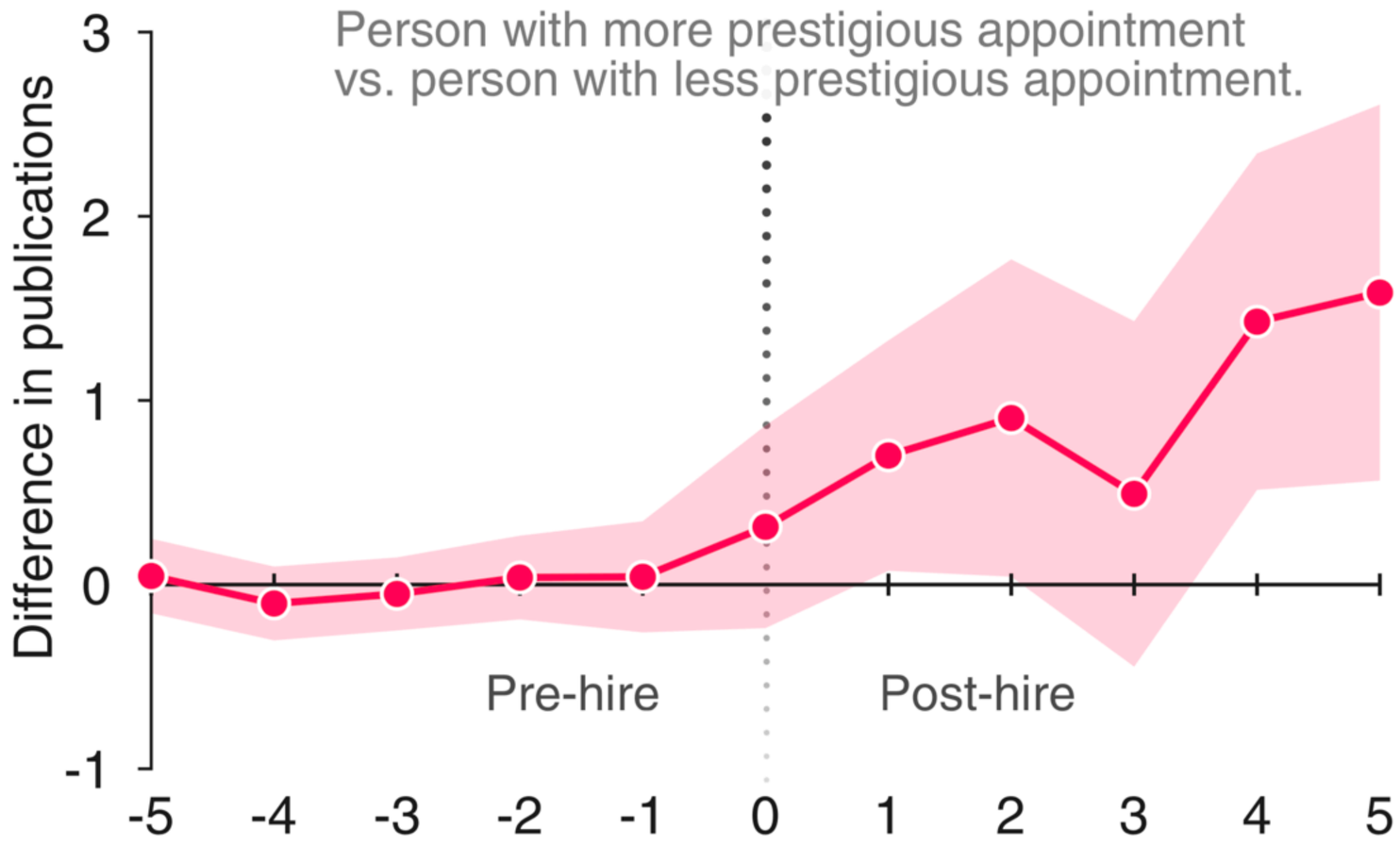
| AD | Andorra | '12 | Europe | Catalan |
| ES | Spain | '08 | Europe | Spanish |
| US | United States | '11 | N. America | English |
| PH | Philippines | '14 | Asia | English |
| ID | Indonesia | '16 | Asia | Indonesian |
| MY | Malaysia | '13 | Asia | Malay |
| SG | Singapore | '13 | Asia | English |
| JP | Japan | '16 | Asia | Japanese |
| VN | Viet Nam | '18 | Asia | Vietnamese |
| TW | Taiwan | '13 | Asia | Chinese |
| HK | Hong Kong | '13 | Asia | English |
| TH | Thailand | '17 | Asia | Thai |
| CA | Canada | '14 | N. America | English |
| AU | Australia | '12 | Oceania | English |
| NZ | New Zealand | '12 | Oceania | English |
| TN | Tunisia | '18 | Africa | Arabic |
| DZ | Algeria | '18 | Africa | Arabic |
| MA | Morocco | '18 | Africa | Arabic |
| LB | Lebanon | '18 | Asia | Arabic |
| EG | Egypt | '18 | Africa | Arabic |
| PS | Palestine | '18 | Asia | Arabic |
| JO | Jordan | '18 | Asia | Arabic |
| QA | Qatar | '18 | Asia | Arabic |
| OM | Oman | '18 | Asia | Arabic |
| AE | United Arab Emirates | '18 | Asia | Arabic |
| SA | Saudi Arabia | '18 | Asia | Arabic |
| BH | Bahrain | '18 | Asia | Arabic |
| KW | Kuwait | '18 | Asia | Arabic |
| BR | Brazil | '14 | S. America | Portuguese |
| PT | Portugal | '13 | Europe | Portuguese |
| CH | Switzerland | '11 | Europe | German |
| FR | France | '08 | Europe | French |
| BE | Belgium | '11 | Europe | Dutch |
| NL | Netherlands | '10 | Europe | Dutch |
| ZA | South Africa | '18 | Africa | English |

# Aim to visualize a sentence.

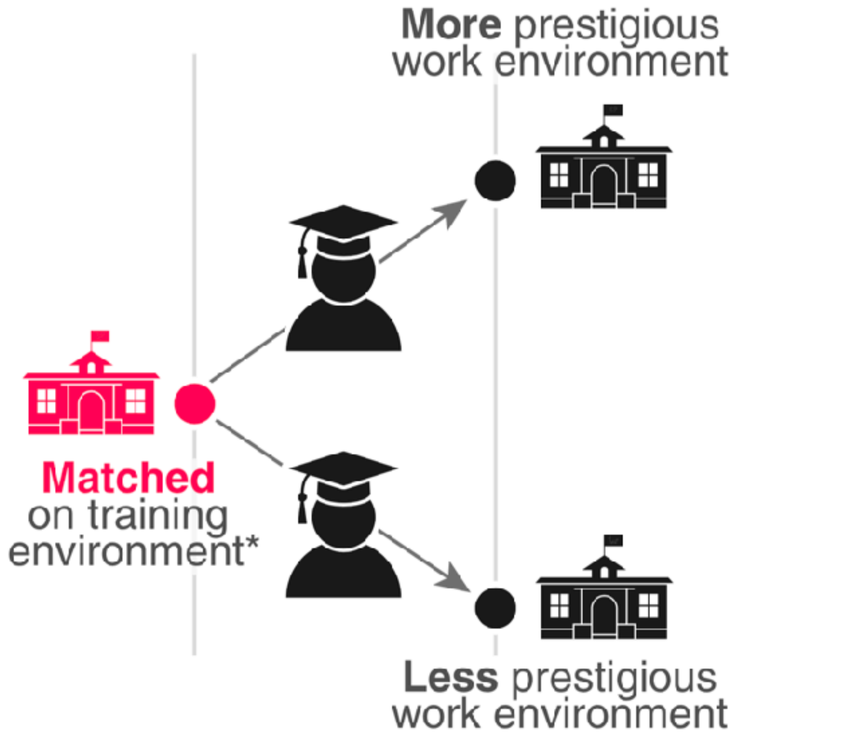
## Focus on clearly communicating a single idea.



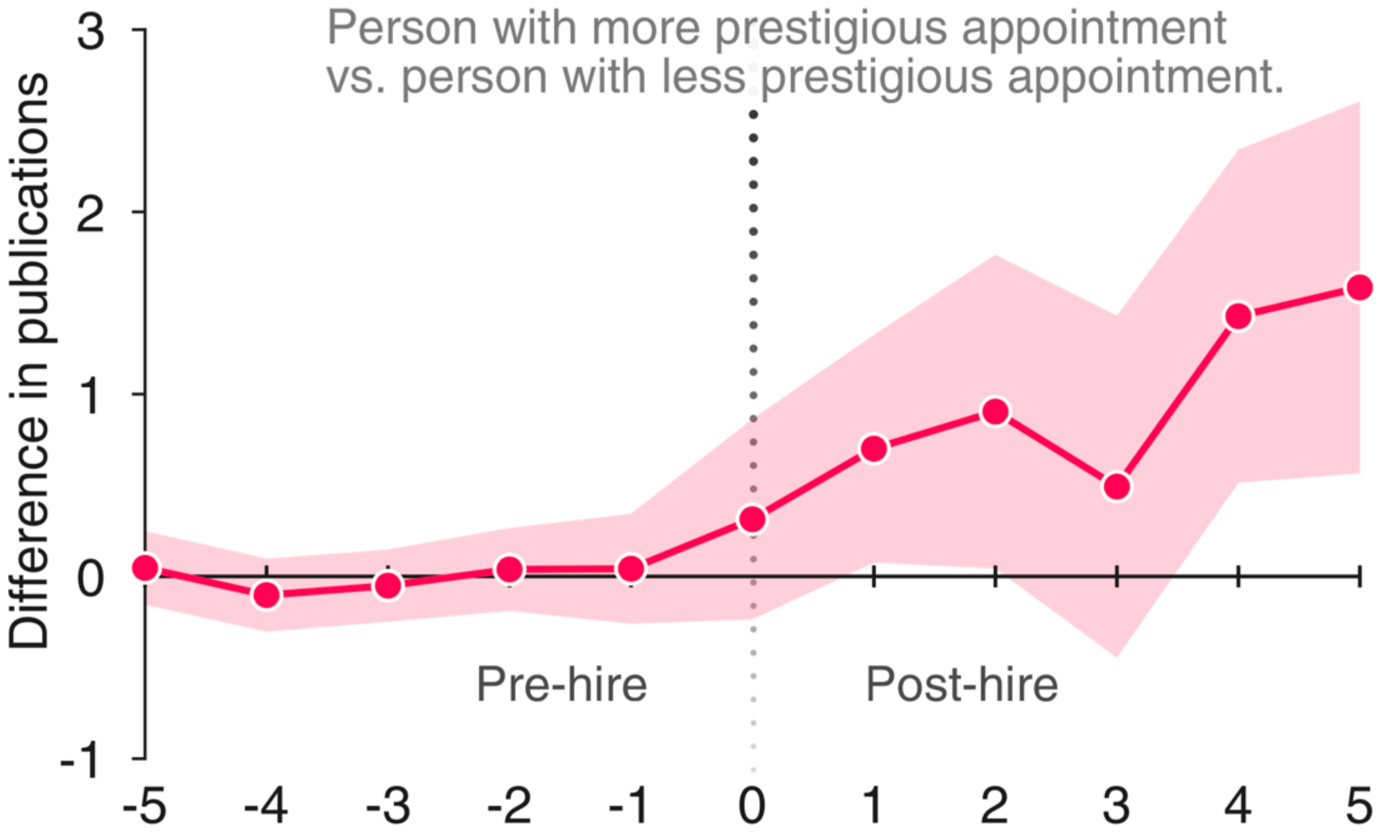

The sentence here: if you take two researchers with similar training and give one a more prestigious job than the other, that person tends to become more productive.

# Aim to visualize a sentence.

## Focus on clearly communicating a single idea.



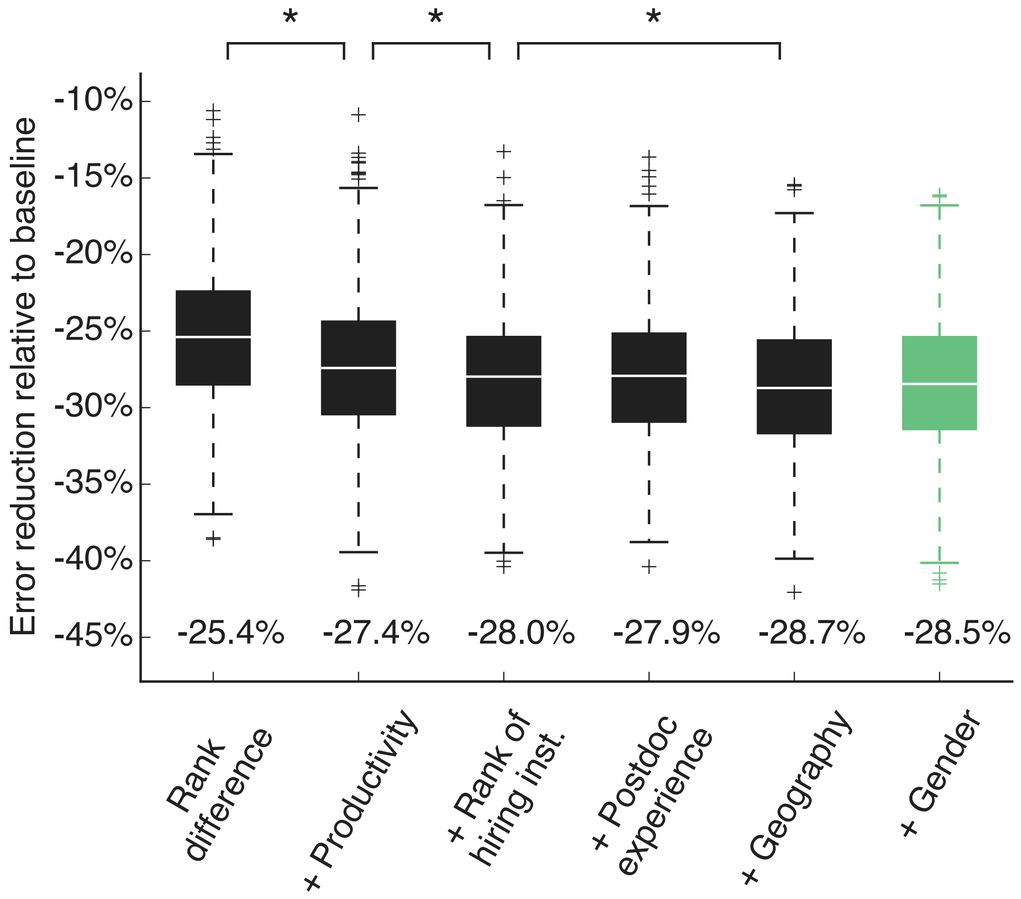

*: Faculty also matched on gender, subfield, and other features. See main text for full details.

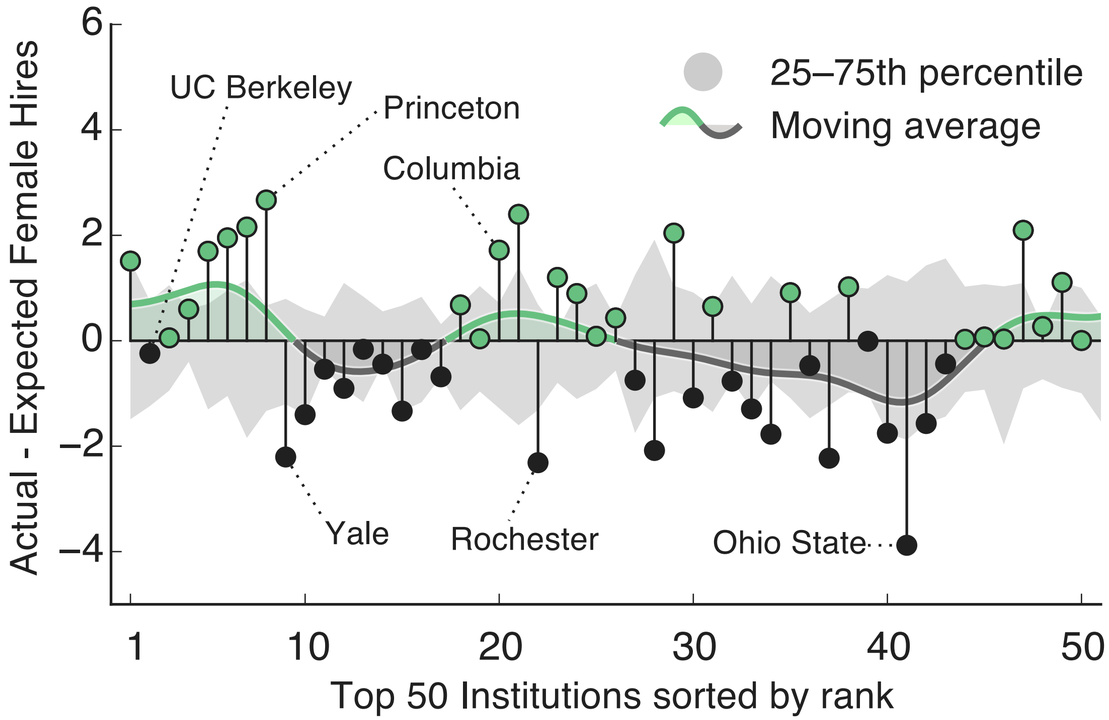



The sentence here: if you take two researchers with similar training and give one a more prestigious job than the other, that person tends to become more productive.

# Use color as an accent.

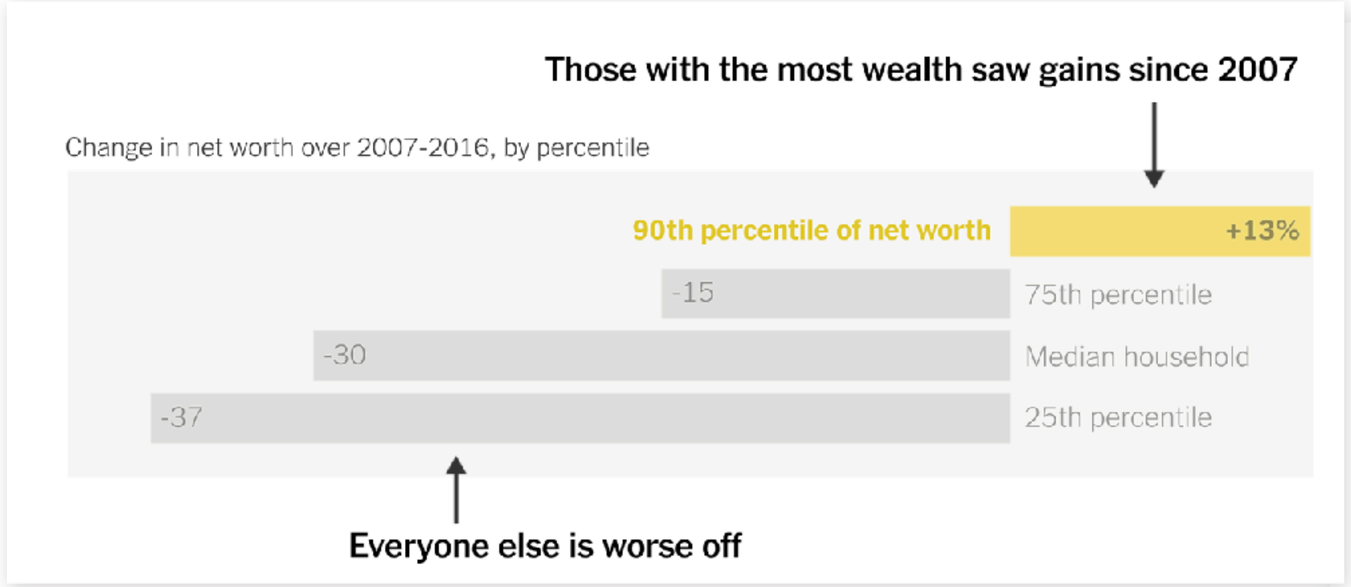
Most of my figures use grayscale + one accent color

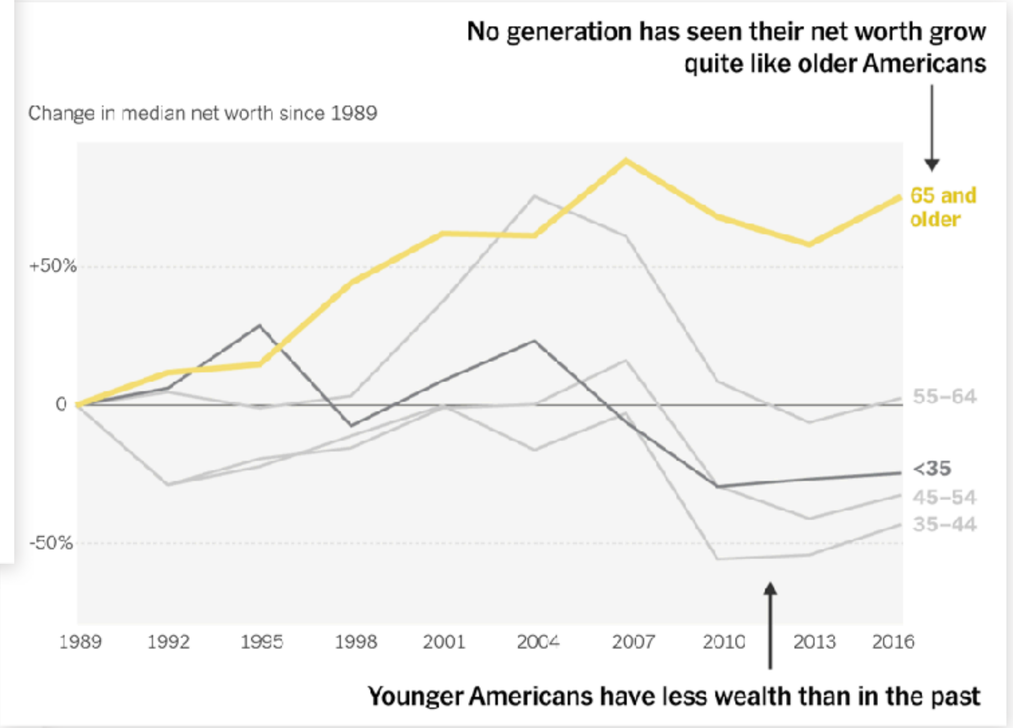


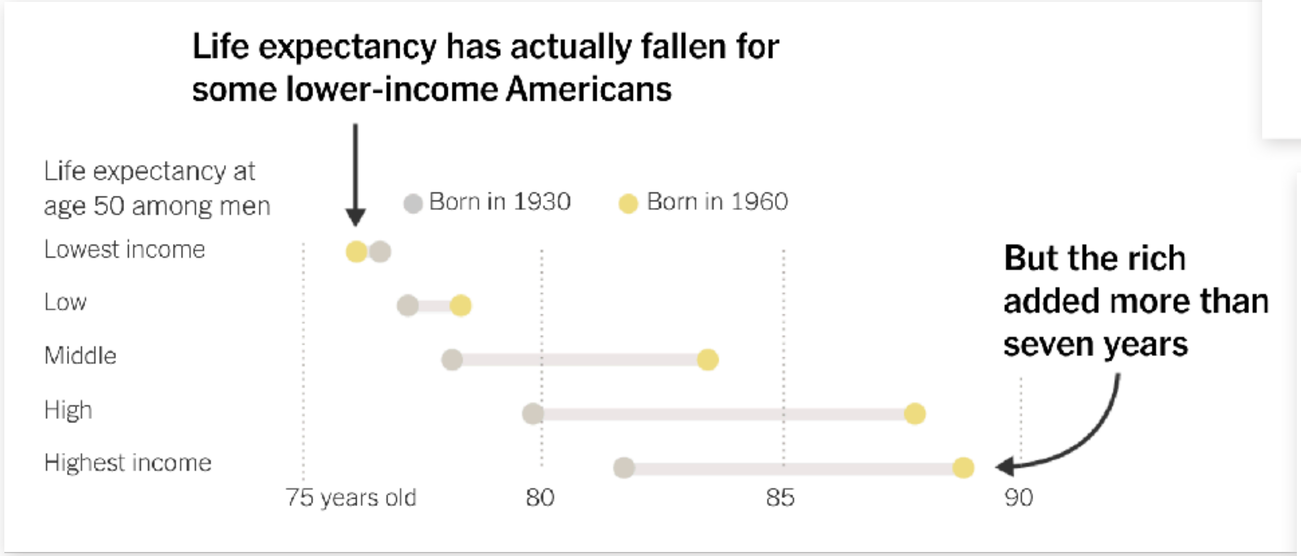



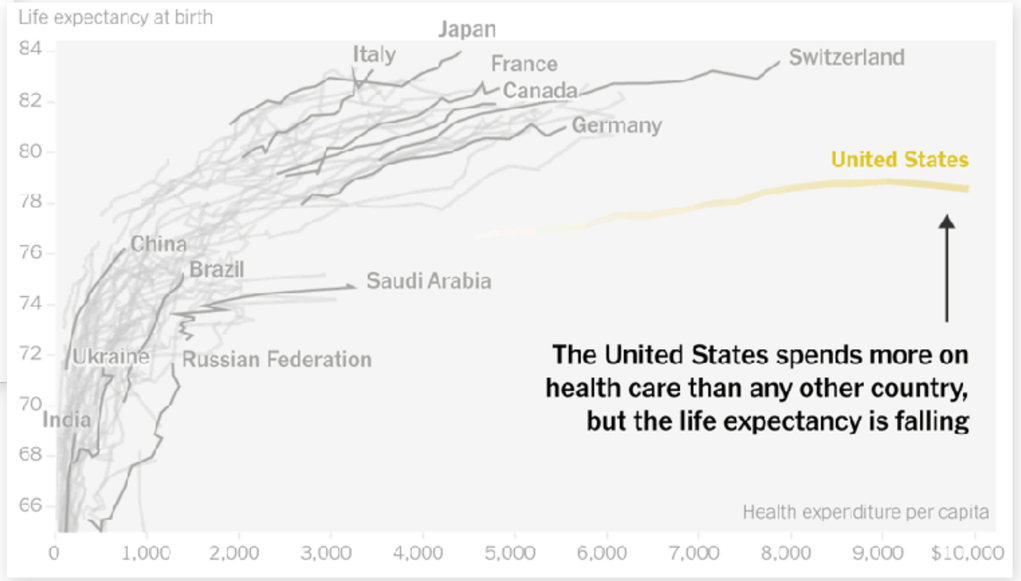

[1] Way et al.. Gender, Productivity, and Prestige in Computer Science Faculty Hiring Networks. (2016)

"Usefully restricting": this gives you two or three grays + a color to play with, which forces you to think about whether you should simplify your visualization.



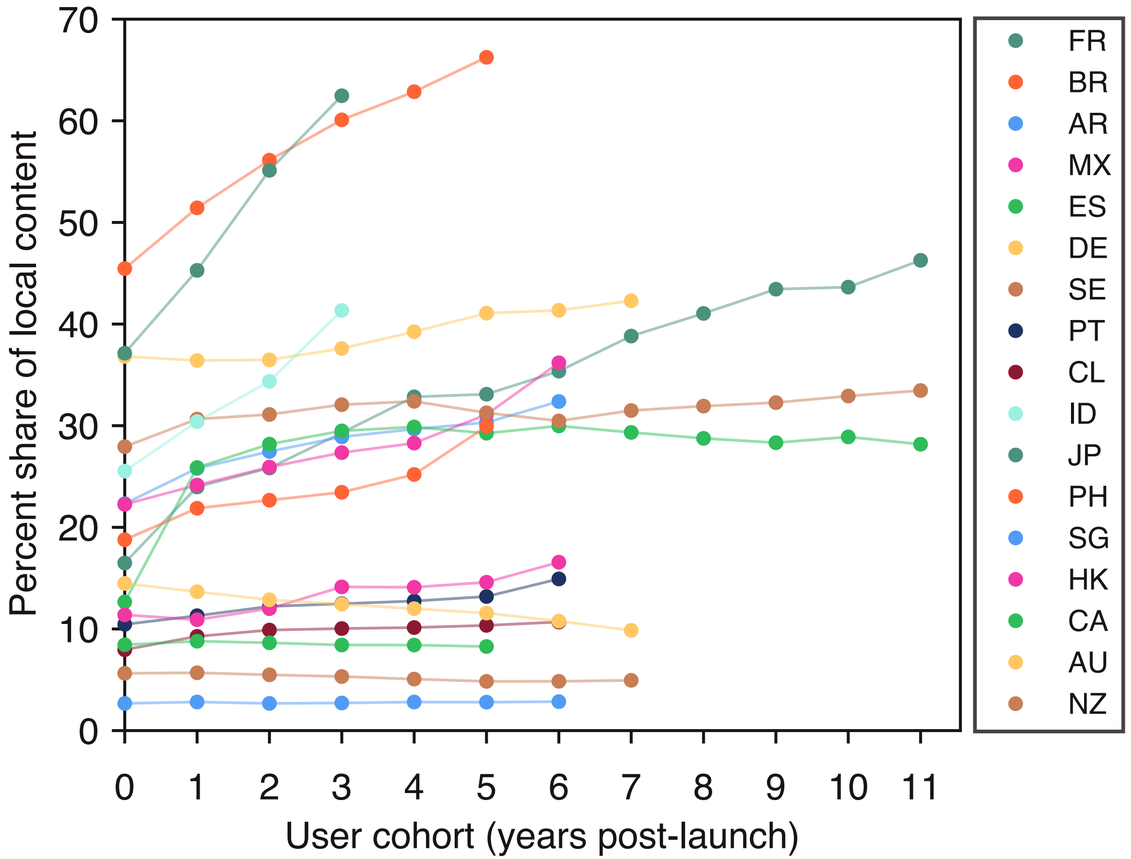




## Recent example from NYTimes

https://www.nytimes.com/interactive/2020/04/10/opinion/coronavirus-us-economy-inequality.html

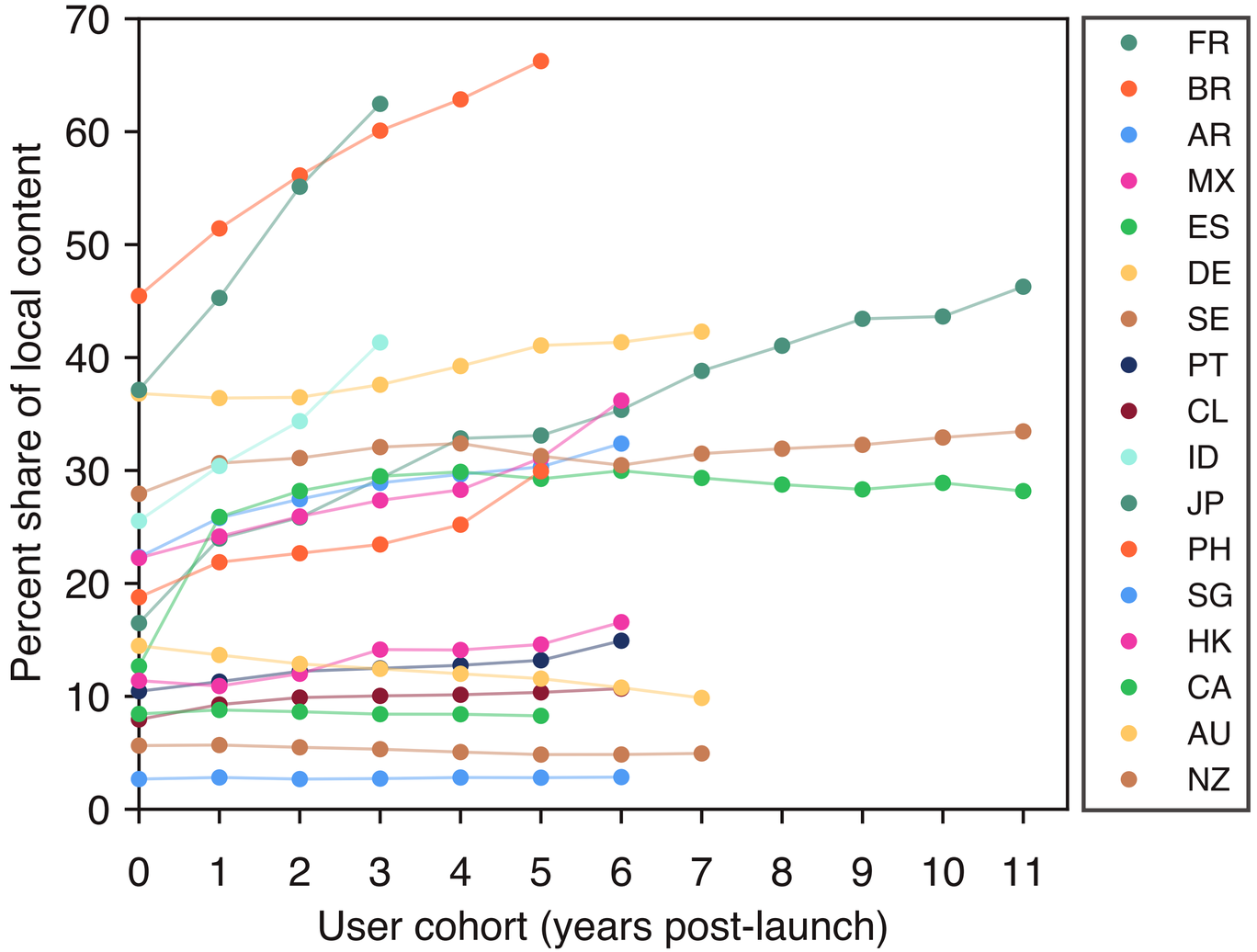
# Remove all non-essentials.

## If it doesn't have a purpose, take it out.

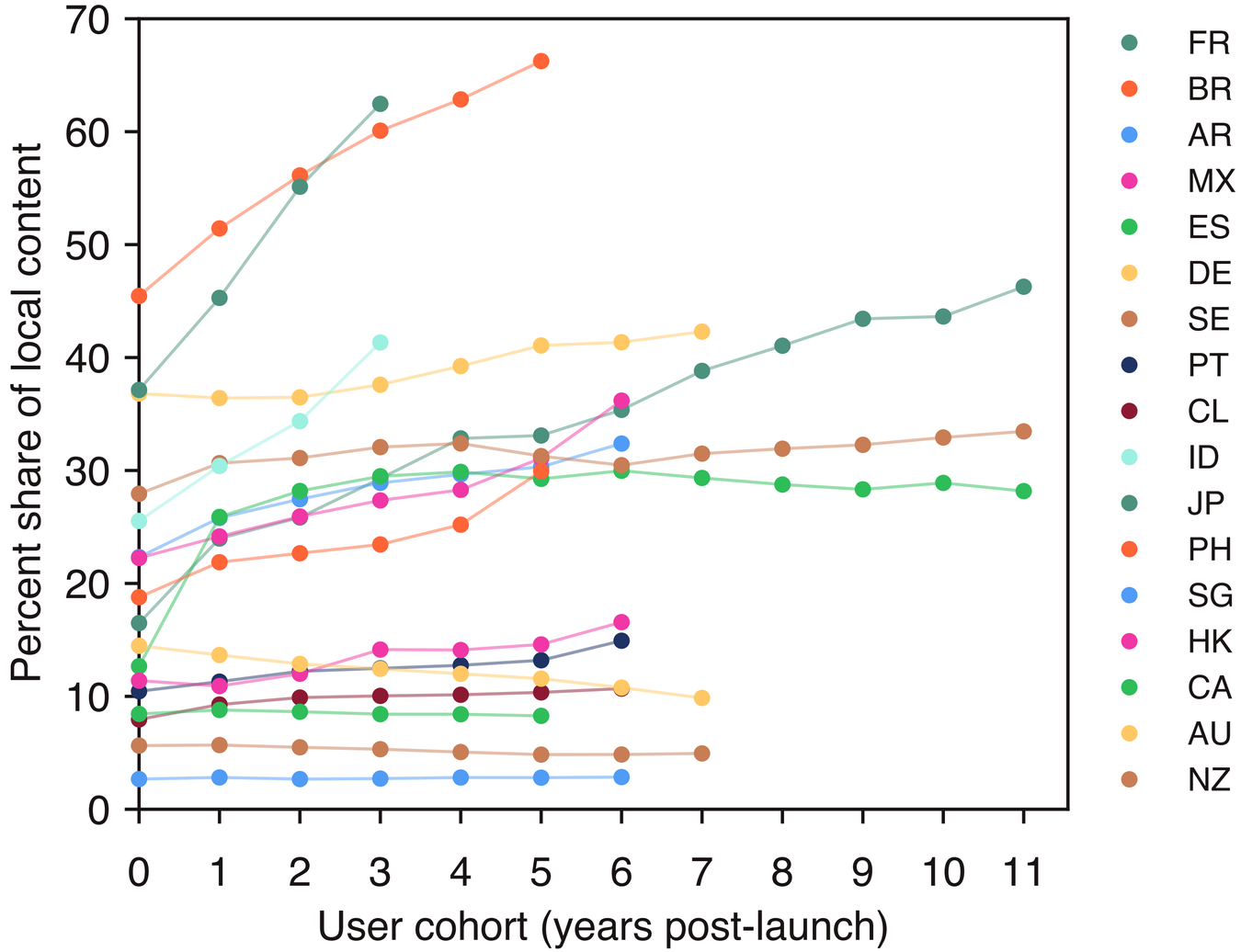



This goes for the design and the data itself: what are you trying to say? Is X required or helpful for saying it?

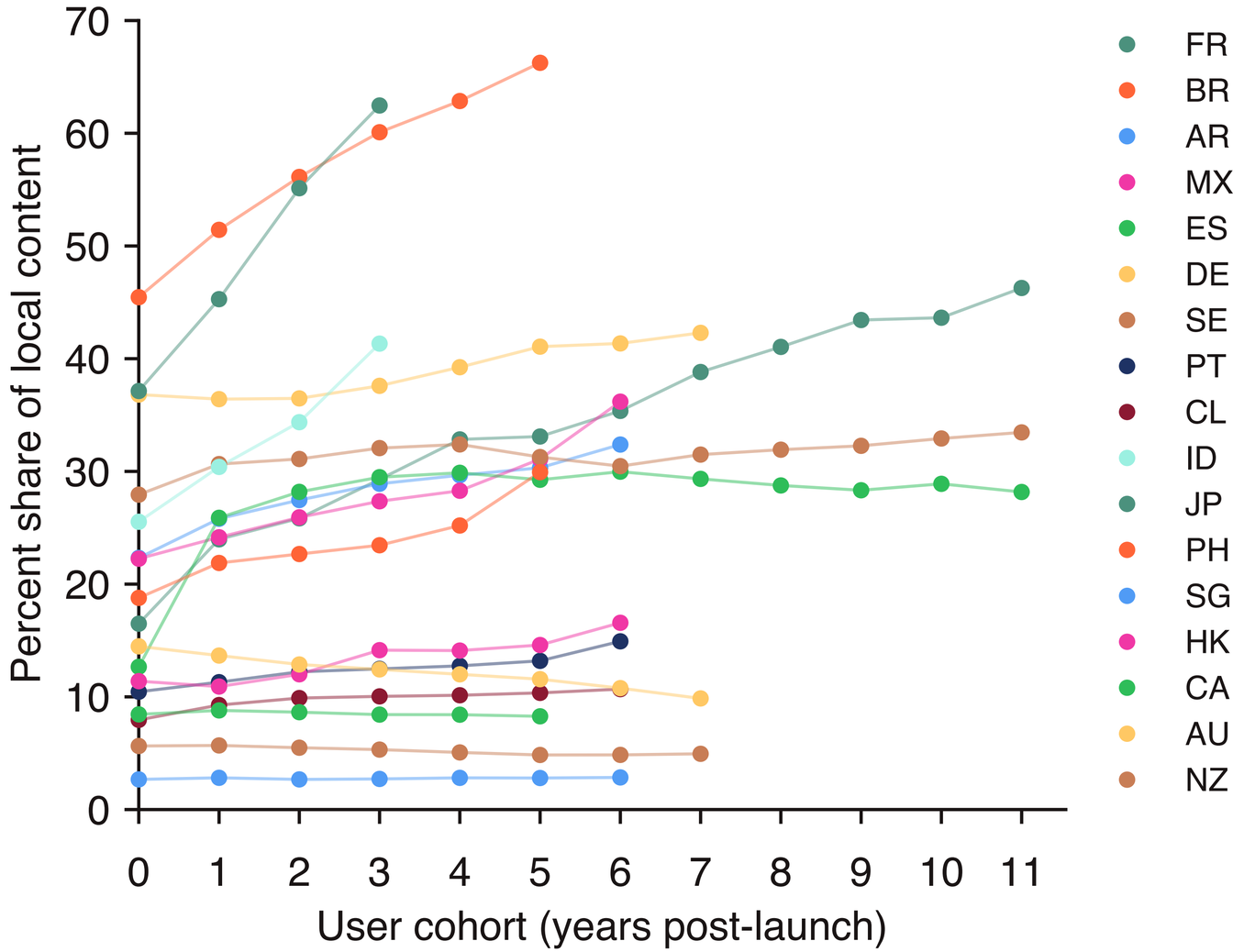
# Remove all non-essentials.



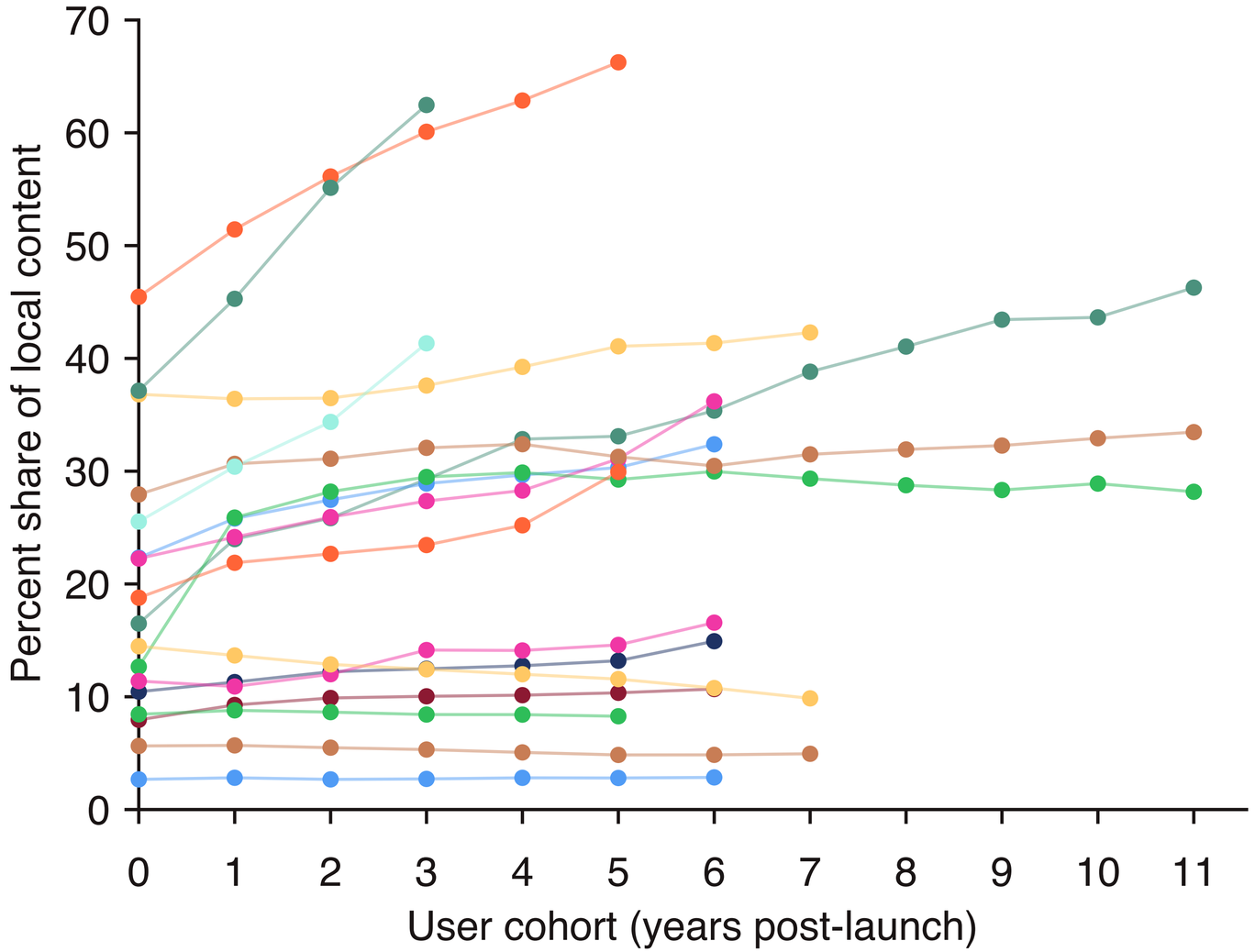
# Remove all non-essentials.



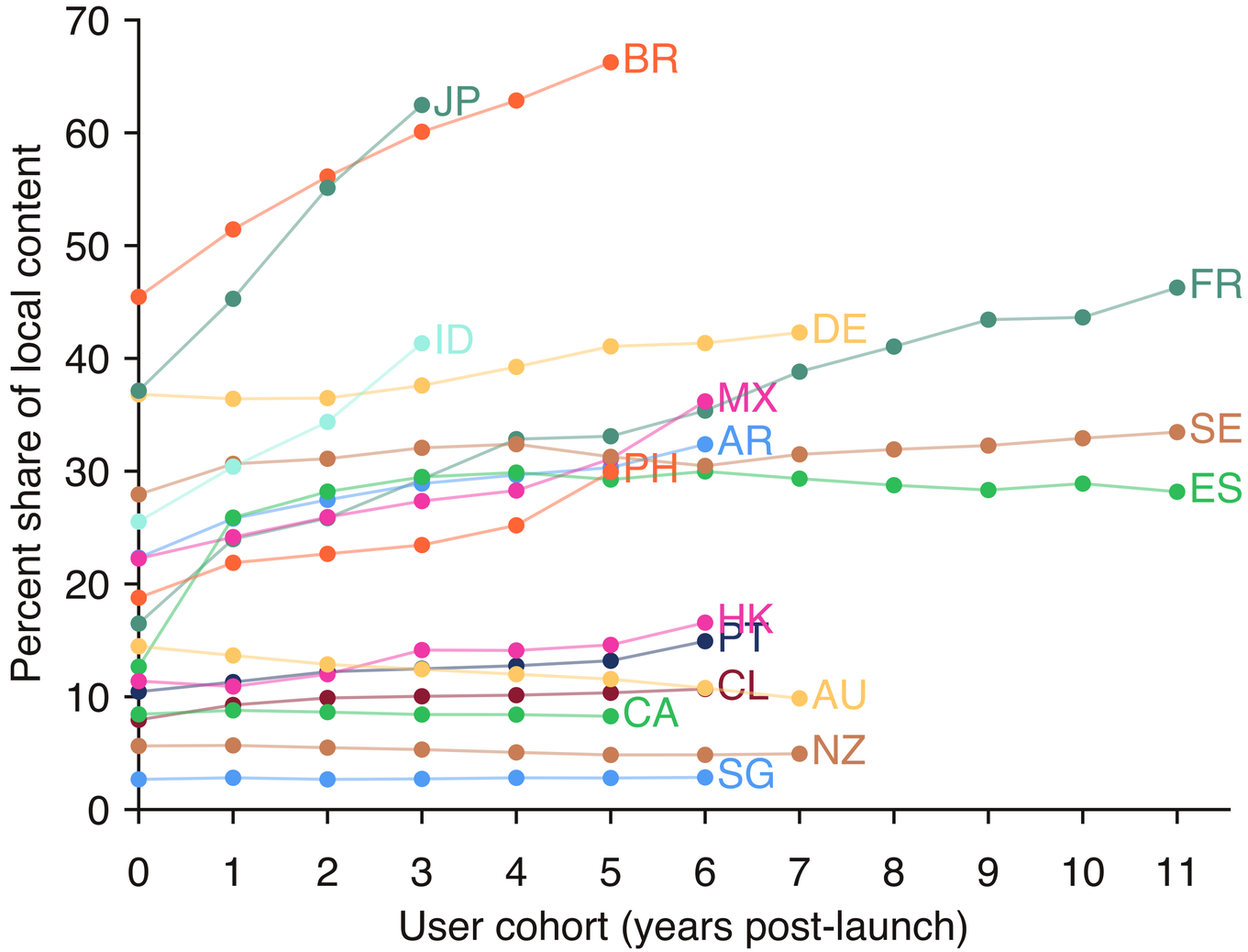
# Remove all non-essentials.



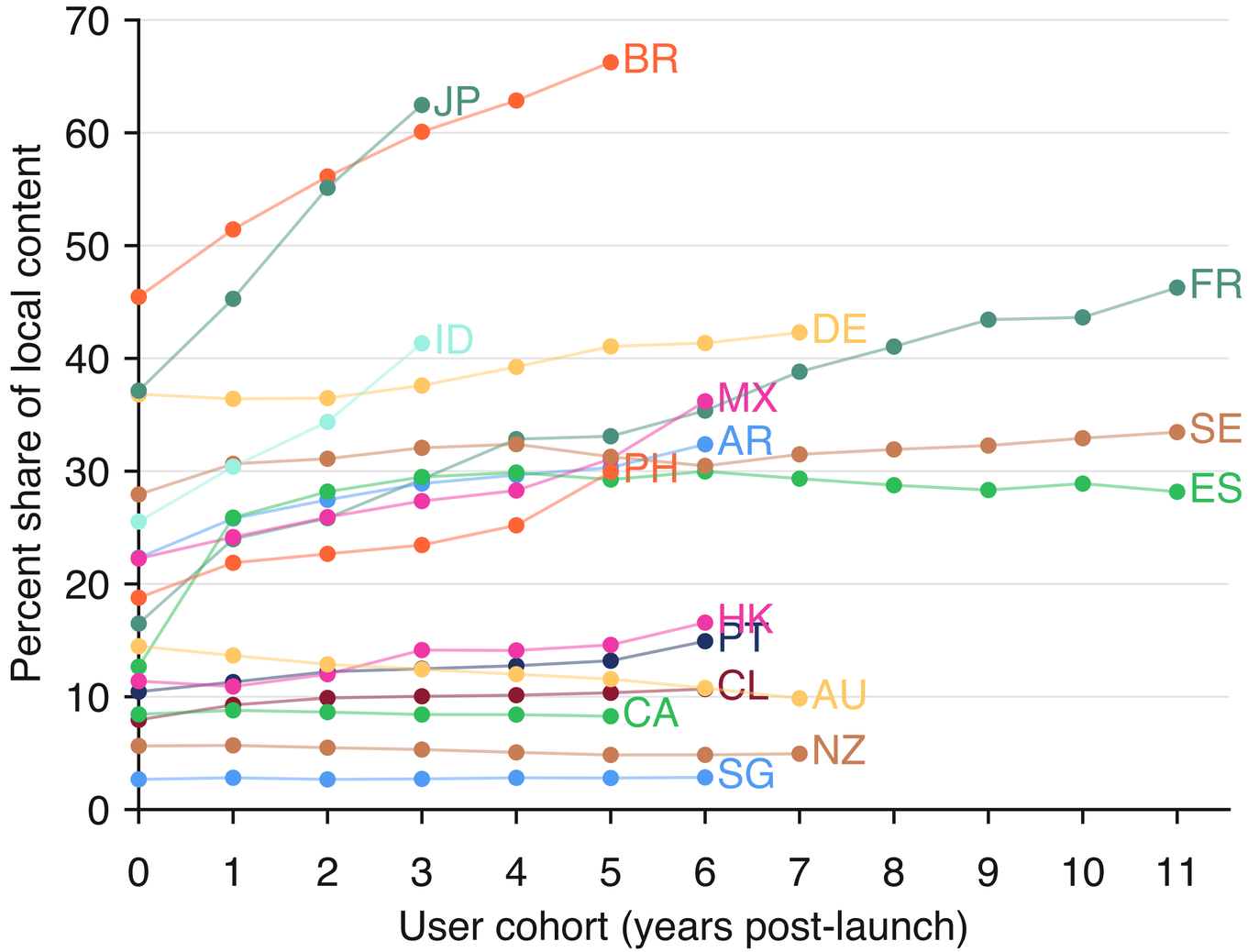
# Remove all non-essentials.



# Remove all non-essentials.



# Remove all non-essentials.



# Remove all non-essentials.

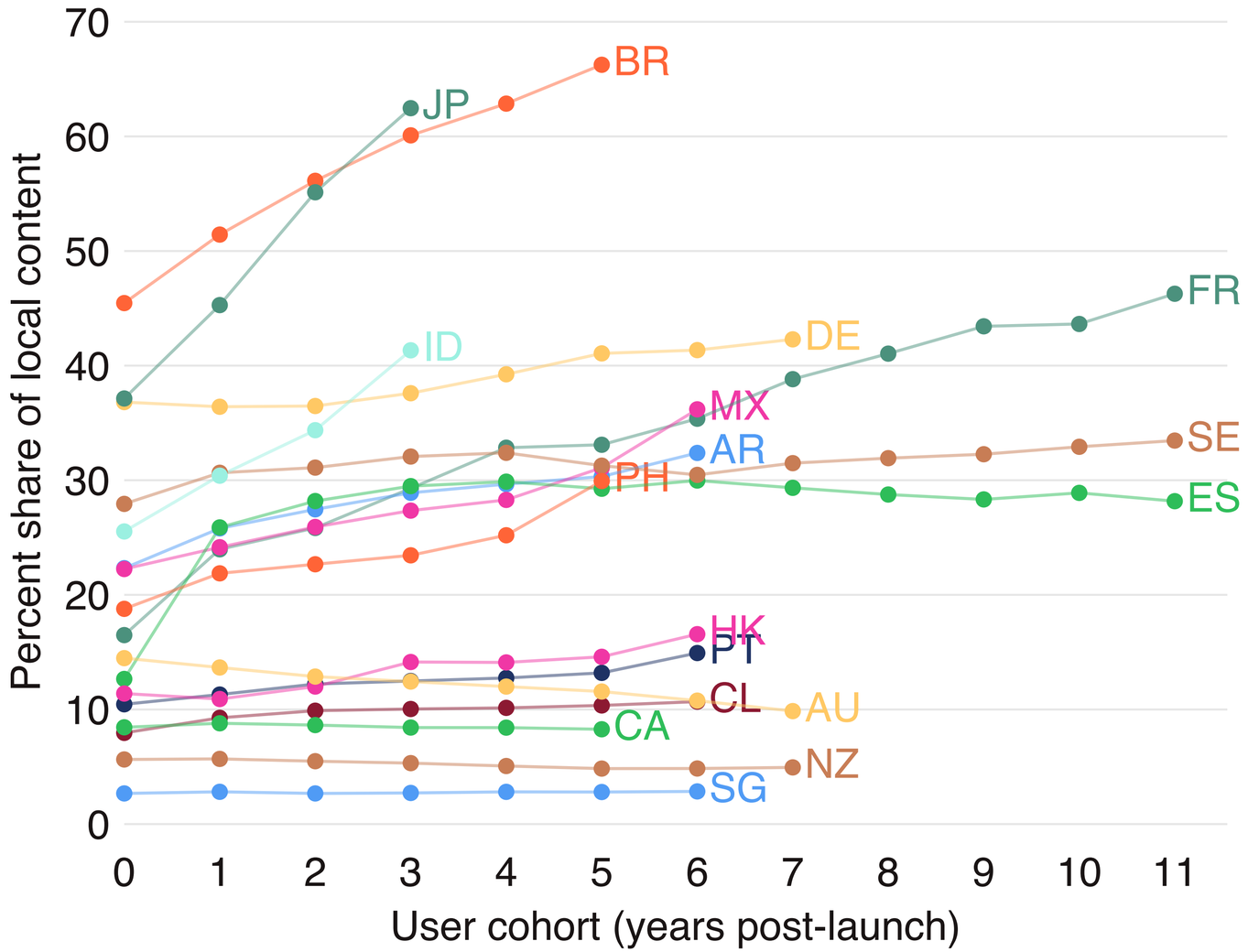


Figure 2: **Most markets exhibit a strong preference for local content, with the exception of newer markets.** Nearly all countries show significant preference for their own music. New markets in 2019 (lighter gray) constitute the earliest adopters of Spotify in the respective countries.

these three attributes more generally. This inspection serves as both an exploratory analysis of our data and highlights complications that will need to be addressed by later analyses.

Corroborating past studies, we confirm that countries' in-

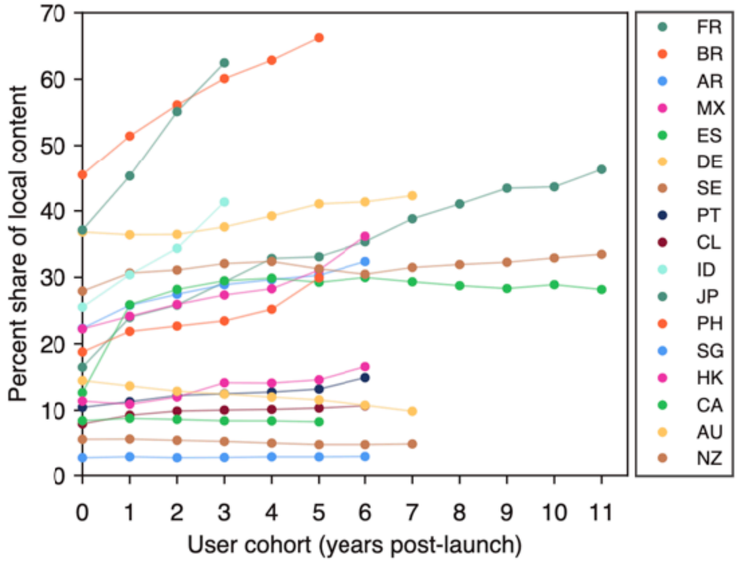



Figure 3: **Late adopters (as registration year cohorts) of Spotify tend to prefer more local content.** Late 2019 consumption patterns reveal that listeners who were late adopters of Spotify tend to stream more local content than listeners who joined the platform earlier.

Figure 2: **Most markets exhibit a strong preference for local content, with the exception of newer markets.** Nearly all countries show significant preference for their own music. New markets in 2019 (lighter gray) constitute the earliest adopters of Spotify in the respective countries.

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Corroborating past studies, we confirm that countries' in-

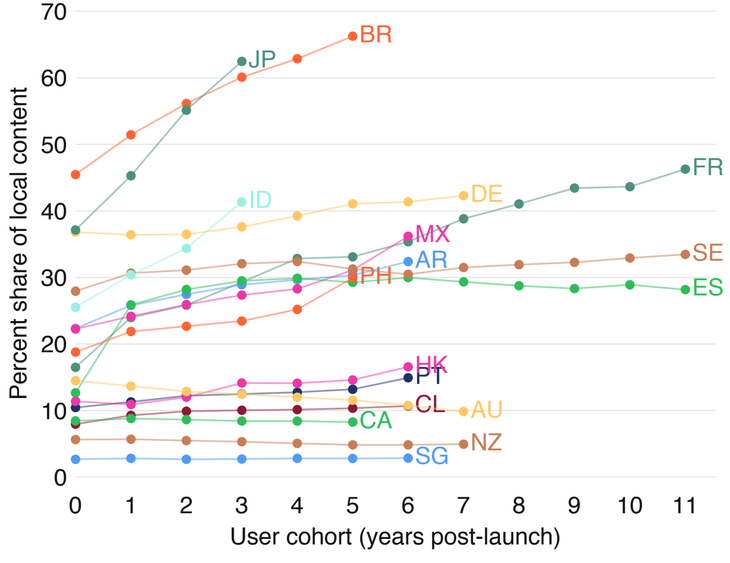
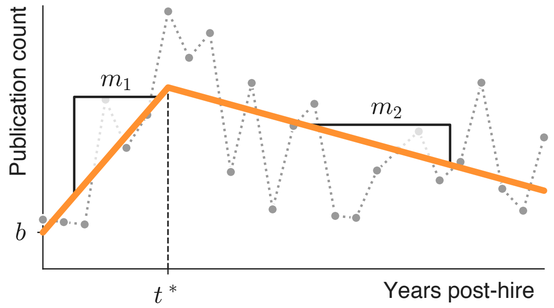


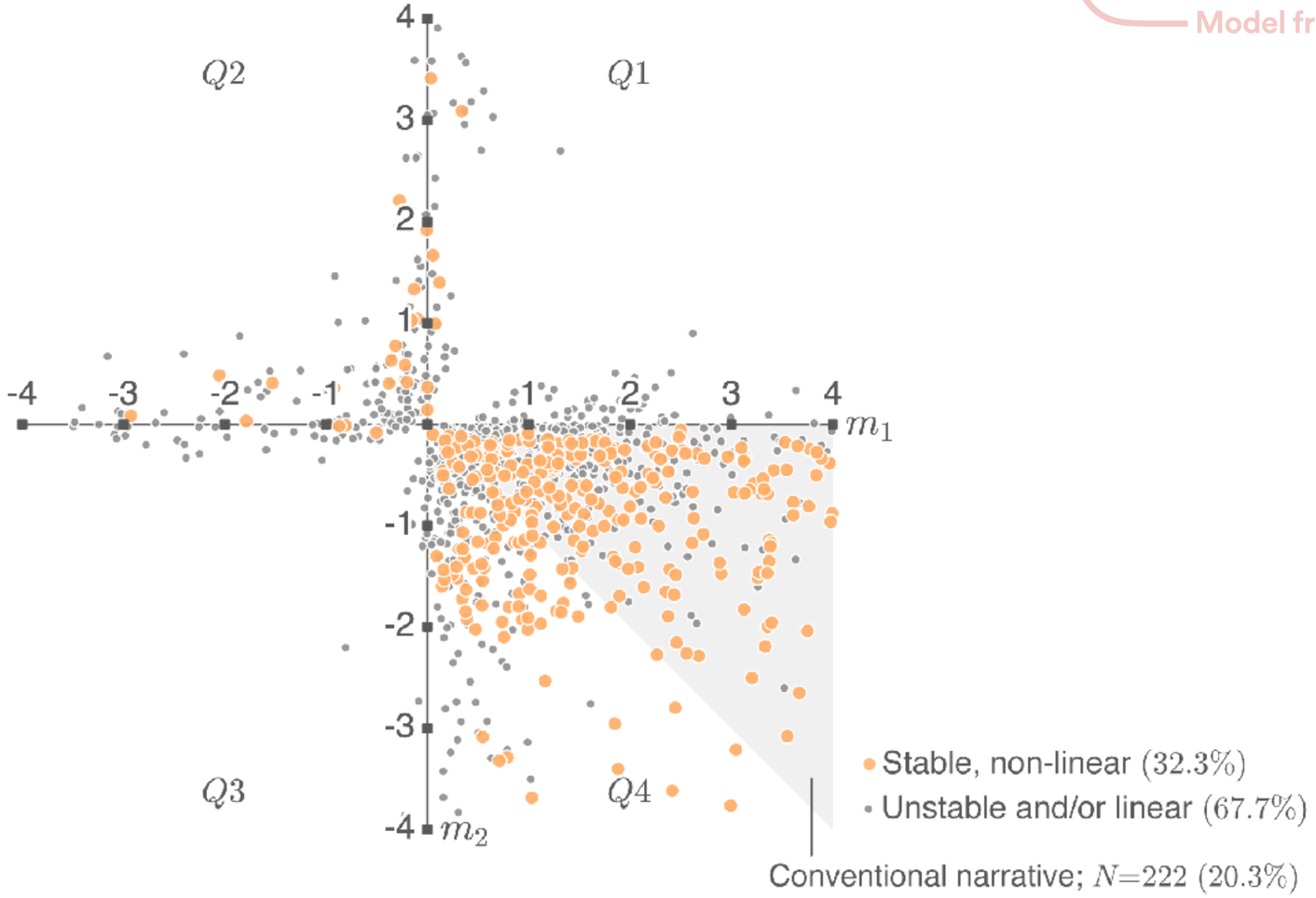

Figure 3: **Late adopters (as registration year cohorts) of Spotify tend to prefer more local content.** Late 2019 consumption patterns reveal that listeners who were late adopters of Spotify tend to stream more local content than listeners who joined the platform earlier.

# Give the viewer instructions.

## Prevent them from having to consult the text.

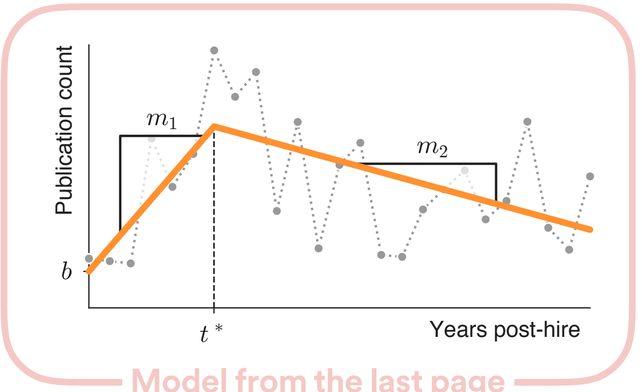



Model from the last page

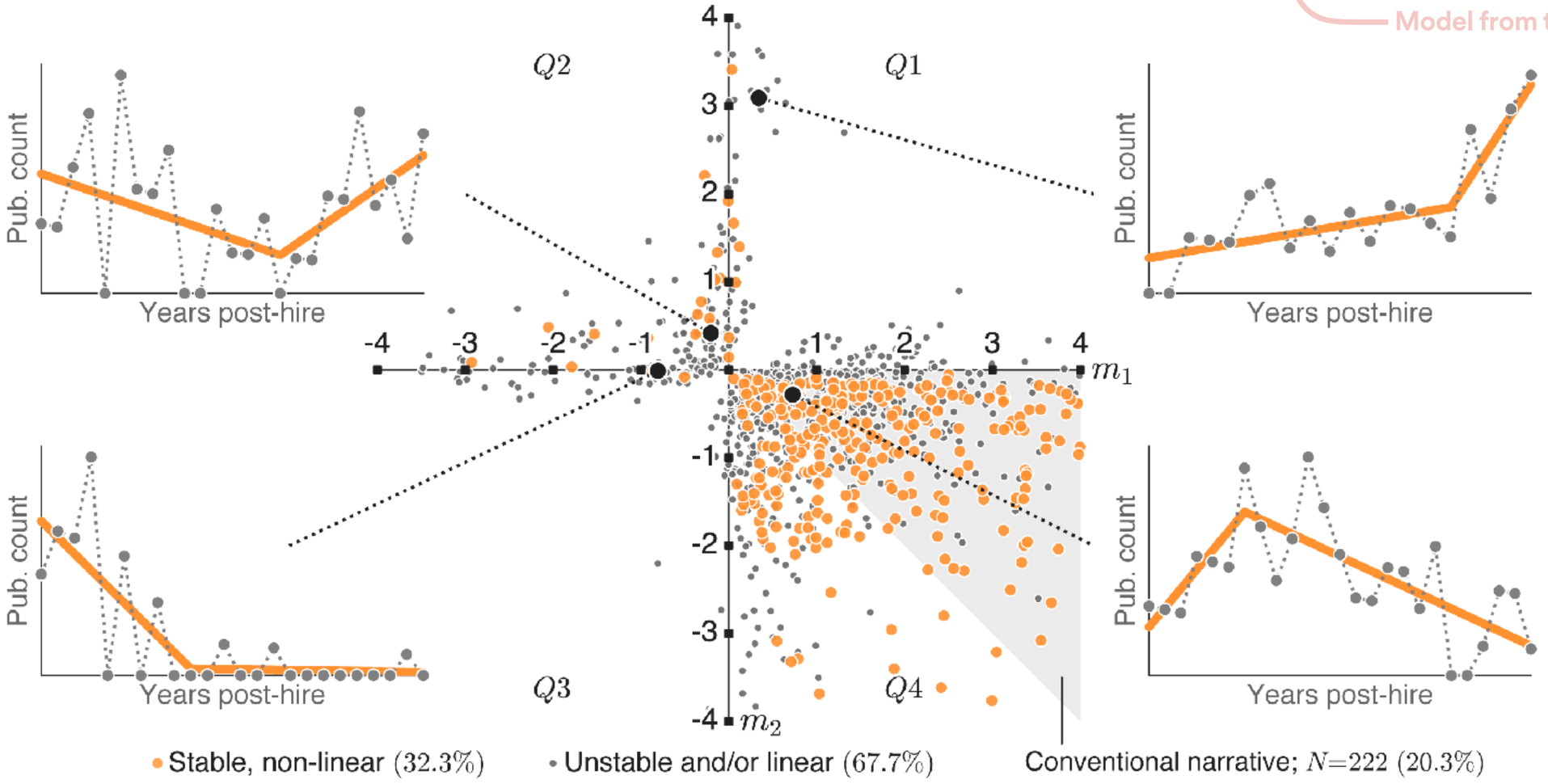


# Give the viewer instructions.

## Prevent them from having to consult the text.




Model from the last page



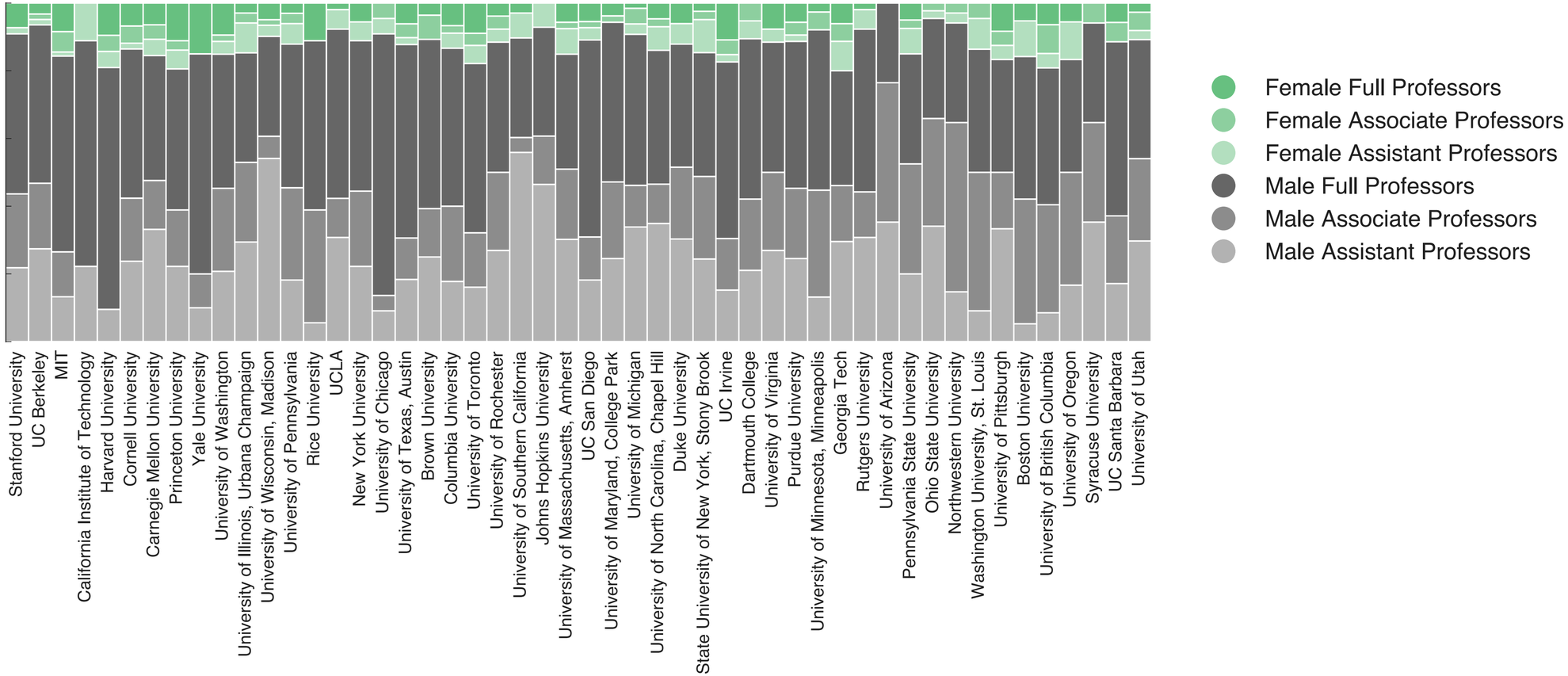
Determining your goals

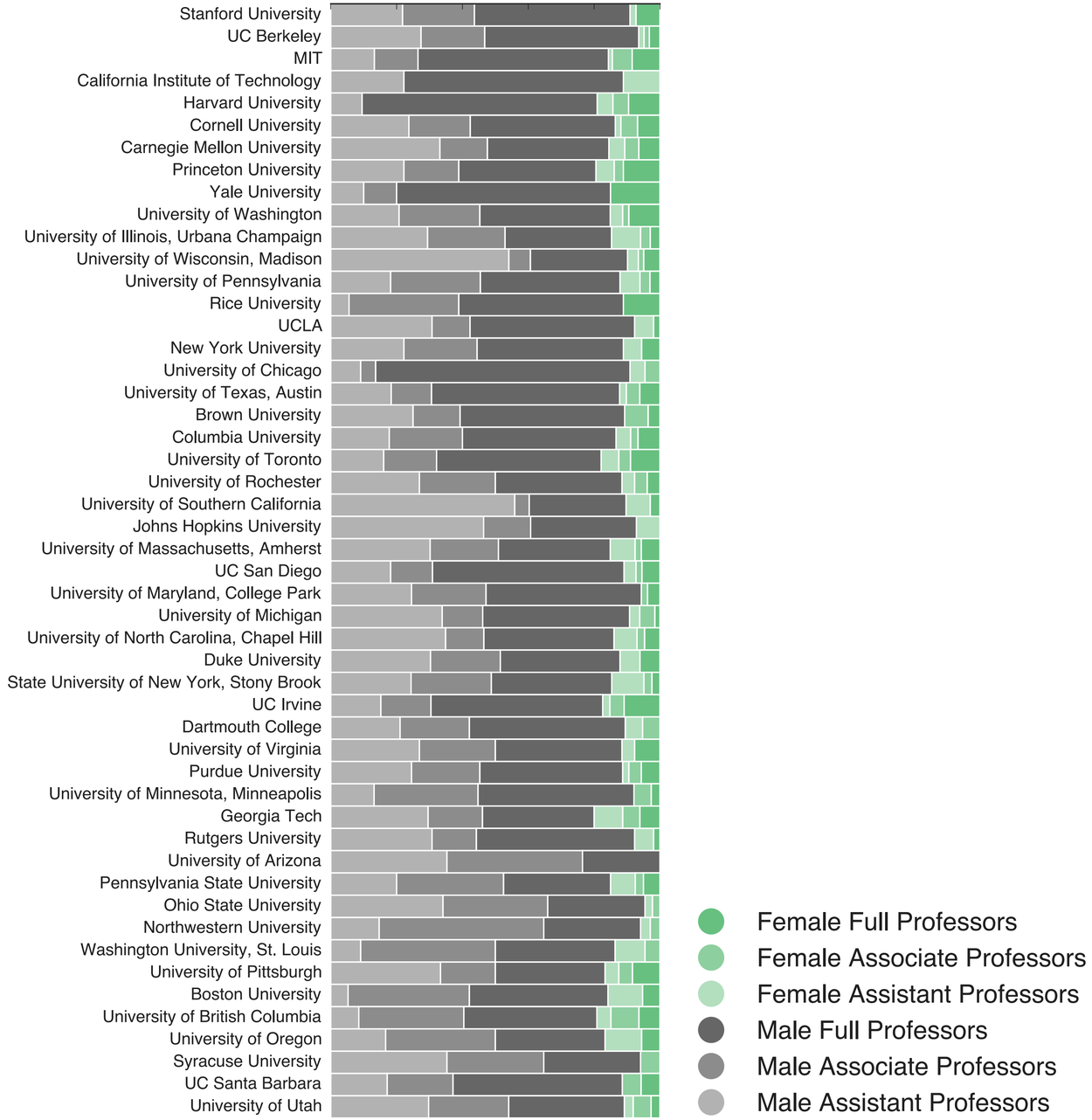
Selecting appropriate visualization

Building prototypes

Gathering feedback

# Simulate your audience.




Stanford University
UC Berkeley
MIT
California Institute of Technology
Harvard University
Cornell University
Carnegie Mellon University
Princeton University
Yale University
University of Washington
University of Illinois, Urbana Champaign
University of Wisconsin, Madison
University of Pennsylvania
Rice University
UCLA
New York University
University of Chicago
University of Texas, Austin
Brown University
Columbia University
University of Toronto
University of Rochester
University of Southern California
Johns Hopkins University
University of Massachusetts, Amherst
UC San Diego
University of Maryland, College Park
University of Michigan
University of North Carolina, Chapel Hill
Duke University
State University of New York, Stony Brook
UC Irvine
Dartmouth College
University of Virginia
Purdue University
University of Minnesota, Minneapolis
Georgia Tech
Rutgers University
University of Arizona
Pennsylvania State University
Ohio State University
Northwestern University
Washington University, St. Louis
University of Pittsburgh
Boston University
University of British Columbia
University of Oregon
Syracuse University
UC Santa Barbara
University of Utah
Female Full Professors
Female Associate Professors
Female Assistant Professors
Male Full Professors
Male Associate Professors
Male Assistant Professors

# Simulate your audience, part 2.

| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -4.320906e-17 | 0.05499178 | -7.857367e-16 | 1.000000e+00 |
| scale(prestige) | 2.625988e-01 | 0.08632739 | -3.041894e+00 | 2.350947e-03 |
| scale(private) | 1.387510e-01 | 0.07156172 | 1.938900e+00 | 5.251353e-02 |
| scale(dept.size) | 1.983602e-01 | 0.07589478 | 2.613622e+00 | 8.958812e-03 |
| scale(jr.sr.ratio) | -9.558408e-03 | 0.06365449 | -1.501608e-01 | 8.806378e-01 |
| scale(gender.ratio) | -7.084867e-02 | 0.06756081 | -1.048665e+00 | 2.943323e-01 |
| scale(phd.gender.ratio) | 9.798437e-03 | 0.06294453 | 1.556678e-01 | 8.762949e-01 |
| scale(phd.per.fac) | 3.848203e-01 | 0.07000914 | 5.496715e+00 | 3.869303e-08 |
| scale(bs.per.fac) | -5.444218e-02 | 0.06352855 | -8.569719e-01 | 3.914604e-01 |
| scale(support.per.fac) | 9.543509e-02 | 0.06547985 | 1.457473e+00 | 1.449859e-01 |
| scale(exfund.per.fac) | 6.856958e-02 | 0.07071276 | 9.696918e-01 | 3.322002e-01 |
| scale(deptsup.per.fac) | -1.674358e-01 | 0.08082410 | -2.071608e+00 | 3.830202e-02 |
| scale(teaching.load) | -7.490268e-02 | 0.07069245 | -1.059557e+00 | 2.893462e-01 |
| scale(avg.asst.sal) | 4.094305e-02 | 0.07299193 | 5.609258e-01 | 5.748481e-01 |
| scale(avg.asst.sal.rel) | -1.789111e-02 | 0.06982525 | -2.562270e-01 | 7.977756e-01 |
| scale(space.per.fac) | 1.098649e-01 | 0.07586357 | 1.448190e+00 | 1.475638e-01 |
| scale(grad.sup) | -6.055612e-04 | 0.06713530 | -9.020012e-03 | 9.928032e-01 |
| scale(local.pop) | 6.320005e-02 | 0.06512214 | 9.704849e-01 | 3.318048e-01 |
| scale(parent.sup) | 1.580210e-02 | 0.09118763 | 1.732921e-01 | 8.624218e-01 |
| scale(parent.sup.plus) | -3.885033e-02 | 0.09084825 | -4.276398e-01 | 6.689134e-01 |

| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -1.015627e-16 | 0.05746459 | -1.767396e-15 | 1.000000e+00 |
| scale(dept.size) | 2.772717e-01 | 0.07150747 | 3.877520e+00 | 1.055266e-04 |
| scale(jr.sr.ratio) | -6.417544e-03 | 0.06646028 | -9.656210e-02 | 9.230742e-01 |
| scale(gender.ratio) | -8.493457e-02 | 0.06781088 | -1.252521e+00 | 2.103800e-01 |
| scale(phd.gender.ratio) | -4.790964e-03 | 0.06482548 | -7.390558e-02 | 9.410855e-01 |
| scale(phd.per.fac) | 3.924791e-01 | 0.07038592 | 5.576103e+00 | 2.459666e-08 |
| scale(bs.per.fac) | -1.196690e-01 | 0.06366251 | -1.879740e+00 | 6.014349e-02 |
| scale(support.per.fac) | 1.757839e-01 | 0.06512311 | 2.699255e+00 | 6.949487e-03 |
| scale(exfund.per.fac) | 1.186341e-01 | 0.06999055 | 1.695001e+00 | 9.007517e-02 |
| scale(deptsup.per.fac) | -1.856224e-01 | 0.08165860 | -2.273152e+00 | 2.301704e-02 |
| scale(teaching.load) | -1.284644e-01 | 0.07203570 | -1.783344e+00 | 7.453031e-02 |
| scale(avg.asst.sal) | 8.159199e-02 | 0.07472268 | 1.091931e+00 | 2.748636e-01 |
| scale(avg.asst.sal.rel) | -1.627540e-02 | 0.07217724 | -2.254922e-01 | 8.215964e-01 |
| scale(space.per.fac) | 1.329687e-01 | 0.07762836 | 1.712888e+00 | 8.673307e-02 |
| scale(grad.sup) | 3.940688e-02 | 0.06831598 | 5.768325e-01 | 5.640526e-01 |
| scale(local.pop) | 8.609404e-02 | 0.06596881 | 1.305072e+00 | 1.918684e-01 |
| scale(parent.sup) | 6.581023e-02 | 0.09416931 | 6.988501e-01 | 4.846457e-01 |
| scale(parent.sup.plus) | -3.837969e-02 | 0.09509670 | -4.035859e-01 | 6.865172e-01 |

Here are two of 16 regression tables from a working paper. How do scientists make sense of these tables? How do we do some legwork for them?

# Simulate your audience, part 2.

| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -4.320906e-17 | 0.05499178 | -7.857367e-16 | 1.000000e+00 |
| scale(prestige) | 2.625988e-01 | 0.08632739 | 3.041894e+00 | 2.350947e-03 |
| scale(private) | 1.387510e-01 | 0.07156172 | 1.938900e+00 | 5.251353e-02 |
| scale(dept.size) | 1.983602e-01 | 0.07589478 | 2.613622e+00 | 8.958812e-03 |
| scale(jr.sr.ratio) | -9.558408e-03 | 0.06365449 | -1.501608e-01 | 8.806378e-01 |
| scale(gender.ratio) | -7.084867e-02 | 0.06756081 | -1.048665e+00 | 2.943323e-01 |
| scale(phd.gender.ratio) | 9.798437e-03 | 0.06294453 | 1.556678e-01 | 8.762949e-01 |
| scale(phd.per.fac) | 3.848203e-01 | 0.07000914 | 5.496715e+00 | 3.869303e-08 |
| scale(bs.per.fac) | -5.444218e-02 | 0.06352855 | -8.569719e-01 | 3.914604e-01 |
| scale(support.per.fac) | 9.543509e-02 | 0.06547985 | 1.457473e+00 | 1.449859e-01 |
| scale(exfund.per.fac) | 6.856958e-02 | 0.07071276 | 9.696918e-01 | 3.322002e-01 |
| scale(deptsup.per.fac) | -1.674358e-01 | 0.08082410 | -2.071608e+00 | 3.830202e-02 |
| scale(teaching.load) | -7.490268e-02 | 0.07069245 | -1.059557e+00 | 2.893462e-01 |
| scale(avg.asst.sal) | 4.094305e-02 | 0.07299193 | 5.609258e-01 | 5.748481e-01 |
| scale(avg.asst.sal.rel) | -1.789111e-02 | 0.06982525 | -2.562270e-01 | 7.977756e-01 |
| scale(space.per.fac) | 1.098649e-01 | 0.07586357 | 1.448190e+00 | 1.475638e-01 |
| scale(grad.sup) | -6.055612e-04 | 0.06713530 | -9.020012e-03 | 9.928032e-01 |
| scale(local.pop) | 6.320005e-02 | 0.06512214 | 9.704849e-01 | 3.318048e-01 |
| scale(parent.sup) | 1.580210e-02 | 0.09118763 | 1.732921e-01 | 8.624218e-01 |
| scale(parent.sup.plus) | -3.885033e-02 | 0.09084825 | -4.276398e-01 | 6.689134e-01 |

| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -1.015627e-16 | 0.05746459 | -1.767396e-15 | 1.000000e+00 |
| scale(dept.size) | 2.772717e-01 | 0.07150747 | 3.877520e+00 | 1.055266e-04 |
| scale(jr.sr.ratio) | -6.417544e-03 | 0.06646028 | -9.656210e-02 | 9.230742e-01 |
| scale(gender.ratio) | -8.493457e-02 | 0.06781088 | -1.252521e+00 | 2.103800e-01 |
| scale(phd.gender.ratio) | -4.790964e-03 | 0.06482548 | -7.390558e-02 | 9.410855e-01 |
| scale(phd.per.fac) | 3.924791e-01 | 0.07038592 | 5.576103e+00 | 2.459666e-08 |
| scale(bs.per.fac) | -1.196690e-01 | 0.06366251 | -1.879740e+00 | 6.014349e-02 |
| scale(support.per.fac) | 1.757839e-01 | 0.06512311 | 2.699255e+00 | 6.949487e-03 |
| scale(exfund.per.fac) | 1.186341e-01 | 0.06999055 | 1.695001e+00 | 9.007517e-02 |
| scale(deptsup.per.fac) | -1.856224e-01 | 0.08165860 | -2.273152e+00 | 2.301704e-02 |
| scale(teaching.load) | -1.284644e-01 | 0.07203570 | -1.783344e+00 | 7.453031e-02 |
| scale(avg.asst.sal) | 8.159199e-02 | 0.07472268 | 1.091931e+00 | 2.748636e-01 |
| scale(avg.asst.sal.rel) | -1.627540e-02 | 0.07217724 | -2.254922e-01 | 8.215964e-01 |
| scale(space.per.fac) | 1.329687e-01 | 0.07762836 | 1.712888e+00 | 8.673307e-02 |
| scale(grad.sup) | 3.940688e-02 | 0.06831598 | 5.768325e-01 | 5.640526e-01 |
| scale(local.pop) | 8.609404e-02 | 0.06596881 | 1.305072e+00 | 1.918684e-01 |
| scale(parent.sup) | 6.581023e-02 | 0.09416931 | 6.988501e-01 | 4.846457e-01 |
| scale(parent.sup.plus) | -3.837969e-02 | 0.09509670 | -4.035859e-01 | 6.865172e-01 |

Which relationships are significant?
What's the strength of these relationships?

Here are two of 16 regression tables from a working paper. How do scientists make sense of these tables? How do we do some legwork for them?

# Simulate your audience, part 2.

| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -4.320906e-17 | 0.05499178 | -7.857367e-16 | 1.000000e+00 |
| scale(prestige) | 2.625988e-01 | 0.08632739 | -3.041894e+00 | 2.350947e-03 |
| scale(private) | 1.387510e-01 | 0.07156172 | 1.938900e+00 | 5.251353e-02 |
| scale(dept.size) | 1.983602e-01 | 0.07589478 | 2.613622e+00 | 8.958812e-03 |
| scale(jr.sr.ratio) | -9.558408e-03 | 0.06365449 | -1.501608e-01 | 8.806378e-01 |
| scale(gender.ratio) | -7.084867e-02 | 0.06756081 | -1.048665e+00 | 2.943323e-01 |
| scale(phd.gender.ratio) | 9.798437e-03 | 0.06294453 | 1.556678e-01 | 8.762949e-01 |
| scale(phd.per.fac) | 3.848203e-01 | 0.07000914 | 5.496715e+00 | 3.869303e-08 |
| scale(bs.per.fac) | -5.444218e-02 | 0.06352855 | -8.569719e-01 | 3.914604e-01 |
| scale(support.per.fac) | 9.543509e-02 | 0.06547985 | 1.457473e+00 | 1.449859e-01 |
| scale(exfund.per.fac) | 6.856958e-02 | 0.07071276 | 9.696918e-01 | 3.322002e-01 |
| scale(deptsup.per.fac) | -1.674358e-01 | 0.08082410 | -2.071608e+00 | 3.830202e-02 |
| scale(teaching.load) | -7.490268e-02 | 0.07069245 | -1.059557e+00 | 2.893462e-01 |
| scale(avg.asst.sal) | 4.094305e-02 | 0.07299193 | 5.609258e-01 | 5.748481e-01 |
| scale(avg.asst.sal.rel) | -1.789111e-02 | 0.06982525 | -2.562270e-01 | 7.977756e-01 |
| scale(space.per.fac) | 1.098649e-01 | 0.07586357 | 1.448190e+00 | 1.475638e-01 |
| scale(grad.sup) | -6.055612e-04 | 0.06713530 | -9.020012e-03 | 9.928032e-01 |
| scale(local.pop) | 6.320005e-02 | 0.06512214 | 9.704849e-01 | 3.318048e-01 |
| scale(parent.sup) | 1.580210e-02 | 0.09118763 | 1.732921e-01 | 8.624218e-01 |
| scale(parent.sup.plus) | -3.885033e-02 | 0.09084825 | -4.276398e-01 | 6.689134e-01 |

| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -1.015627e-16 | 0.05746459 | -1.767396e-15 | 1.000000e+00 |
| scale(dept.size) | 2.772717e-01 | 0.07150747 | 3.877520e+00 | 1.055266e-04 |
| scale(jr.sr.ratio) | -6.417544e-03 | 0.06646028 | -9.656210e-02 | 9.230742e-01 |
| scale(gender.ratio) | -8.493457e-02 | 0.06781088 | -1.252521e+00 | 2.103800e-01 |
| scale(phd.gender.ratio) | -4.790964e-03 | 0.06482548 | -7.390558e-02 | 9.410855e-01 |
| scale(phd.per.fac) | 3.924791e-01 | 0.07038592 | 5.576103e+00 | 2.459666e-08 |
| scale(bs.per.fac) | -1.196690e-01 | 0.06366251 | -1.879740e+00 | 6.014349e-02 |
| scale(support.per.fac) | 1.757839e-01 | 0.06512311 | 2.699255e+00 | 6.949487e-03 |
| scale(exfund.per.fac) | 1.186341e-01 | 0.06999055 | 1.695001e+00 | 9.007517e-02 |
| scale(deptsup.per.fac) | -1.856224e-01 | 0.08165860 | -2.273152e+00 | 2.301704e-02 |
| scale(teaching.load) | -1.284644e-01 | 0.07203570 | -1.783344e+00 | 7.453031e-02 |
| scale(avg.asst.sal) | 8.159199e-02 | 0.07472268 | 1.091931e+00 | 2.748636e-01 |
| scale(avg.asst.sal.rel) | -1.627540e-02 | 0.07217724 | -2.254922e-01 | 8.215964e-01 |
| scale(space.per.fac) | 1.329687e-01 | 0.07762836 | 1.712888e+00 | 8.673307e-02 |
| scale(grad.sup) | 3.940688e-02 | 0.06831598 | 5.768325e-01 | 5.640526e-01 |
| scale(local.pop) | 8.609404e-02 | 0.06596881 | 1.305072e+00 | 1.918684e-01 |
| scale(parent.sup) | 6.581023e-02 | 0.09416931 | 6.988501e-01 | 4.846457e-01 |
| scale(parent.sup.plus) | -3.837969e-02 | 0.09509670 | -4.035859e-01 | 6.865172e-01 |

**Which relationships are significant?**
**What's the strength of these relationships?**

Here are two of 16 regression tables from a working paper. How do scientists make sense of these tables? How do we do some legwork for them?

# Simulate your audience, part 2.

| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -4.320906e-17 | 0.05499178 | -7.857367e-16 | 1.000000e+00 |
| scale(prestige) | 2.625988e-01 | 0.08632739 | -3.041894e+00 | 2.350947e-03 |
| scale(private) | 1.387510e-01 | 0.07156172 | 1.938900e+00 | 5.251353e-02 |
| scale(dept.size) | 1.983602e-01 | 0.07589478 | 2.613622e+00 | 8.958812e-03 |
| scale(jr.sr.ratio) | -9.558408e-03 | 0.06365449 | -1.501608e-01 | 8.806378e-01 |
| scale(gender.ratio) | -7.084867e-02 | 0.06756081 | -1.048665e+00 | 2.943323e-01 |
| scale(phd.gender.ratio) | 9.798437e-03 | 0.06294453 | 1.556678e-01 | 8.762949e-01 |
| scale(phd.per.fac) | 3.848203e-01 | 0.07000914 | 5.496715e+00 | 3.869303e-08 |
| scale(bs.per.fac) | -5.444218e-02 | 0.06352855 | -8.569719e-01 | 3.914604e-01 |
| scale(support.per.fac) | 9.543509e-02 | 0.06547985 | 1.457473e+00 | 1.449859e-01 |
| scale(exfund.per.fac) | 6.856958e-02 | 0.07071276 | 9.696918e-01 | 3.322002e-01 |
| scale(deptsup.per.fac) | -1.674358e-01 | 0.08082410 | -2.071608e+00 | 3.830202e-02 |
| scale(teaching.load) | -7.490268e-02 | 0.07069245 | -1.059557e+00 | 2.893462e-01 |
| scale(avg.asst.sal) | 4.094305e-02 | 0.07299193 | 5.609258e-01 | 5.748481e-01 |
| scale(avg.asst.sal.rel) | -1.789111e-02 | 0.06982525 | -2.562270e-01 | 7.977756e-01 |
| scale(space.per.fac) | 1.098649e-01 | 0.07586357 | 1.448190e+00 | 1.475638e-01 |
| scale(grad.sup) | -6.055612e-04 | 0.06713530 | -9.020012e-03 | 9.928032e-01 |
| scale(local.pop) | 6.320005e-02 | 0.06512214 | 9.704849e-01 | 3.318048e-01 |
| scale(parent.sup) | 1.580210e-02 | 0.09118763 | 1.732921e-01 | 8.624218e-01 |
| scale(parent.sup.plus) | -3.885033e-02 | 0.09084825 | -4.276398e-01 | 6.689134e-01 |

| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -1.015627e-16 | 0.05746459 | -1.767396e-15 | 1.000000e+00 |
| scale(dept.size) | 2.772717e-01 | 0.07150747 | 3.877520e+00 | 1.055266e-04 |
| scale(jr.sr.ratio) | -6.417544e-03 | 0.06646028 | -9.656210e-02 | 9.230742e-01 |
| scale(gender.ratio) | -8.493457e-02 | 0.06781088 | -1.252521e+00 | 2.103800e-01 |
| scale(phd.gender.ratio) | -4.790964e-03 | 0.06482548 | -7.390558e-02 | 9.410855e-01 |
| scale(phd.per.fac) | 3.924791e-01 | 0.07038592 | 5.576103e+00 | 2.459666e-08 |
| scale(bs.per.fac) | -1.196690e-01 | 0.06366251 | -1.879740e+00 | 6.014349e-02 |
| scale(support.per.fac) | 1.757839e-01 | 0.06512311 | 2.699255e+00 | 6.949487e-03 |
| scale(exfund.per.fac) | 1.186341e-01 | 0.06999055 | 1.695001e+00 | 9.007517e-02 |
| scale(deptsup.per.fac) | -1.856224e-01 | 0.08165860 | -2.273152e+00 | 2.301704e-02 |
| scale(teaching.load) | -1.284644e-01 | 0.07203570 | -1.783344e+00 | 7.453031e-02 |
| scale(avg.asst.sal) | 8.159199e-02 | 0.07472268 | 1.091931e+00 | 2.748636e-01 |
| scale(avg.asst.sal.rel) | -1.627540e-02 | 0.07217724 | -2.254922e-01 | 8.215964e-01 |
| scale(space.per.fac) | 1.329687e-01 | 0.07762836 | 1.712888e+00 | 8.673307e-02 |
| scale(grad.sup) | 3.940688e-02 | 0.06831598 | 5.768325e-01 | 5.640526e-01 |
| scale(local.pop) | 8.609404e-02 | 0.06596881 | 1.305072e+00 | 1.918684e-01 |
| scale(parent.sup) | 6.581023e-02 | 0.09416931 | 6.988501e-01 | 4.846457e-01 |
| scale(parent.sup.plus) | -3.837969e-02 | 0.09509670 | -4.035859e-01 | 6.865172e-01 |

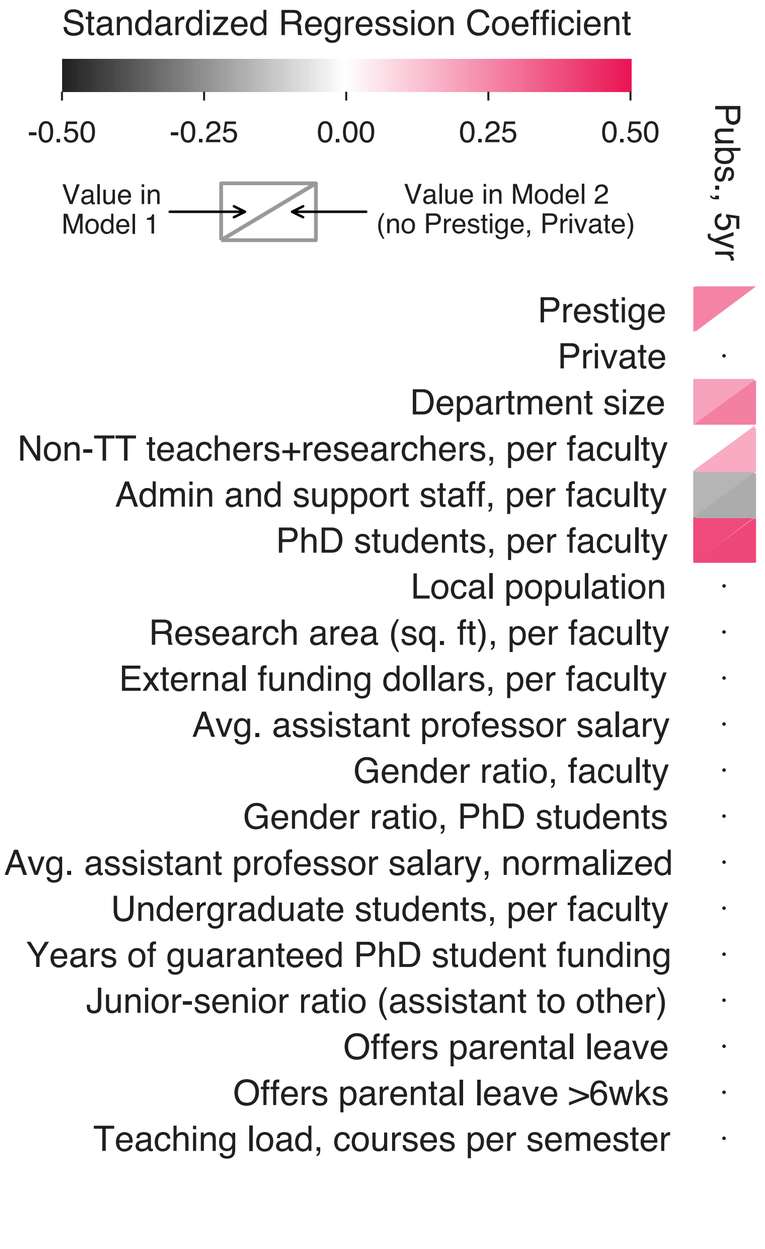
How do they compare between
Model 1 (left) and Model 2 (right)?

Here are two of 16 regression tables from a working paper. How do scientists make sense of these tables? How do we do some legwork for them?

| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -1.015627e-16 | 0.05746459 | -1.767396e-15 | 1.000000e+00 |

| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -4.320906e-17 | 0.05499178 | -7.857367e-16 | 1.000000e+00 |
| scale(prestige) | -2.625988e-01 | 0.08632739 | -3.041894e+00 | 2.350947e-03 |
| scale(private) | 1.387510e-01 | 0.07156172 | 1.938900e+00 | 5.251353e-02 |
| scale(dept.size) | 1.983602e-01 | 0.07589478 | 2.613622e+00 | 8.958812e-03 |
| scale(jr.sr.ratio) | -9.558408e-03 | 0.06365449 | -1.501608e-01 | 8.806378e-01 |
| scale(gender.ratio) | -7.084867e-02 | 0.06756081 | -1.048665e+00 | 2.943323e-01 |
| scale(phd.gender.ratio) | 9.798437e-03 | 0.06294453 | 1.556678e-01 | 8.762949e-01 |
| scale(phd.per.fac) | 3.848203e-01 | 0.07000914 | 5.496715e+00 | 3.869303e-08 |
| scale(bs.per.fac) | -5.444218e-02 | 0.06352855 | -8.569719e-01 | 3.914604e-01 |
| scale(support.per.fac) | 9.543509e-02 | 0.06547985 | 1.457473e+00 | 1.449859e-01 |
| scale(exfund.per.fac) | 6.856958e-02 | 0.07071276 | 9.696918e-01 | 3.322002e-01 |
| scale(deptsup.per.fac) | -1.674358e-01 | 0.08082410 | -2.071608e+00 | 3.830202e-02 |
| scale(teaching.load) | -7.490268e-02 | 0.07069245 | -1.059557e+00 | 2.893462e-01 |
| scale(avg.asst.sal) | 4.094305e-02 | 0.07299193 | 5.609258e-01 | 5.748481e-01 |
| scale(avg.asst.sal.rel) | -1.789111e-02 | 0.06982525 | -2.562270e-01 | 7.977756e-01 |
| scale(space.per.fac) | 1.098649e-01 | 0.07586357 | 1.448190e+00 | 1.475638e-01 |
| scale(grad.sup) | -6.055612e-04 | 0.06713530 | -9.020012e-03 | 9.928032e-01 |
| scale(local.pop) | 6.320005e-02 | 0.06512214 | 9.704849e-01 | 3.318048e-01 |
| scale(parent.sup) | 1.580210e-02 | 0.09118763 | 1.732921e-01 | 8.624218e-01 |
| scale(parent.sup.plus) | -3.885033e-02 | 0.09084825 | -4.276398e-01 | 6.689134e-01 |





| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -1.015627e-16 | 0.05746459 | -1.767396e-15 | 1.000000e+00 |

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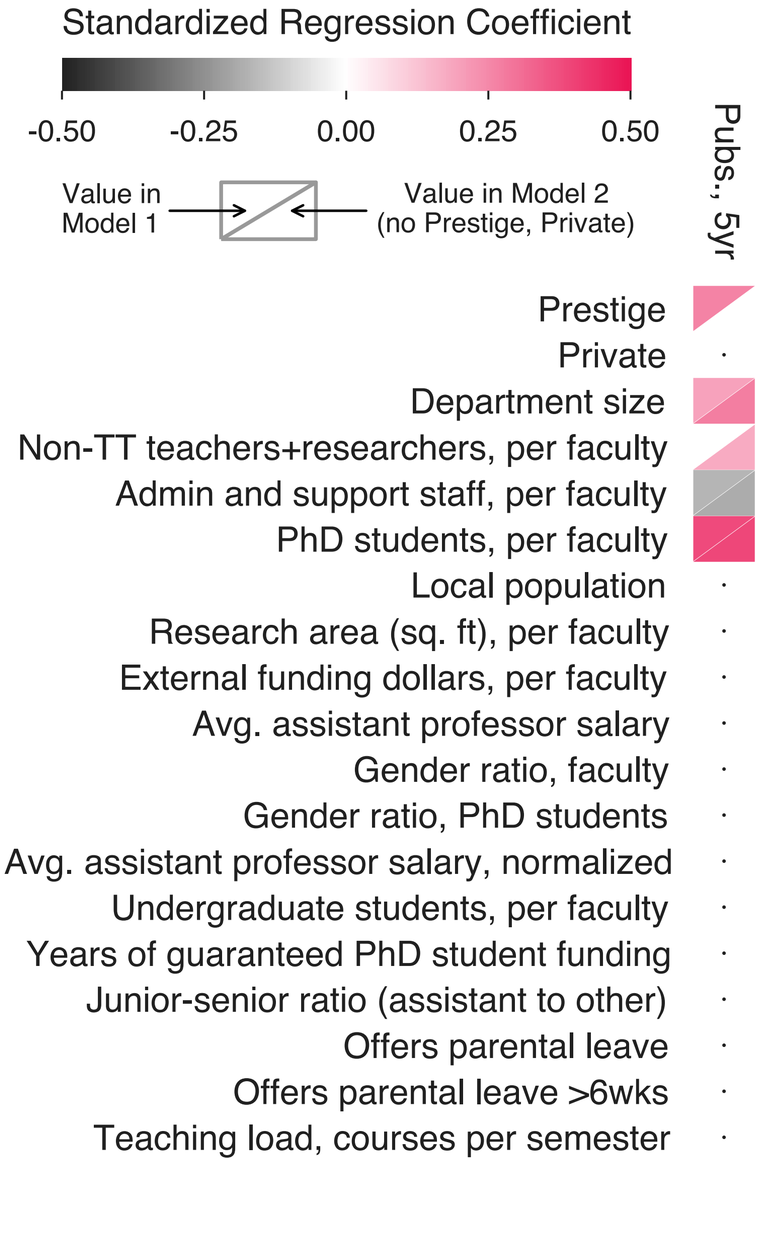
| (Intercept) | -4.320906e-17 | 0.05499178 | -7.857367e-16 | 1.000000e+00 |
| scale(prestige) | -2.625988e-01 | 0.08632739 | -3.041894e+00 | 2.350947e-03 |
| scale(private) | 1.387510e-01 | 0.07156172 | 1.938900e+00 | 5.251353e-02 |
| scale(dept.size) | 1.983602e-01 | 0.07589478 | 2.613622e+00 | 8.958812e-03 |
| scale(jr.sr.ratio) | -9.558408e-03 | 0.06365449 | -1.501608e-01 | 8.806378e-01 |
| scale(gender.ratio) | -7.084867e-02 | 0.06756081 | -1.048665e+00 | 2.943323e-01 |
| scale(phd.gender.ratio) | 9.798437e-03 | 0.06294453 | 1.556678e-01 | 8.762949e-01 |
| scale(phd.per.fac) | 3.848203e-01 | 0.07000914 | 5.496715e+00 | 3.869303e-08 |
| scale(bs.per.fac) | -5.444218e-02 | 0.06352855 | -8.569719e-01 | 3.914604e-01 |
| scale(support.per.fac) | 9.543509e-02 | 0.06547985 | 1.457473e+00 | 1.449859e-01 |
| scale(exfund.per.fac) | 6.856958e-02 | 0.07071276 | 9.696918e-01 | 3.322002e-01 |
| scale(deptsup.per.fac) | -1.674358e-01 | 0.08082410 | -2.071608e+00 | 3.830202e-02 |
| scale(teaching.load) | -7.490268e-02 | 0.07069245 | -1.059557e+00 | 2.893462e-01 |
| scale(avg.asst.sal) | 4.094305e-02 | 0.07299193 | 5.609258e-01 | 5.748481e-01 |
| scale(avg.asst.sal.rel) | -1.789111e-02 | 0.06982525 | -2.562270e-01 | 7.977756e-01 |
| scale(space.per.fac) | 1.098649e-01 | 0.07586357 | 1.448190e+00 | 1.475638e-01 |
| scale(grad.sup) | -6.055612e-04 | 0.06713530 | -9.020012e-03 | 9.928032e-01 |
| scale(local.pop) | 6.320005e-02 | 0.06512214 | 9.704849e-01 | 3.318048e-01 |
| scale(parent.sup) | 1.580210e-02 | 0.09118763 | 1.732921e-01 | 8.624218e-01 |
| scale(parent.sup.plus) | -3.885033e-02 | 0.09084825 | -4.276398e-01 | 6.689134e-01 |





| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -1.015627e-16 | 0.05746459 | -1.767396e-15 | 1.000000e+00 |

| | coef | se | zvalue | p |
|---|---|---|---|---|
| (Intercept) | -4.320906e-17 | 0.05499178 | -7.857367e-16 | 1.000000e+00 |
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| scale(dept.size) | 1.983602e-01 | 0.07589478 | 2.613622e+00 | 8.958812e-03 |
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| scale(phd.per.fac) | 3.848203e-01 | 0.07000914 | 5.496715e+00 | 3.869303e-08 |
| scale(bs.per.fac) | -5.444218e-02 | 0.06352855 | -8.569719e-01 | 3.914604e-01 |
| scale(support.per.fac) | 9.543509e-02 | 0.06547985 | 1.457473e+00 | 1.449859e-01 |
| scale(exfund.per.fac) | 6.856958e-02 | 0.07071276 | 9.696918e-01 | 3.322002e-01 |
| scale(deptsup.per.fac) | -1.674358e-01 | 0.08082410 | -2.071608e+00 | 3.830202e-02 |
| scale(teaching.load) | -7.490268e-02 | 0.07069245 | -1.059557e+00 | 2.893462e-01 |
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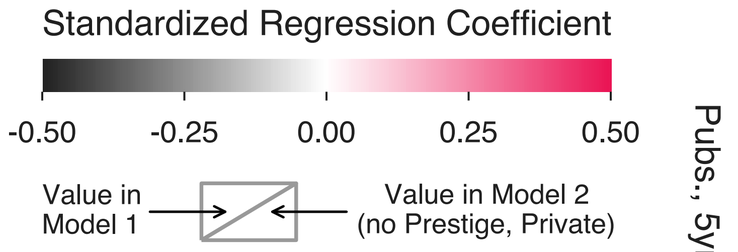
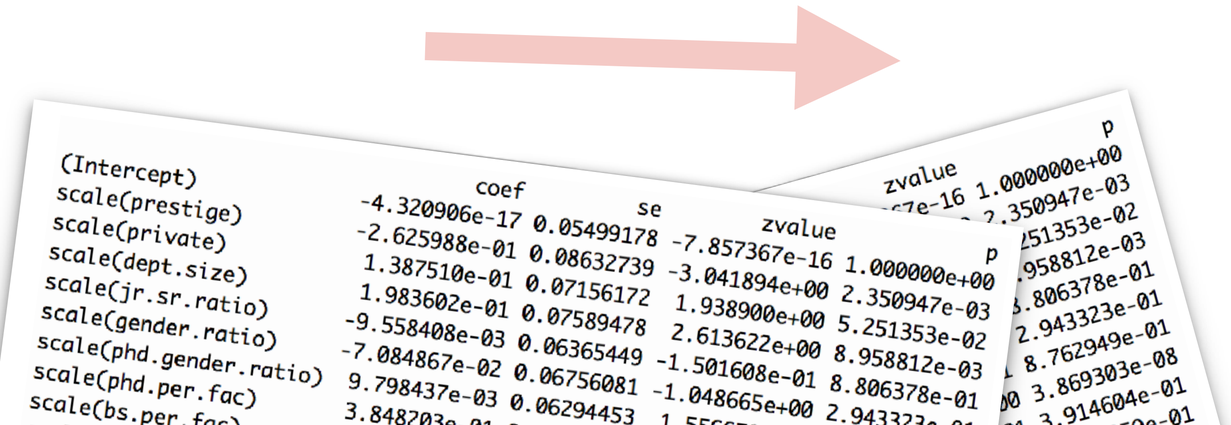
| scale(avg.asst.sal.rel) | -1.789111e-02 | 0.06982525 | -2.562270e-01 | 7.977756e-01 |
| scale(space.per.fac) | 1.098649e-01 | 0.07586357 | 1.448190e+00 | 1.475638e-01 |
| scale(grad.sup) | -6.055612e-04 | 0.06713530 | -9.020012e-03 | 9.928032e-01 |
| scale(local.pop) | 6.320005e-02 | 0.06512214 | 9.704849e-01 | 3.318048e-01 |
| scale(parent.sup) | 1.580210e-02 | 0.09118763 | 1.732921e-01 | 8.624218e-01 |
| scale(parent.sup.plus) | -3.885033e-02 | 0.09084825 | -4.276398e-01 | 6.689134e-01 |

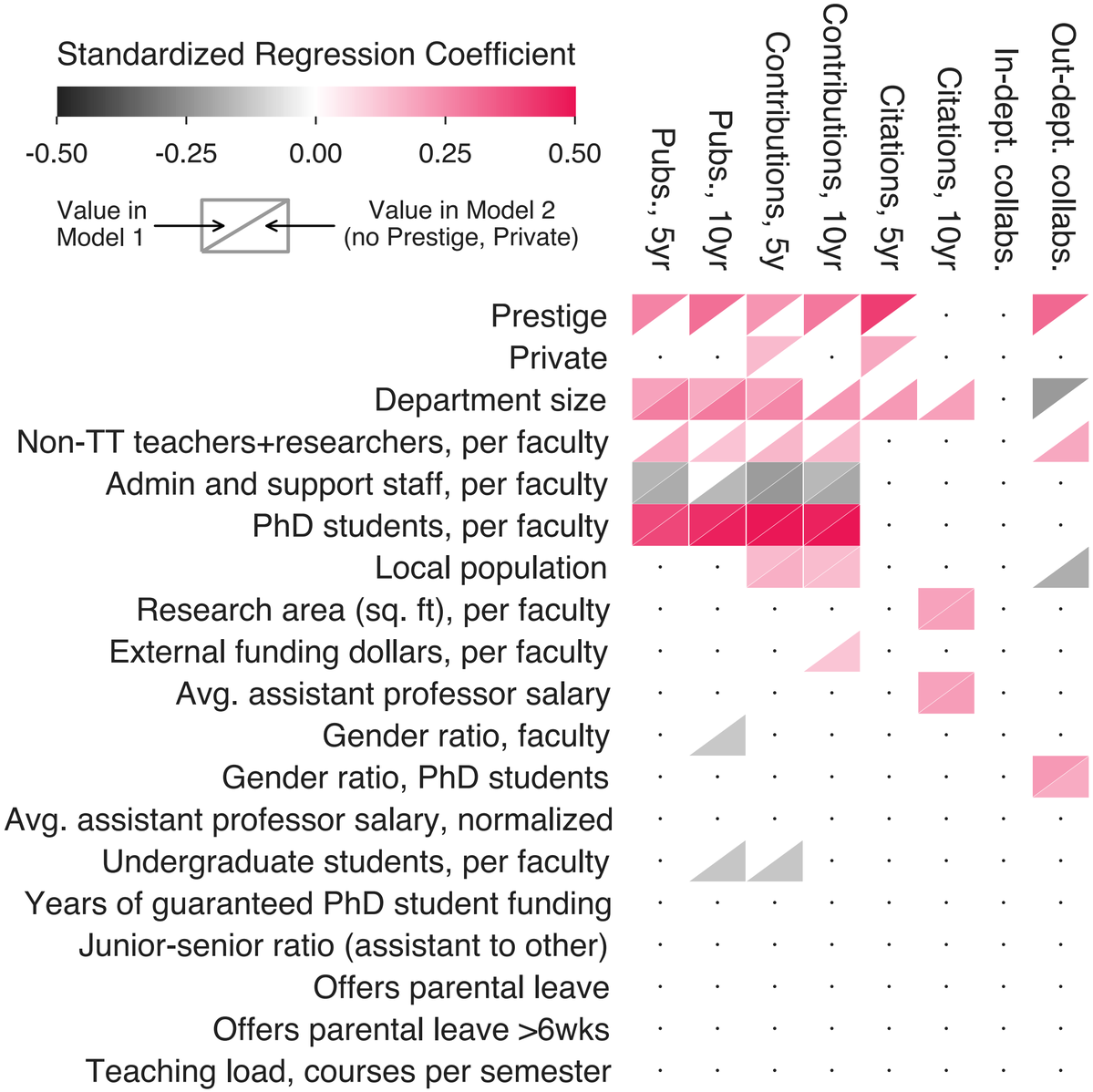





Pubs., 5yr

Prestige
Private
Department size
Non-TT teachers+researchers, per faculty
Admin and support staff, per faculty
PhD students, per faculty
Local population
Research area (sq. ft), per faculty
External funding dollars, per faculty
Avg. assistant professor salary
Gender ratio, faculty
Gender ratio, PhD students
Avg. assistant professor salary, normalized
Undergraduate students, per faculty
Years of guaranteed PhD student funding
Junior-senior ratio (assistant to other)
Offers parental leave
Offers parental leave >6wks
Teaching load, courses per semester





Standardized Regression Coefficient
-0.50
-0.25
0.00
0.25
0.50
Value in Model 1
Value in Model 2 (no Prestige, Private)
Pubs., 5yr
Pubs., 10yr
Contributions, 5y
Contributions, 10yr
Citations, 5yr
Citations, 10yr
In-dept. collabs.
Out-dept. collabs.
Prestige
Private
Department size
Non-TT teachers+researchers, per faculty
Admin and support staff, per faculty
PhD students, per faculty
Local population
Research area (sq. ft), per faculty
External funding dollars, per faculty
Avg. assistant professor salary
Gender ratio, faculty
Gender ratio, PhD students
Avg. assistant professor salary, normalized
Undergraduate students, per faculty
Years of guaranteed PhD student funding
Junior-senior ratio (assistant to other)
Offers parental leave
Offers parental leave >6wks
Teaching load, courses per semester

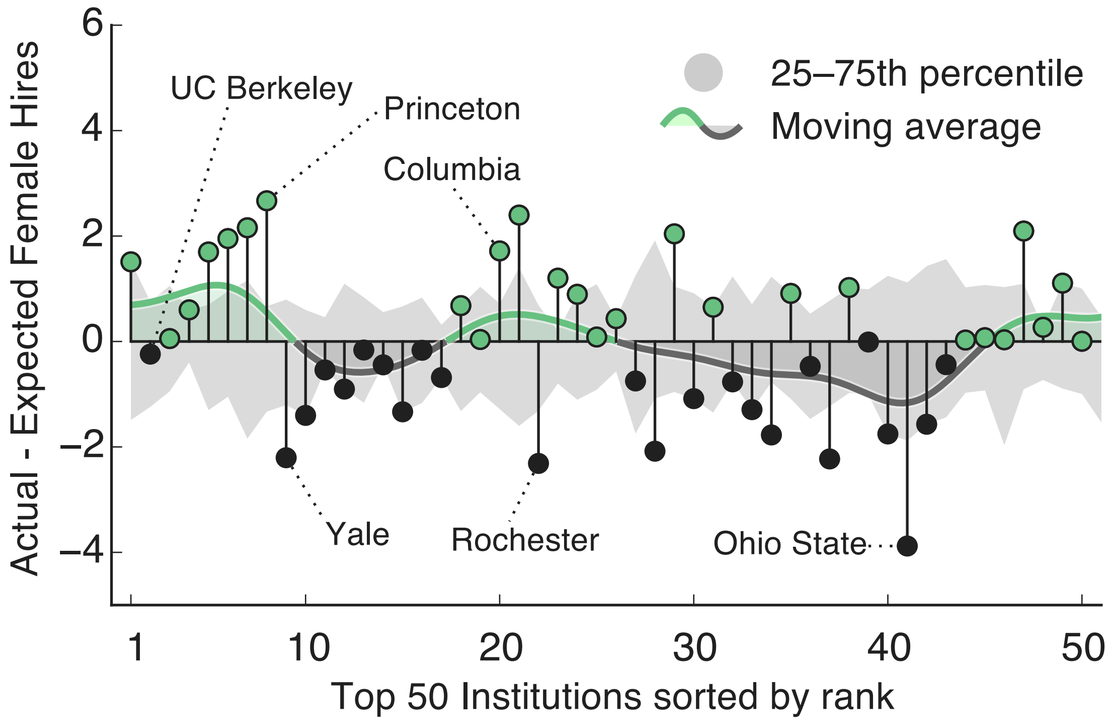
# Seek out peer review.

Ask for feedback and listen.

**Be willing to change it.**

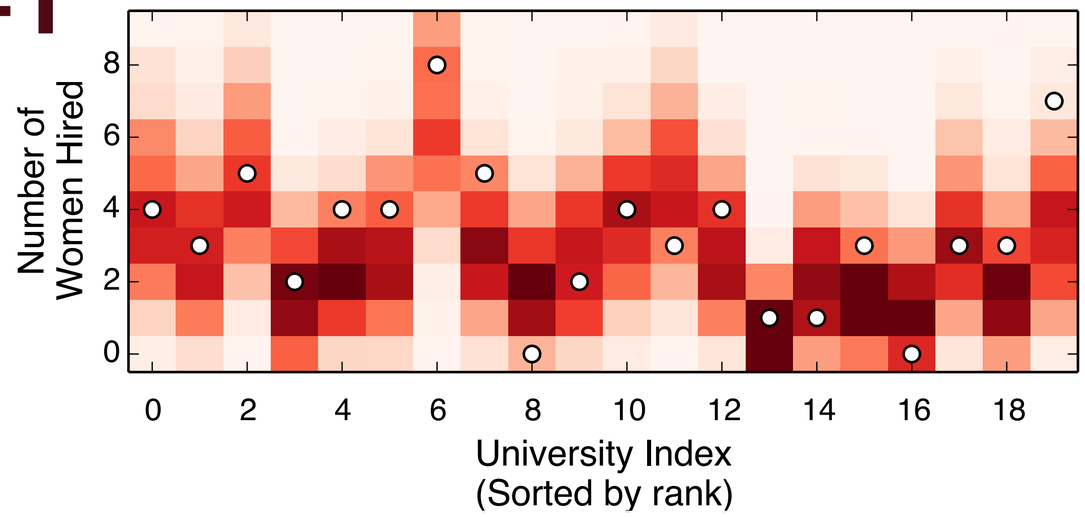
Ask for their summary.

Iterate on your design.




* Ask for feedback from someone you trust will be honest and critical. Don't wait until you're already married to an idea/design.

# #1




# #2




# #3

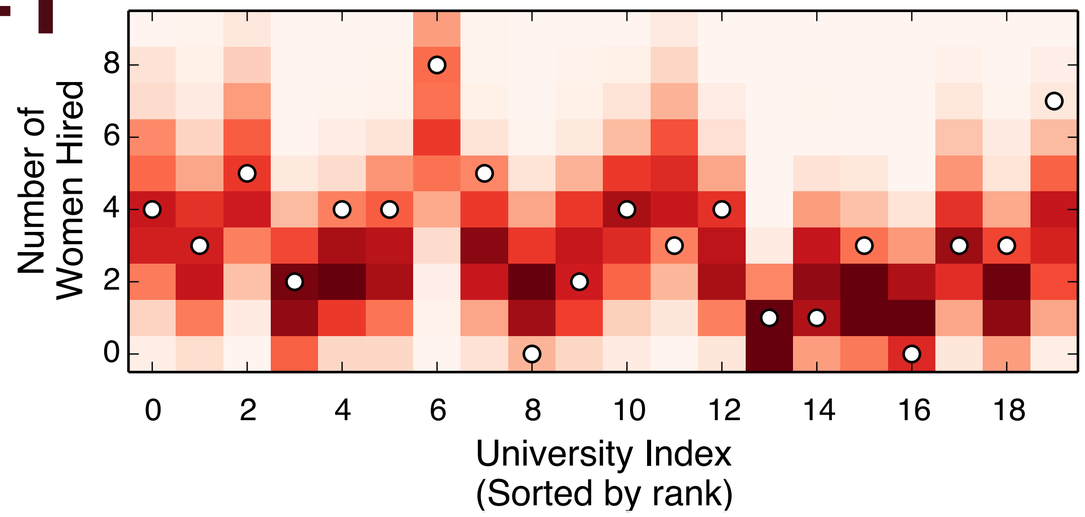



# #4

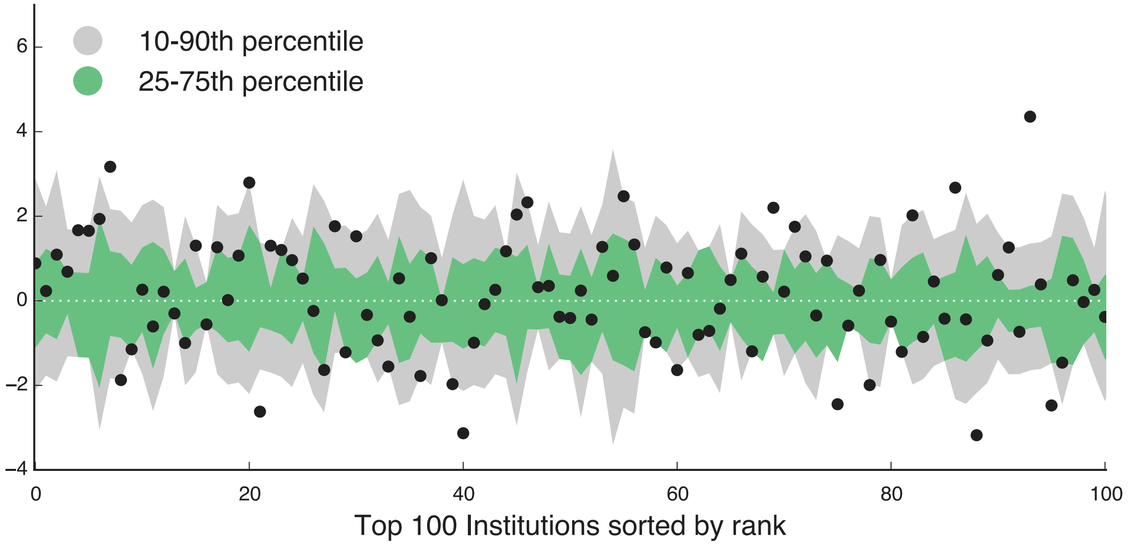



How do actual hires compare to expectations under our model? Which schools are above/below expectations? Are these differences reasonable?

# #1




# #2




# #3




# #4

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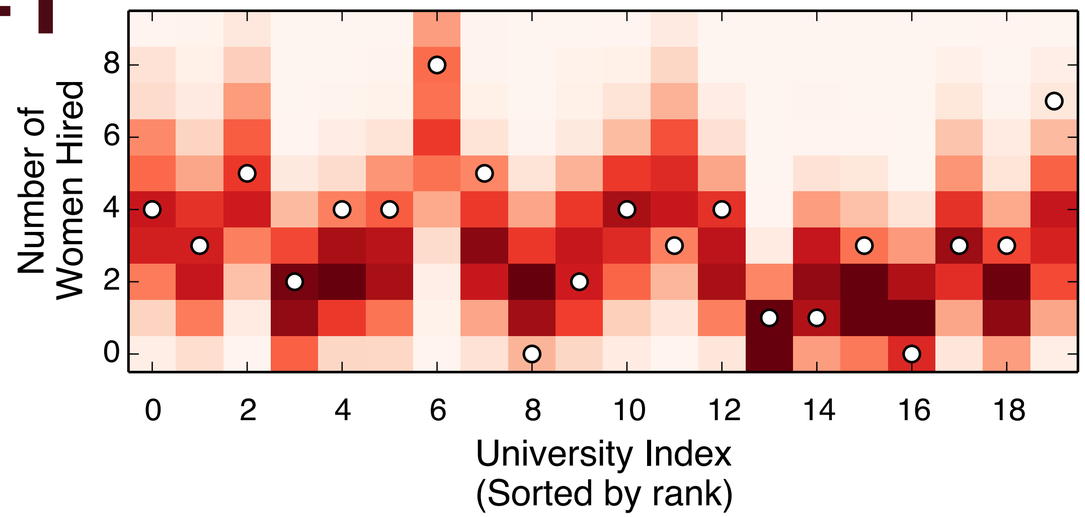
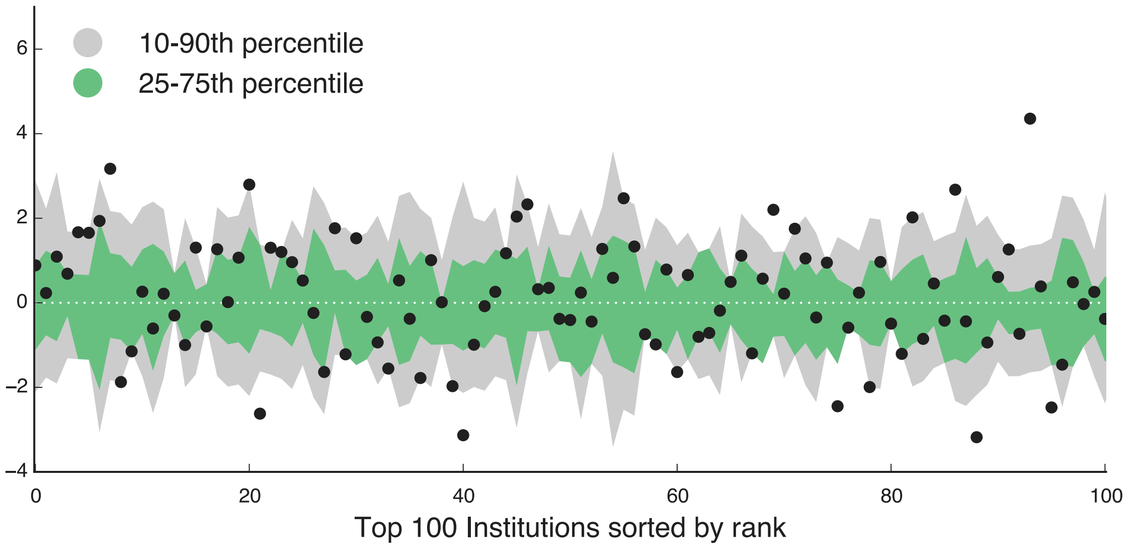
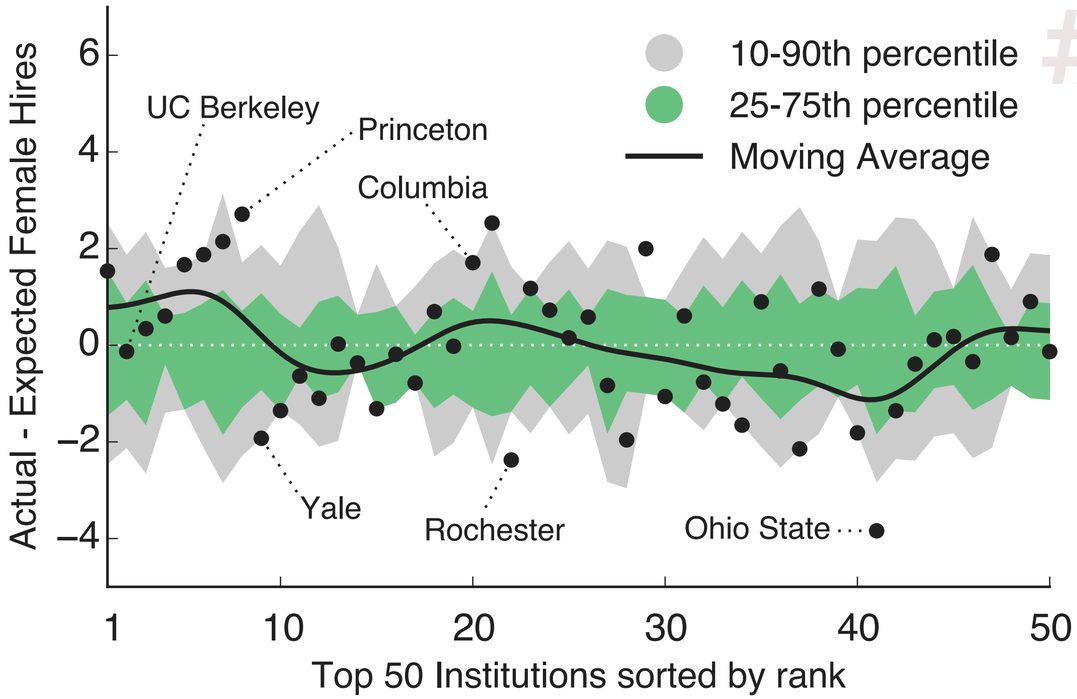
# #1




# #2




# #3

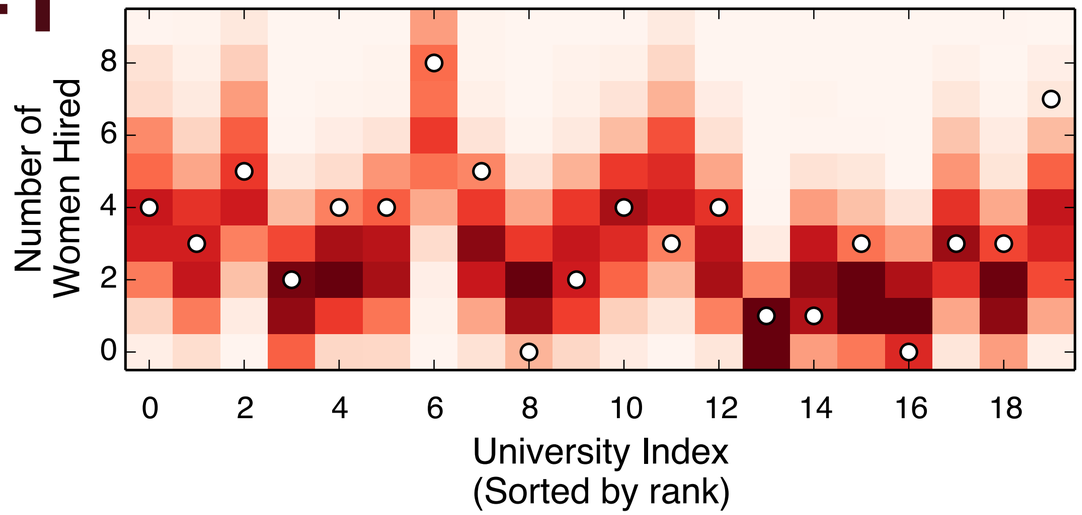



# #4

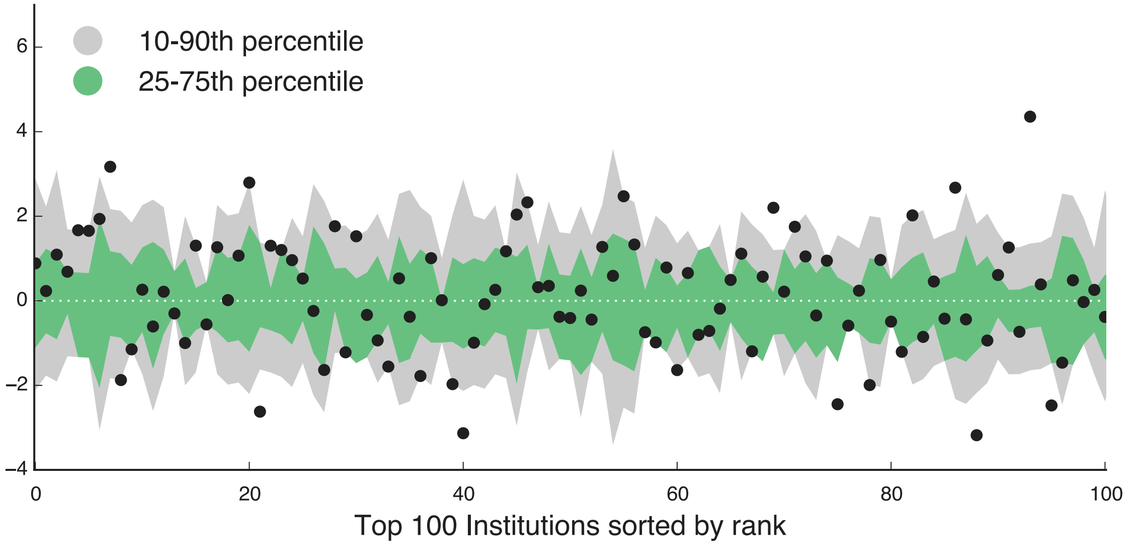



How do actual hires compare to expectations under our model? Which schools are above/below expectations? Are these differences reasonable?

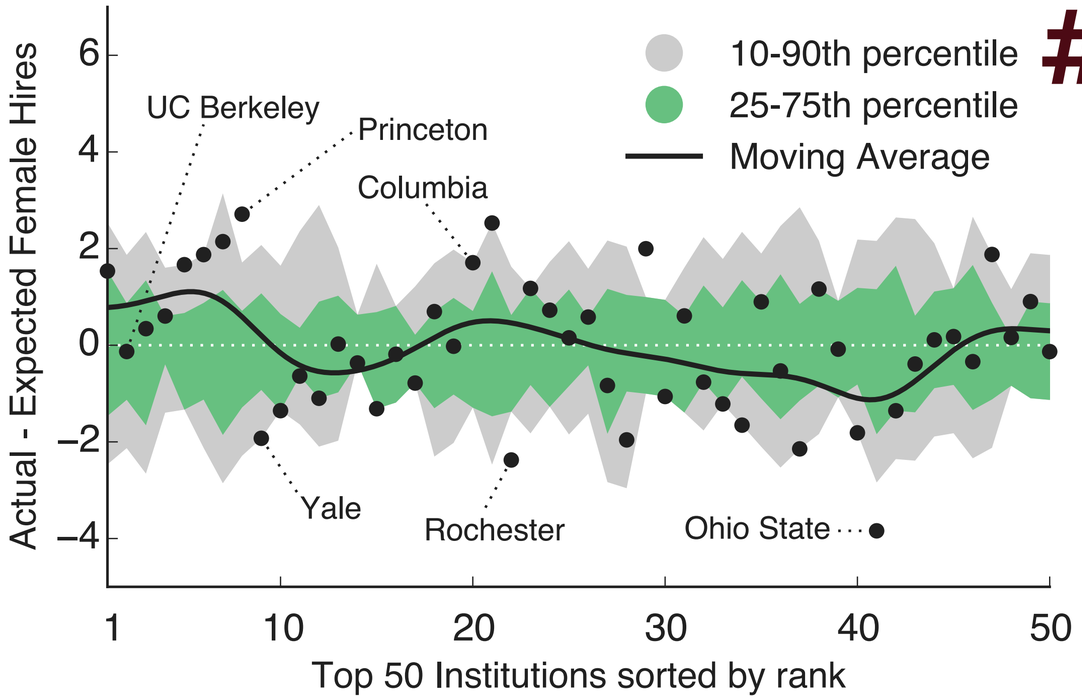
# #1



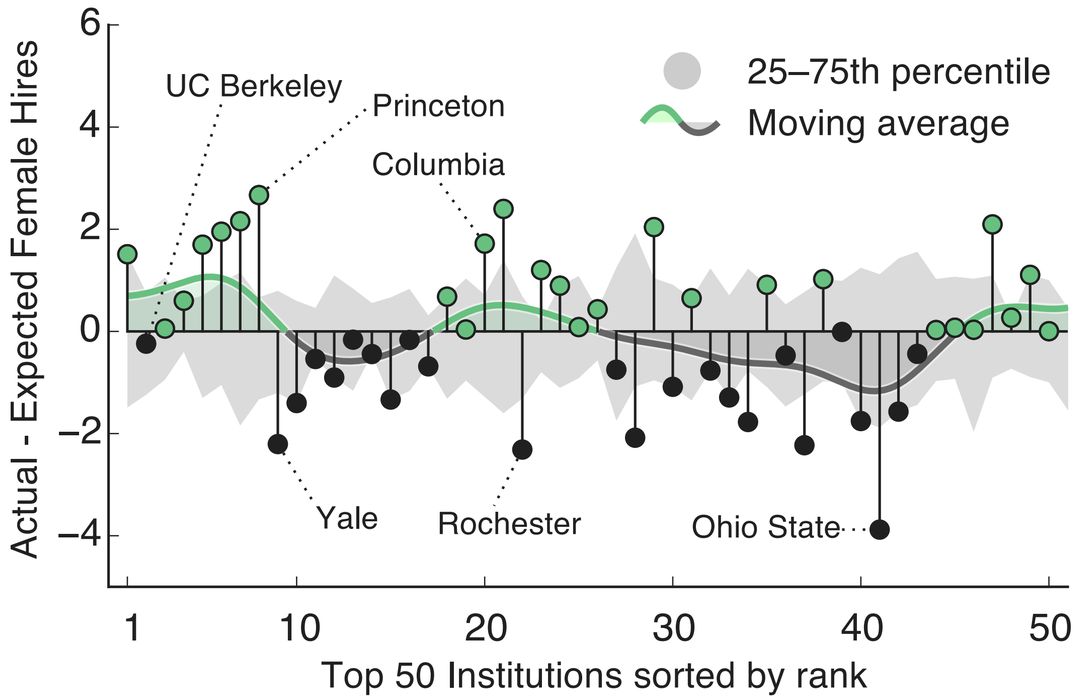

# #2




# #3




# #4




How do actual hires compare to expectations under our model? Which schools are above/below expectations? Are these differences reasonable?

# Thanks for listening

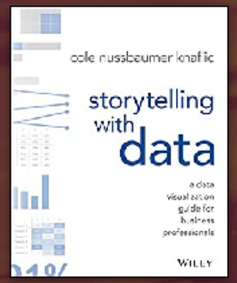

## Sam Way

Research Scientist, Spotify

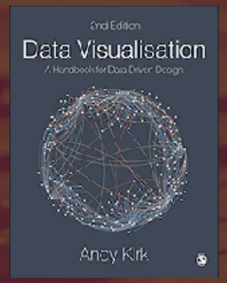
samfway@spotify.com

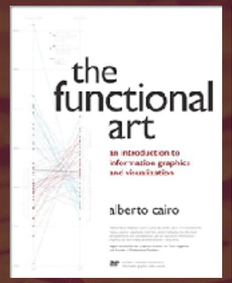
# For your bookshelves

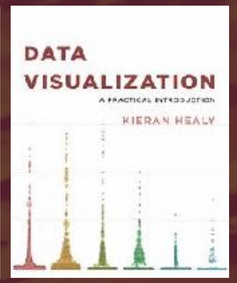
(attention, R users)

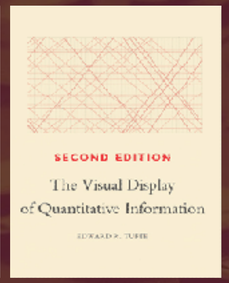



Great intro
Fast read + accessible

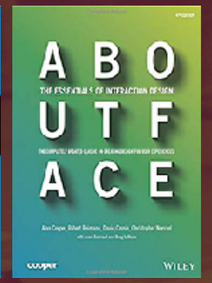


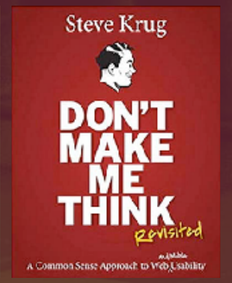




For those who want more




Design perspective

For inspiration

## General resources

- visualisingdata.com/resources/
- Caveats to data visualization (by data-to-viz.com)
- The R Graph Gallery (Yan Holtz)
- D3 Gallery

## Color

- coolors.co, palettable.io (custom color palettes)
- jiffyclub.github.io/palettable (colors in Python)
- colororacle.org (color blind test app)
- Avoiding #000000 (by Ian Taylor)

## Python-specific

- Randal Olson's matplotlib tips
- Becoming an "Artist in Matplotlib"
- jiffyclub.github.io/palettable (colors in Python)
- Avoiding #000000 (by Ian Taylor)

## Science as Art

- Scientific Communication as Sequential Art (Bret Victor)
- A Visual Introduction to Machine Learning (R2D3)
- Simulated Dendrochronology of U.S. Immigration

## Papers containing example visualizations

- Systematic inequality and hierarchy in faculty hiring networks (Science Advances)
- The misleading narrative of the canonical faculty productivity trajectory (PNAS)
- Productivity, prominence, and the effects of academic environment (PNAS)
- Gender, Productivity, and Prestige in Computer Science Faculty Hiring Networks (WWW)
- Environmental Changes and the Dynamics of Musical Identity (ICWSM)
- Local Trends in Global Music Streaming (to appear at ICWSM)

## Special thanks


- Tech Research and the design teams at Spotify
- Aaron Clauset, Dan Larremore, and Allie Morgan at CU Boulder, who helped shape my approach to visualizations and this presentation


## Complexity

- complexity-explorables.org
- complexityexplorer.org

## Contact info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@samfway (Twitter), samfway.com

# Other rules of thumb*

## Don’t use hard-to-read fonts.

https://pubs.acs.org/doi/pdfplus/10.1021/acs.chemmater.6b00306

## Try Helvetica instead.

https://olgabotvinnik.com/blog/how-to-set-helvetica-as-the-default-sans-serif-font-in/

Make text large enough to be read…

## Don’t use #000000.

https://ianstormtaylor.com/design-tip-never-use-black/

## Try something less harsh.

http://uxmovement.com/content/why-you-should-never-use-pure-black-for-text-or-backgrounds/

## Don’t use rainbow colormaps.

http://people.cs.vt.edu/~npolys/IT/FDI/spring2011/color_07.pdf

## Try something more functional.

http://people.cs.vt.edu/~npolys/IT/FDI/spring2011/color_07.pdf

https://jiffyclub.github.io/palettable/

## Don’t make pie charts.

https://www.perceptualedge.com/articles/visual_business_intelligence/save_the_pies_for_dessert.pdf

## Try… literally anything else.

https://github.com/d3/d3/wiki/Gallery

* There are absolutely situations where violating these rules makes sense. Use your discretion.