

Uncertainty and Review

DSC 106: Data Visualization

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UC San Diego

Announcements

Final Project Prototype due tomorrow.

No class Wed and Fri (happy Thanksgiving!)

Final Project Demo Video due next week Tues

FAQs:

1. **Why is the demo video due next week (before we've even finished our final projects)?** To make your demo video, your final project doesn't need to be 100% working. Just show the 20% that is working well! We want you to start thinking seriously about your project story.

A peek behind the curtain: demo videos

File Home Insert Formulas Data Review View Automate Help **TweakIt** Open in Desktop App Tell me what you want to do Editing Share Comments

Toggle Scratchpad Save Output to Sheet

A3 UUA


	A	B	C	D	E	F	G
1	CUCG						
2	AAAU						
3	UUA						
4	GGGG						
5	CCCC						
6	UCAC						
7	AAUU						
8	RRRR						
9							
10							
11							
12							
13							
14							
15							
16							

TweakIt

Available Python variables:

A = A3

```
1 # Example 1
2 i = "AUGC"
3 j = "UACG"
4 tbl = str.maketrans(i, j)
5 my_str = "GUAC"
6 my_str.translate(tbl)
7
8 # Example 2
9 from Bio.Seq import Seq
10 my_dna = Seq("CCGATAG")
11 my_dna.complement()
```



The screenshot shows a spreadsheet application with a menu bar (File, Home, Insert, Formulas, Data, Review, View, Automate, Help, TweakIt, Open in Desktop App, Tell me what you want to do, Editing, Share, Comments) and a toolbar (Toggle Scratchpad, Save Output to Sheet). The spreadsheet has columns A through G and rows 1 through 10. Column A contains the following text: 1 CUCG, 2 AAAU, 3 UUAA, 4 GGGG, 5 CCCC, 6 UCAC, 7 AAUU, 8 RRRR. Cell B4 contains the text 'CCCC' and is highlighted with a blue dashed border. A mouse cursor is pointing at cell A5, which also contains 'CCCC'. A Python code editor window titled 'TweakIt' is open on the right, showing the following code:

```
1 from Bio.Seq import Seq
2 my_dna = Seq(A)
3 my_dna.complement()
```

 The code editor also displays 'Available Python variables: A = A4'.

	A	B	C	D	E	F	G
1	CUCG						
2	AAAU						
3	UUAA						
4	GGGG	CCCC					
5	CCCC						
6	UCAC						
7	AAUU						
8	RRRR						
9							
10							

Looks sophisticated, but really I'm just erasing ALL cells in column B and then writing into the cell to the right of the selection.

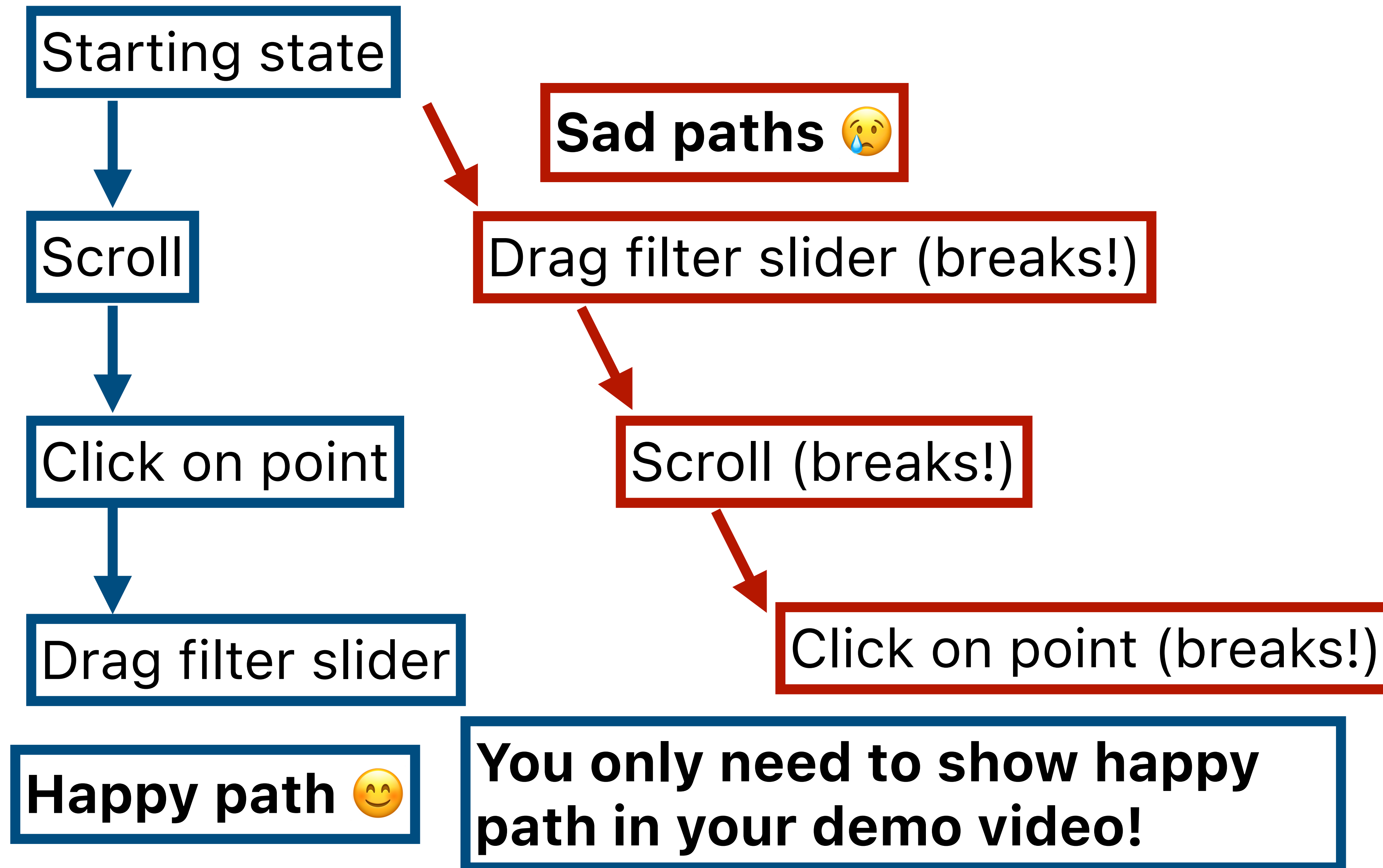
If there was other data in the spreadsheet, it would be wiped out!

The screenshot shows a spreadsheet interface with the following data:

	A	B	C
1	CUCG	GAGC	
2	AAAU	UUUA	
3	UUAA	AAUU	
4	GGGG	CCCC	
5	CCCC	GGGG	
6	UCAC	AGUG	
7	AAUU	UUAA	
8	RRRR	YYYY	
9			

Clicking "Save Output" just removes the blue background from column B. (It doesn't actually work!)

Making a cool demo video



How to ace your final project

Component	Excellent	Satisfactory	Poor
Web page URL, video URL, and Repo		The web page is publicly viewable on GitHub pages, the project video is linked (or embedded) within the web page, and the repository is publicly available. (+1 point)	The submitted web page URL, project video, or repository URL is broken. (+0 points)
Hook		The project opens with a hook – an interesting research question or attention-grabbing statement. (+1 point)	The project doesn't open with a hook (e.g. it immediately shows a visualization without explanation). (+0 points)
Storytelling	The project tells a compelling story. It follows the and-but-therefore structure and also incorporates elements of surprise, personalization, or emotion. (+3 points)	The project tells a story – it follows the and-but-therefore structure. (+2 points)	The project does not tell a story (e.g. it doesn't follow the and-but-therefore structure or something similar). (+1 point)
Visual Encodings	The project visualizations do not violate the expressiveness criteria and the design choices (marks and encoding channels) are clear, evocative, and effective. (+3 points)	The project visualizations do not violate the expressiveness criteria, but another set of design choices (marks and encoding channels) could have been more effective (e.g. using the area visual channel instead of position when possible). (+2 points)	The project visualizations violate the expressiveness criteria (e.g. heavy overplotting, encodings that imply incorrect readings, etc.), and these violations are not addressed using the available interactions (e.g. overplotting that cannot be filtered or zoomed into). (+1 point)

Component	Excellent	Satisfactory	Poor
Web page URL, video URL, and Repo		The web page is publicly viewable on GitHub pages, the project video is linked (or embedded) within the web page, and the repository is publicly available. (+1 point)	Most common mistake: no video linked in webpage
Hook		The project opens with a hook – an interesting research question or attention-grabbing statement. (+1 point)	The project doesn't open with a hook (e.g. it immediately shows a visualization without explanation). (+0 points)
Storytelling	The project tells a compelling story. It follows the and-but-therefore structure and also incorporates elements of surprise, personalization, or emotion. (+3 points)	The project tells a story – it follows the and-but-therefore structure. (+2 points)	The project does not tell a story (e.g. it doesn't follow the and-but-therefore structure or something similar). (+1 point)
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Most common mistake: straight into visualization without hook

Component

Require "surprise, personalization, or emotion" for Excellent.

Web page URL, video URL, and Repo

See Narrative lecture for ideas.

Hook

Missing and-but-therefore? Score capped at Poor!

Storytelling

The project tells a compelling story. It follows the and-but-therefore structure and also incorporates elements of surprise, personalization, or emotion. (+3 points)

The project tells a story – it follows the and-but-therefore structure. (+2 points)

The project does not tell a story (e.g. it doesn't follow the and-but-therefore structure or something similar). (+1 point)

Visual Encodings

The project visualizations do not violate the expressiveness criteria and the design choices (marks and encoding channels) are clear, evocative, and effective. (+3 points)

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Hook		The project opens with a hook – an interesting research question or attention-grabbing statement. (+1 point)	The project doesn't open with a hook (e.g. it immediately shows a visualization without explanation). (+0 points)

As always, will grade on visual encodings. Avoid overplotting, use appropriate channels, bin your colors, etc.

Storytelling	emotion. (+3 points)		
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Visual Encodings	The project visualizations do not violate the expressiveness criteria and the design choices (marks and encoding channels) are clear, evocative, and effective. (+3 points)	The project visualizations do not violate the expressiveness criteria, but another set of design choices (marks and encoding channels) could have been more effective (e.g. using the area visual channel instead of position when possible). (+2 points)	The project visualizations violate the expressiveness criteria (e.g. heavy overplotting, encodings that imply incorrect readings, etc.), and these violations are not addressed using the available interactions (e.g. overplotting that cannot be filtered or zoomed into). (+1 point)
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Interaction

The interactive elements of the project are polished, bug-free, and enable the reader to discover interesting patterns in the data or the concept being explored. (+3 points)

The interactive elements of the project are functional and enable the reader to discover interesting patterns, but a static plot (perhaps with a different encoding) could have conveyed the same information just as effectively. (+2 points)

The plot would have been substantially more effective as a static plot without the interaction; or, the interaction has major bugs that preclude use. (+1 point)

Annotations

Similar to Project 3; do we learn something new from your interactions that isn't possible without the interactions?

Takeaways

First question to answer is: What is interesting about your **data**? (Not: what is interesting about your interactions?)

Viewing experience

The project is easy to view: all images are clearly visible and all text is legible on a typical laptop screen size. (+1 point)

The project is difficult to view (e.g. some images and text are too small to see clearly). (+0 points)

Interaction	The interactive elements of the project are polished, bug-free, and enable the reader to discover interesting patterns in the data or the concept being explored. (+3 points)	The interactive elements of the project are functional and enable the reader to discover interesting patterns, but a static plot (perhaps with a different encoding) could have conveyed the same information just as effectively. (+2 points)	The plot would have been substantially more effective as a static plot without the interaction; or, the interaction has major bugs that preclude use. (+1 point)
Annotations		The visualizations contain helpful annotations (e.g. text, coloring, shading) that draw attention to interesting findings. (+1 point)	The visualizations contain no annotations. (+0 points)
Takeaways		one thing that everyone should learn from your project? And why does your project succeed at explaining it? (+2 points)	focuses too much on the implementation of the visualization). (+1 point)
Viewing experience		The project is easy to view: all images are clearly visible and all text is legible on a typical laptop screen size. (+1 point)	The project is difficult to view (e.g. some images and text are too small to see clearly). (+0 points)

Common mistake: lots of plots, no annotations on plots themselves

Interaction

The interactive elements of the project are polished, bug-free, and enable the reader to discover interesting patterns in the data or the concept being

The interactive elements of the project are functional and enable the reader to discover interesting patterns, but a static plot (perhaps with a different encoding) could have conveyed the same information just as effectively. (+2

The plot would have been substantially more effective as a static plot without the interaction; or, the interaction has major bugs that preclude use. (+1 point)

Annotations

Common mistake: takeaway that is common knowledge (e.g. "there are lots of forest fires, so we should support firefighters")

Takeaways

The project ends with an interesting takeaway and explains why your visualization demonstrates this takeaway effectively. What is the one thing that everyone should learn from your project? And why does your project succeed at explaining it? (+2 points)

The project is missing a takeaway, or ends with a takeaway message but the presentation could be improved (e.g. the takeaway isn't surprising, or focuses too much on the implementation of the visualization). (+1 point)

Viewing experience

The project is easy to view: all images are clearly visible and all text is legible on a typical laptop screen size. (+1 point)

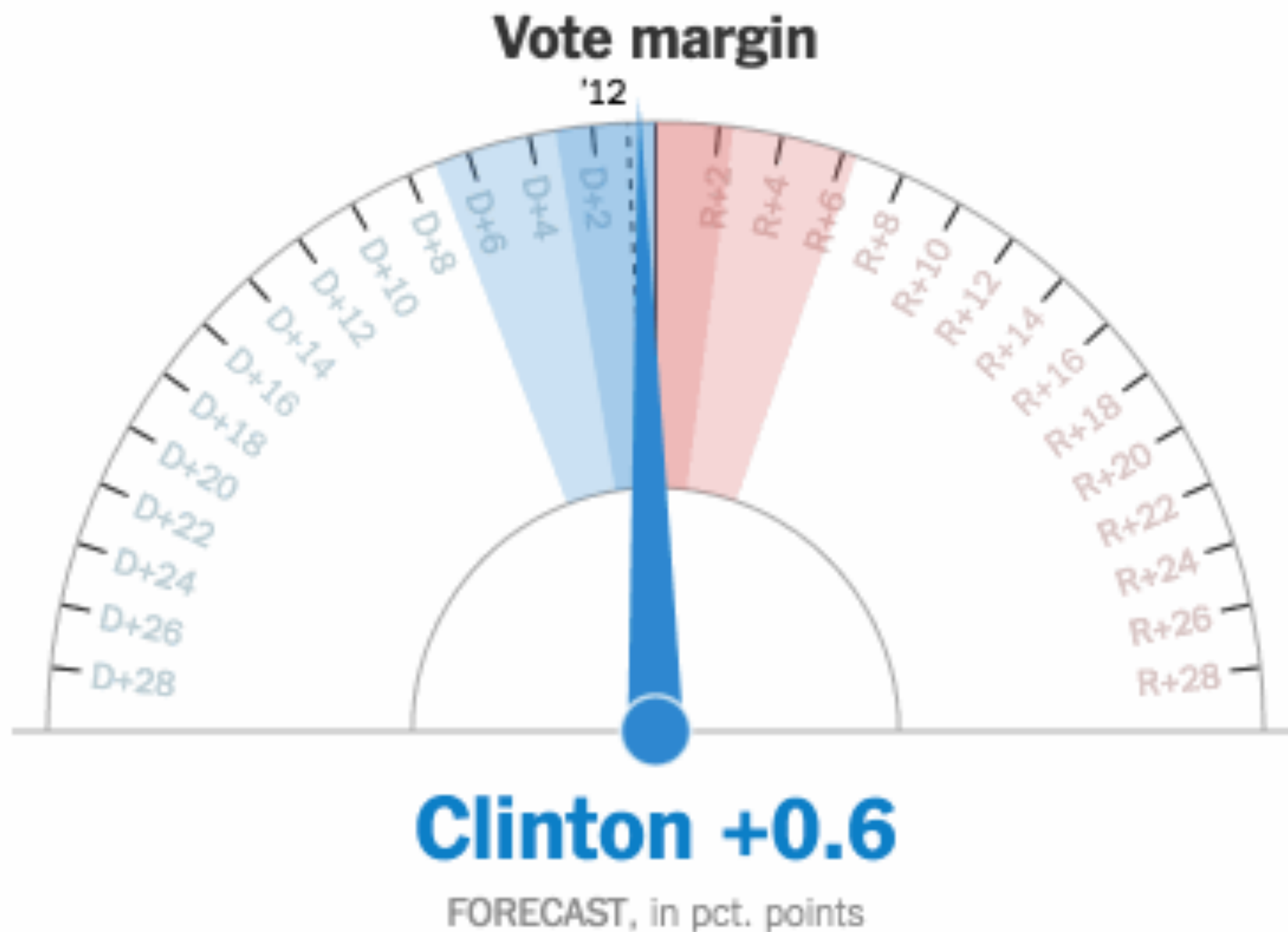
The project is difficult to view (e.g. some images and text are too small to see clearly). (+0 points)

Interaction	The interactive elements of the project are polished, bug-free, and enable the reader to discover interesting patterns in the data or the concept being explored. (+3 points)	The interactive elements of the project are functional and enable the reader to discover interesting patterns, but a static plot (perhaps with a different encoding) could have conveyed the same information just as effectively. (+2 points)	The plot would have been substantially more effective as a static plot without the interaction; or, the interaction has major bugs that preclude use. (+1 point)
Annotations		The visualizations contain helpful annotations (e.g. text, coloring, shading) that draw attention to interesting findings. (+1 point)	The visualizations contain no annotations. (+0 points)
Takeaways		The project ends with an interesting takeaway and explains why your visualization demonstrates this takeaway effectively. What is the one thing that everyone should learn from your project? And why does	The project is missing a takeaway, or ends with a takeaway message but the presentation could be improved (e.g. the takeaway isn't surprising, or focuses too much on the

Common mistake: fonts too small, images blurry

Viewing experience		The project is easy to view: all images are clearly visible and all text is legible on a typical laptop screen size. (+1 point)	The project is difficult to view (e.g. some images and text are too small to see clearly). (+0 points)
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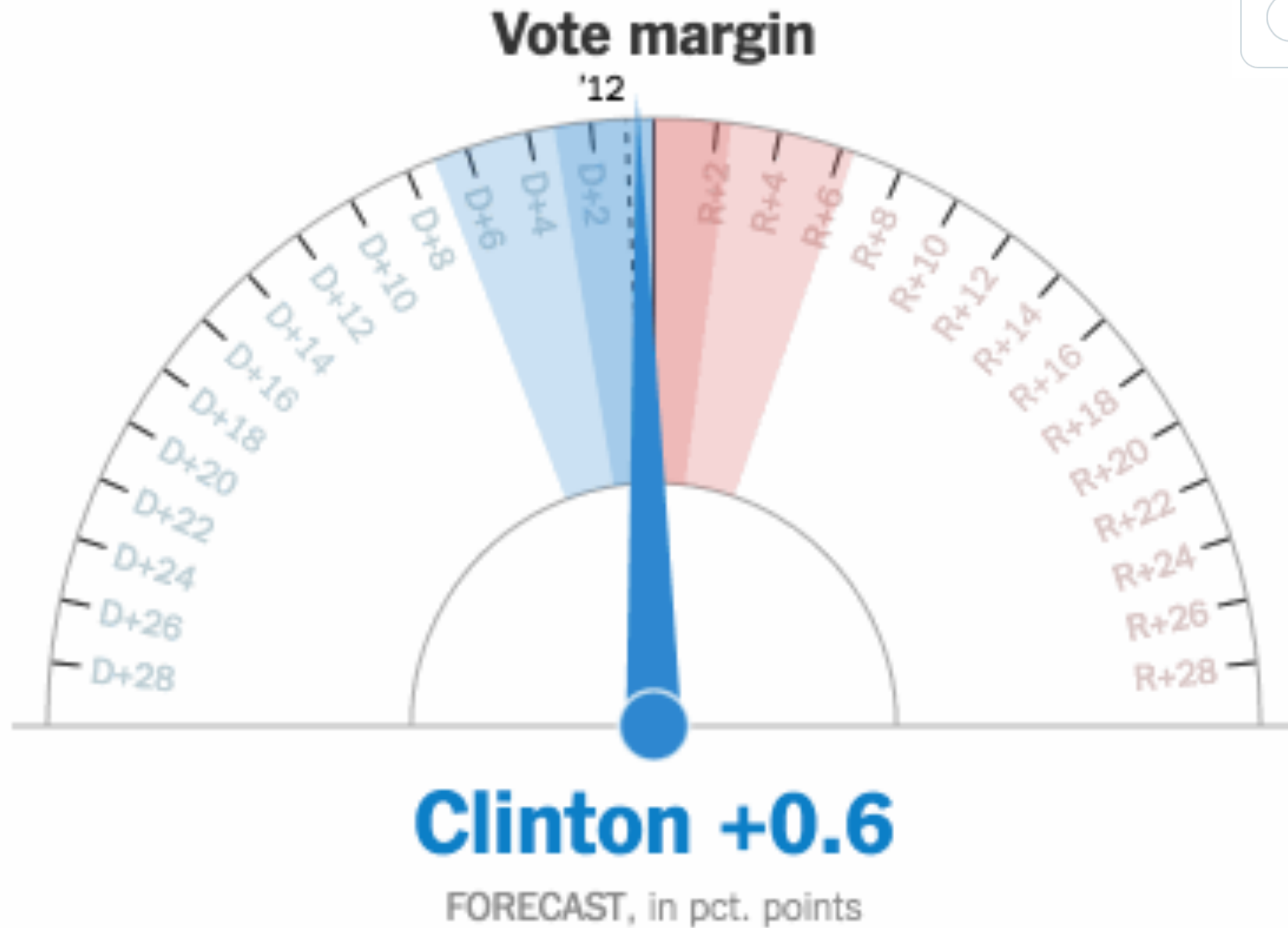
Uncertainty



What is being visualized?

What are the strengths and weaknesses of this visualization?

tryclassbuzz.com
Code: **needle**



(gobsmacked)
@nytimes

I'm taking damn NY

10:08 PM ·

2

Danielle Rosen
@Daniel_Rosen · Follow

The NYT needle jittering is going to be in my nightmares no matter what happens tonight.

10:00 PM · Nov 8, 2016

2

Paul D. Shinkman ✓
@PDSrinkman · Follow

Has @nytimes caught on to Dems' election-night hair-greying freakout?

Heads-up: Forecasts may become more trustworthy on

Our best guess right now is the estimates of three key indicators

66% Trump FORECAST

10:03 PM · Nov 8, 2016

Reply

Alp Toker ✓ · Nov 8, 2016
@atoker · Follow

Looking for trends in @nytimes's presidential forecast needle? Don't look too hard - the bounce is random jitter from your PC, not live data

Clinton +3.3 FORECAST, in pct. points

278 Clinton FORECAST

```

range_05 = range_05 * damping + range_05_tgt * (1-damping);
range_25 = range_25 * damping + range_25_tgt * (1-damping);
range_75 = range_75 * damping + range_75_tgt * (1-damping);
range_95 = range_95 * damping + range_95_tgt * (1-damping);

var jitter = DITTER.get(jit_id) * jitter_range * 0.5 * (eln_forecast);

// if (opts.class != 'dem') jitter *= -1;

needle.attr('transform', 'scale('+scale+') rotate('+angle(cur_val)');
if (opts.colors) {

```

@gka@vis.social
@driven_by_data · Follow

not just random. this noise is conveying the uncertainty in our forecast (jitter range is from 25th–75th pctl in sims.)

10:01 PM · Nov 8, 2016

33

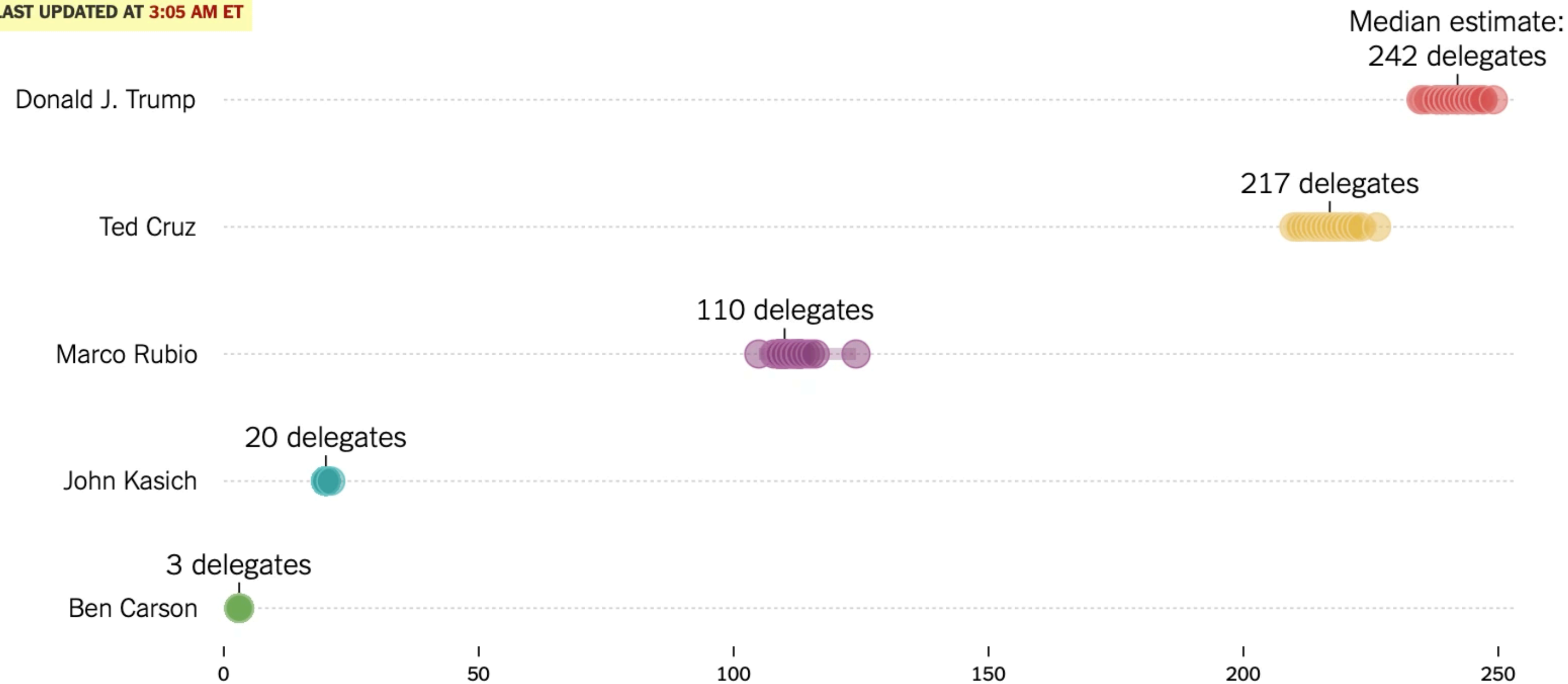
Reply Share

Read 5 replies

Who Will Win Super Tuesday? Live Estimates of Tonight's Final Republican Delegate Count

By AMANDA COX, JOSH KATZ and KEVIN QUEALY MARCH 1, 2016

LAST UPDATED AT 3:05 AM ET



We're simulating the number of delegates each candidate will pick up on Super Tuesday. The dots above represent a range of possible outcomes.

What is being visualized?

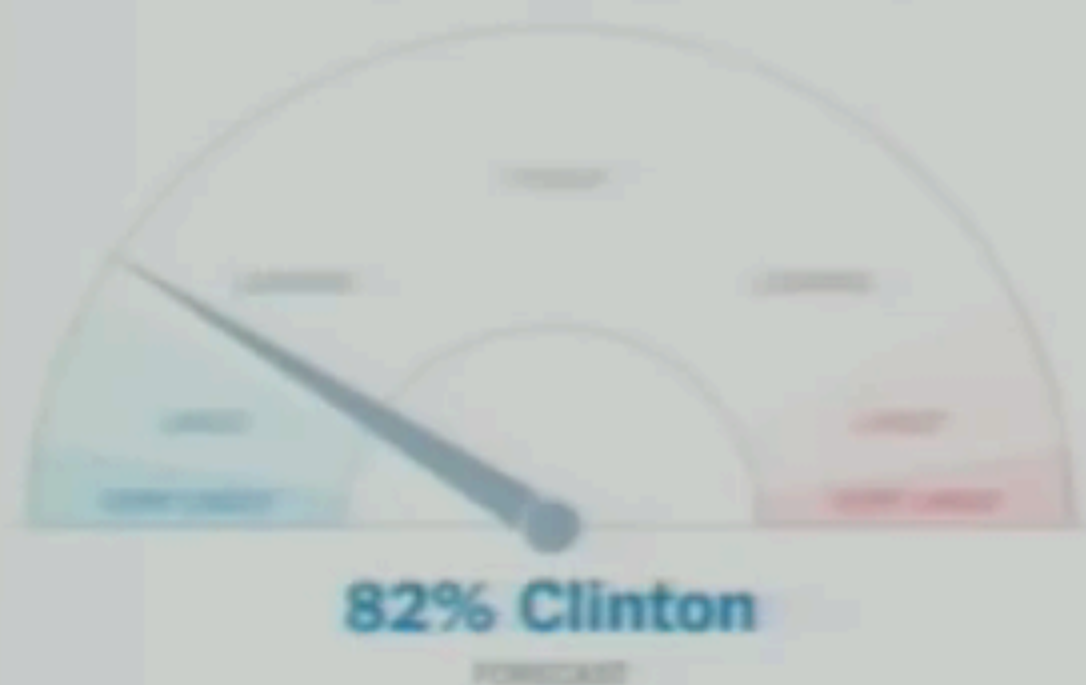
What are the strengths and weaknesses of this visualization?

How does it compare to the needle?

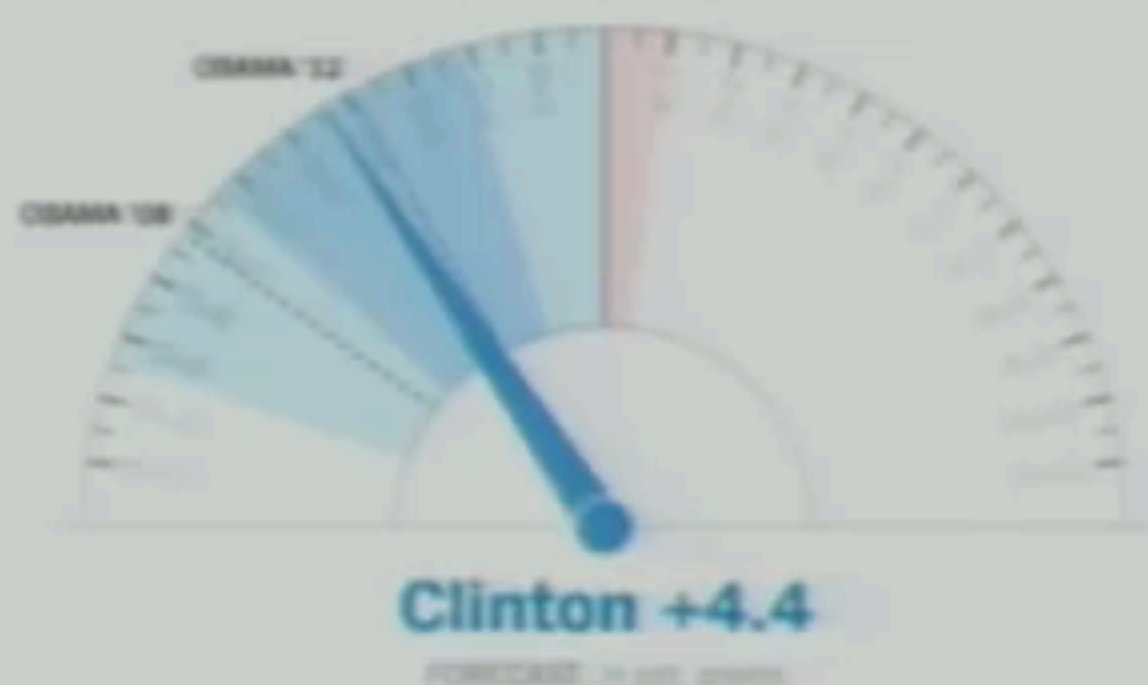
Live Presidential Forecast

Updated 7:55:14 PM ET

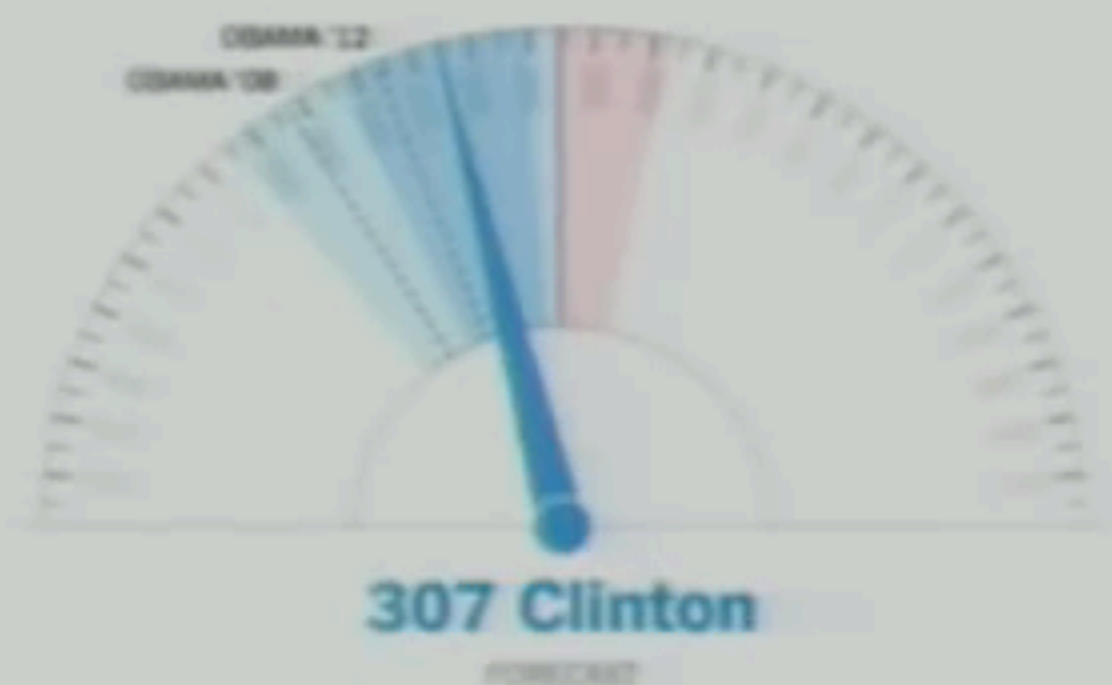
Chance of Winning Presidency



Popular vote margin



Electoral votes



The projections for each state are based on the votes reported so far and how those places have voted in previous elections.

We're showing the closest states by default. [Show all states](#)

State	Est. pct. of voters	Reported margin	NYT projection	NYT win prob.	10%	20%	5%	Even	+5%	+10%	+15%	+20%
Michigan	0%		Clinton +6.5	75% Dem.								
New Mexico	0%		Clinton +6.4	75% Dem.								
Wisconsin	0%		Clinton +5.4	75% Dem.								



OPEN
VIS 2017
CONF

Uncertainty

What does it mean?

How should I visualize it?

Uncertainty

What does it mean?

How should I visualize it?

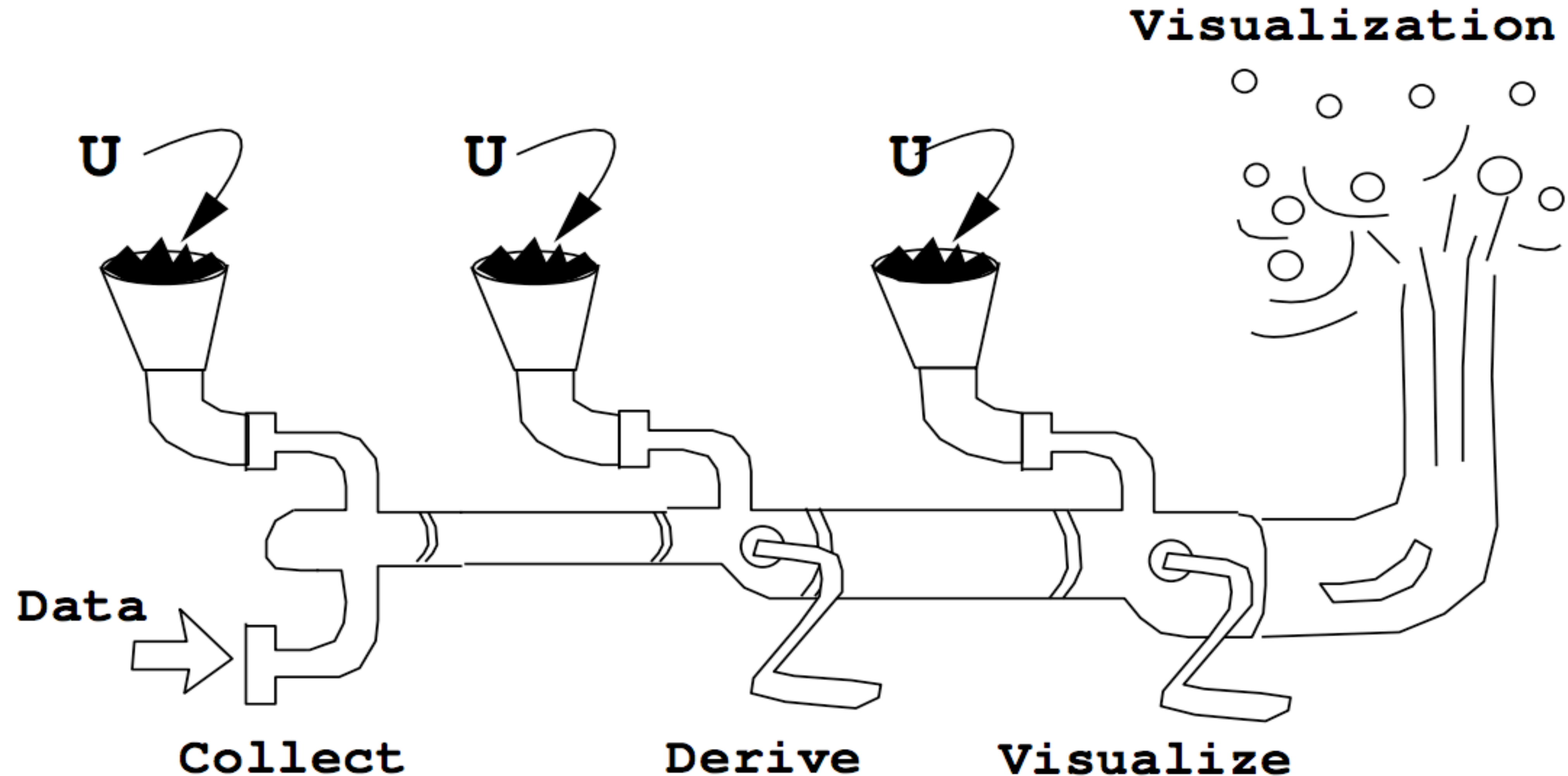
Uncertainty

What does it mean?

How should I visualize it?

Doubt
Risk
Variability
Error
Lack of knowledge
Hedging
etc...

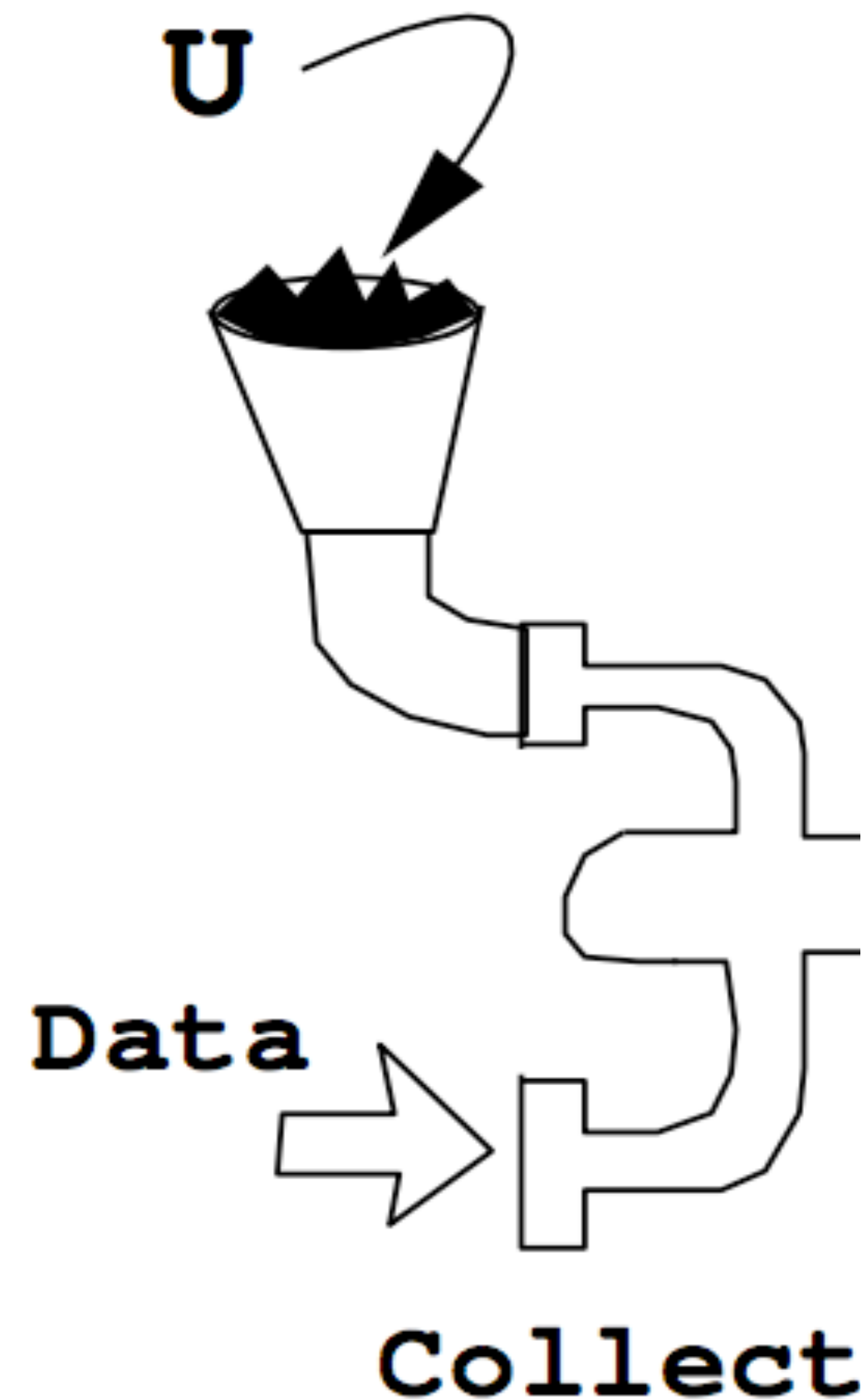
Sources and Types of Uncertainty



Sources and Types of Uncertainty

Measurement Uncertainty

How and how much should we sample the data?



Precision

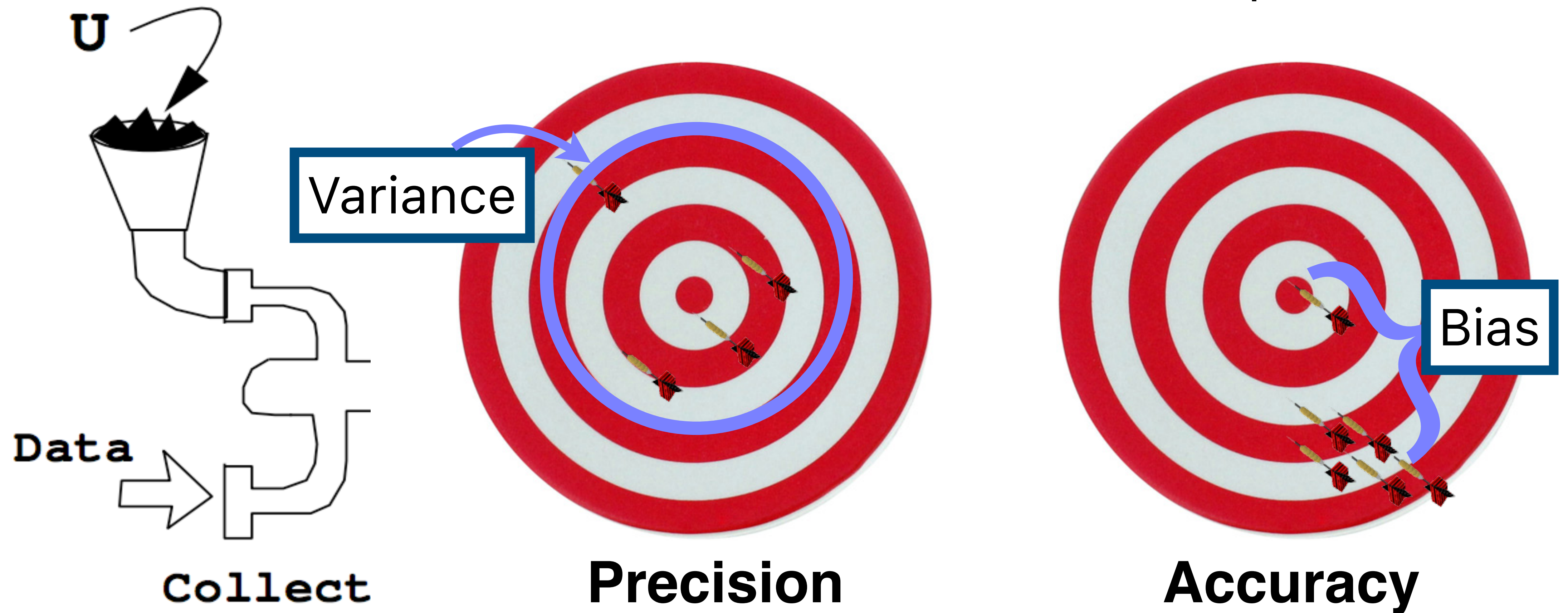


Accuracy

Sources and Types of Uncertainty

Measurement Uncertainty

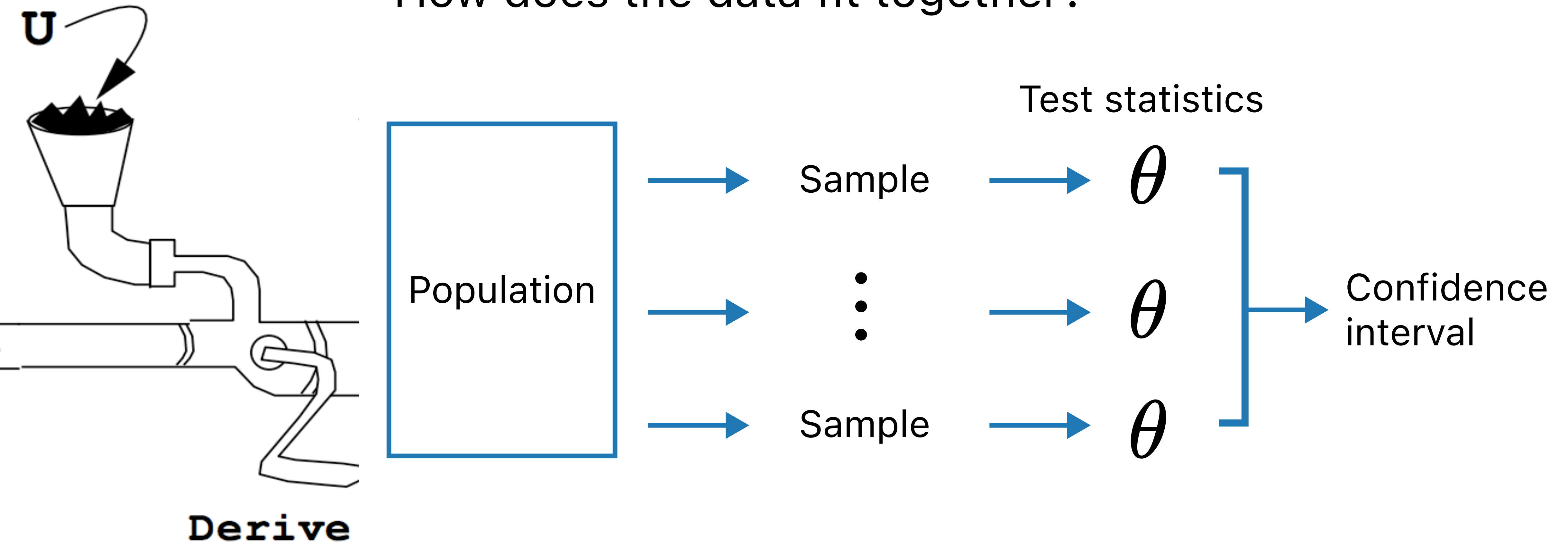
How and how much should we sample the data?



Sources and Types of Uncertainty

Model Uncertainty

How does the data fit together?



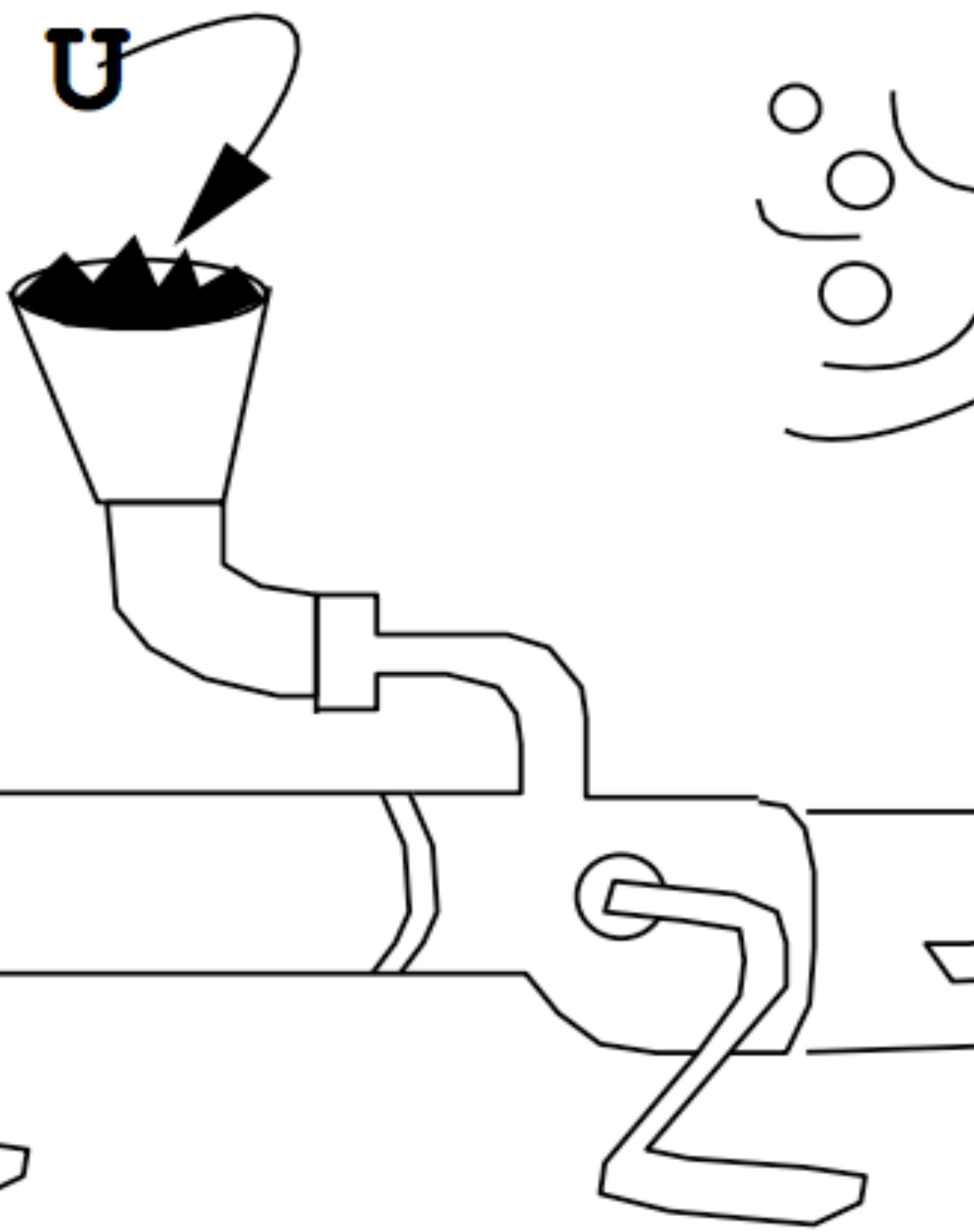
Sources and Types of Uncertainty

Visuali



Decision/Forecast Uncertainty

How do I assess the risk or error?



Visualize



Sources and Types of Uncertainty

Visuali





Visualize

Decision/Forecast Uncertainty

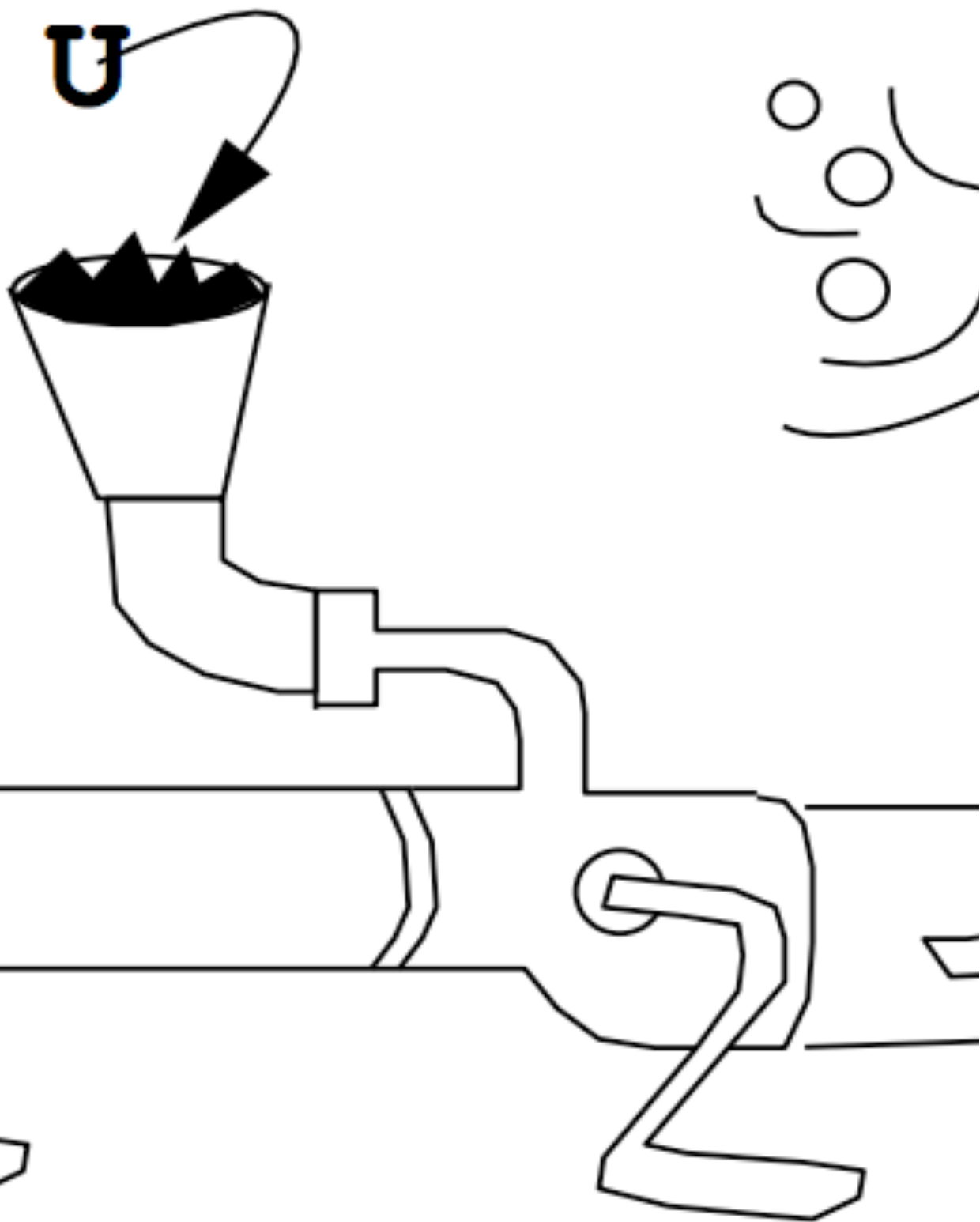
How do I assess the risk or error?



Sources and Types of Uncertainty

Visuali





Visualize

Decision/Forecast Uncertainty

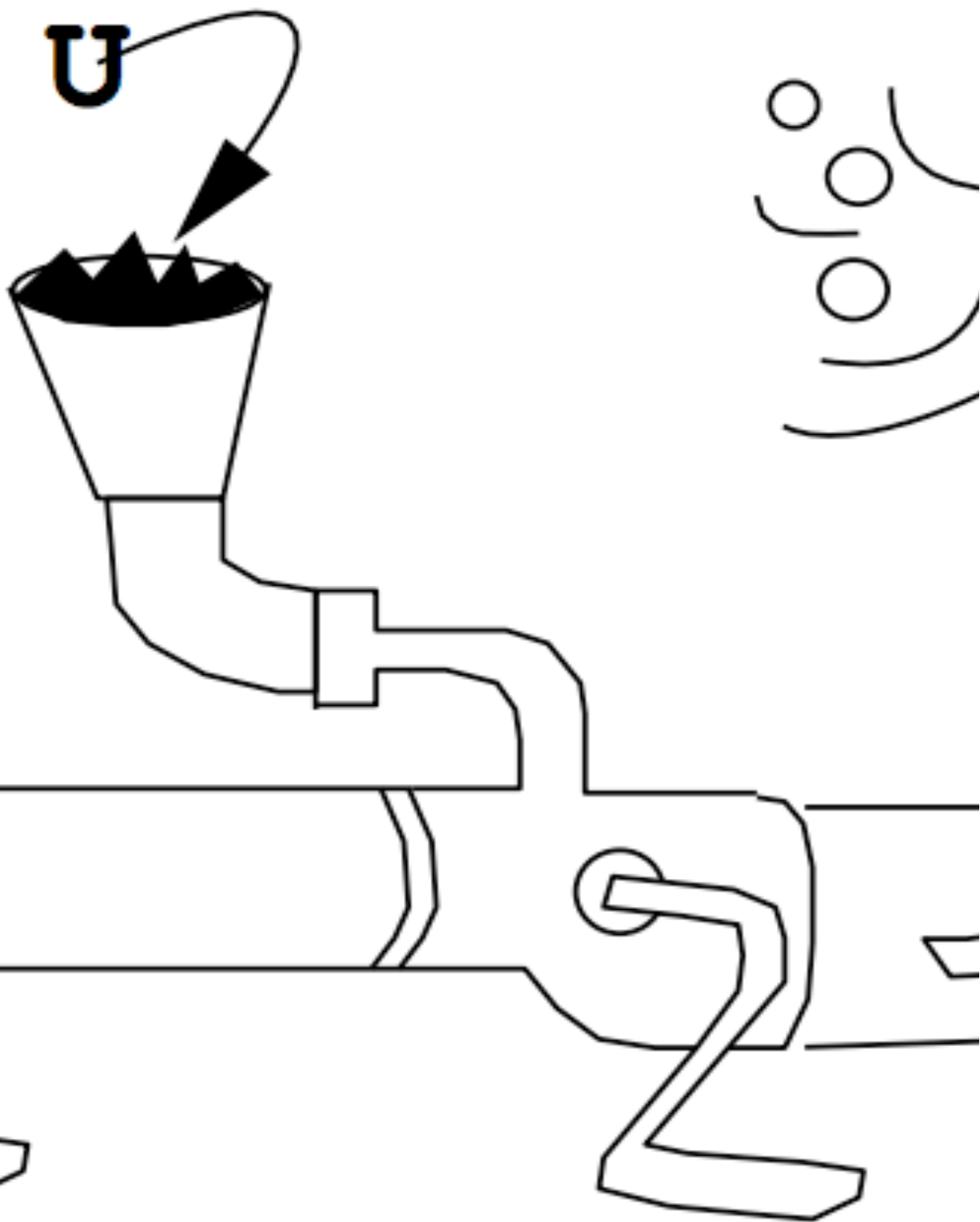
How do I assess the risk or error?



	Type I False Positive
	

Sources and Types of Uncertainty

Visuali



Visualize

Decision/Forecast Uncertainty

How do I assess the risk or error?



**Type I
False
Positive**

**Type II
False
Negative**



Uncertainty

What does it mean?

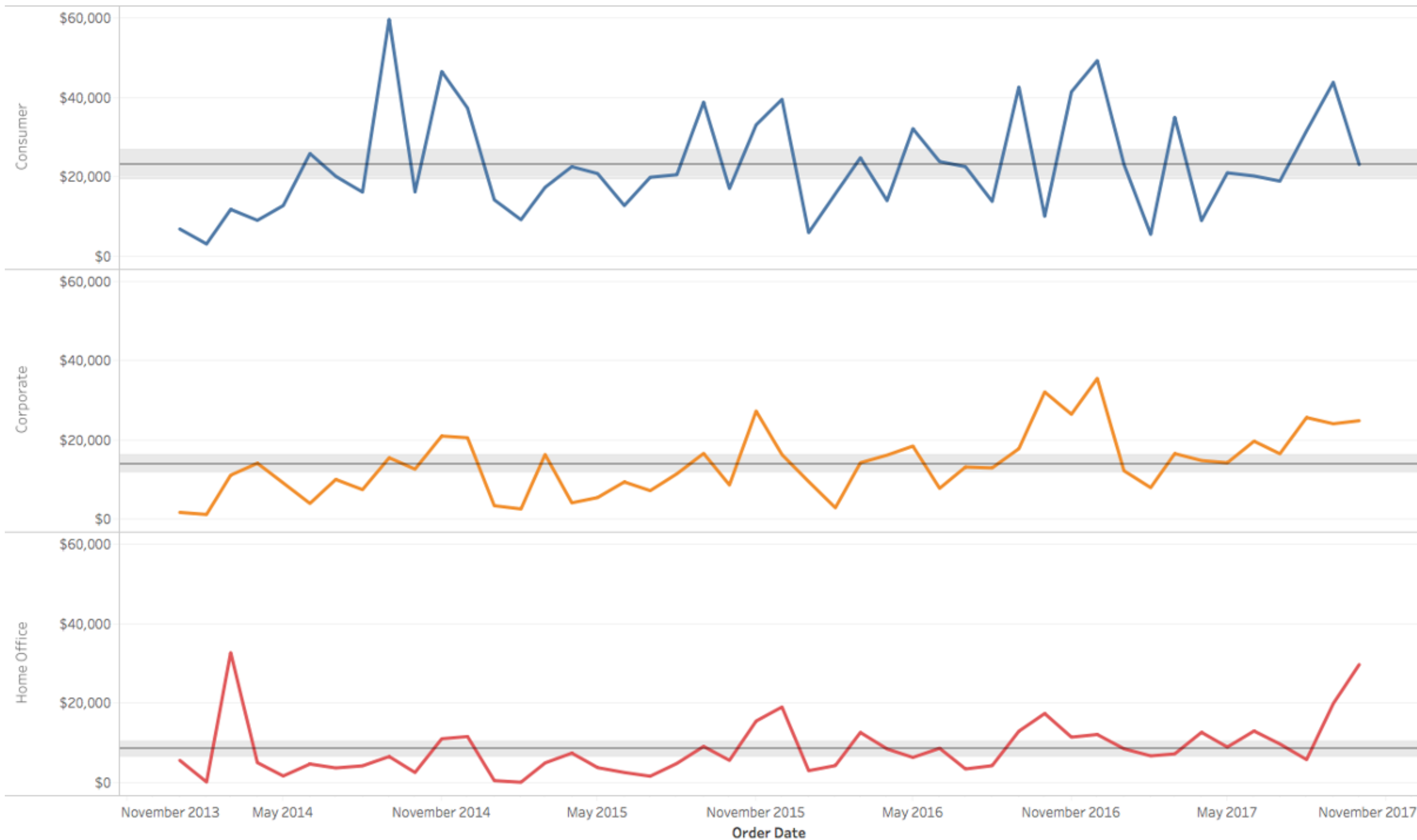
Lots of things!

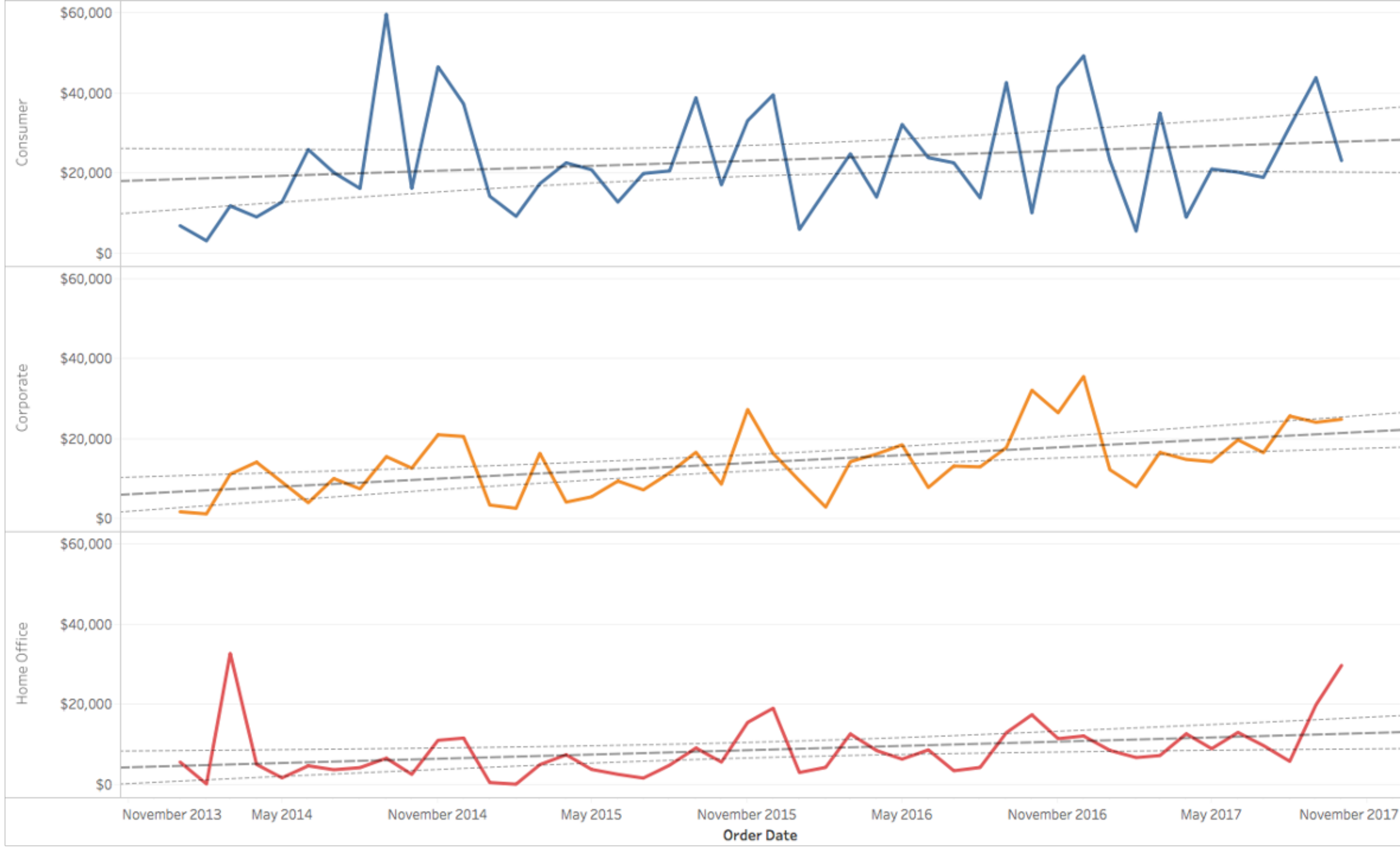
How should I visualize it?

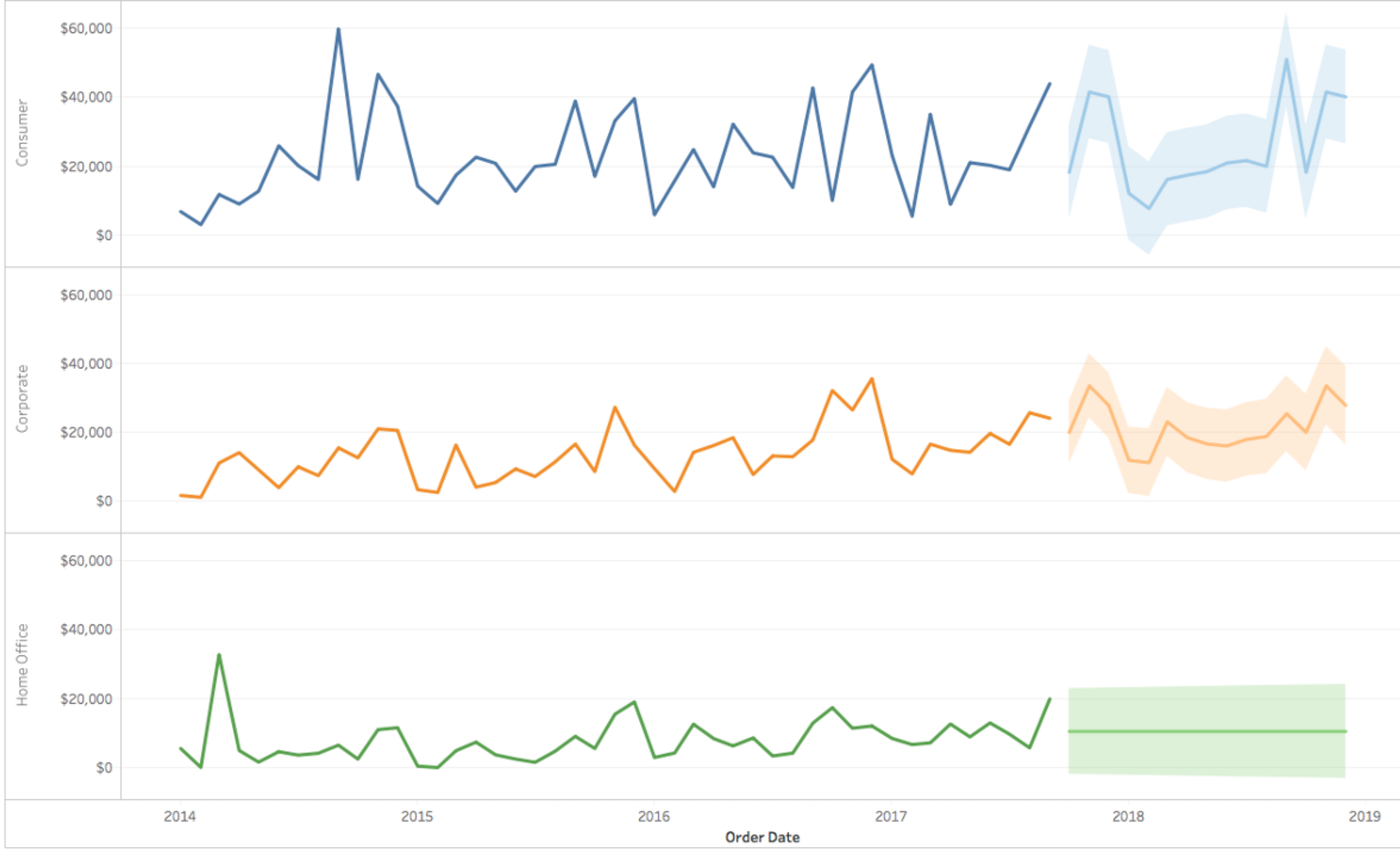
Uncertainty

What does it mean?

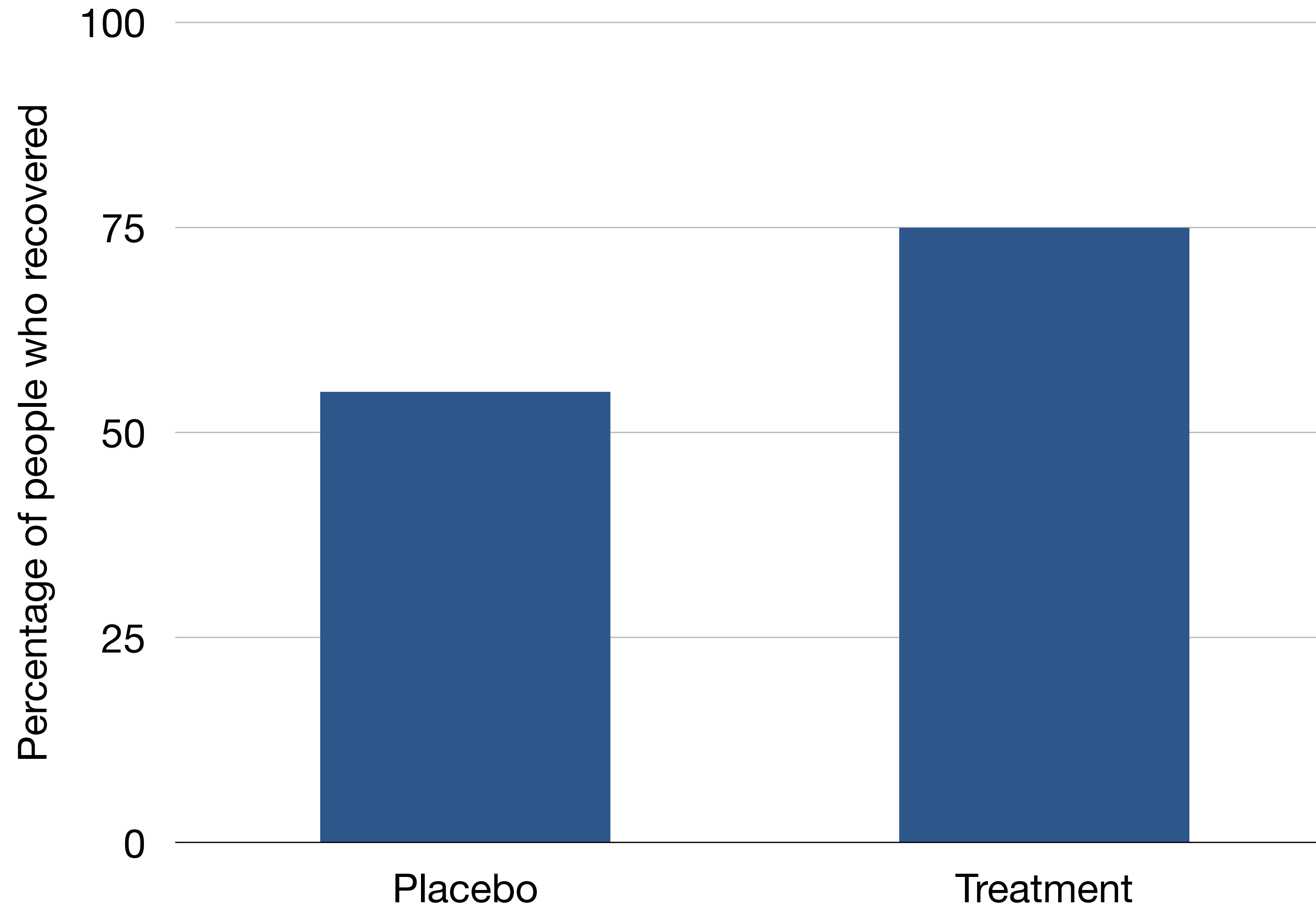
How should I visualize it?



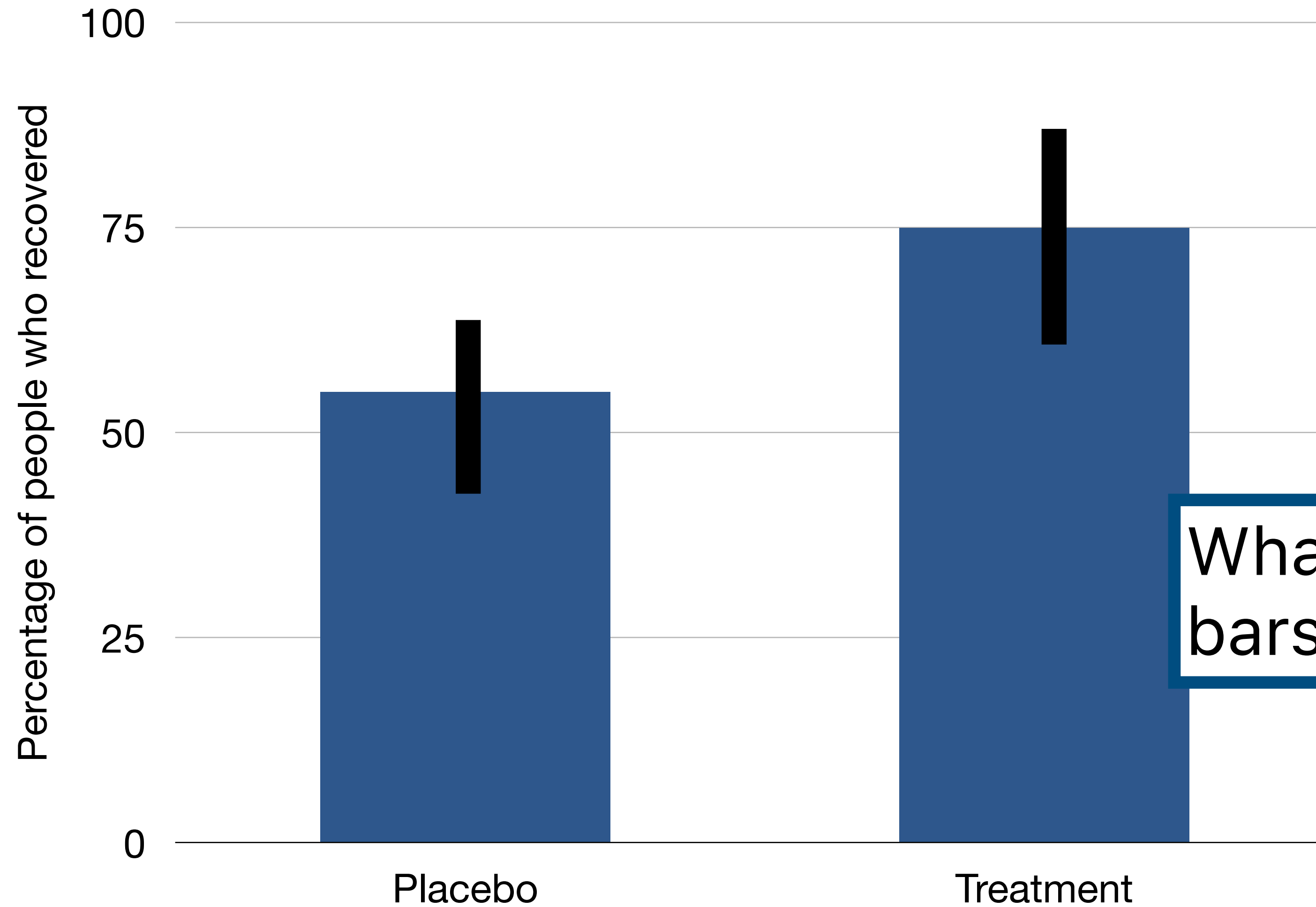




Trial of new medicine



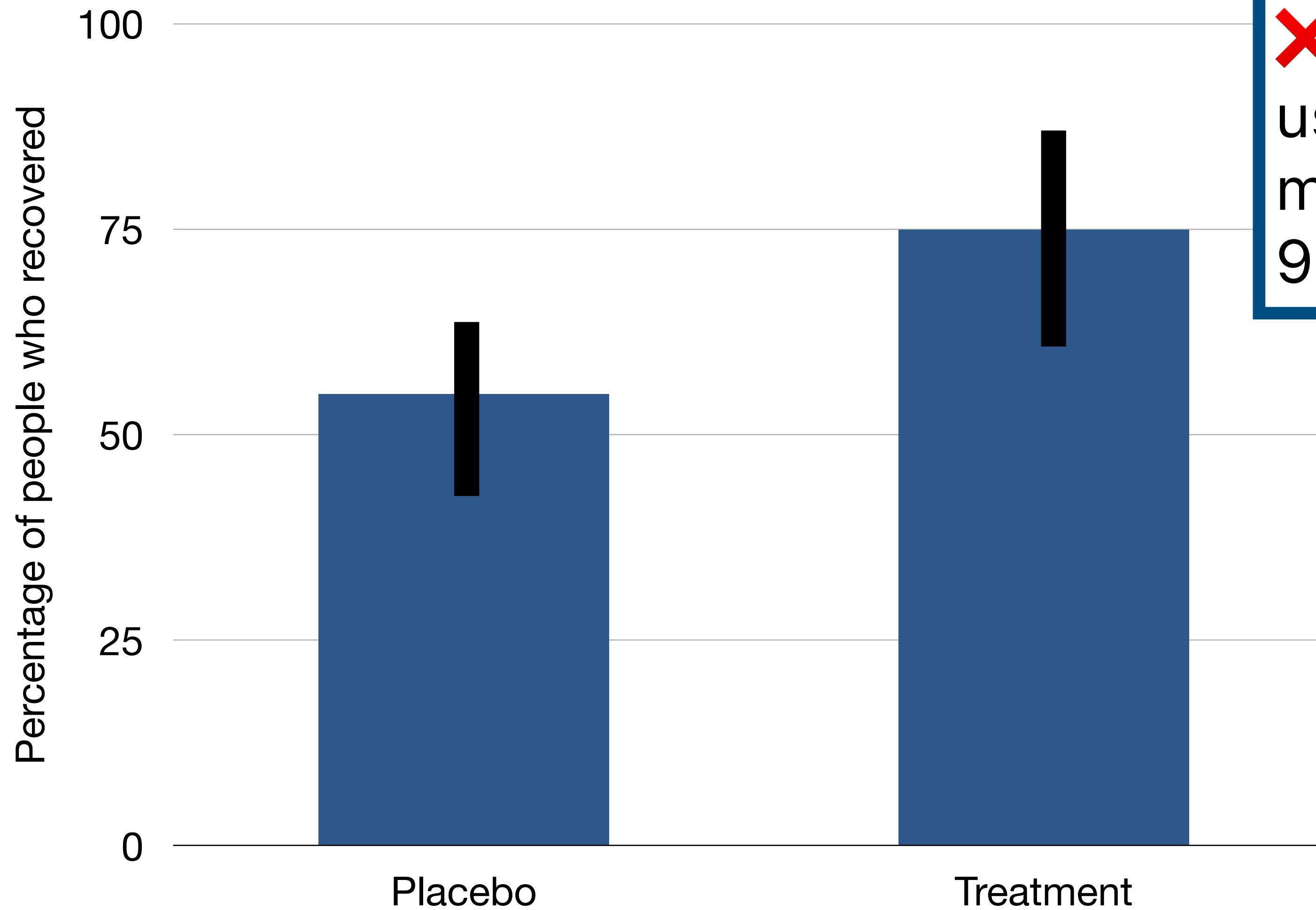
Trial of new medicine



What do you think these error bars are implying?

tryclassbuzz.com
Code: **errorbars**

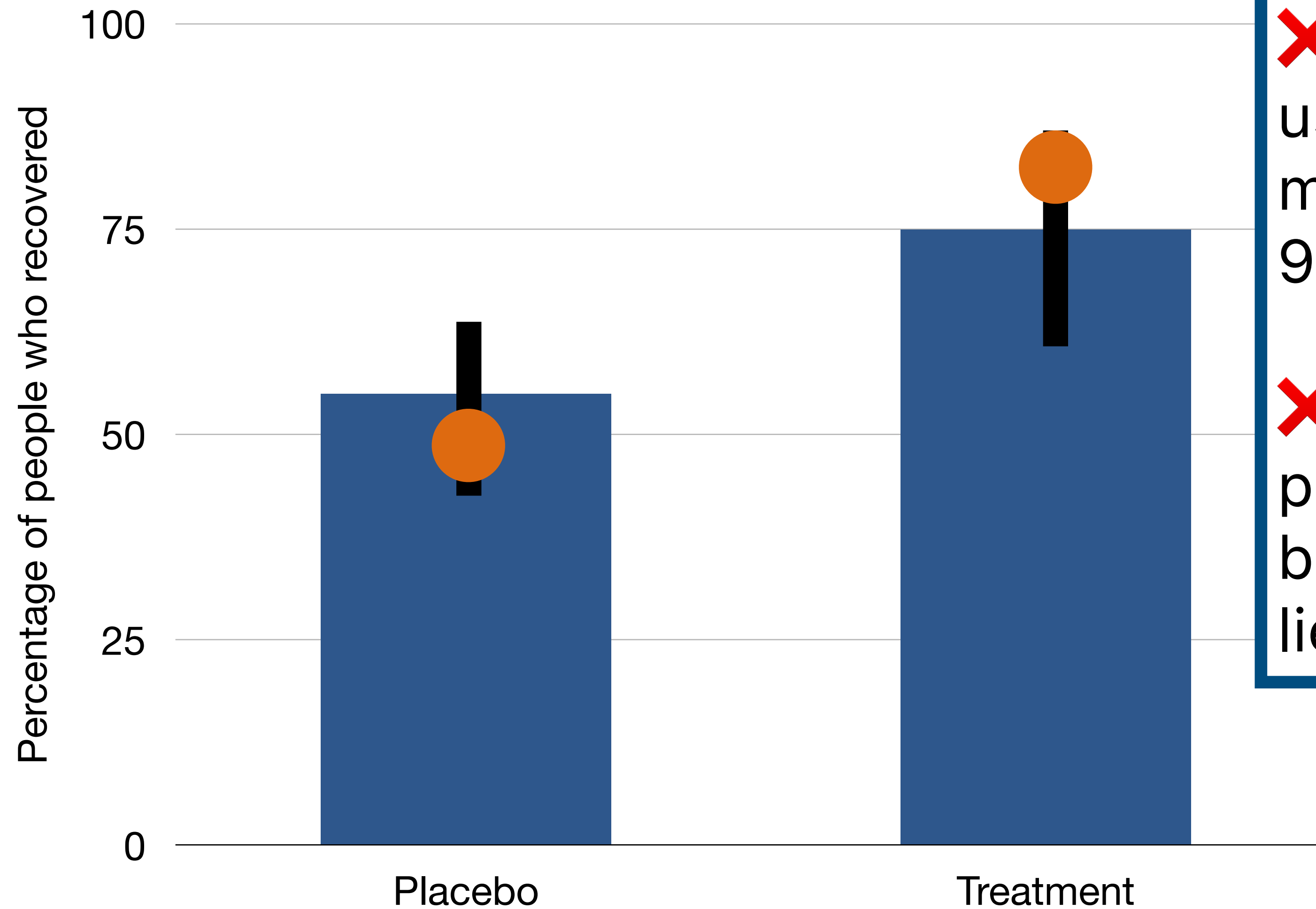
Trial of new medicine



Expressiveness?

✘ Error bars aren't consistently used to visualize the same measure (standard error, IQR, 95% CI, etc.).

Trial of new medicine

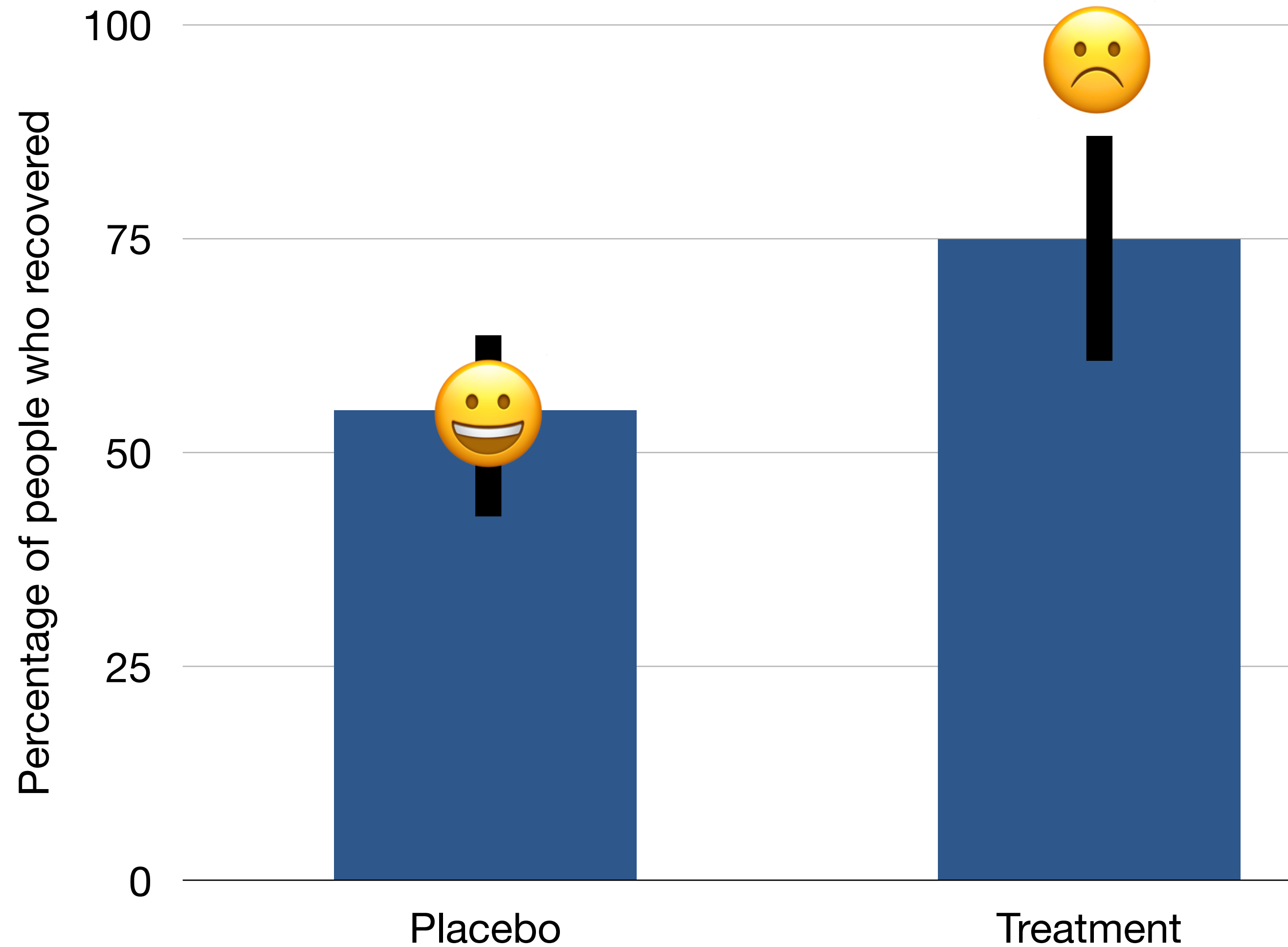


Expressiveness?

✗ Error bars aren't consistently used to visualize the same measure (standard error, IQR, 95% CI, etc.).

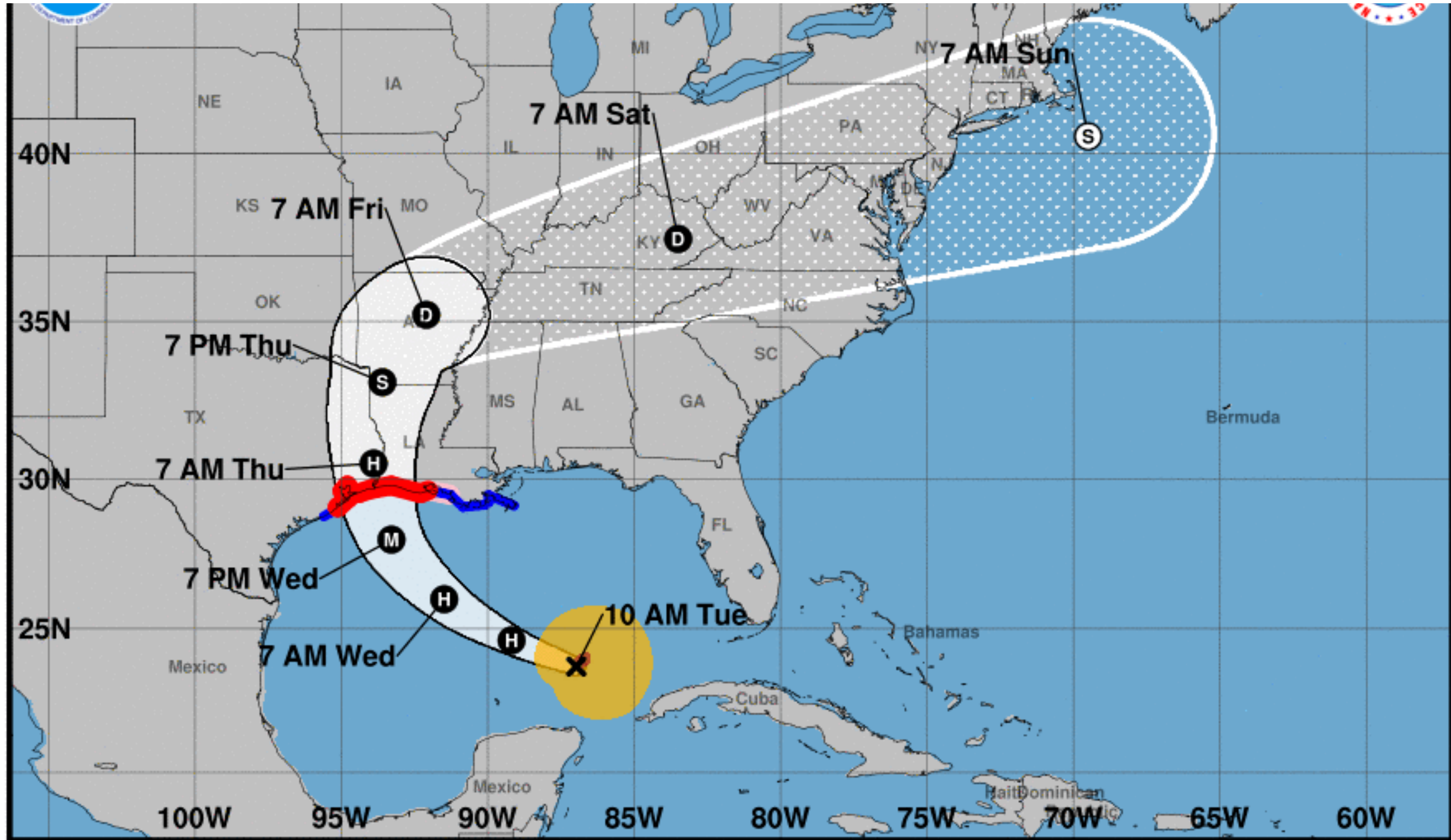
✗ Within-the-bar bias: people perceive points falling within the bar as more likely than those that lie outside.

Trial of new medicine



Expressiveness?

- ✗ Error bars aren't consistently used to visualize the same measure (standard error, IQR, 95% CI, etc.).
- ✗ Within-the-bar bias: people perceive points falling within the bar as more likely than those that lie outside.
- ✗ Binary bias: people perceive values to either be in or out of the margins of error.

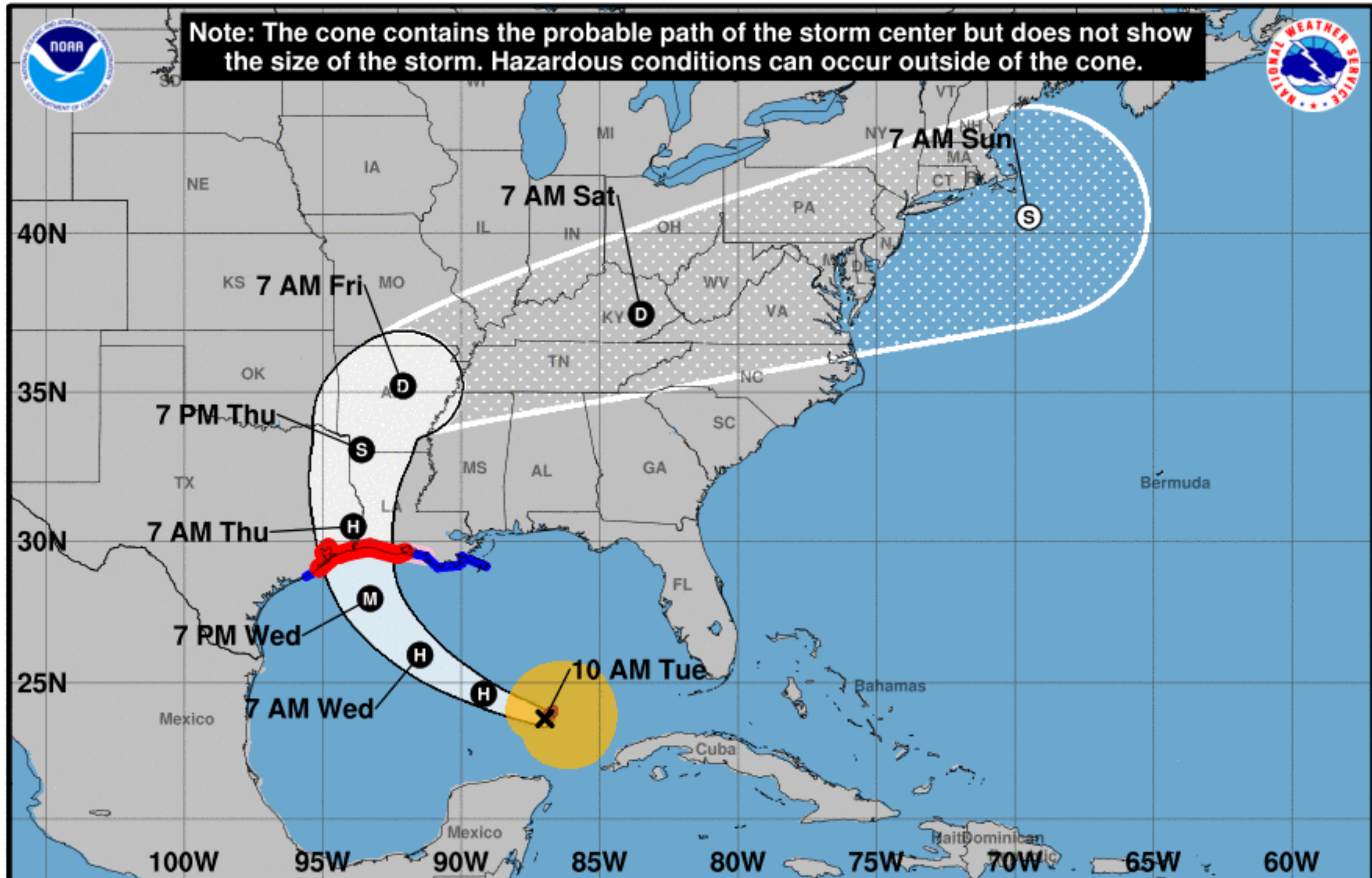


Hurricane Laura Tuesday August 25, 2020 10 AM CDT Advisory 23 NWS National Hurricane Center		Current information: x Center location 23.7 N 87.0 W Maximum sustained wind 75 mph Movement WNW at 16 mph		Forecast positions: ● Tropical Cyclone ○ Post/Potential TC Sustained winds: D < 39 mph S 39-73 mph H 74-110 mph M > 110 mph	
Potential track area: ▽ Day 1-3 ▨ Day 4-5	Watches: ■ Hurricane ■ Trop Stm	Warnings: ■ Hurricane ■ Trop Stm	Current wind extent: ■ Hurricane ■ Trop Stm		

What is being visualized?

What are the strengths and weaknesses of this visualization?

tryclassbuzz.com
 Code: hurricane



Note: The cone contains the probable path of the storm center but does not show the size of the storm. Hazardous conditions can occur outside of the cone.

Hurricane Laura
 Tuesday August 25, 2020
 10 AM CDT Advisory 23
 NWS National Hurricane Center

Current information: x
 Center location 23.7 N 87.0 W
 Maximum sustained wind 75 mph
 Movement WNW at 16 mph

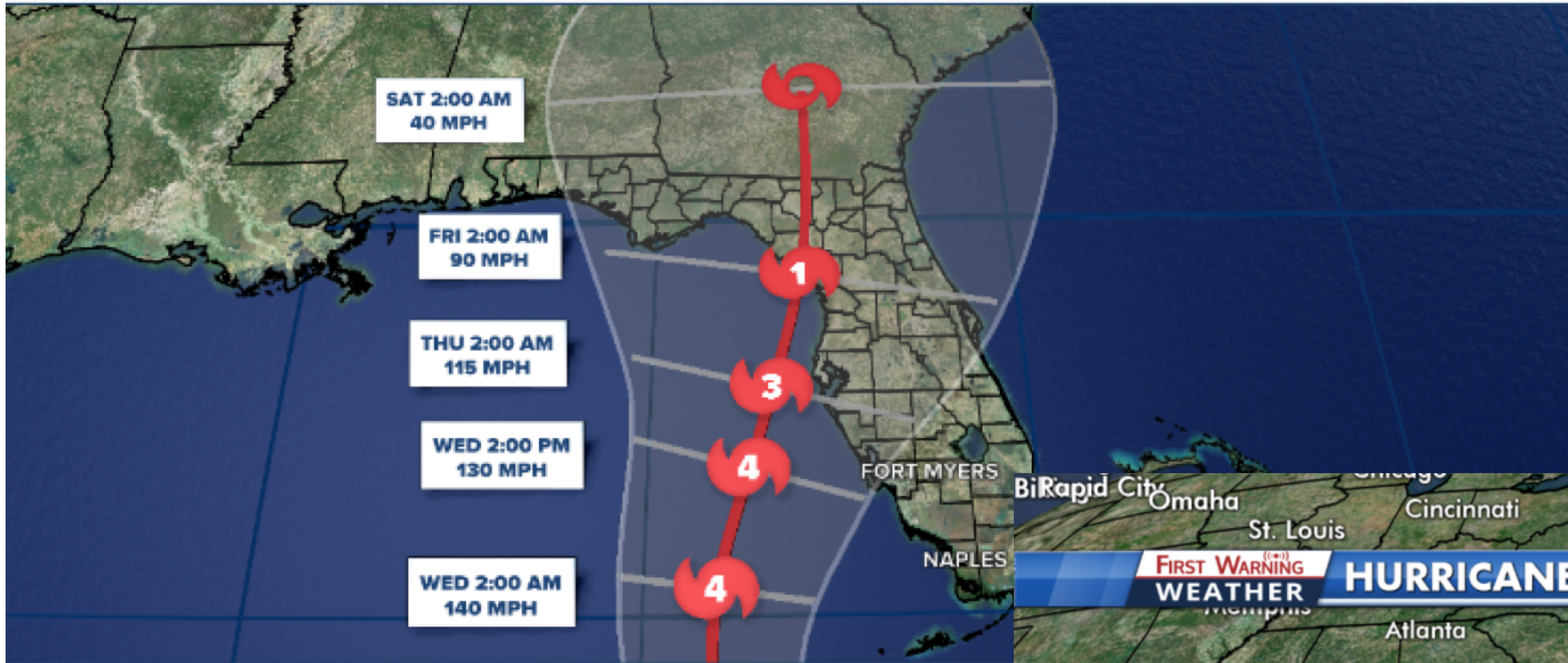
Forecast positions:
 ● Tropical Cyclone ○ Post/Potential TC
 Sustained winds: D < 39 mph
 S 39-73 mph H 74-110 mph M > 110 mph

Potential track area: Day 1-3 (solid line), Day 4-5 (dotted line)
Watches: Hurricane (pink), Trop Stm (yellow)
Warnings: Hurricane (red), Trop Stm (blue)
Current wind extent: Hurricane (brown), Trop Stm (orange)

What is being visualized?
 What are the strengths and weaknesses of this visualization?

FOX 4 HURRICANE IAN

5:00 AM ADVISORY



CURRENT LOCATION: 90 MI SW OF G

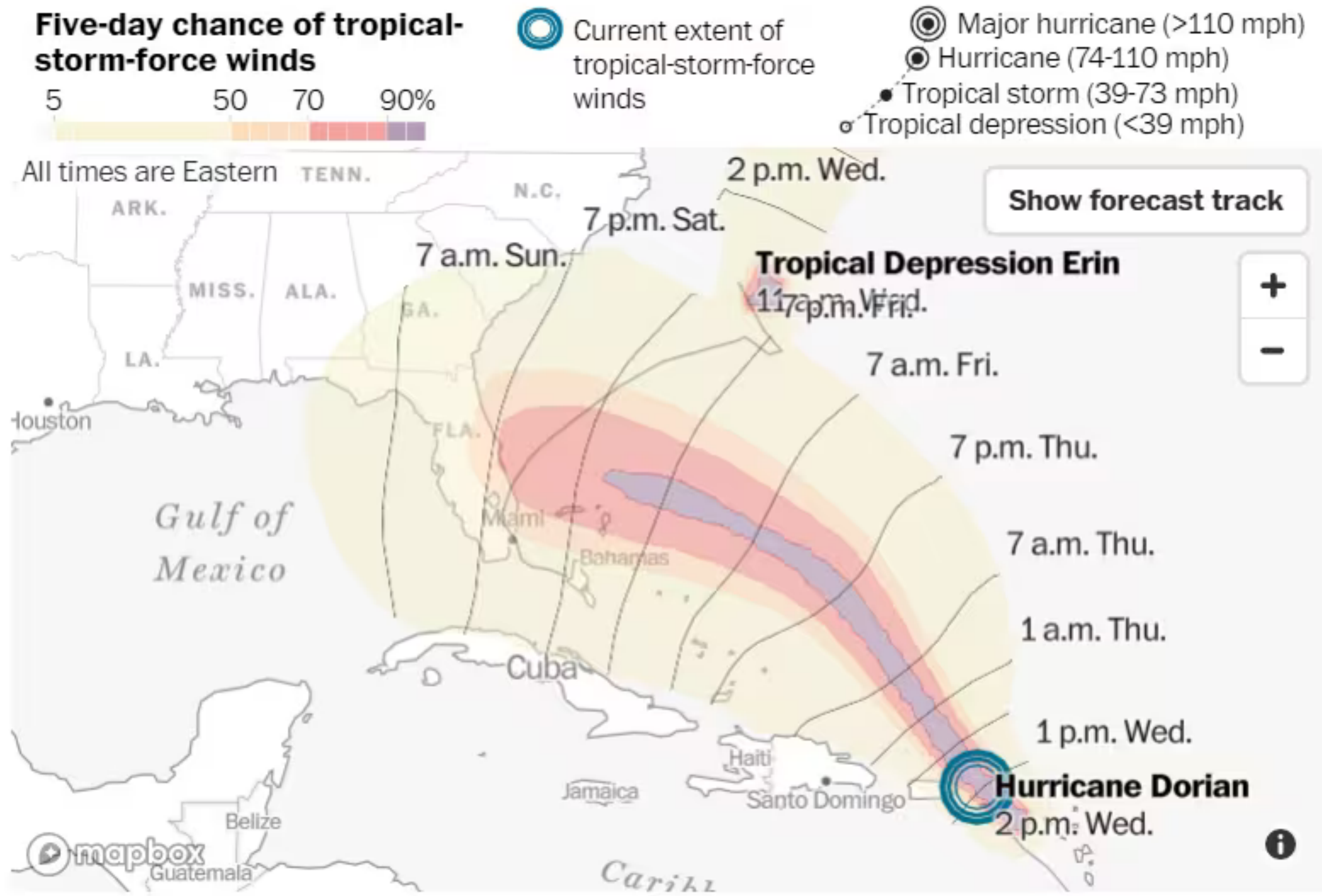


FIRST WARNING WEATHER HURRICANE DORIAN



Hurricane Dorian Forecast Track and Intensity

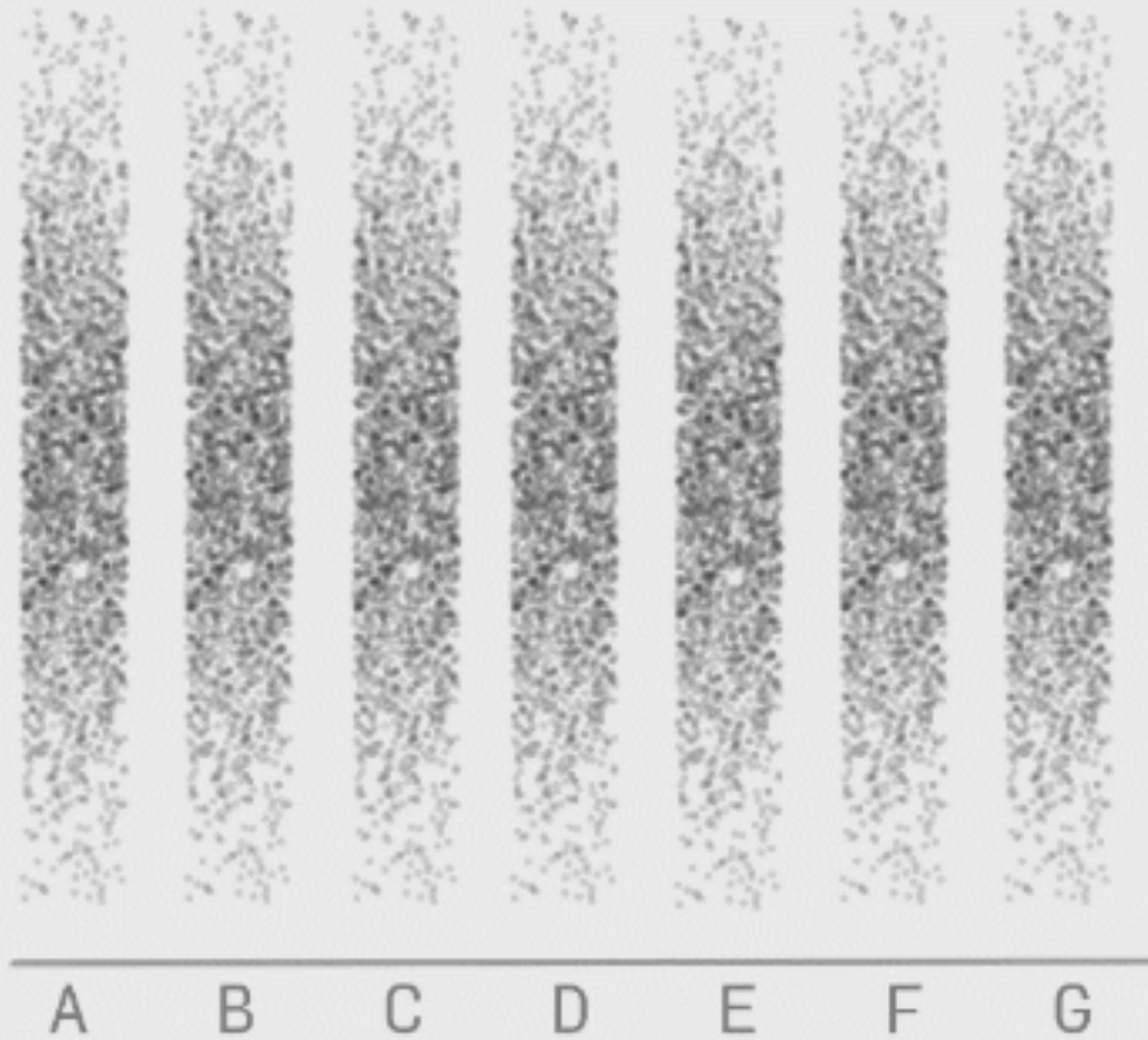




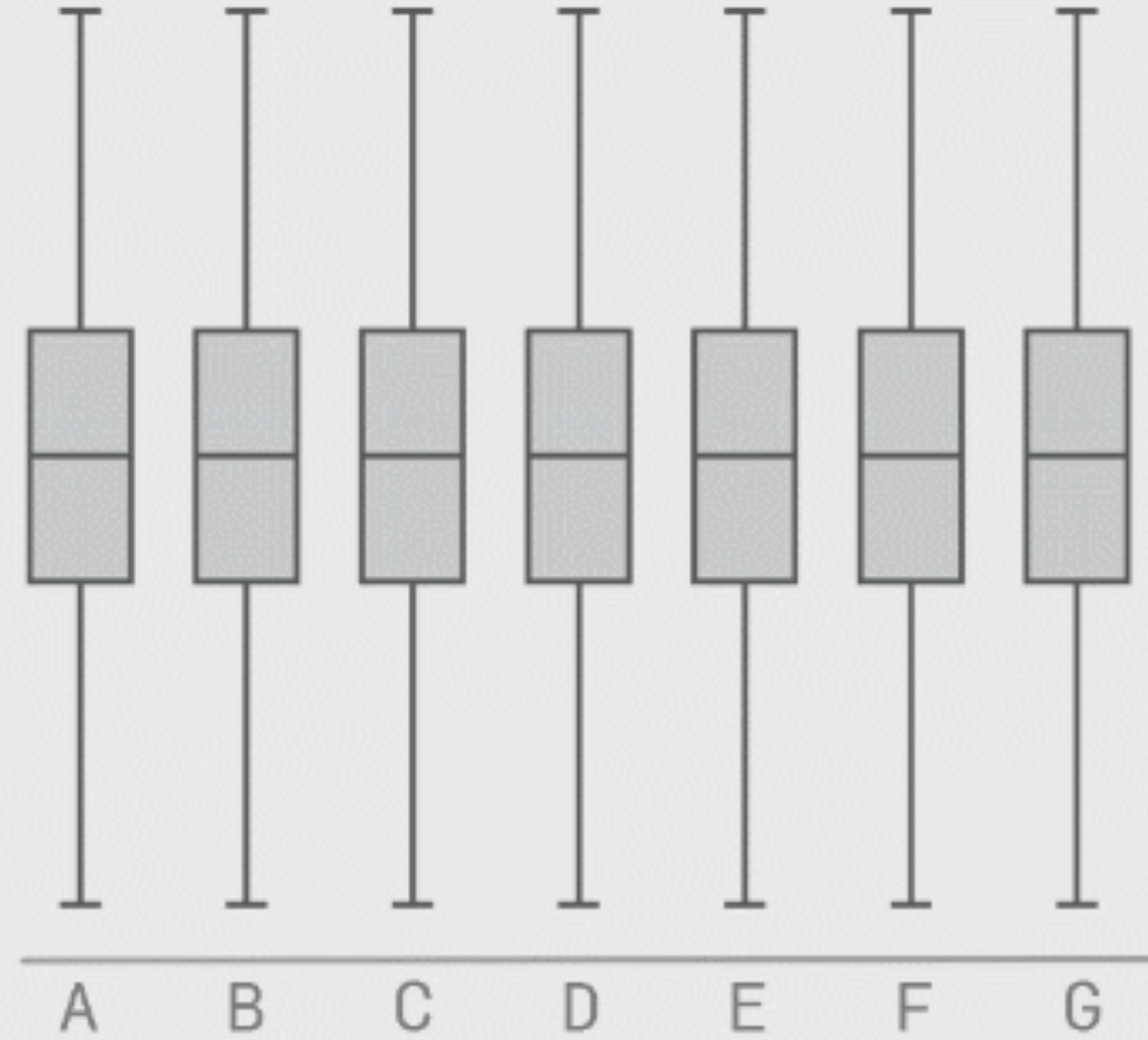
Source: National Weather Service. Note: Impact lines represent the earliest reasonable arrival time of tropical-storm-force winds.

For uncertainty, use **visual variables** instead of visualizing point estimates

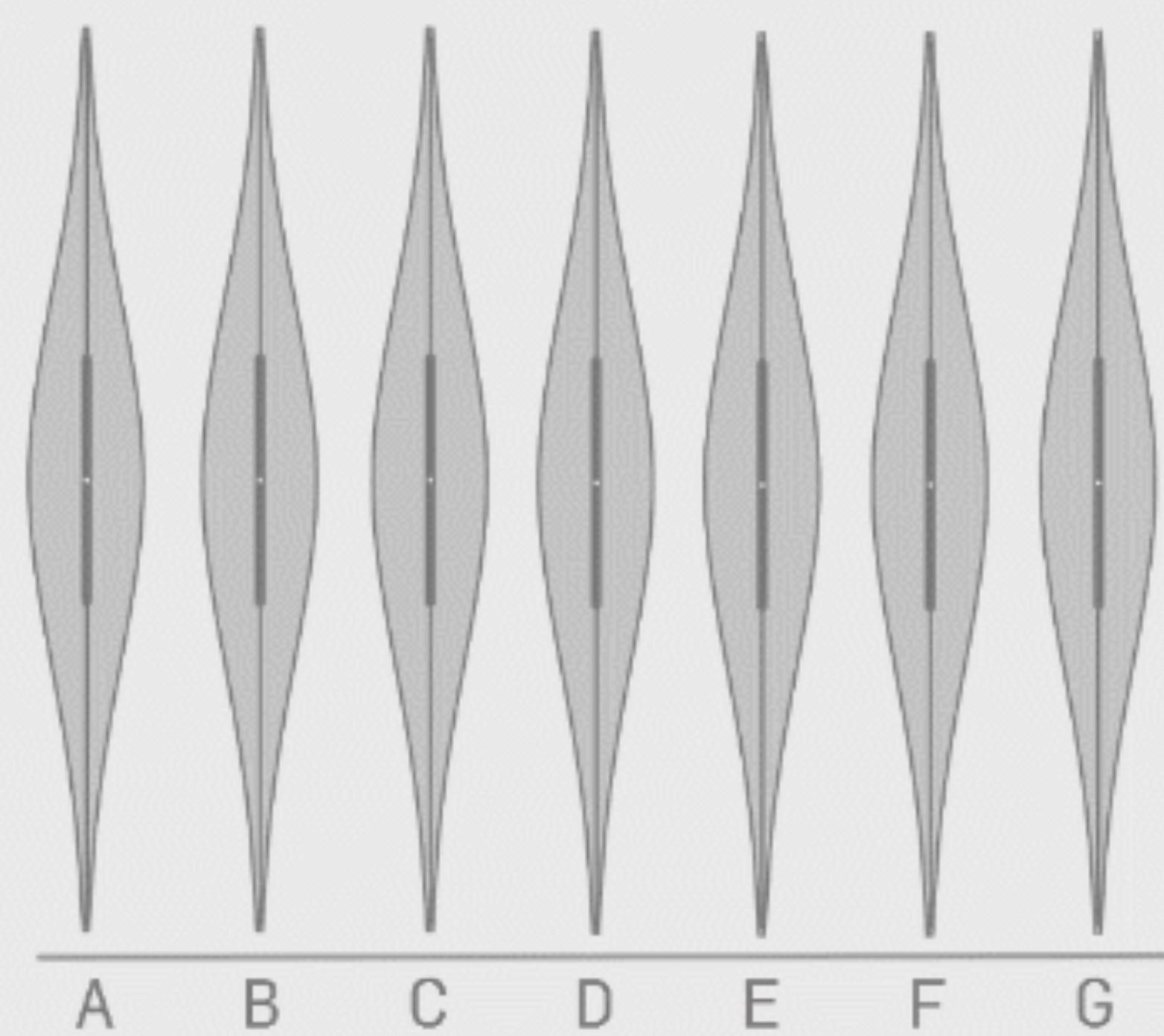
Raw Data



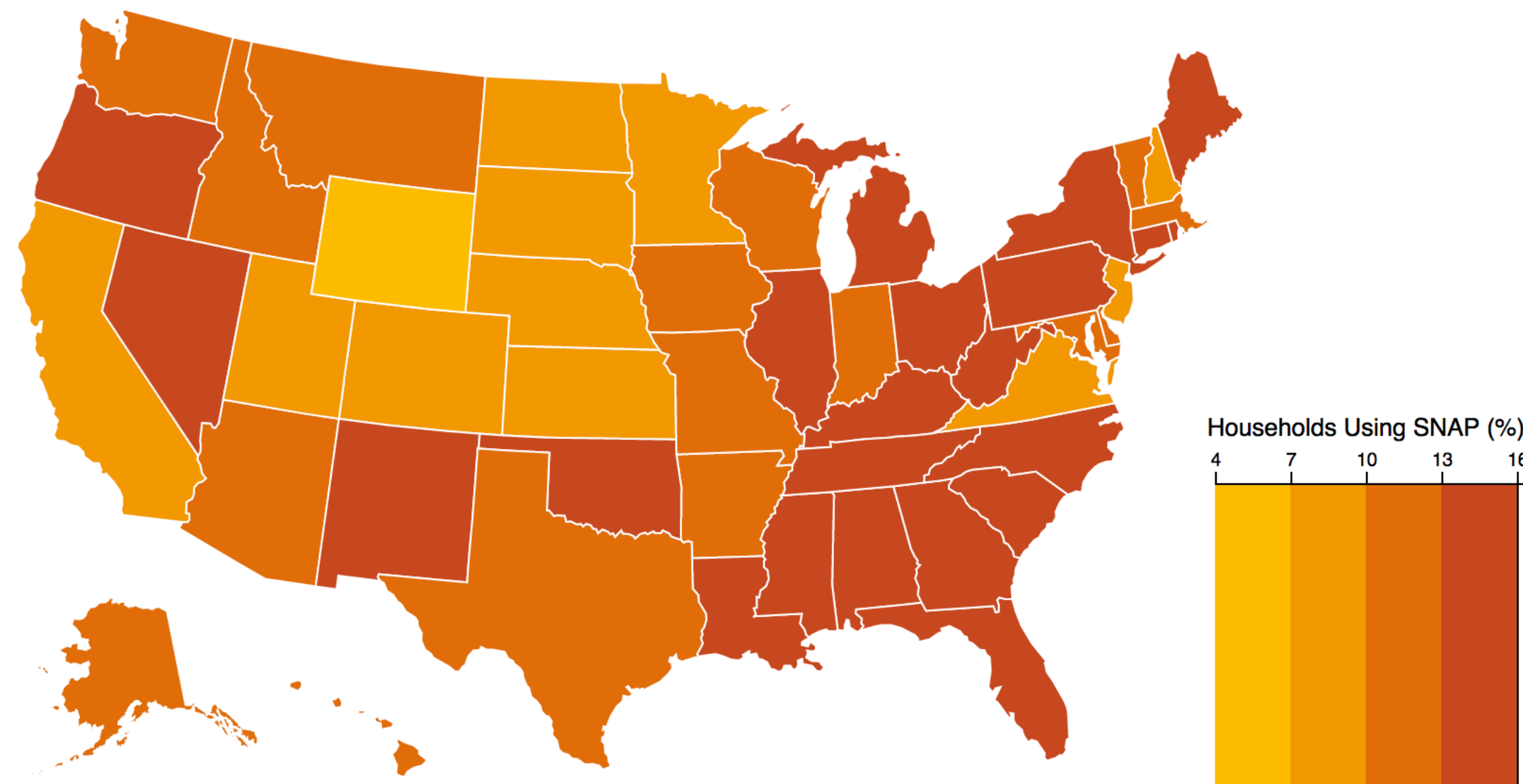
Box-plot of the Data



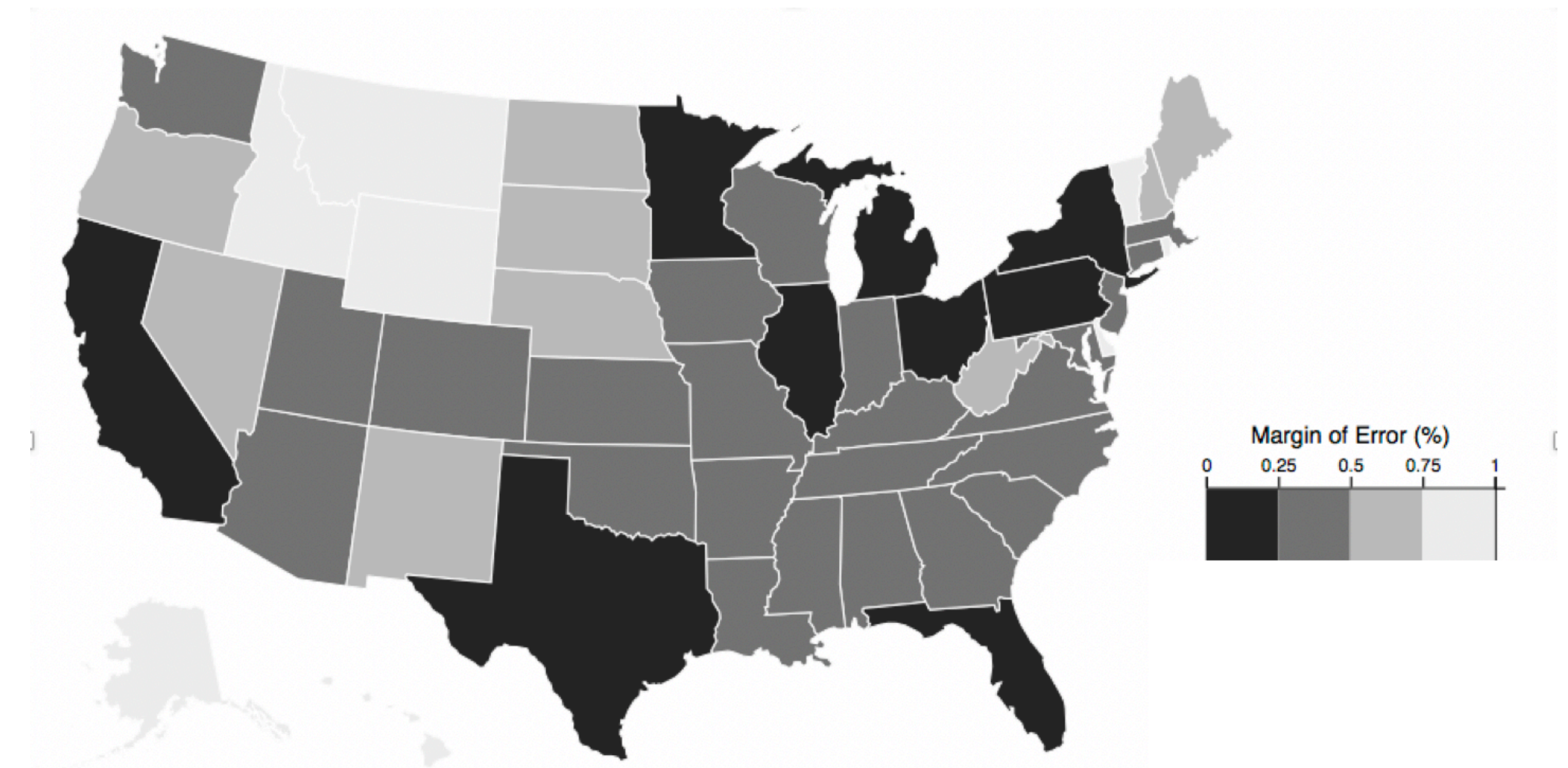
Violin-plot of the Data



For uncertainty, use **visual variables** instead of visualizing point estimates

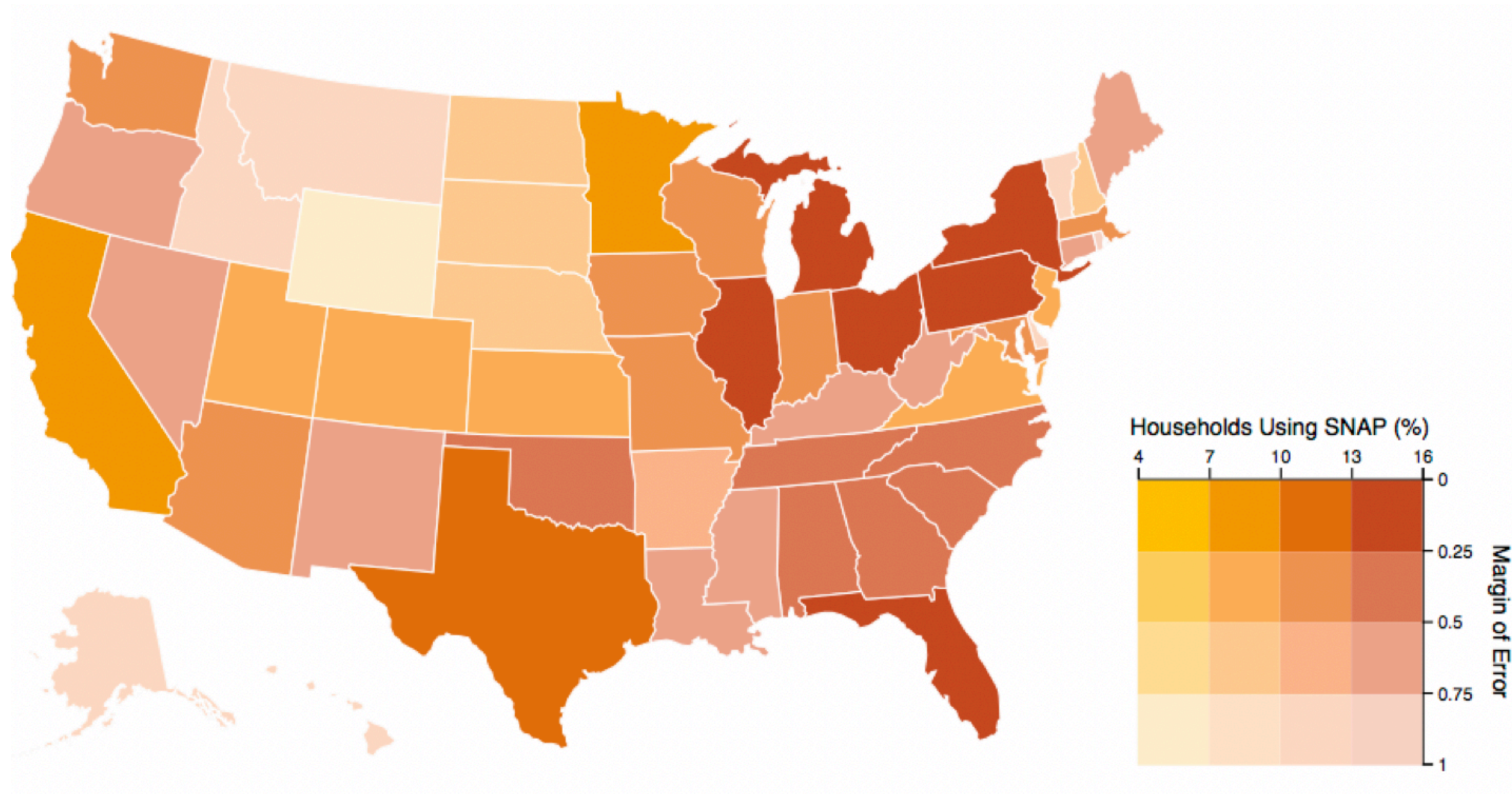


Data Map

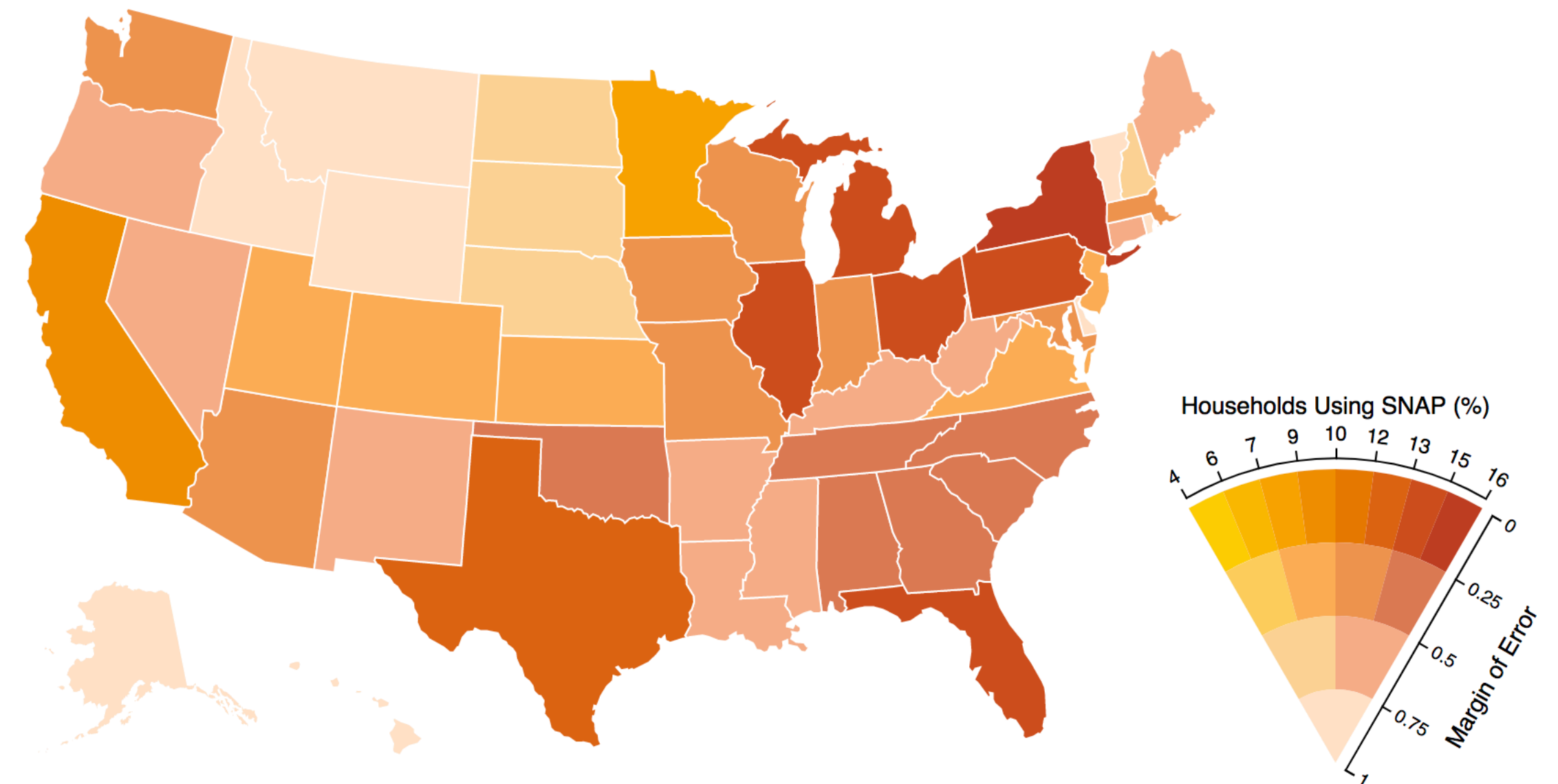


Uncertainty Map

For uncertainty, use **visual variables** instead of visualizing point estimates

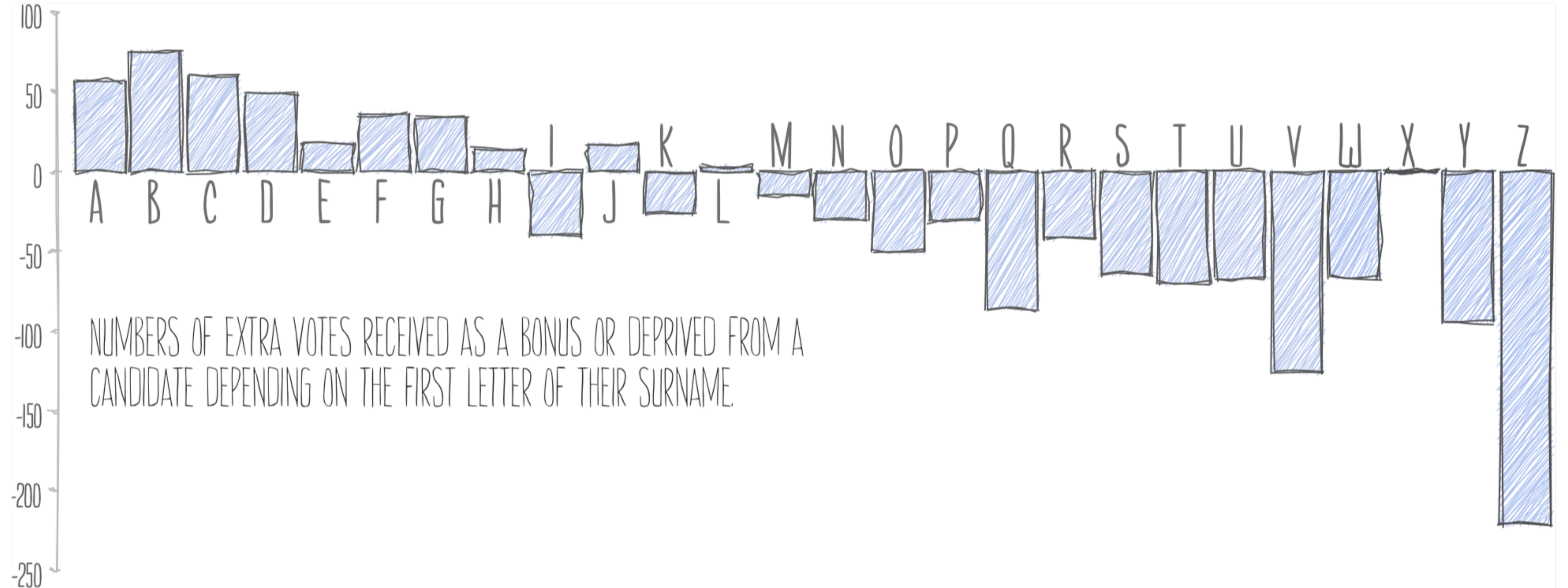


Bivariate Map (Data + Uncertainty)



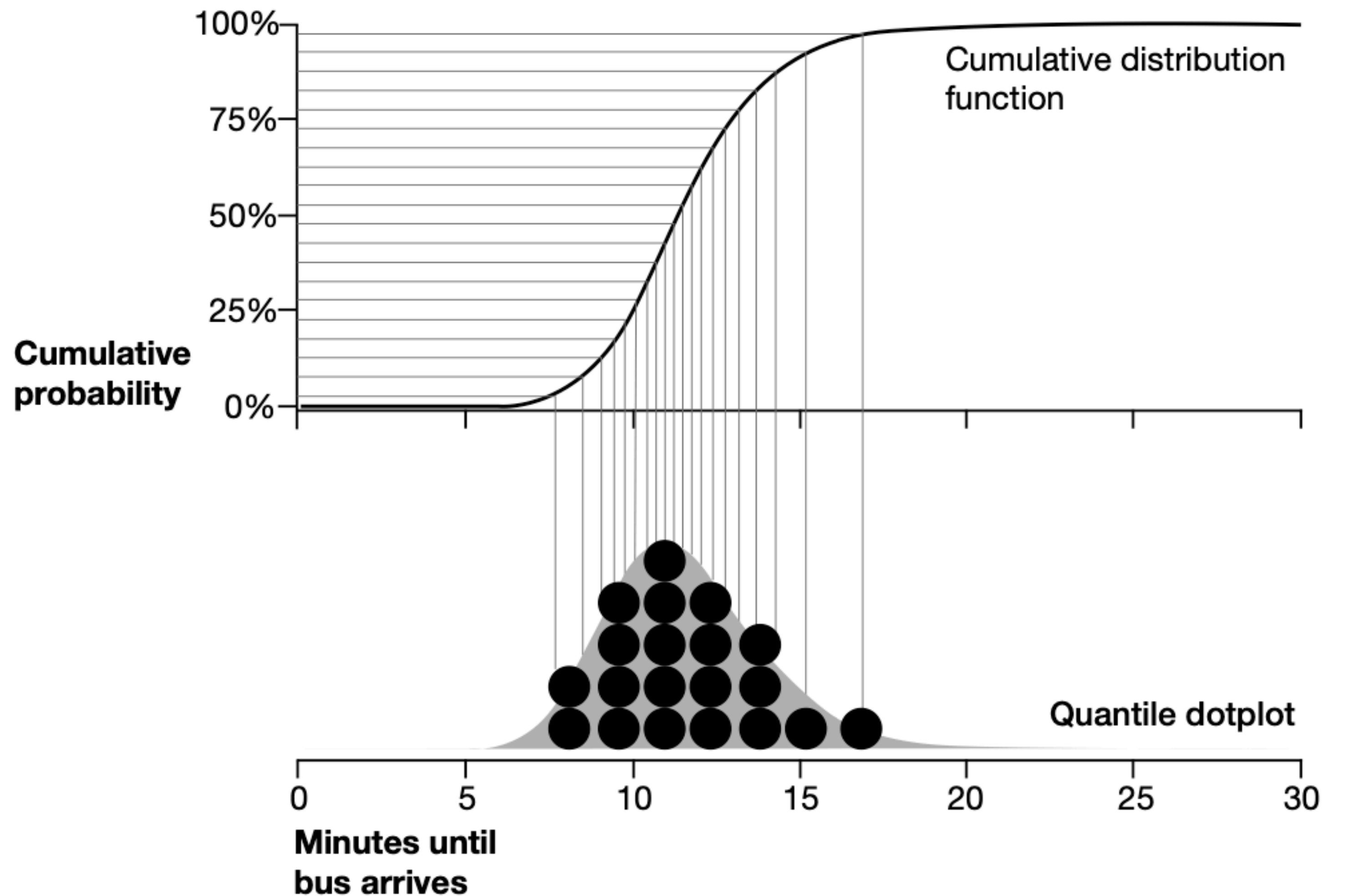
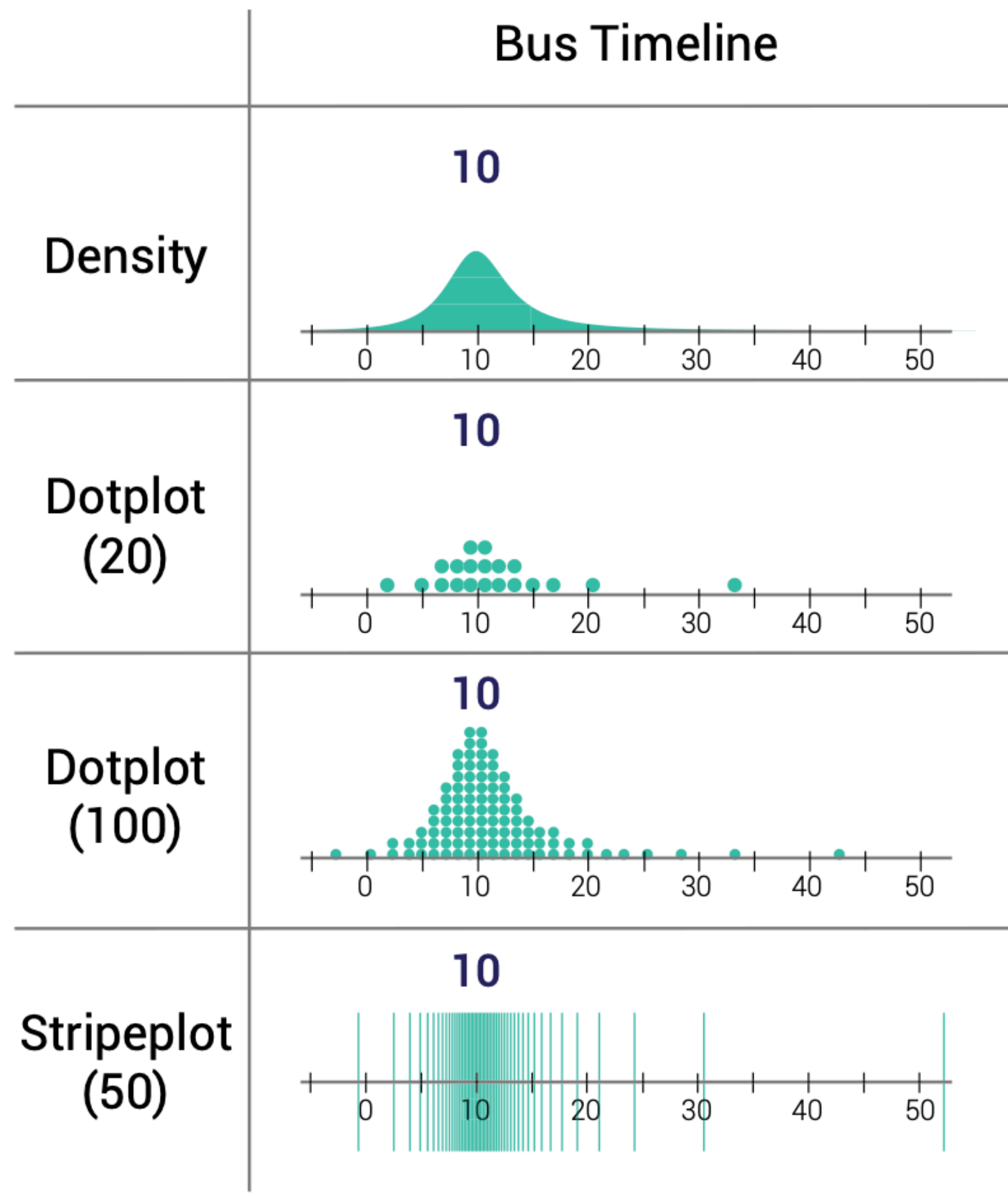
Value-Suppressing Uncertainty Map

For uncertainty, use **visual variables** instead of visualizing point estimates

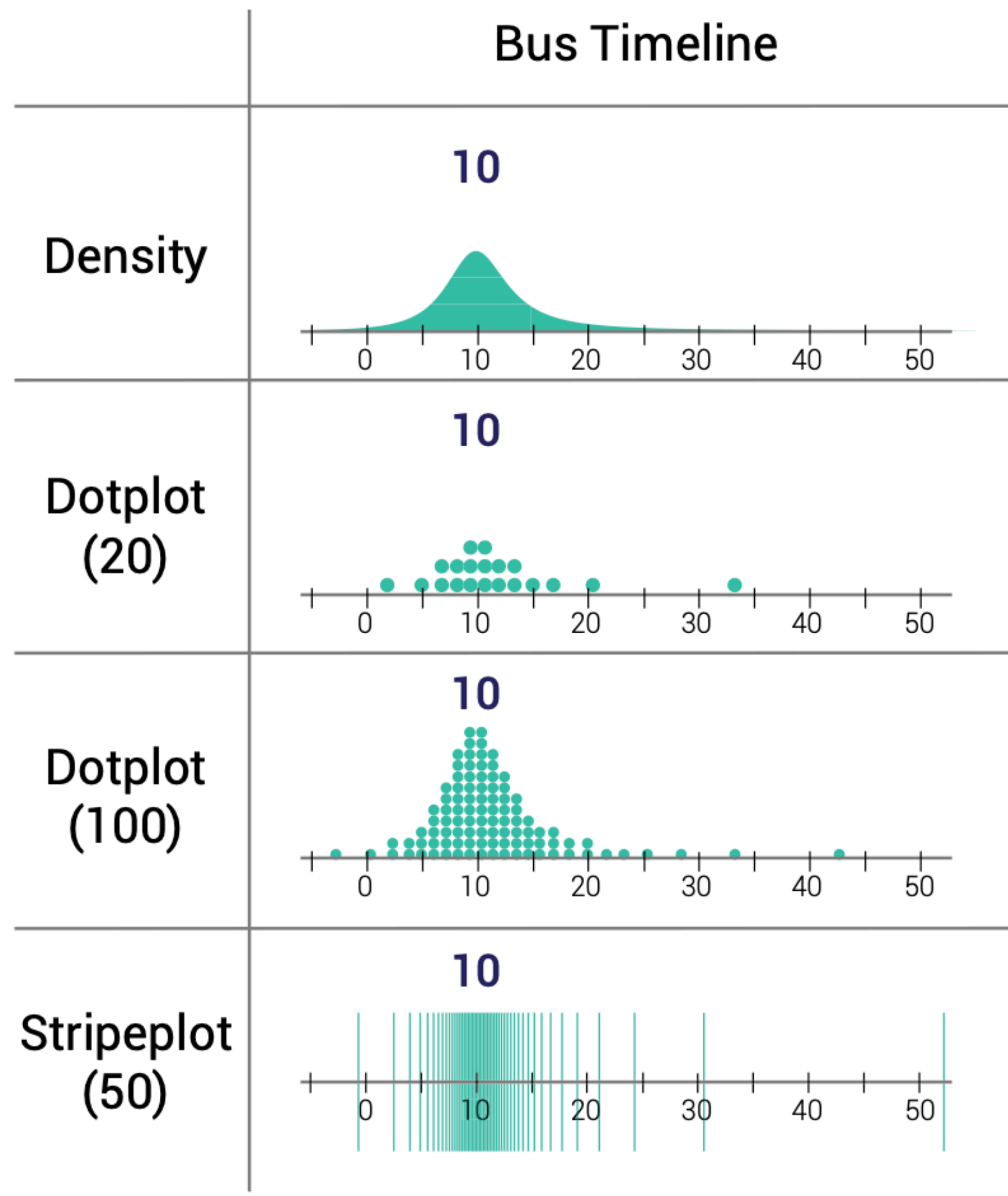


[Wood et al., 2012]
[Boukhelifa et al., 2012]

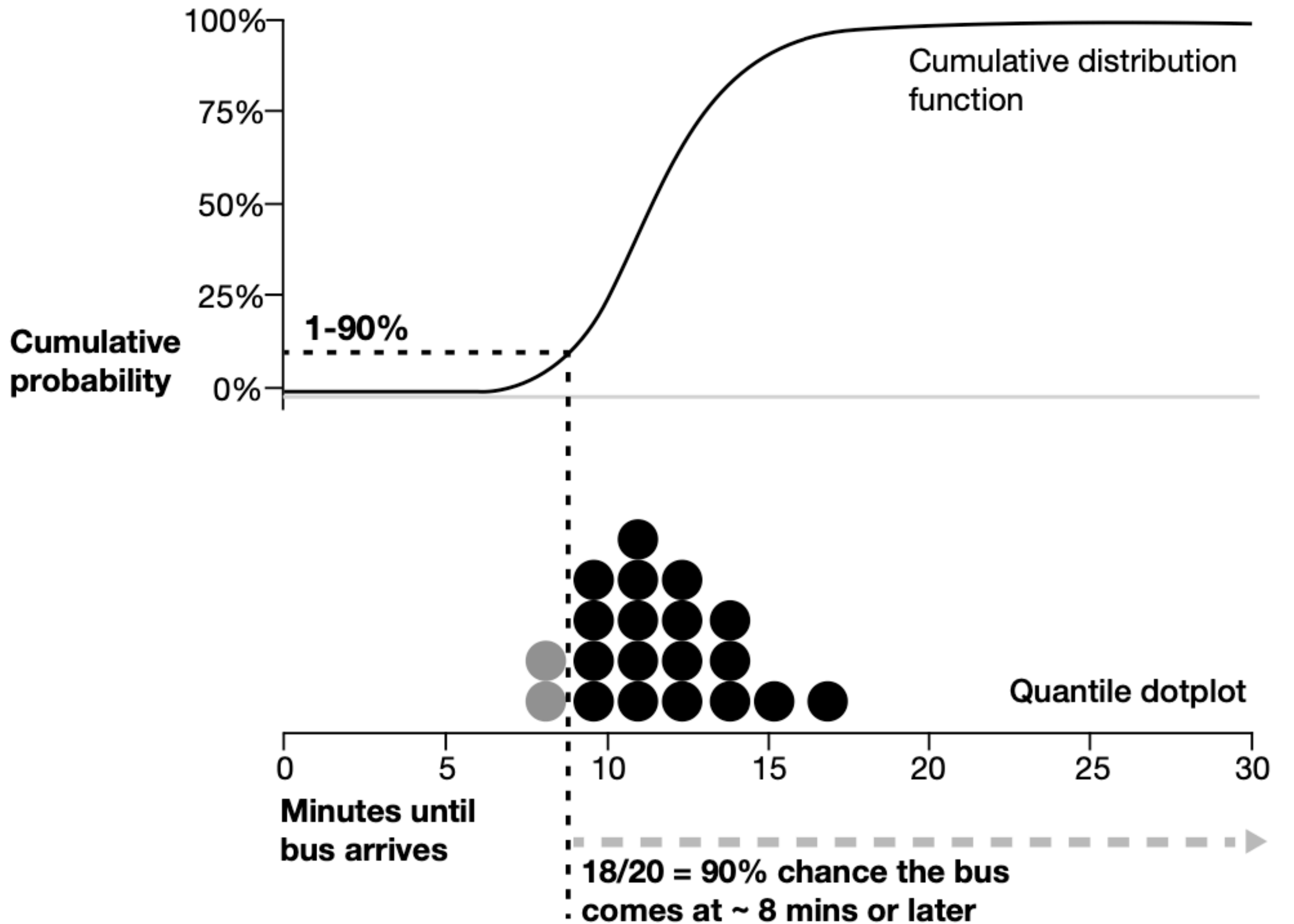
"Set of draws" technique



"Set of draws" technique

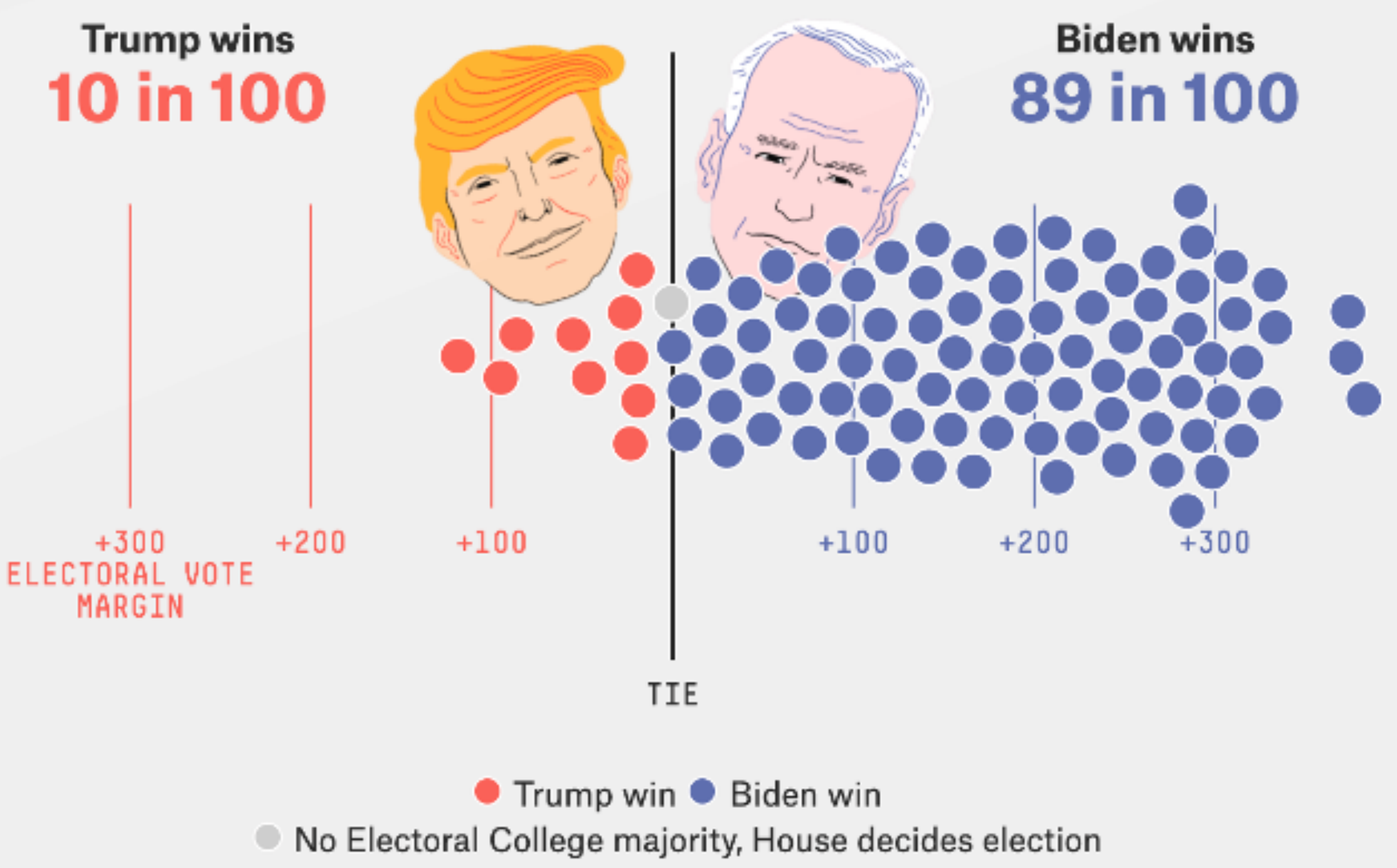


[Kay et al., 2016]



Biden is favored to win the election

We simulate the election 40,000 times to see who wins most often. The sample of 100 outcomes below gives you a good idea of the range of scenarios our model thinks is possible.



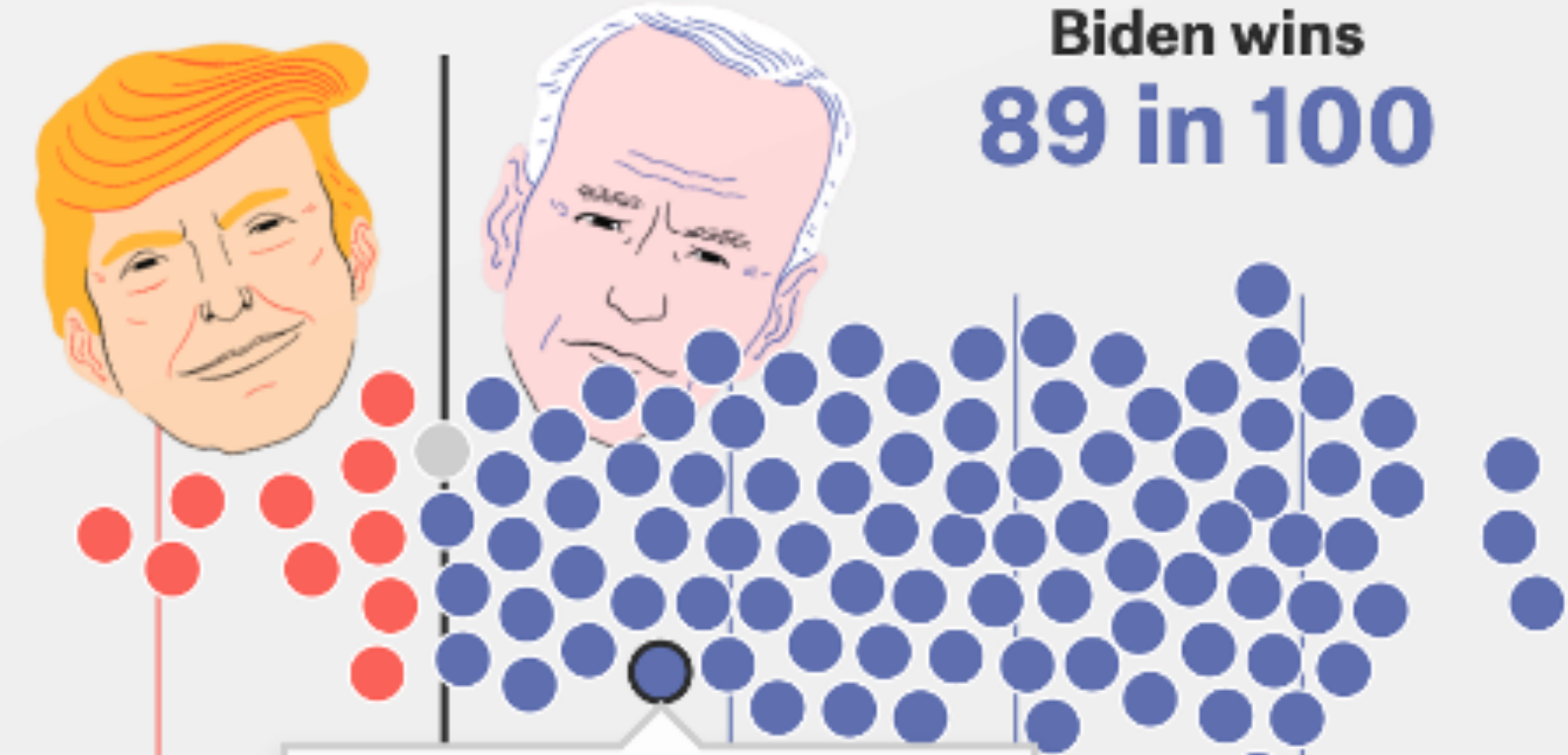
Don't count the underdog out! Upset wins are surprising but not impossible.

Biden is *favored* to win the election

We simulate the election 40,000 times to see who wins most often. The sample of 100 outcomes below gives you a good idea of the range of scenarios our model thinks is possible.

Trump wins
10 in 100

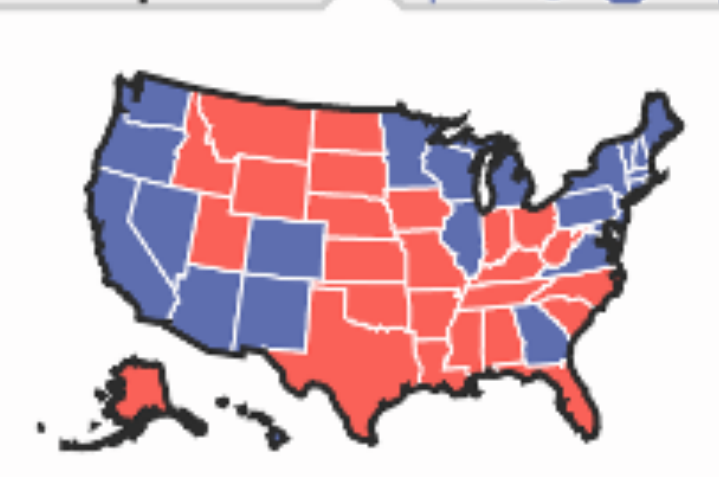
Biden wins
89 in 100



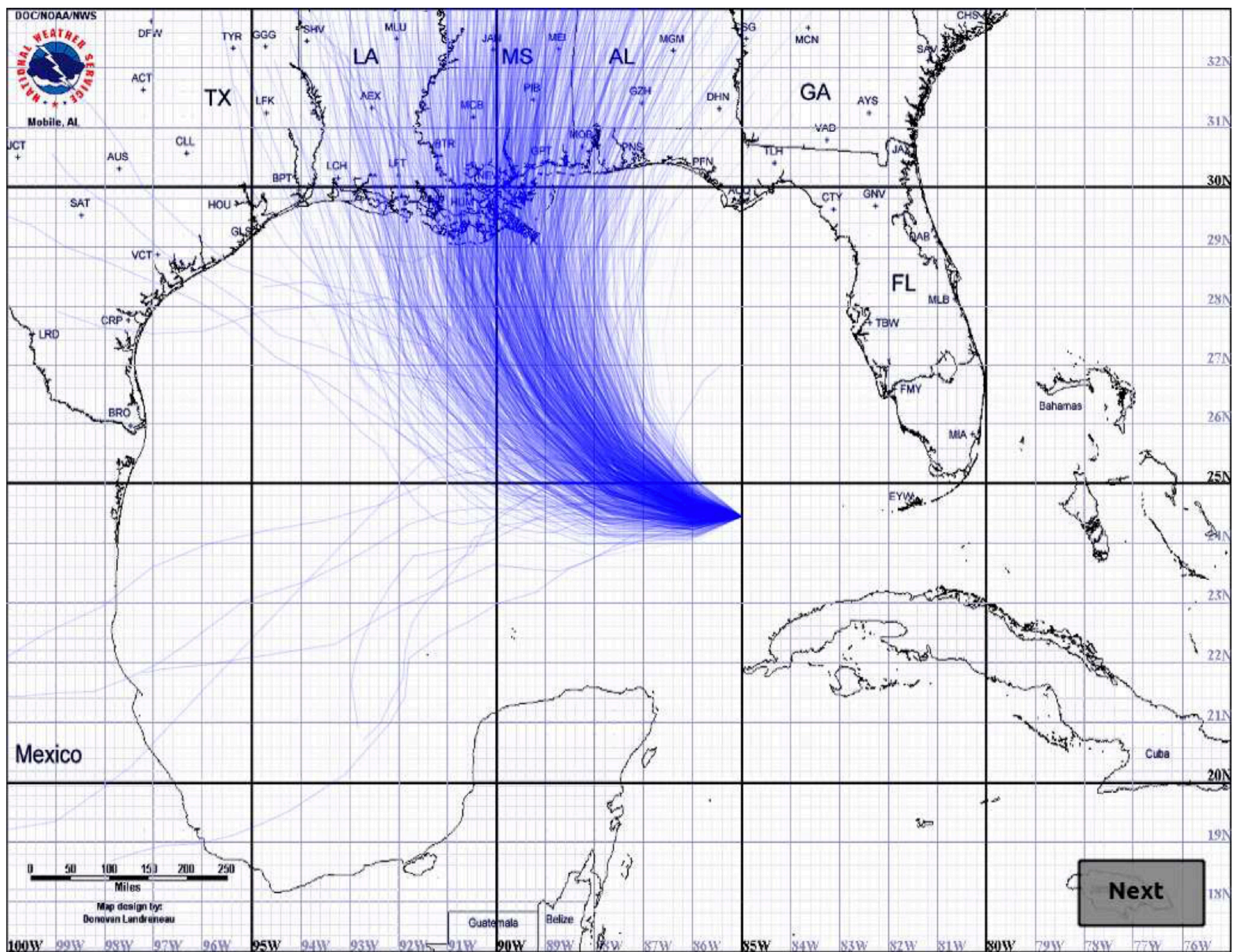
+300
+200
+100
ELECTORAL VOTE MARGIN

0
+300

Don't count the underdog out! Upset wins are surprising but not impossible.



● Trump
● No Electoral College
— ELECTORAL VOTES —
Biden ✓ 306
Trump 232



• TheUpshot

STATISTICAL NOISE

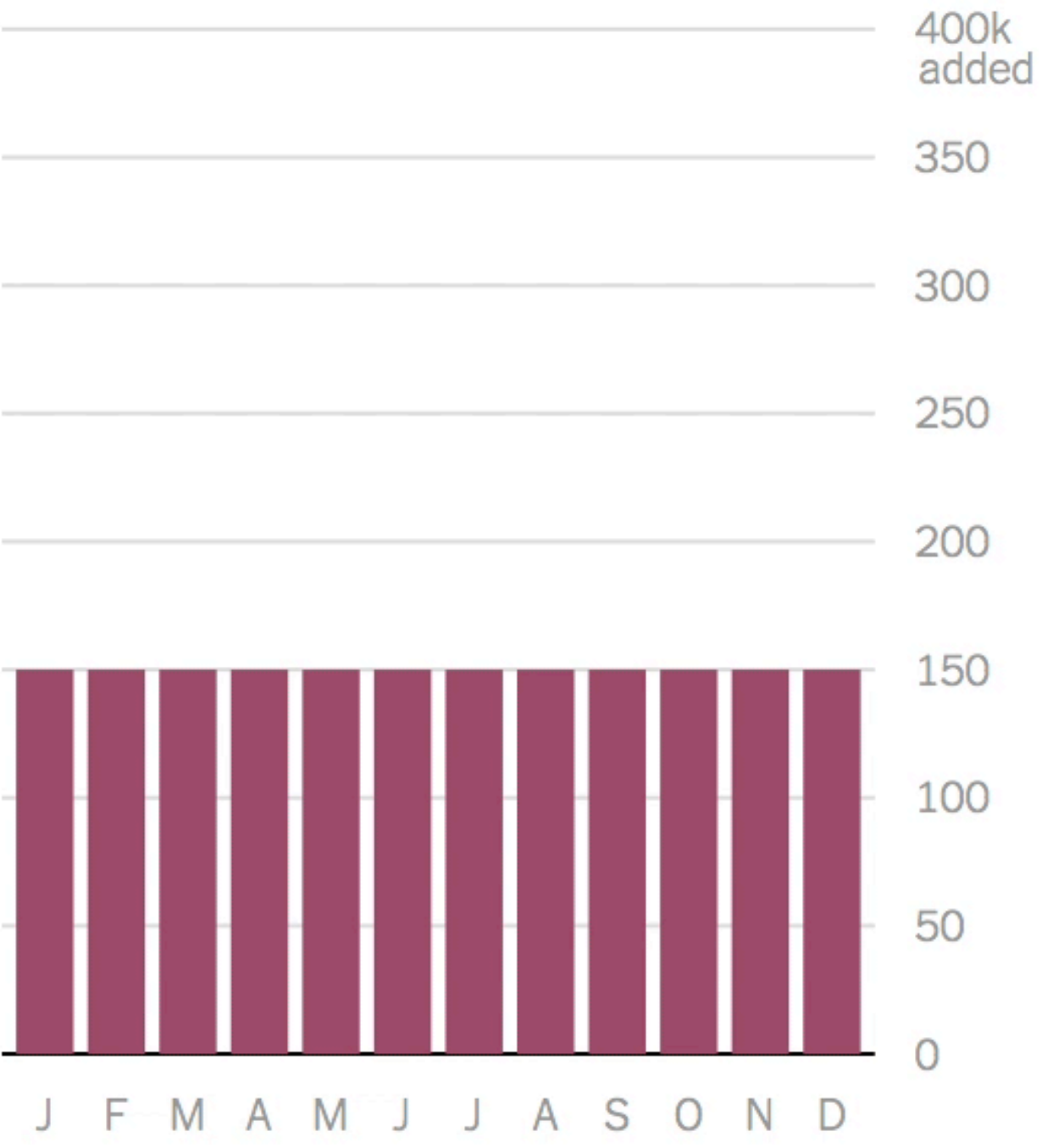
How Not to Be Misled by the Jobs Report

If the economy actually added 150,000 jobs last month, it would be possible to see any of these headlines:

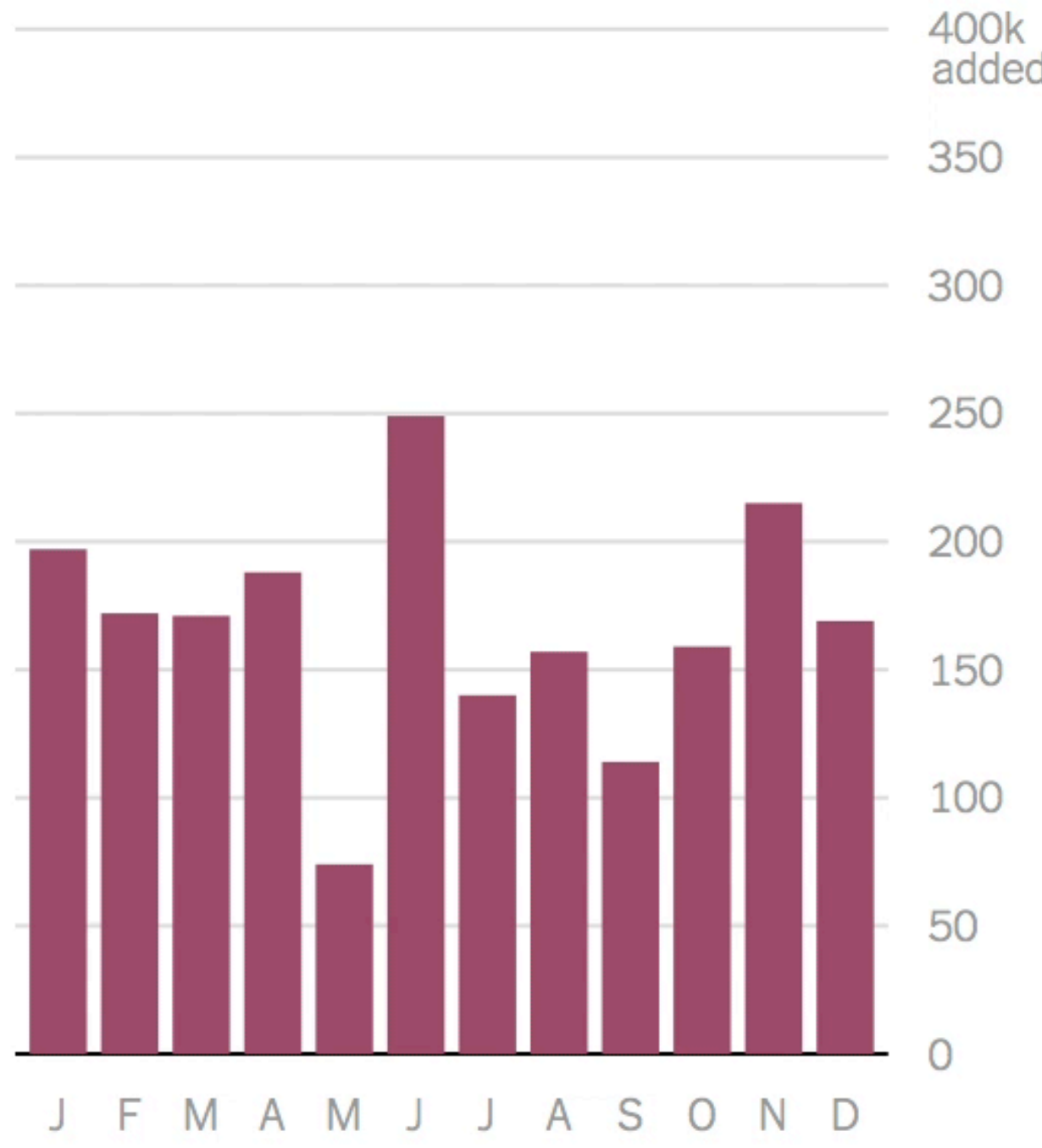
The jobs number is just an estimate, and it comes with uncertainty.



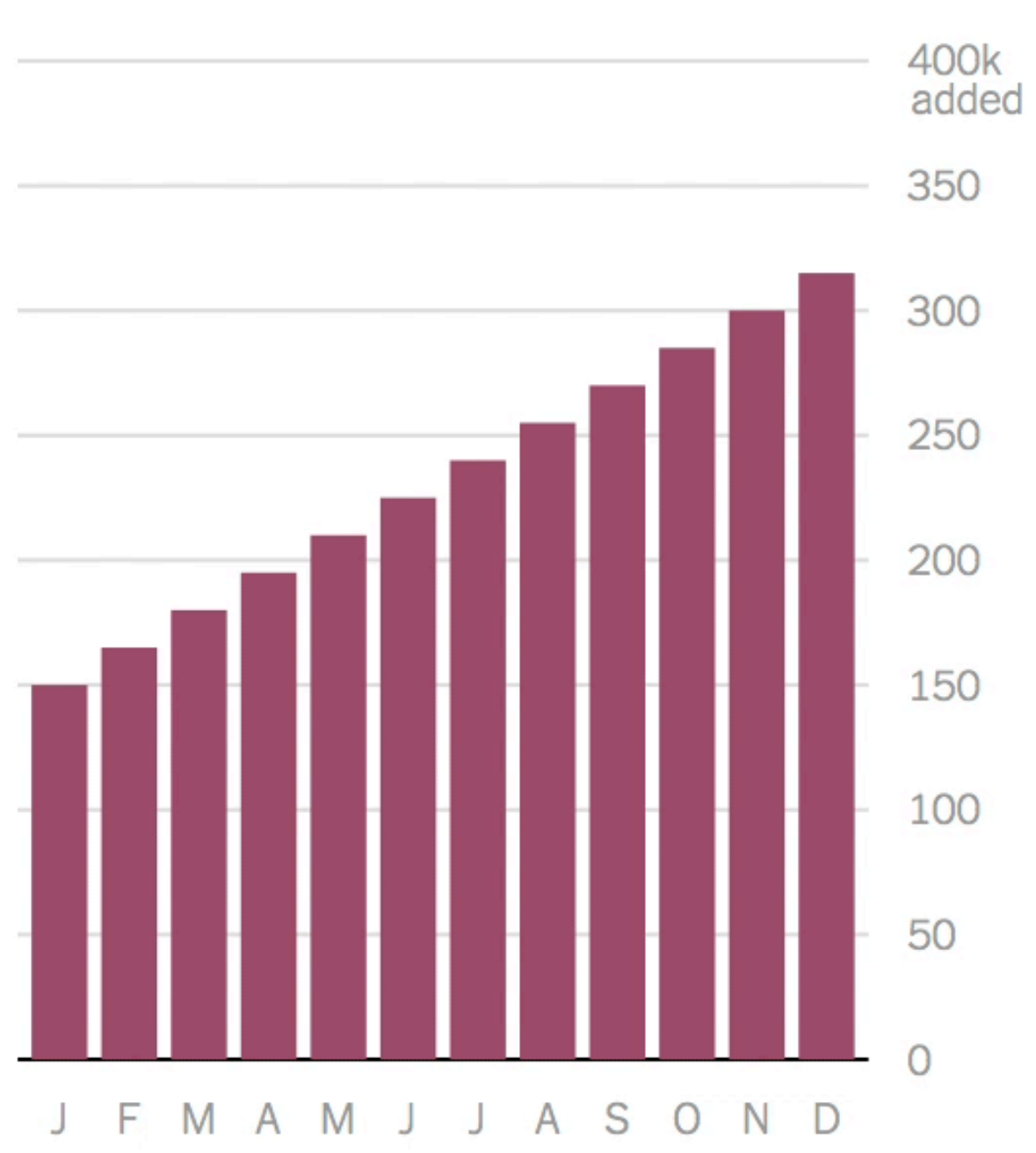
If job growth **were actually steady** over the last 12 months...



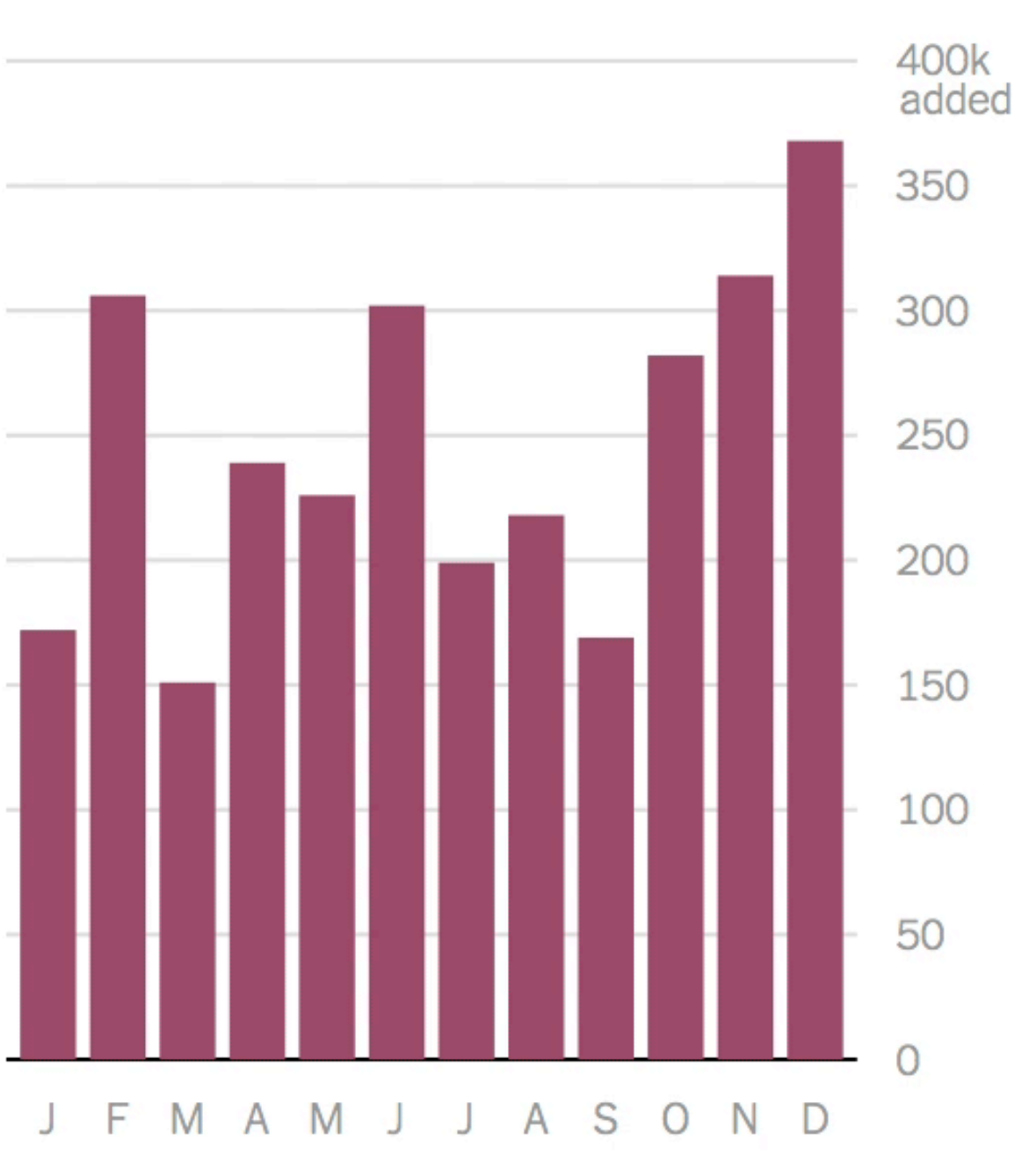
...the jobs report **could look like this:**



If job growth **had been accelerating...**



...the jobs report **could look like this:**



SPIN

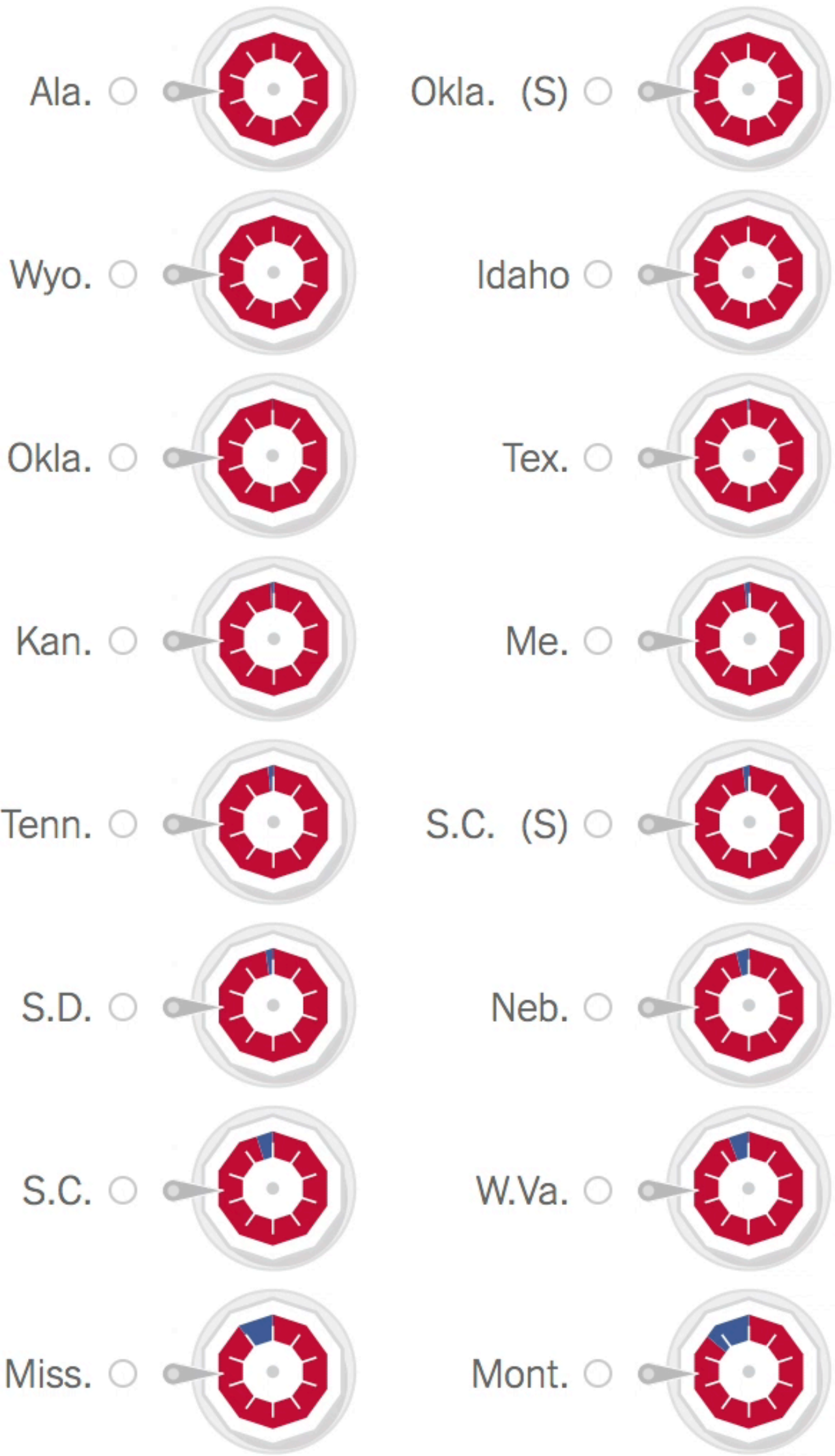
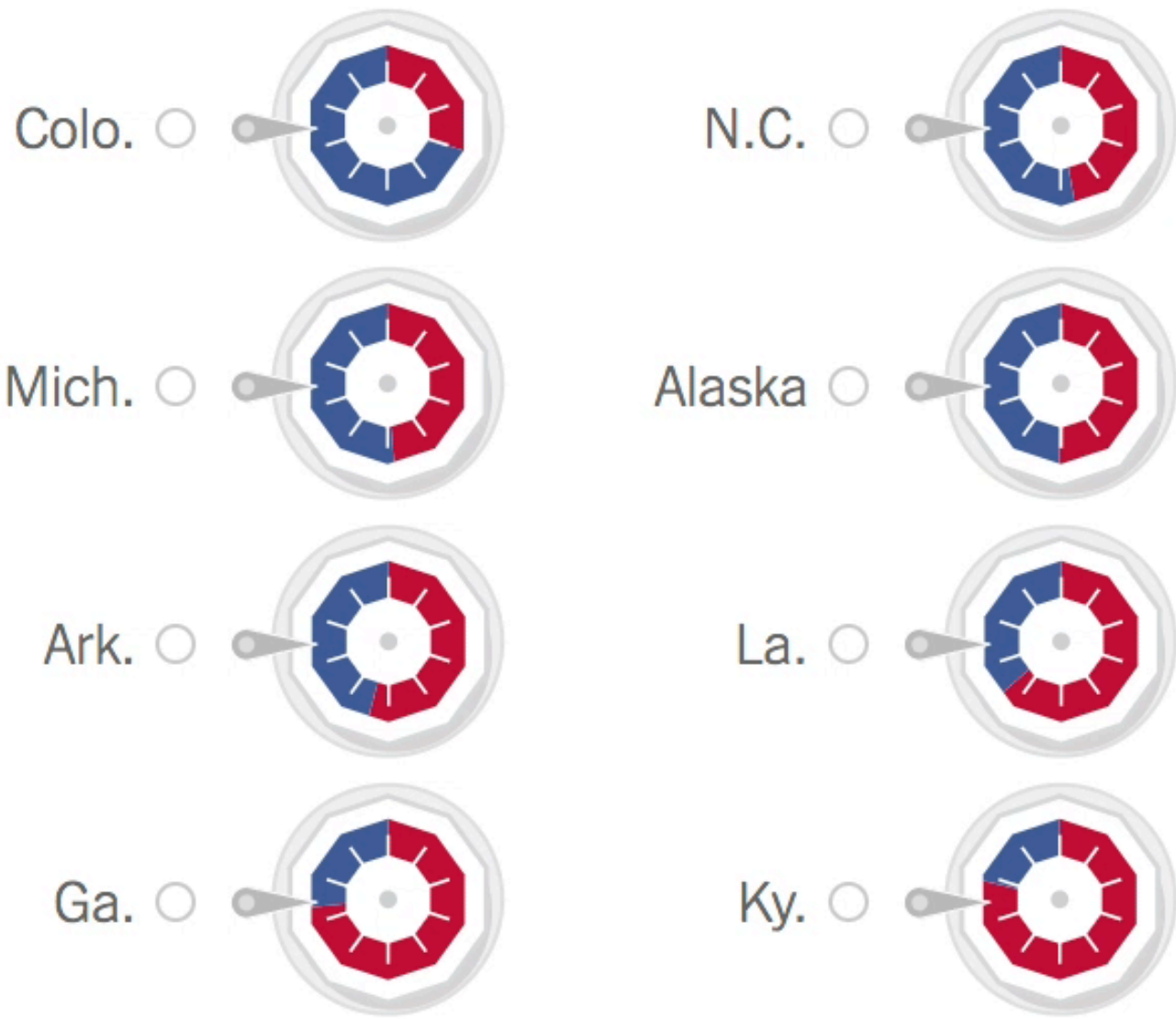
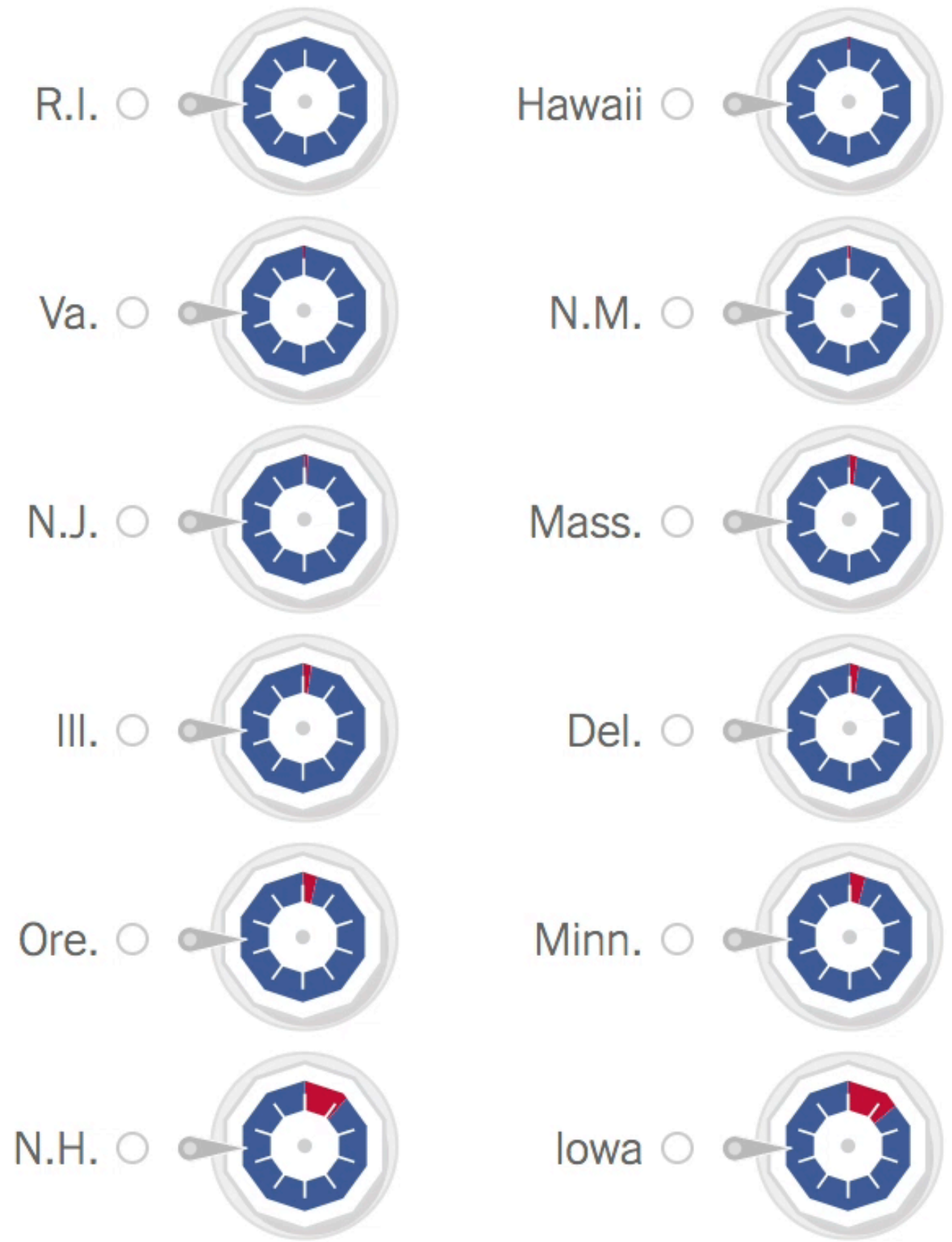
Democrats: ??

Republicans: ??

Likely Democratic

Competitive

Likely Republican



Here's a simulation of who could be in and who could be out if the candidates' averages were rounded to the nearest whole number.

If the averages are correct, but rounding is to the nearest whole number:



Rounding to fewer decimal places could be welcome news for candidates on the cusp like Mr. Santorum (who has already [called](#) the debate rules “a miscarriage”), Mr. Kasich or Mr. Jindal.

Uncertainty

What does it mean?

How should I visualize it?

Building models is necessary to quantify uncertainty.

It is important to communicate the variability in model outcomes.

Dynamic or ensemble displays can help communicate complex models.

Why Authors Sometimes Don't Visualize Uncertainty

A visualization expresses a signal

Authors simplify, crystallize, abstract the complexity of data.

Process validates signal

Authors decide whether process has "low enough" uncertainty.

Uncertainty obfuscates signal

Could distract, or require too much work from the reader.

Uncertainty

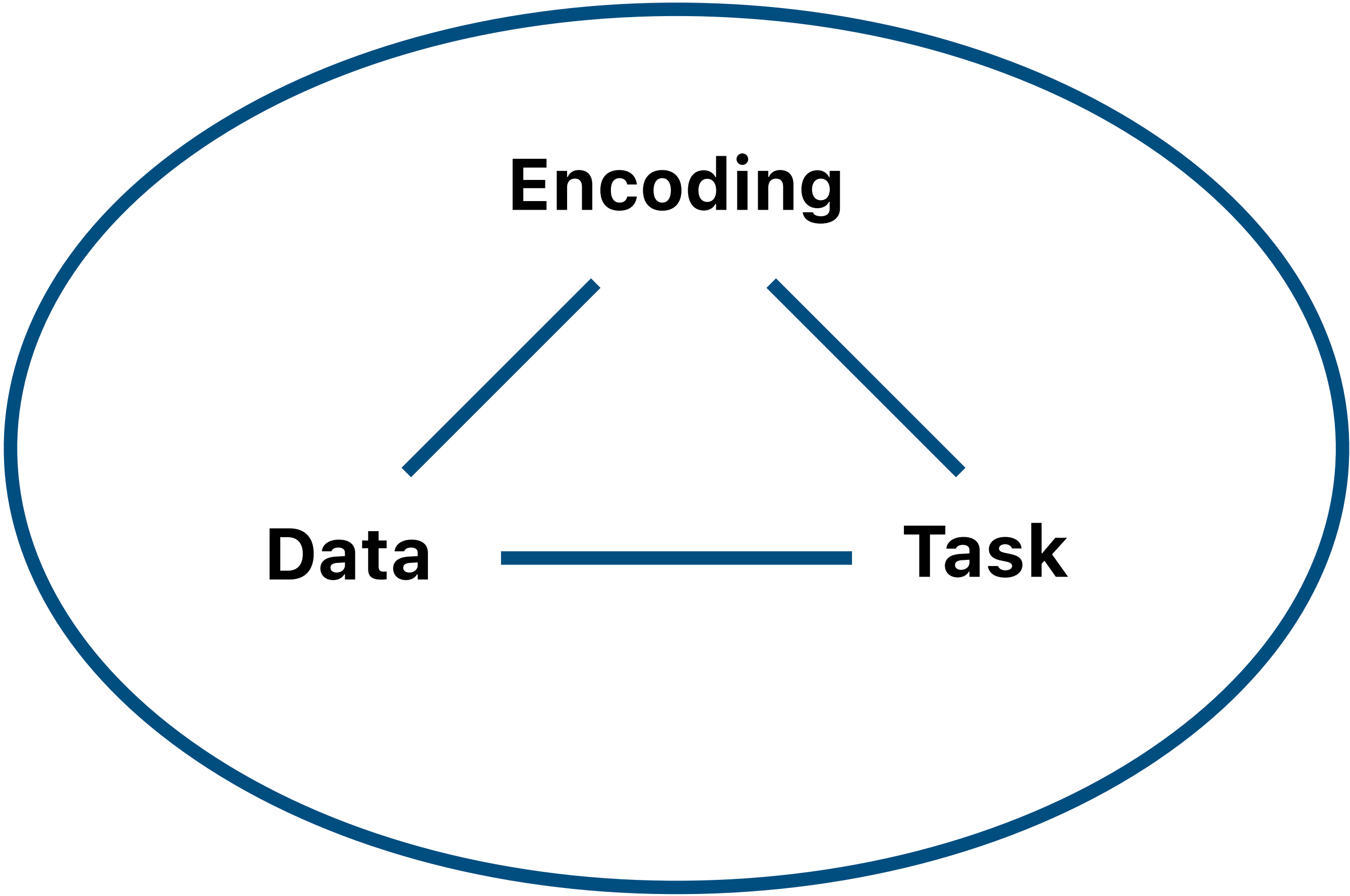
What does it mean?

Lots of things!

How should I visualize it?

It depends!

Conclusion



Users & Domain

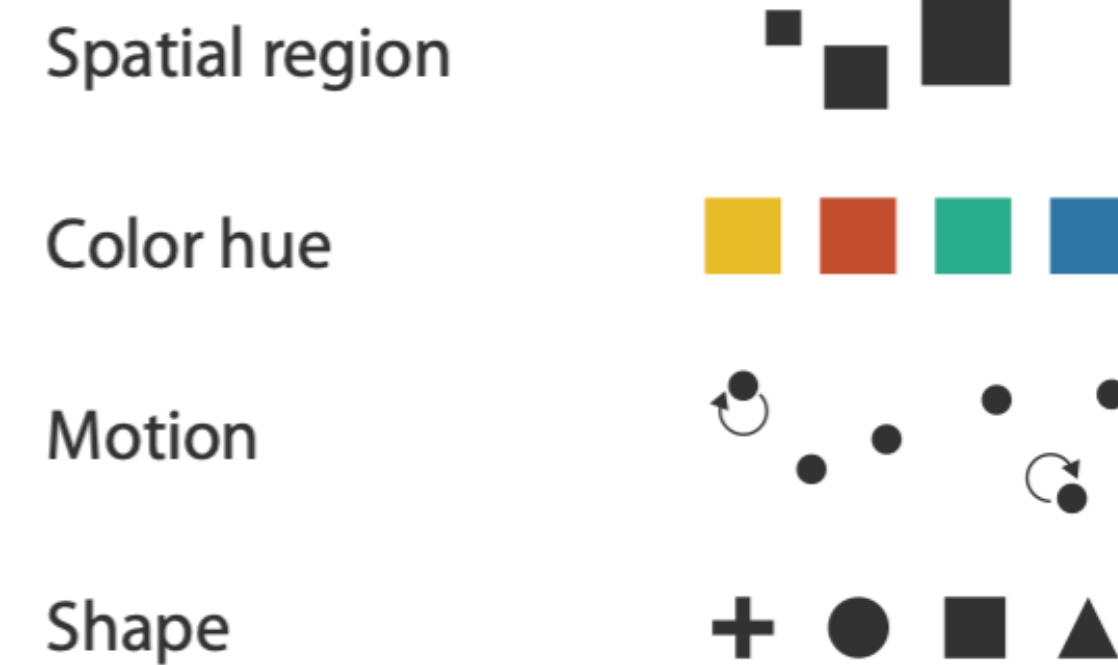
Data and Image Models

Channels: Expressiveness Types and Effectiveness Ranks

➔ Magnitude Channels: Ordered Attributes



➔ Identity Channels: Categorical Attributes



Tamara Munzner, *Visualization Analysis and Design* (2014).

Visual Encoding and Dark Patterns

Truncating the y-axis?

To emphasize Q-interval (vs. Q-ratio)
If the zero value doesn't make much sense.
If it is the norm (e.g., stock charts).

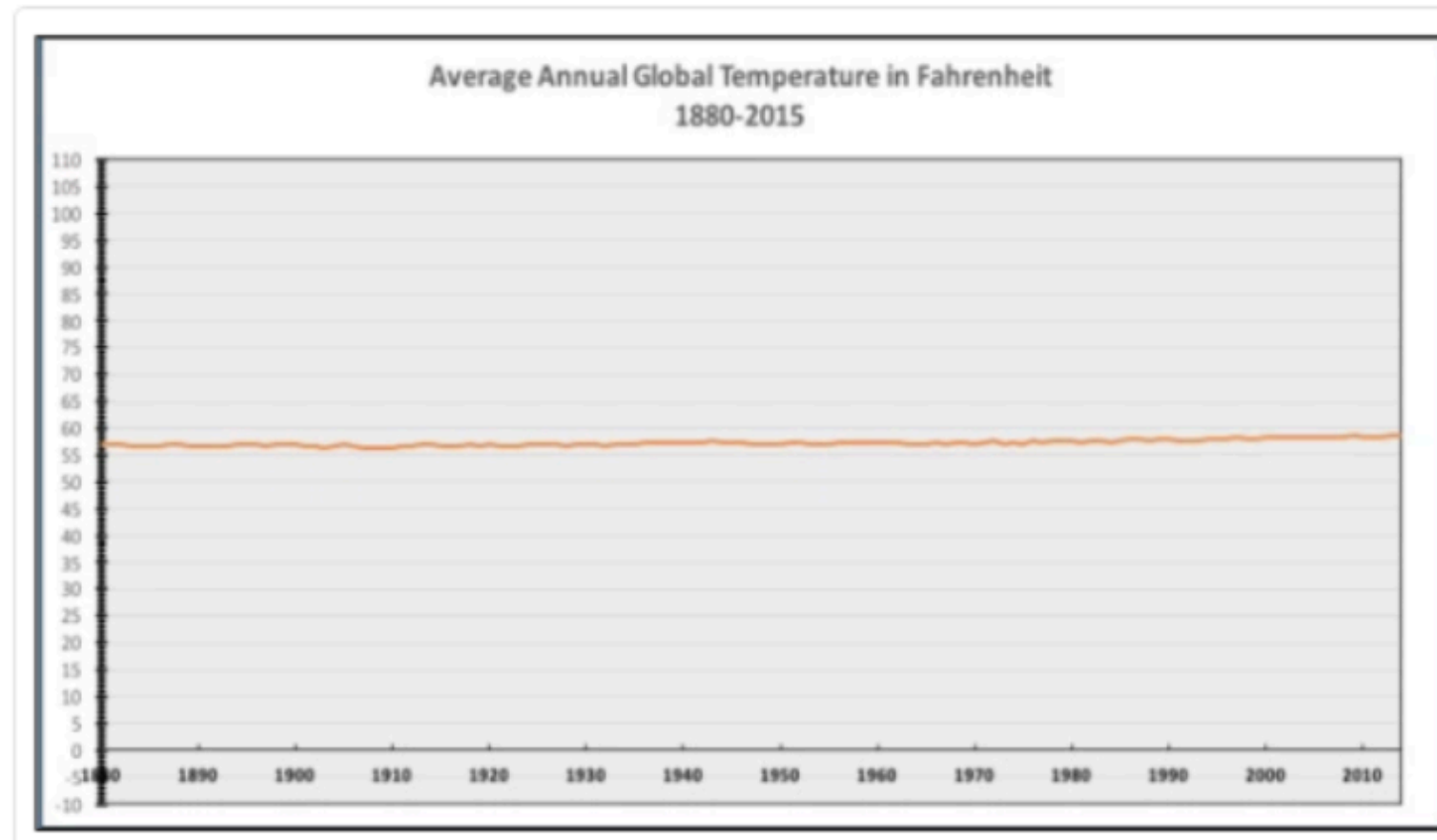


National Review
@NRO

Follow

The only #climatechange chart you need to see. natl.re/wPKpro

(h/t @powerlineUS)



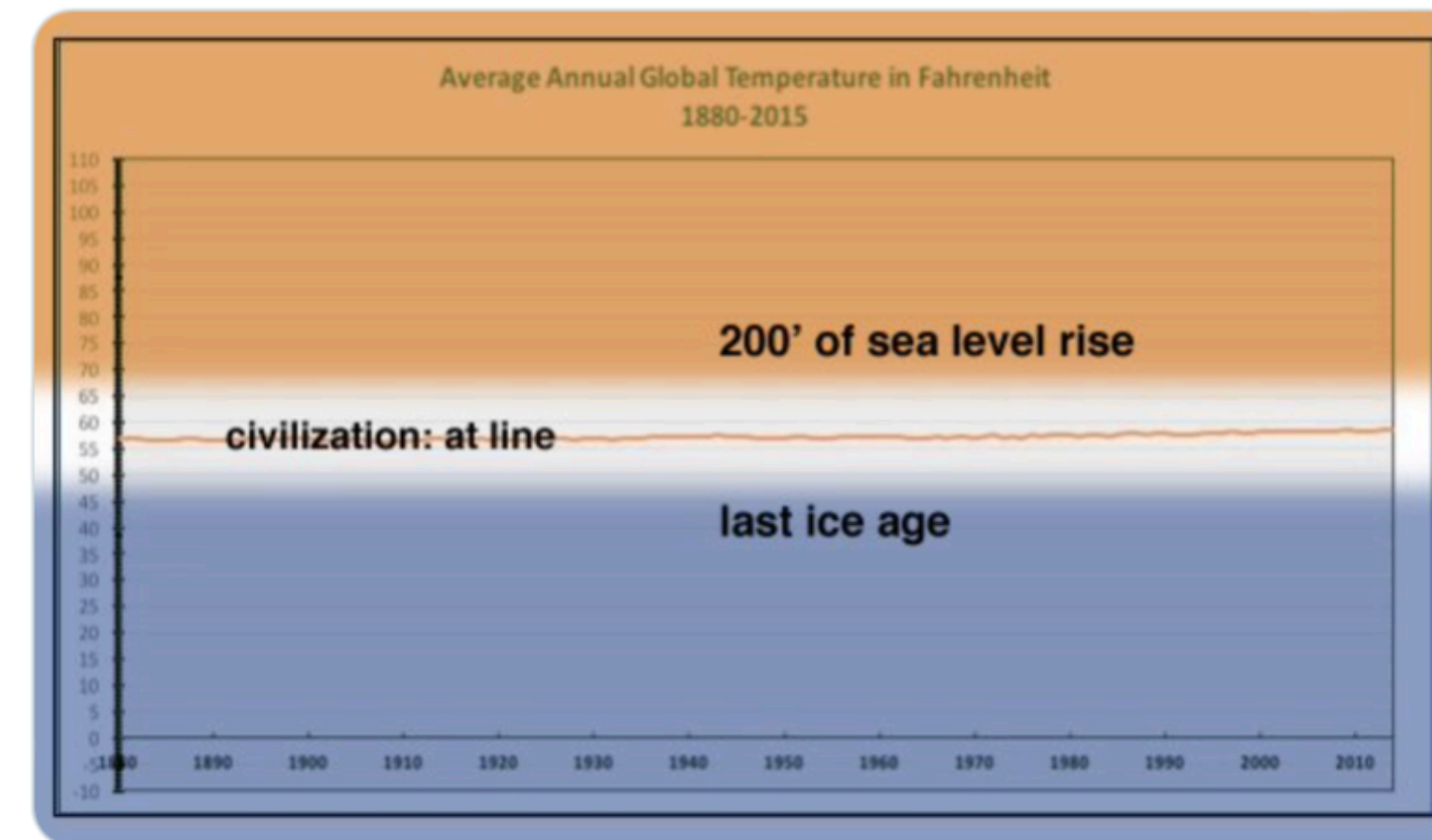
12:36 PM - 14 Dec 2015



City Atlas
@cityatlas

Replying to @NRO

.@NRO @powerlineUS @bradplumer I'm sure someone else has fixed this for you, but here you go. Great idea, thx --



5:28 PM · Dec 14, 2015

78 Retweets 1 Quote Tweet 208 Likes

39

Perception

Graphical Perception Studies

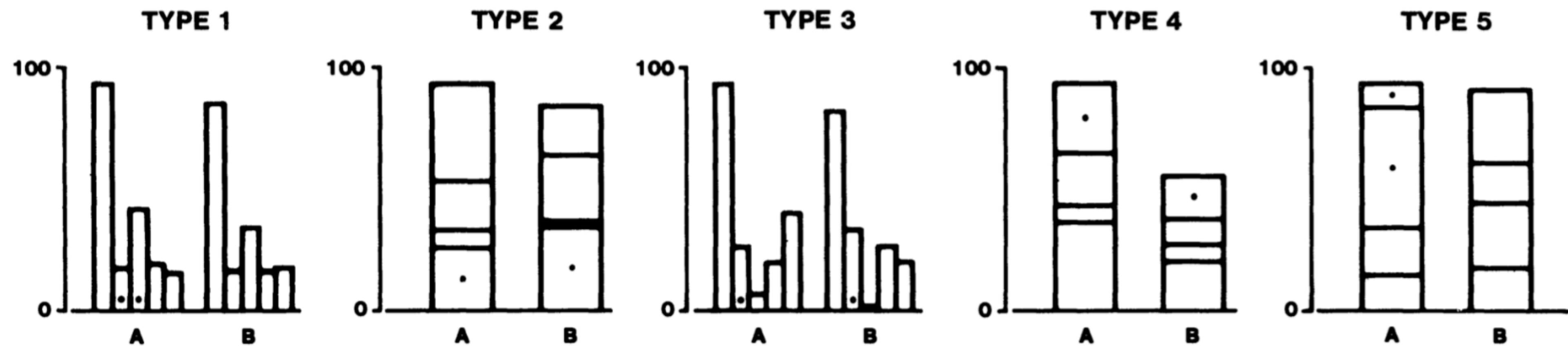


Figure 4. Graphs from position-length experiment.

What proportion is the smaller marked section of the larger?

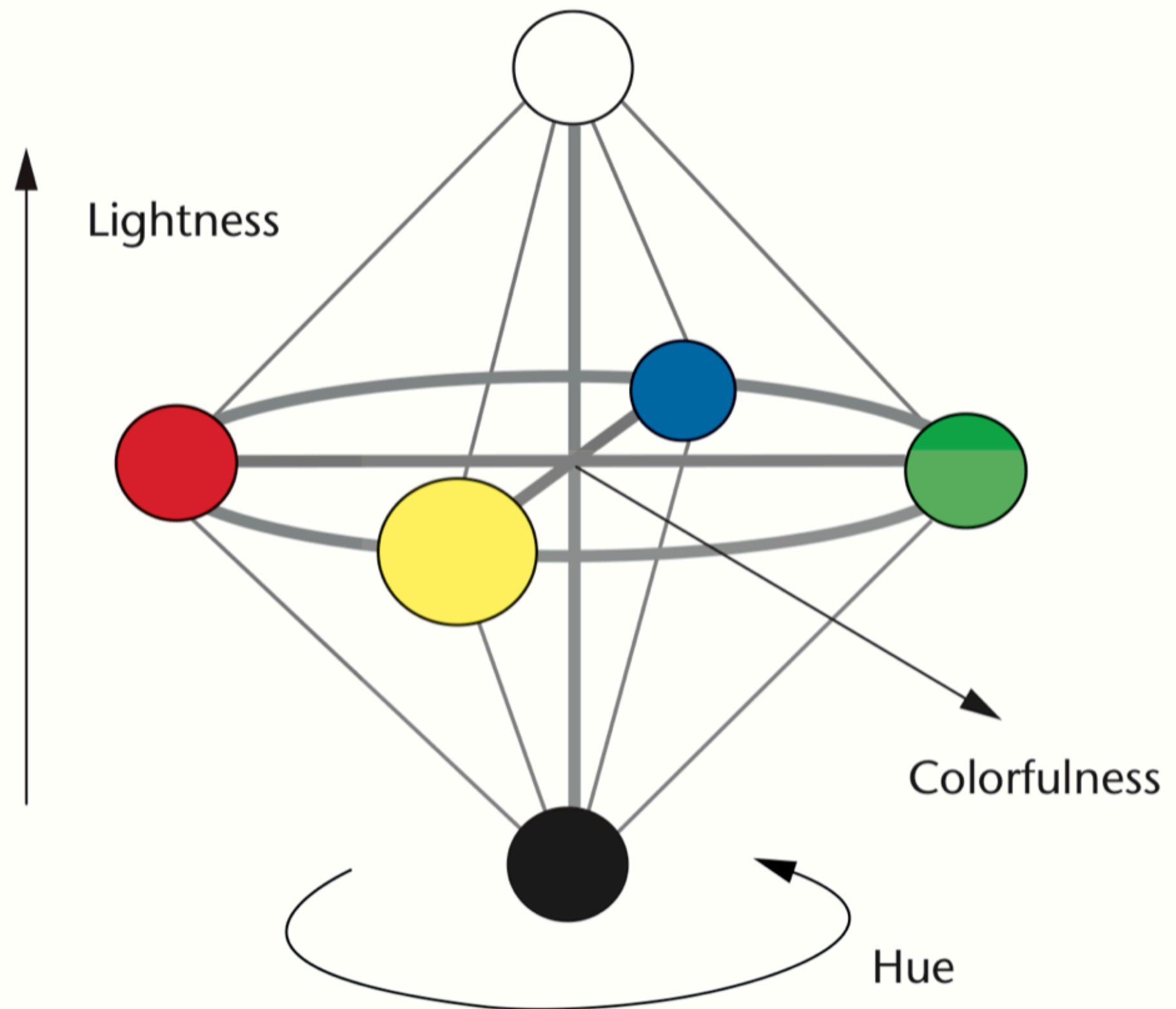
Color

OKLAB Color Space

Oklab is modern version of CIELAB that we recommend

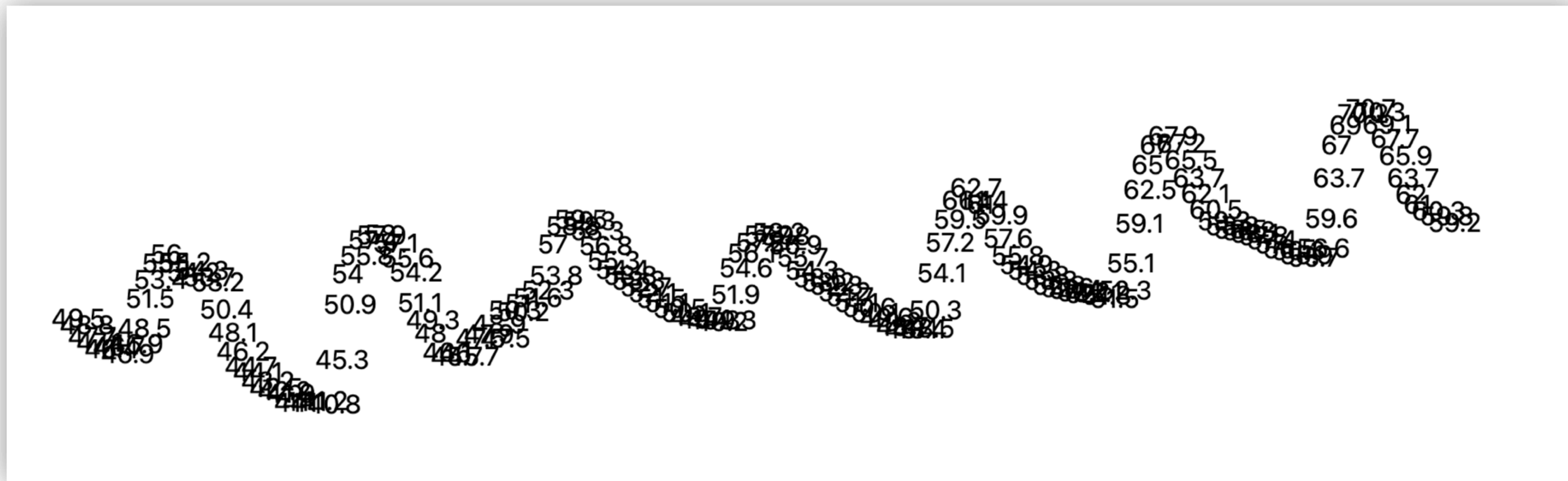
In CSS:

```
oklch(65% 50% 0)
```



JavaScript

Now, let's make our very first data visualization in JS:



[js-lecture/weather02/](#)

(demo)

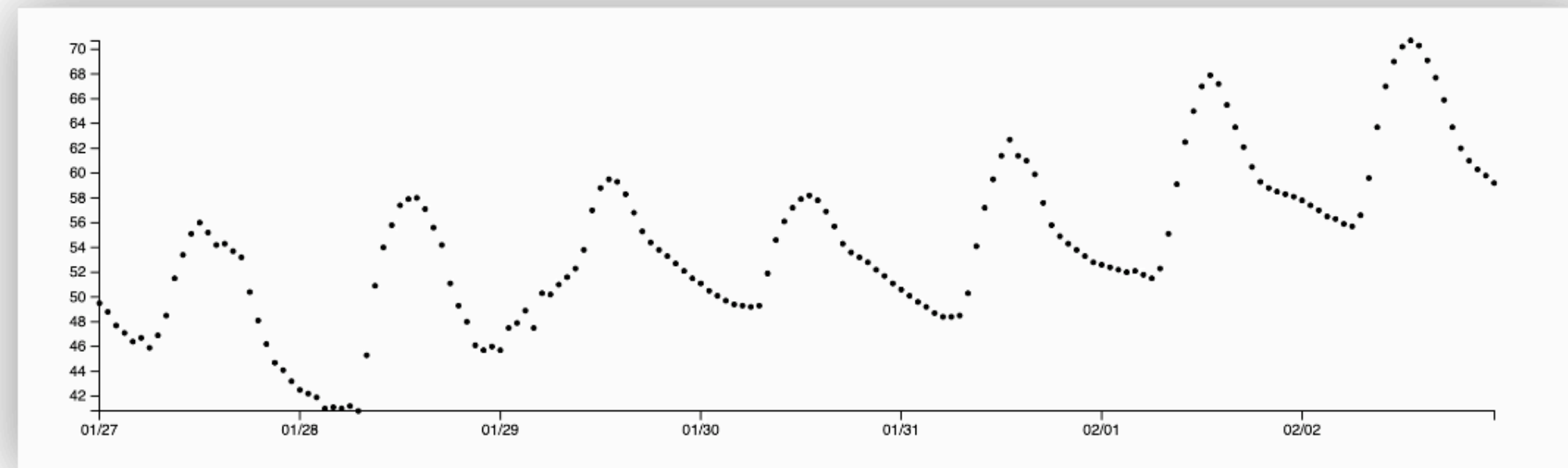
[js-lecture/weather03/](#)

(demo)

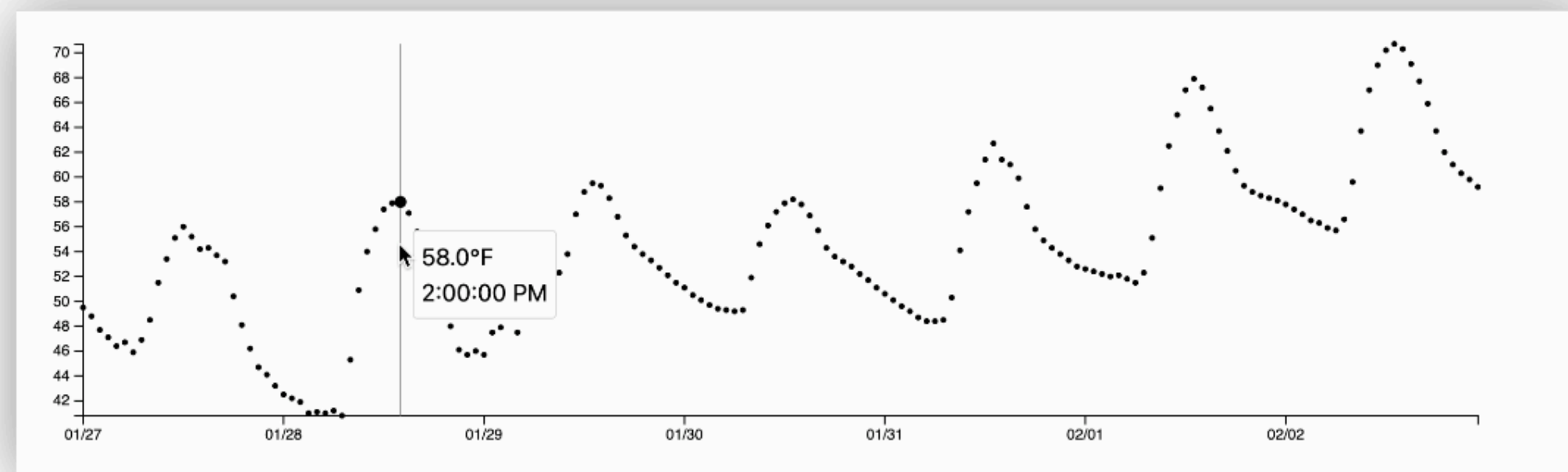
D3

Step 5: Improving our tooltip

Before:

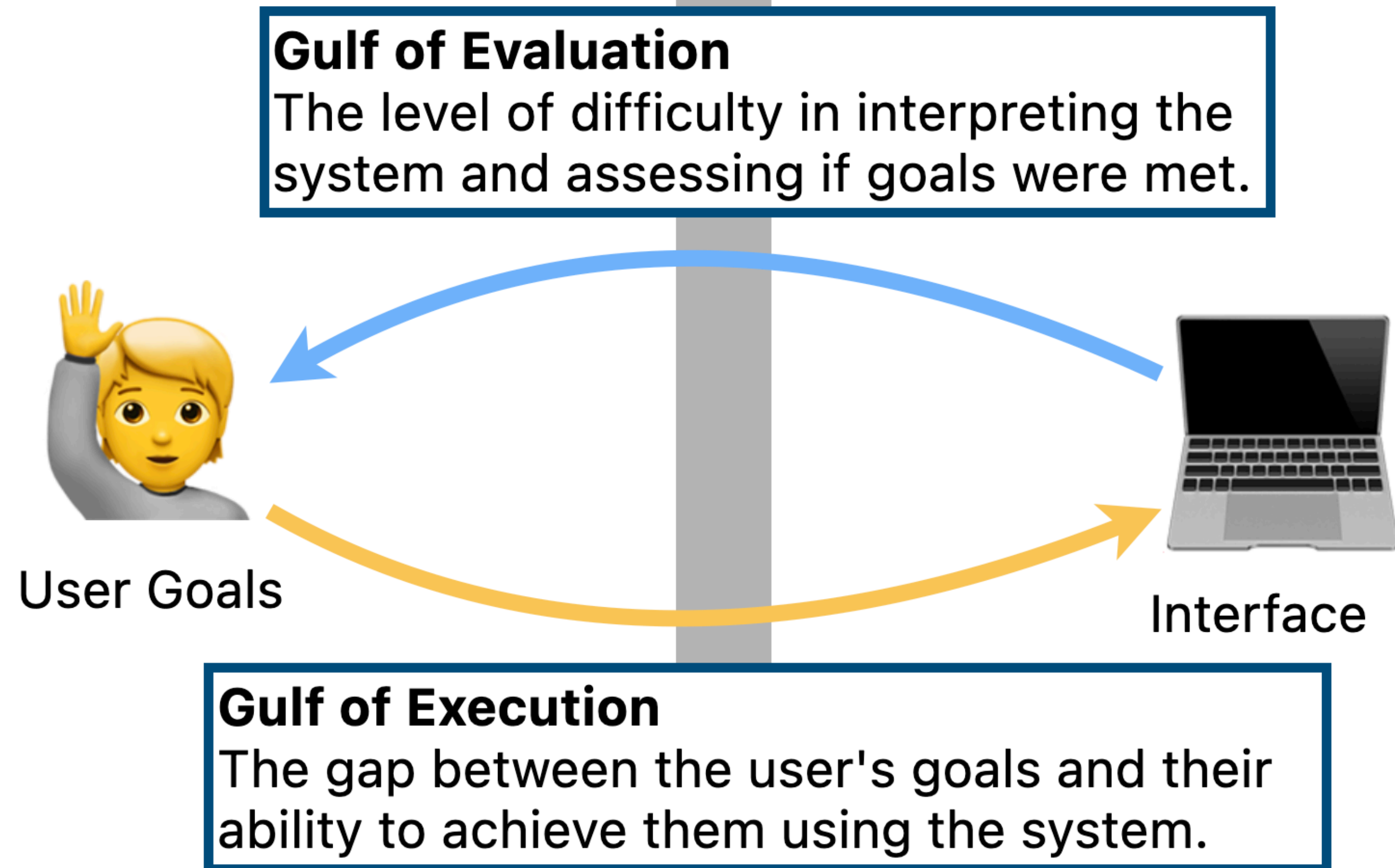


After:



Demo: [d3-lecture/weather05](#)

Interaction



Maps

Choropleth

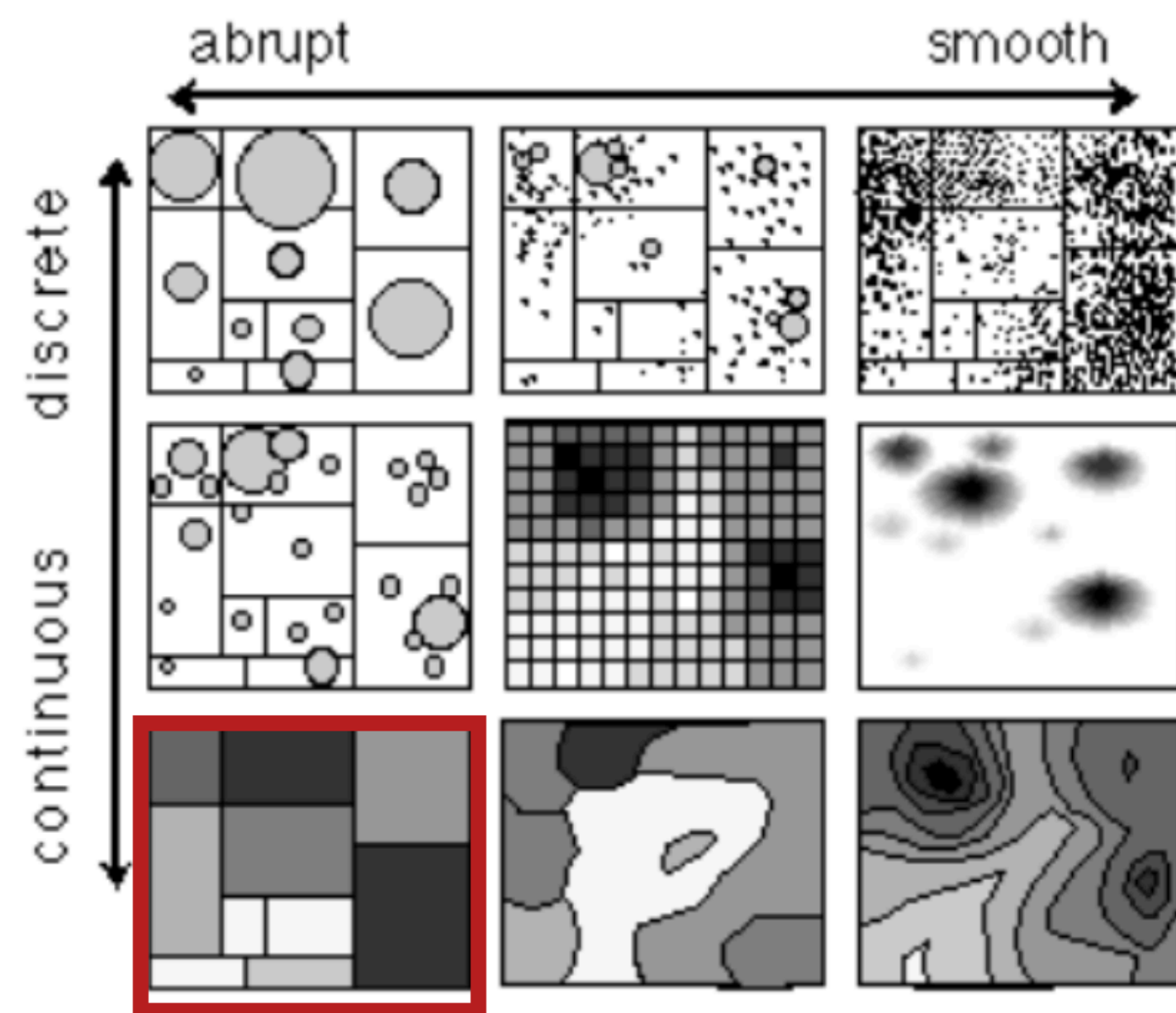
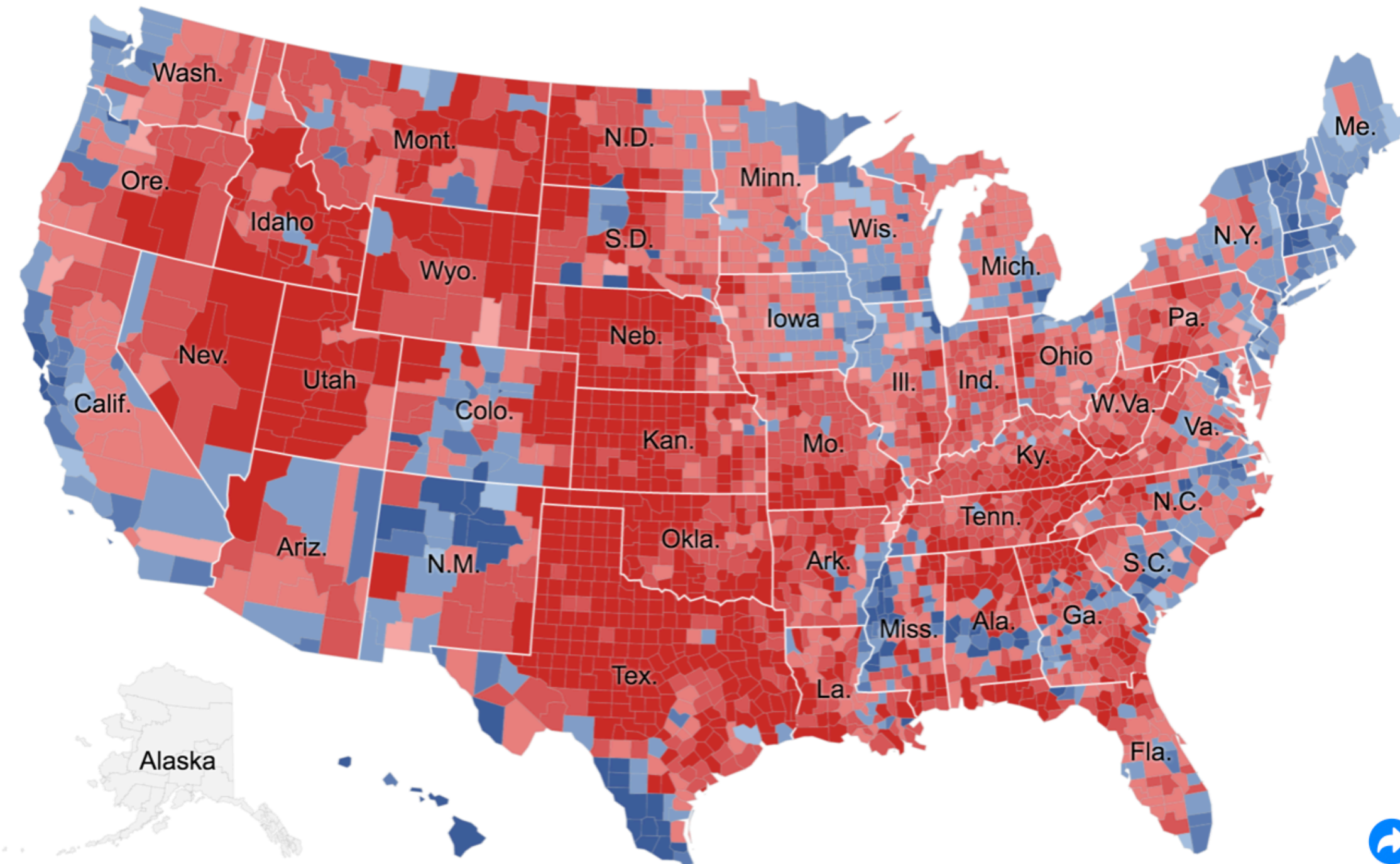


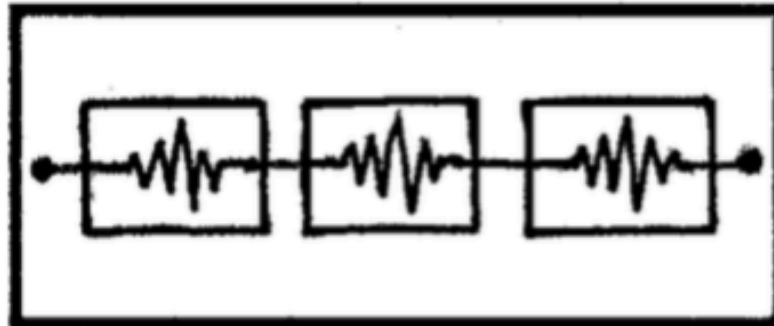
Fig. 9. Possible 2D translations of the 3D data models shown in figure 8.



<https://www.nytimes.com/interactive/2016/11/01/upshot/many-ways-to-map-election-results.html>

Narrative

Interactive Slideshow



R2
D3

A visual introduction to machine learning

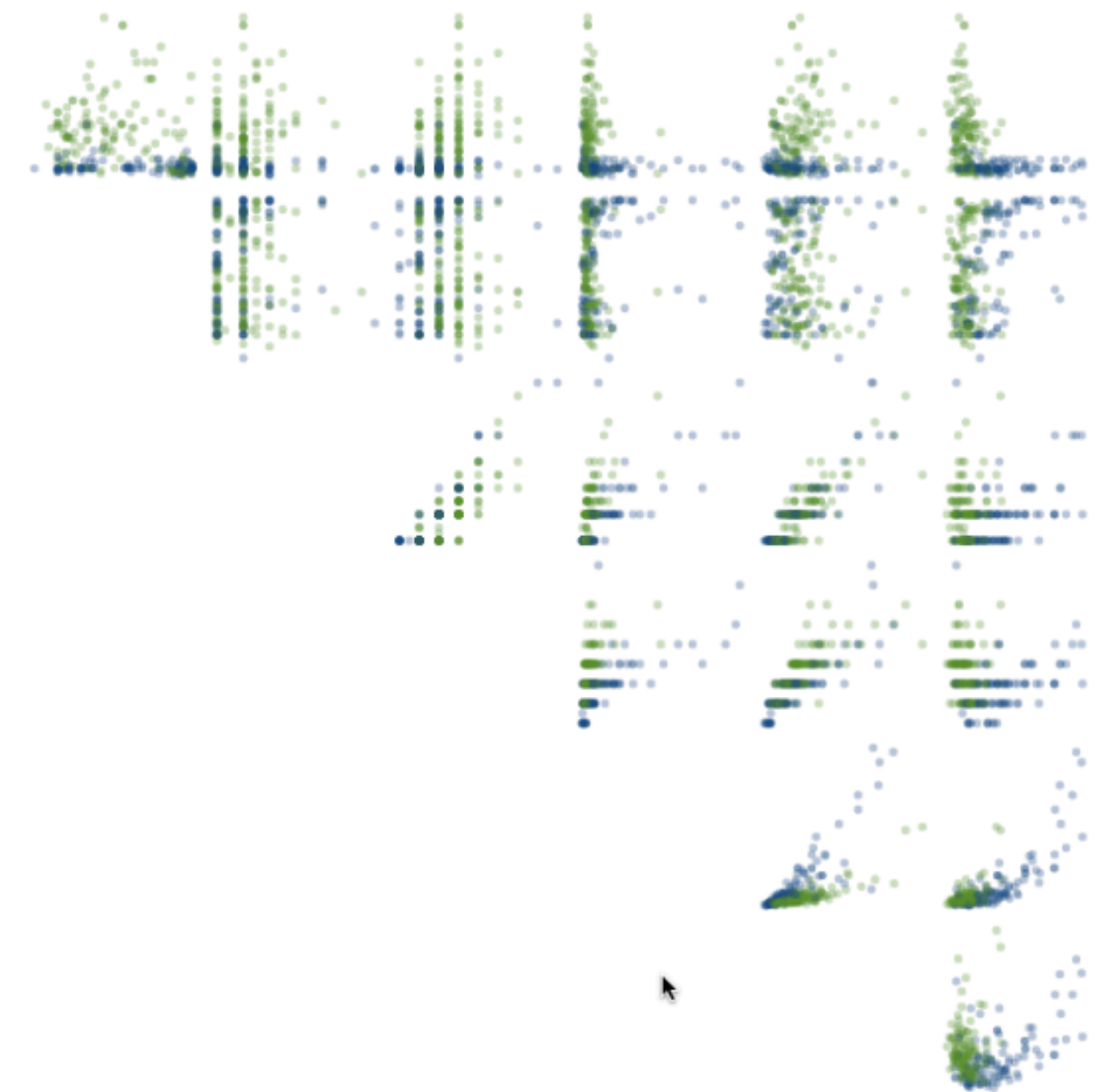
English

In machine learning, computers apply **statistical learning** techniques to automatically identify patterns in data. These techniques can be used to make highly accurate predictions.

Keep scrolling. Using a data set about homes, we will create a machine learning model to distinguish homes in New York from homes in San Francisco.

“Scrolly”-telling

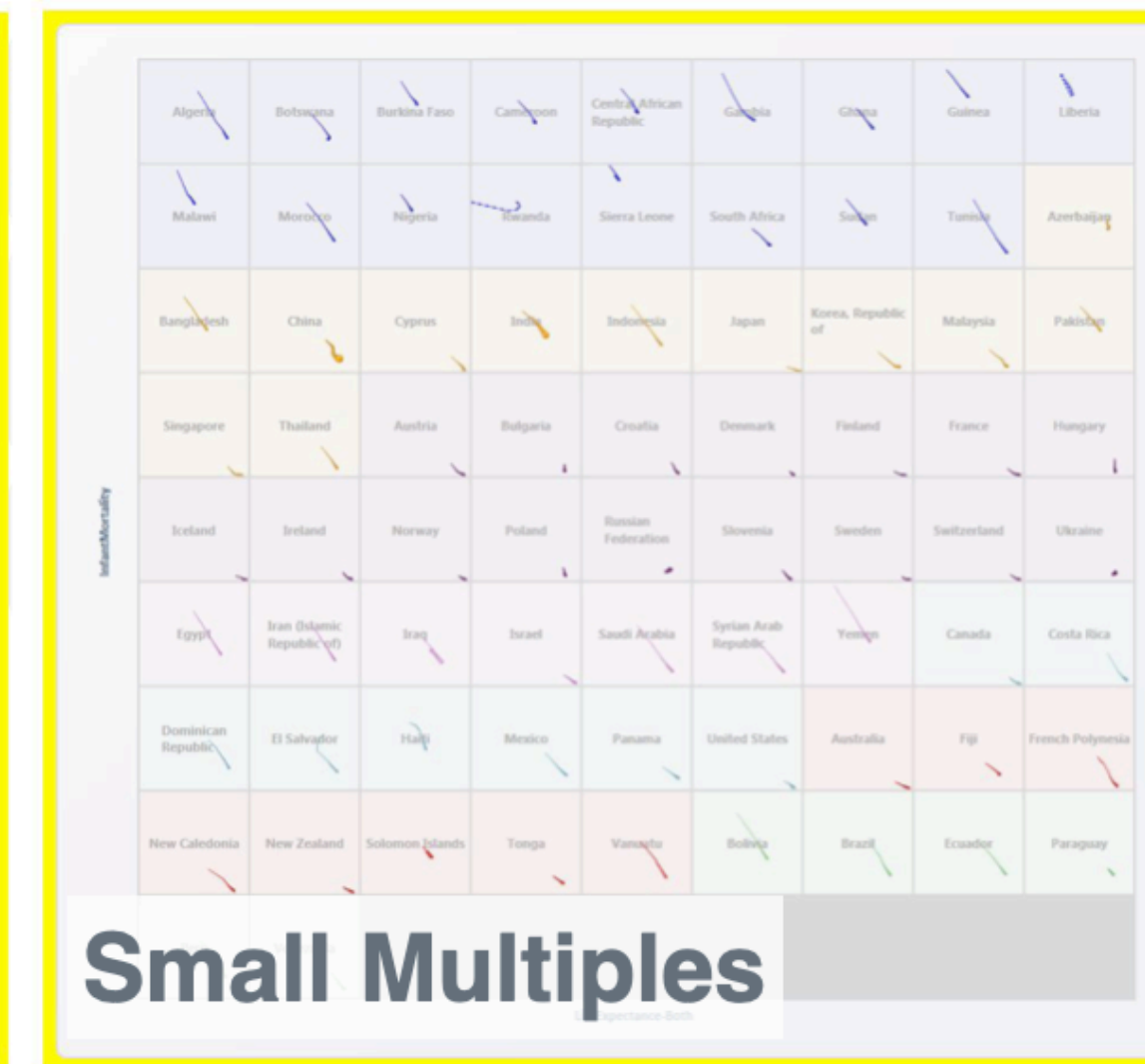
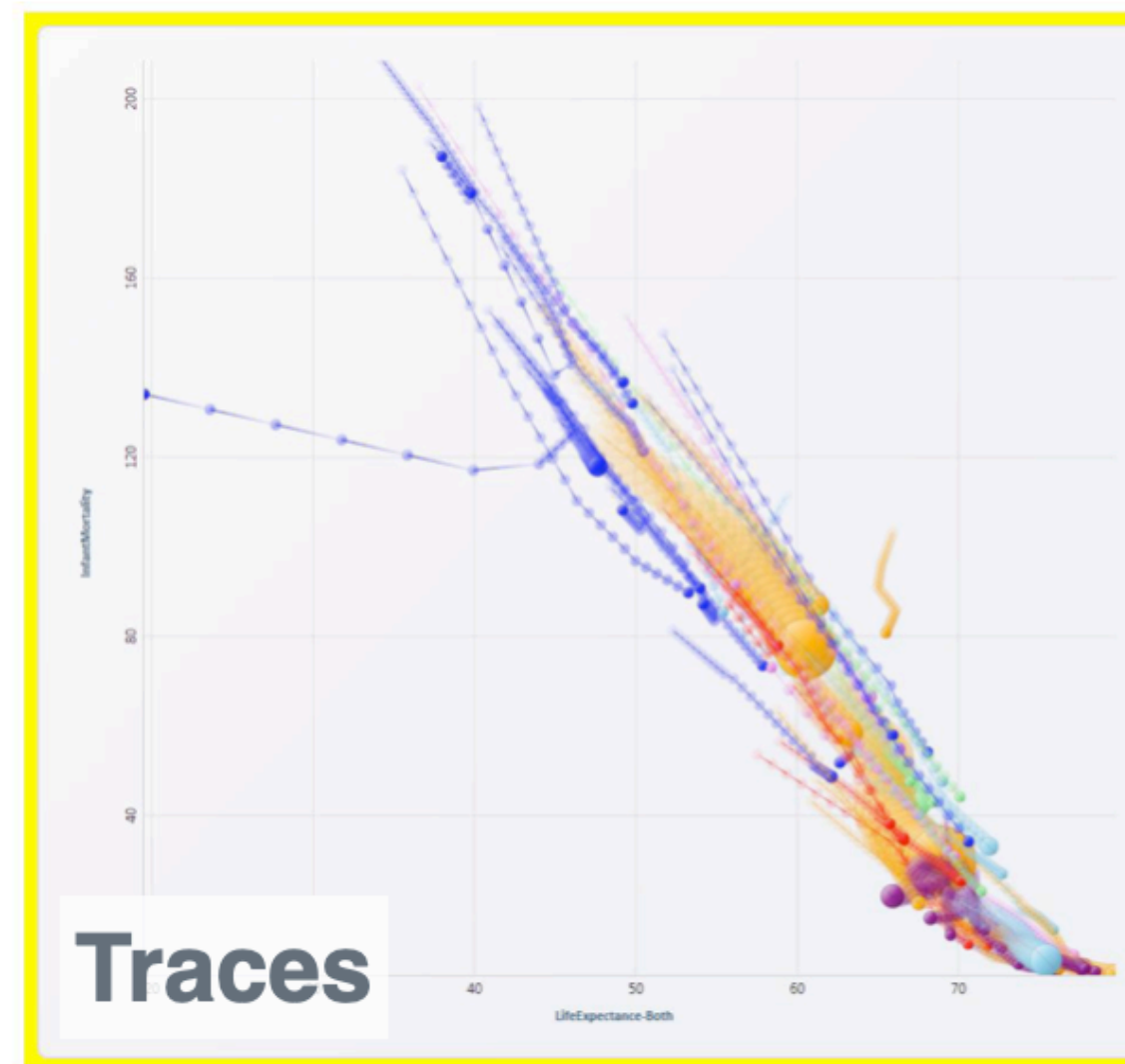
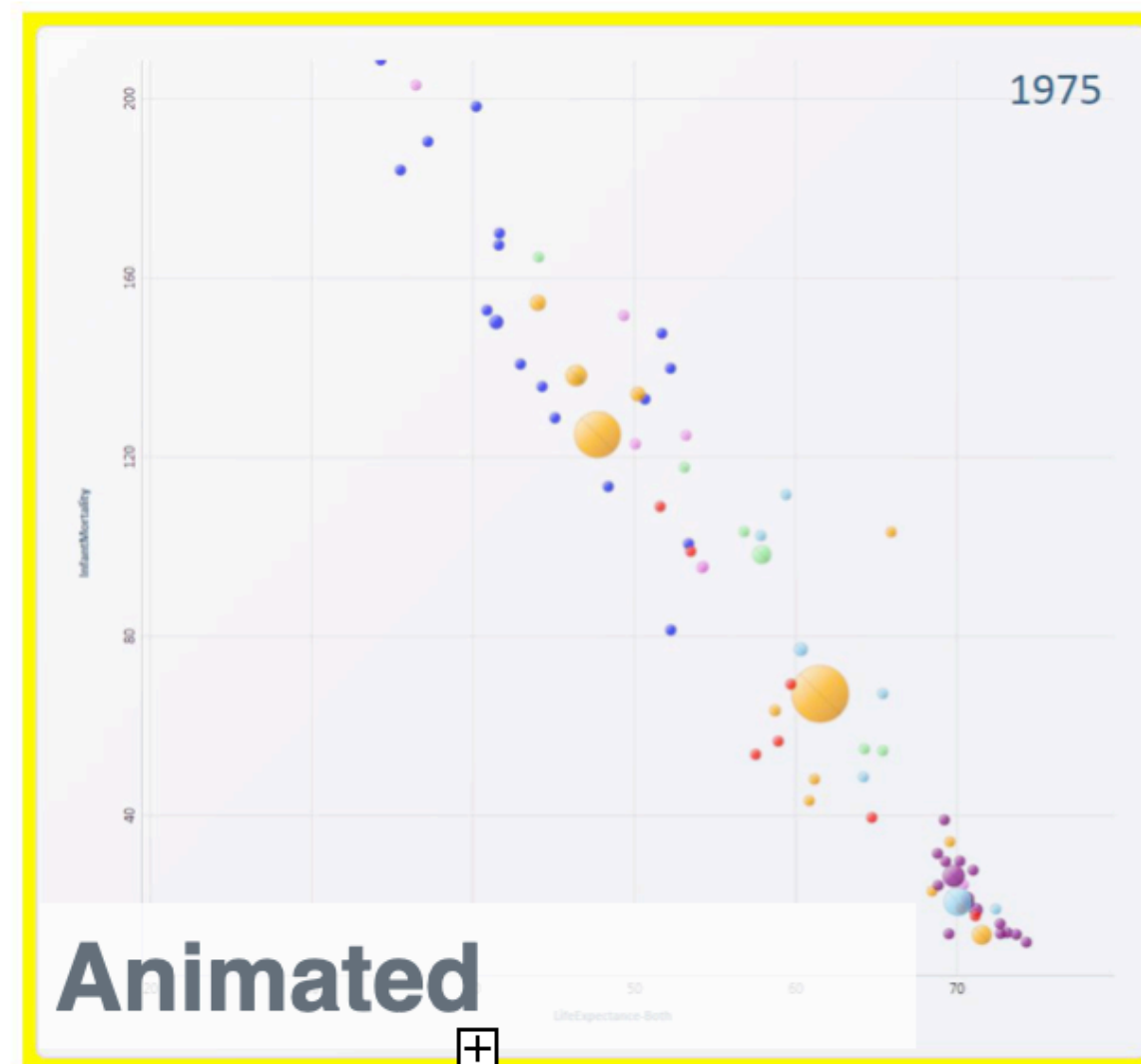
SCROLL



Animation

Study Conclusions

Analysis Task and Presentation Task.
Presentation condition included narration.
Subjects asked comprehension questions.

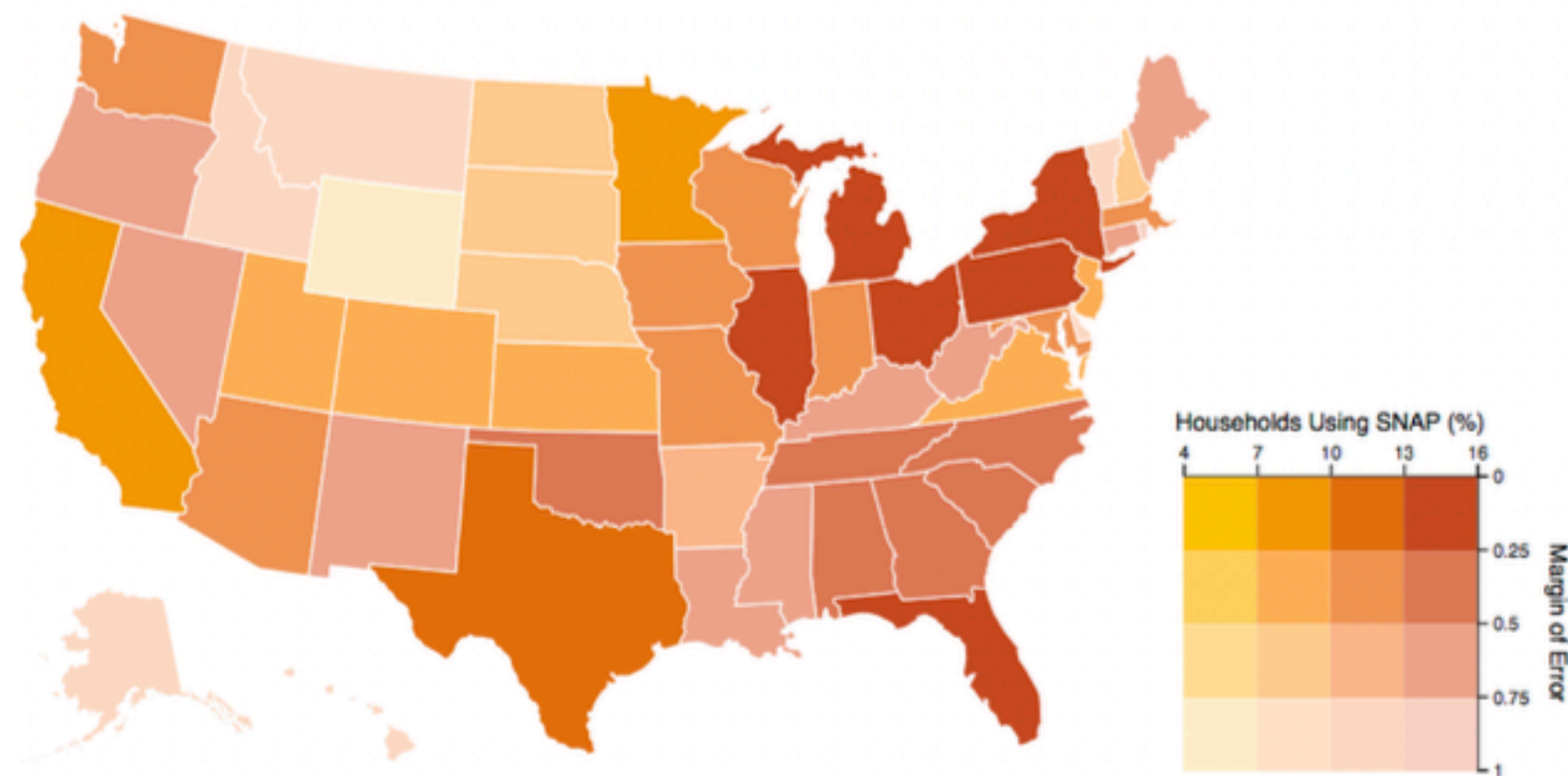


Which condition would participants:
be more **accurate**, be **faster**, and **prefer**?

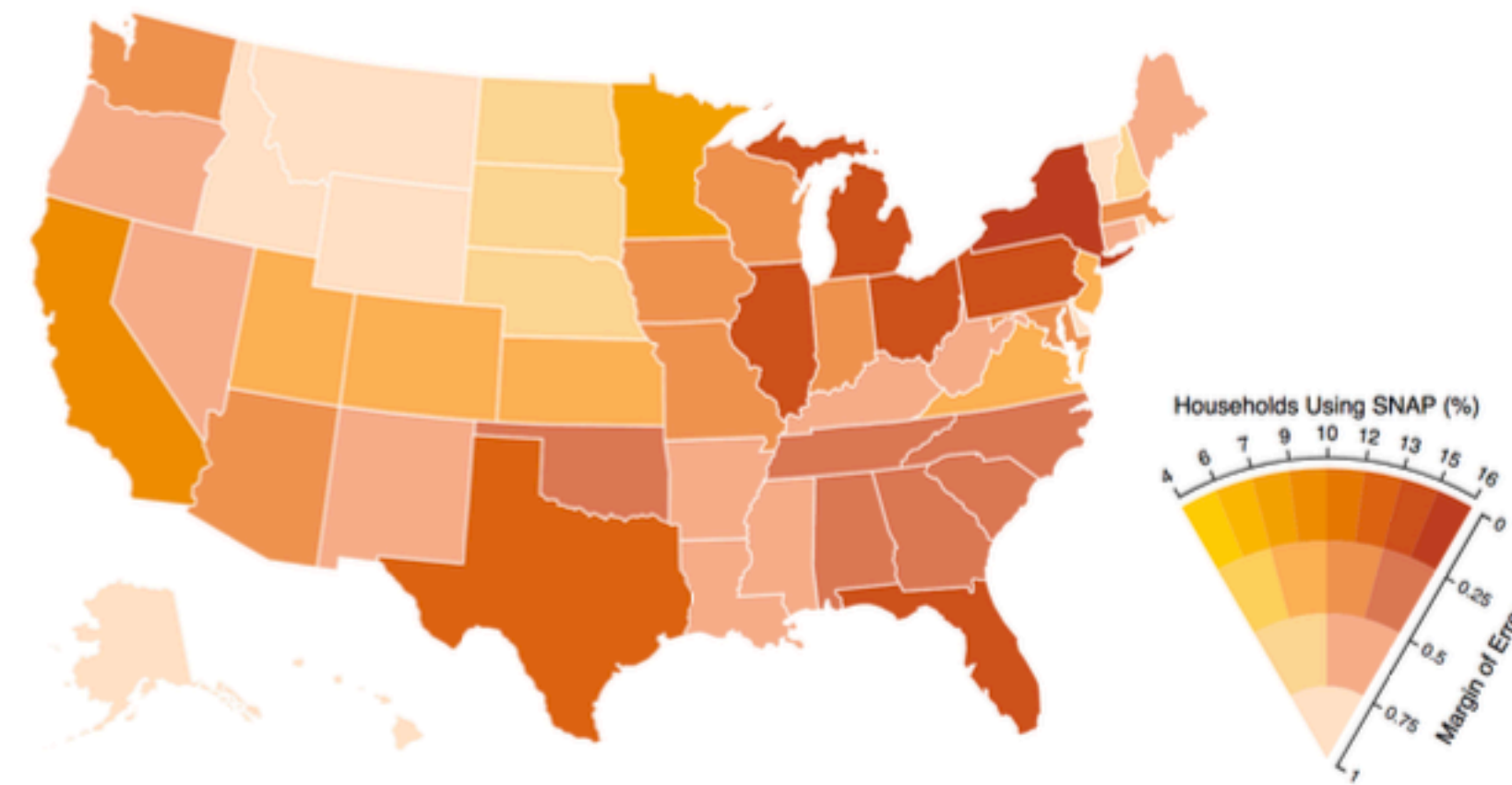
tryclassbuzz.com
Code: **anim**

Uncertainty

For uncertainty, use **visual variables** instead of visualizing point estimates



Bivariate Map (Data + Uncertainty)



Value-Suppressing Uncertainty Map

Thank You!

TAs: Jacob, Hemanth

As you can see, we're often short on tutors, so consider applying to be a tutor in the future!