

Accessibility and Visualization

An introduction.



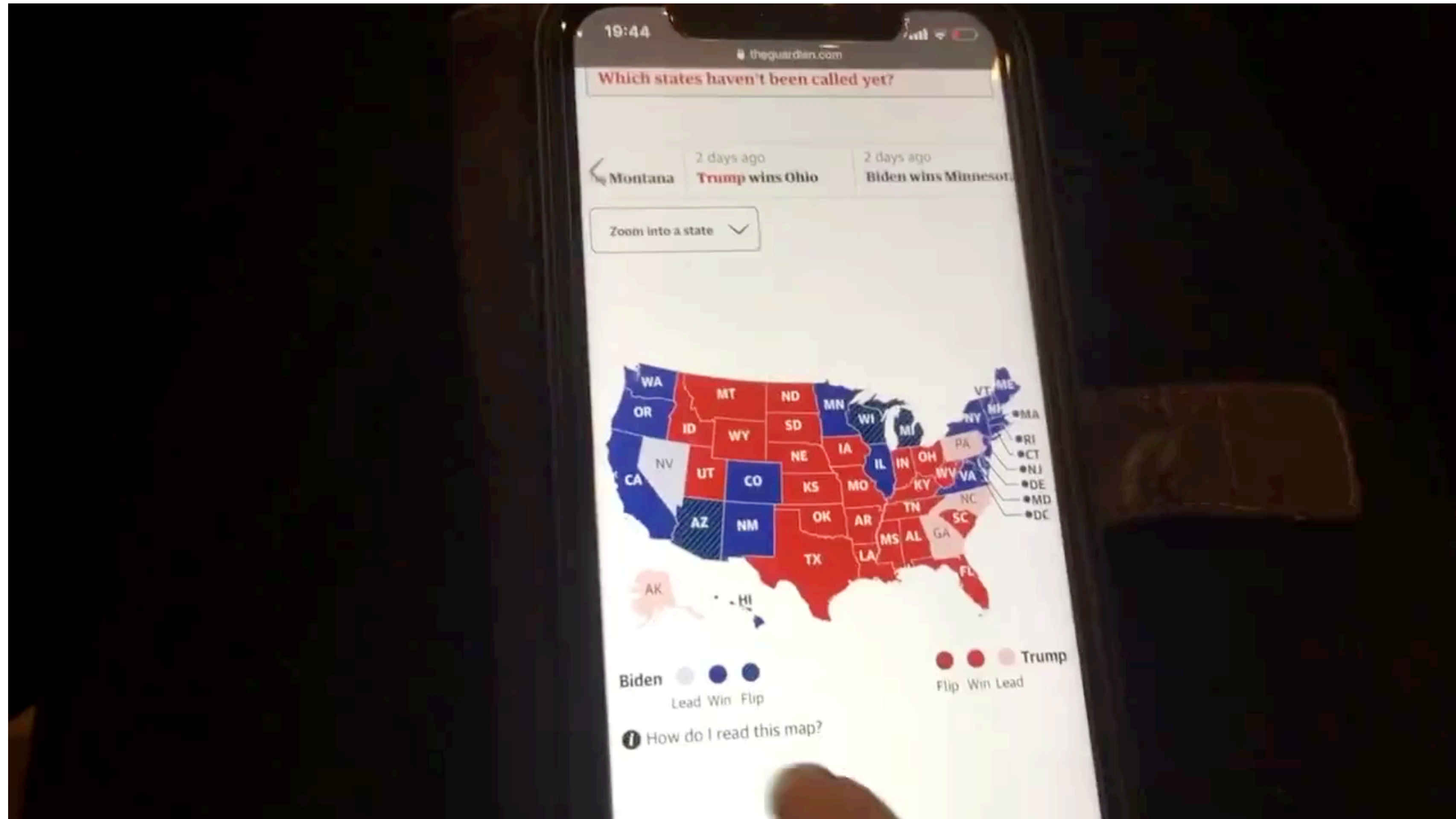
Frank Elavsky



hcii.cmu.edu, axle-lab.com, dig.cmu.edu

What is an inaccessible experience like?

Credit: Sarah Fossheim [on twitter](#)

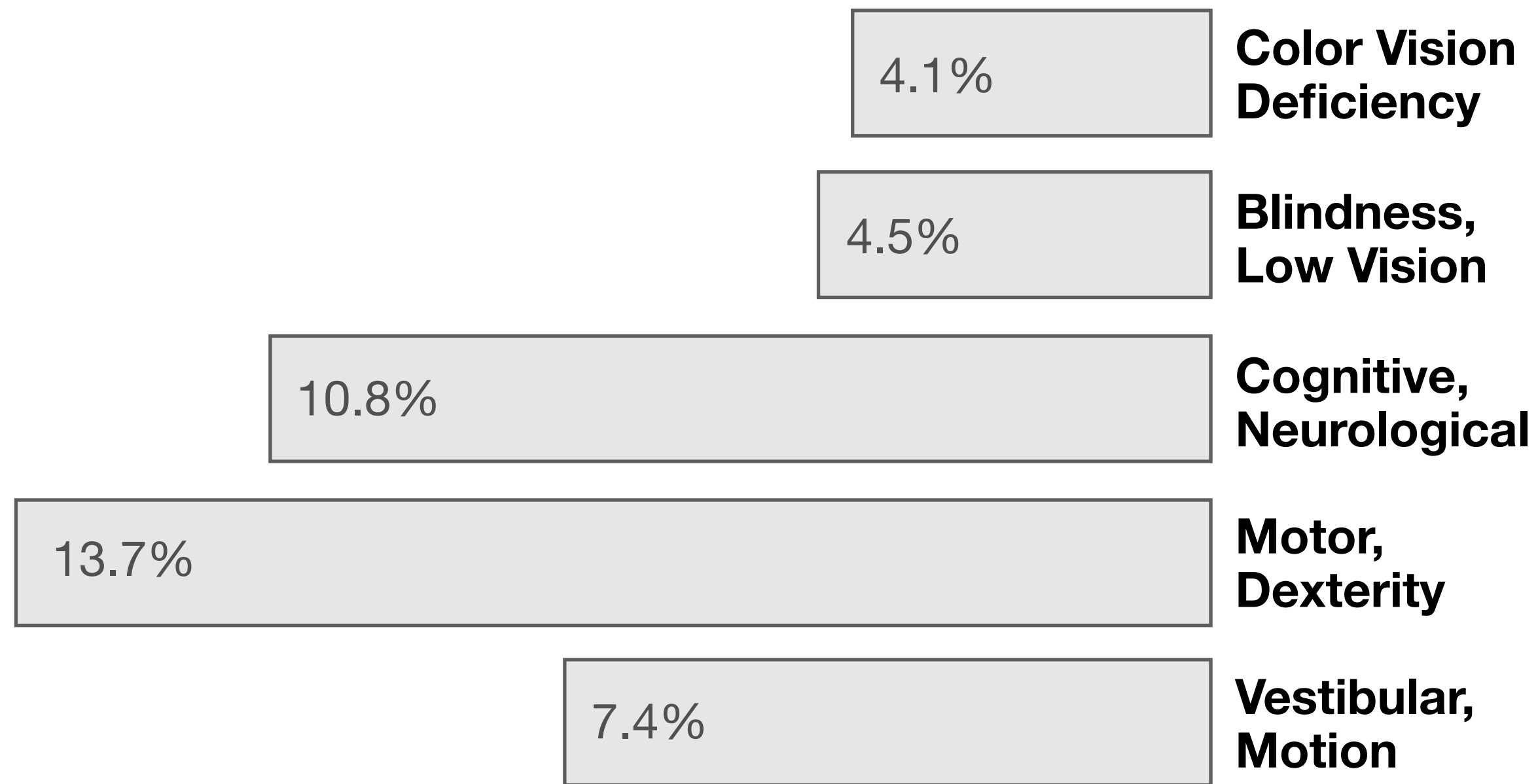


Access is a human right

Accessibility for people with disabilities is an internationally recognized human right.

It is the morally and ethically correct thing to do.

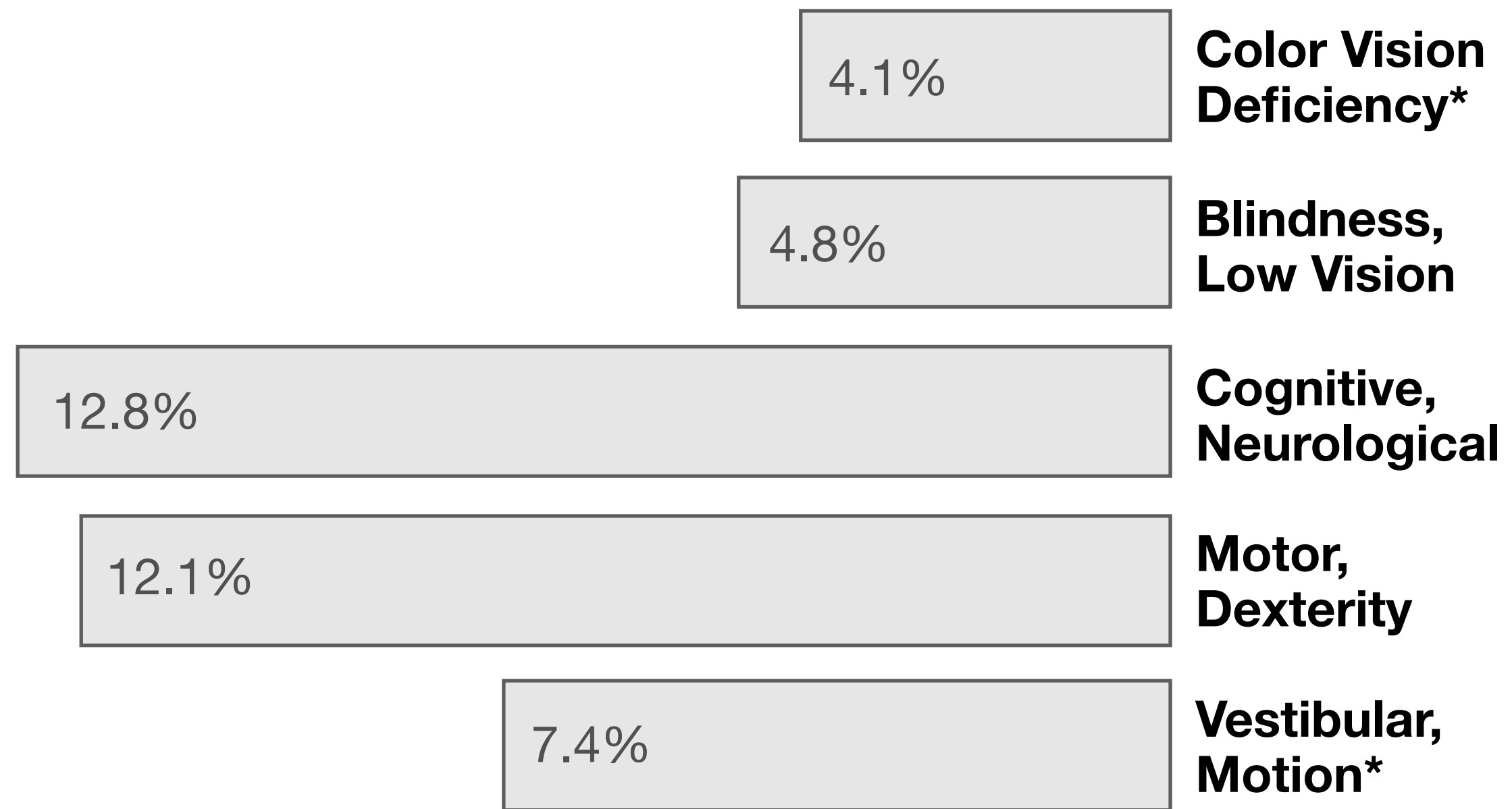




Source: Okoro et al. "Prevalence of Disabilities and Health Care Access by Disability Status and Type Among Adults"

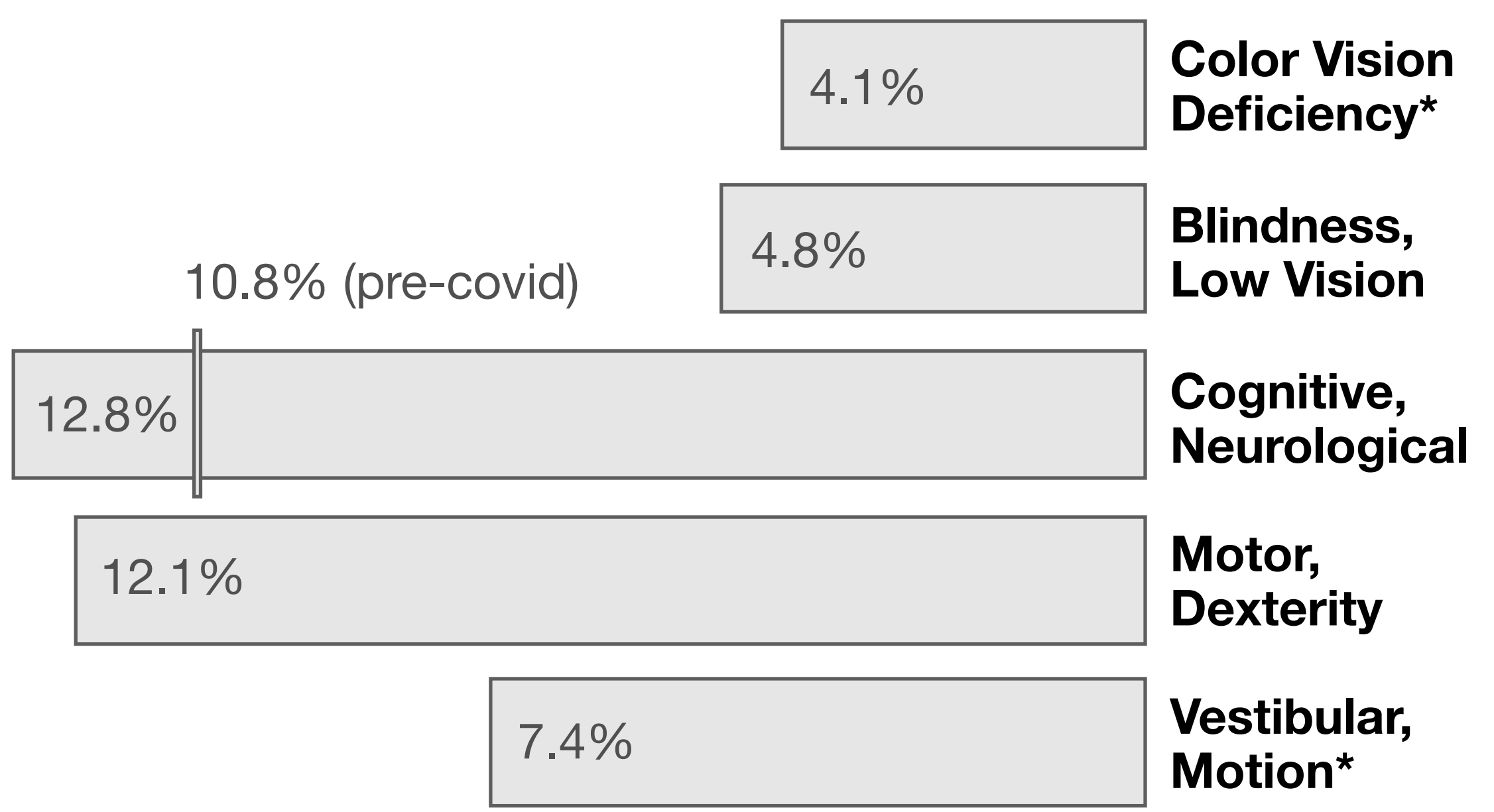
~26% of people living in the United States self-report living with a disability that affects their daily life (2017)

~27% of people living in the United States self-report living with a disability that affects their daily life (2023)



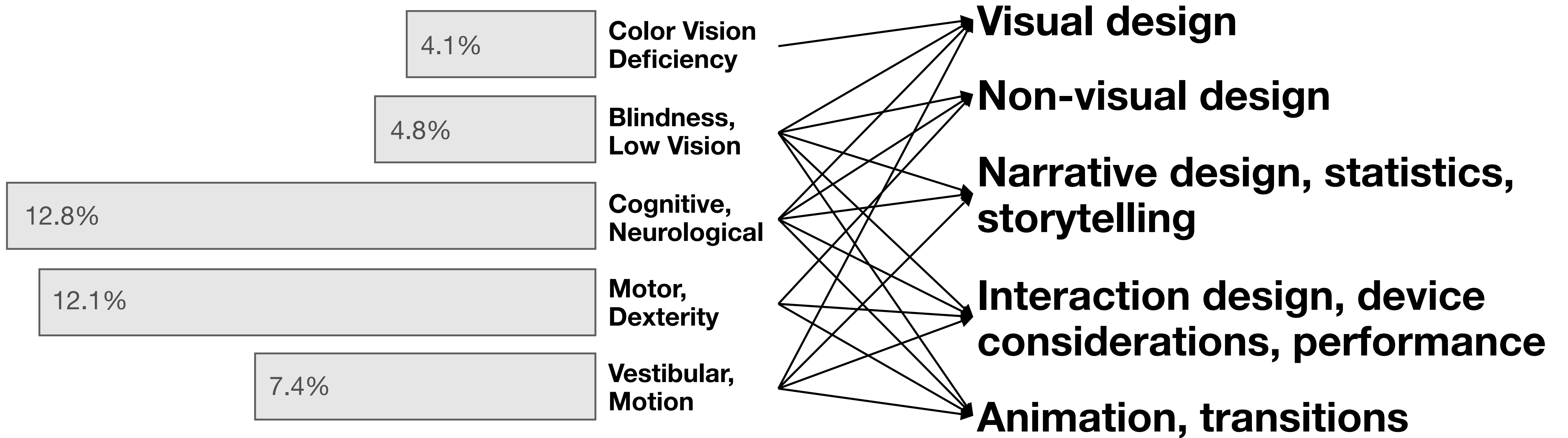
Centers for Disease Control and Prevention. Disability and Health Data System (DHDS). 2023. Available from: <http://dhds.cdc.gov>
*No new data

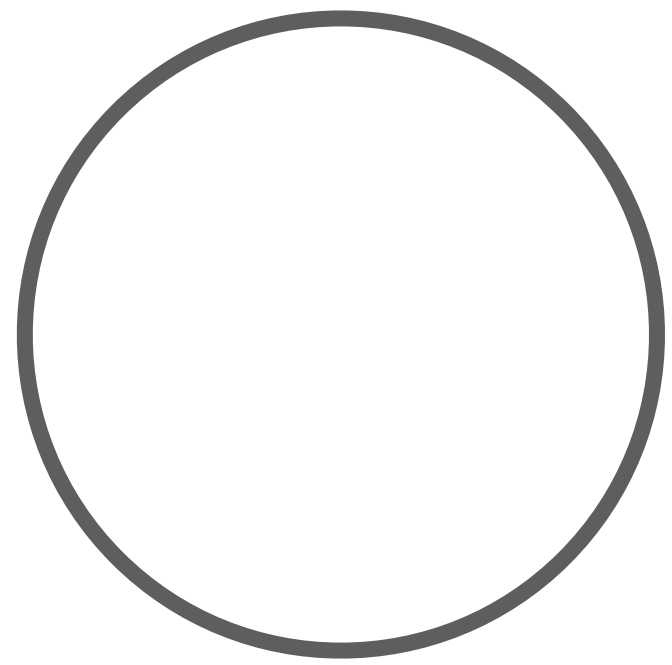
Cognitive disability is on the rise



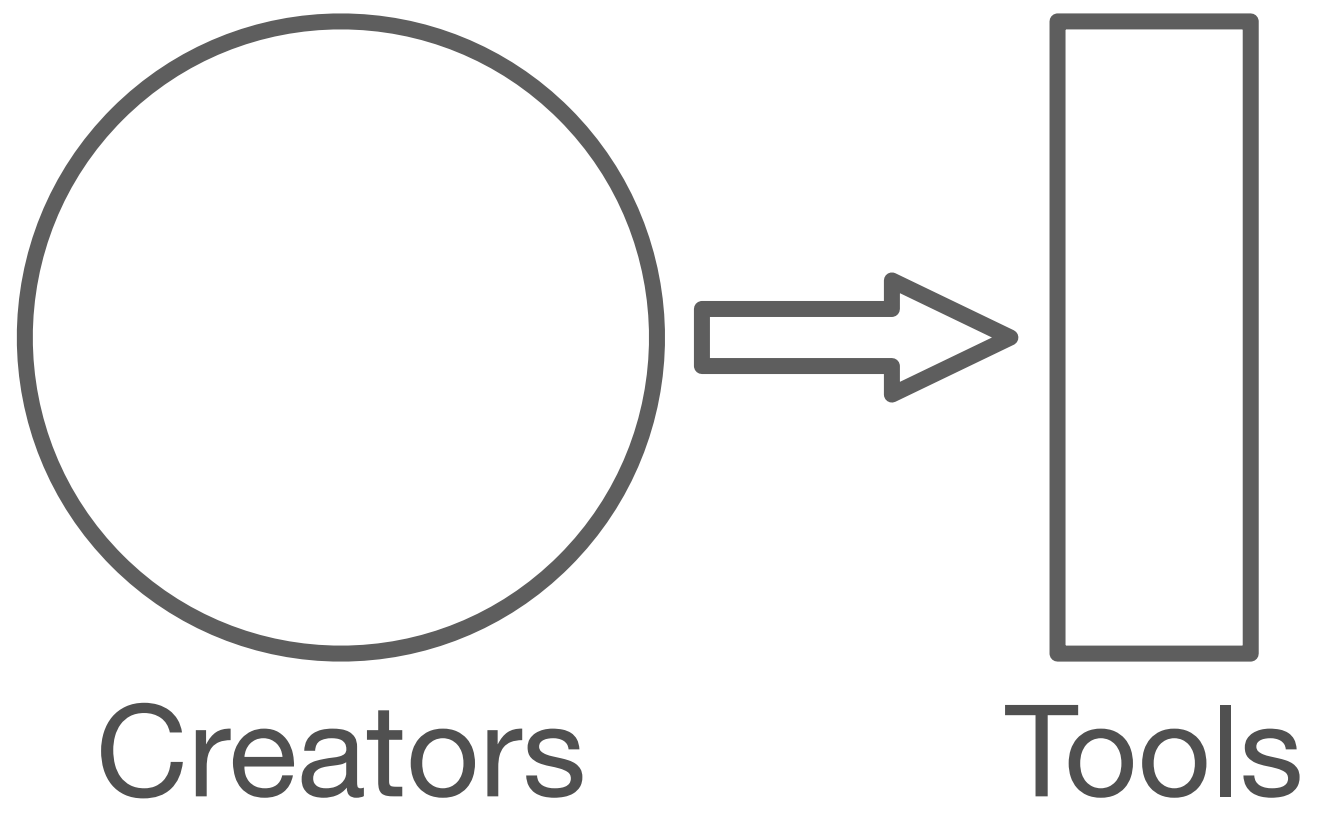
Centers for Disease Control and Prevention. Disability and Health Data System (DHDS). 2023. Available from: <http://dhds.cdc.gov>
*No new data

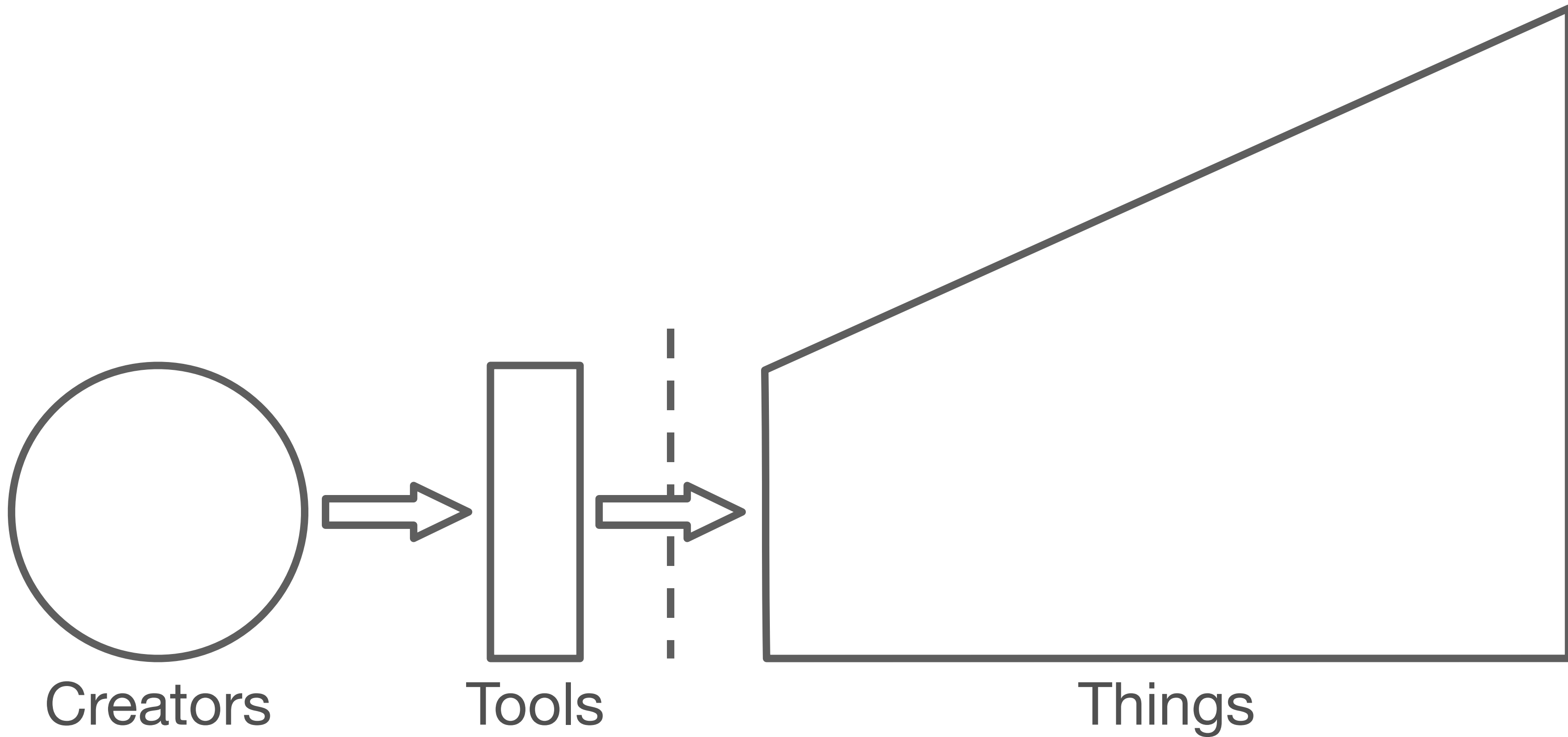
Accessibility affects every aspect of visualization work

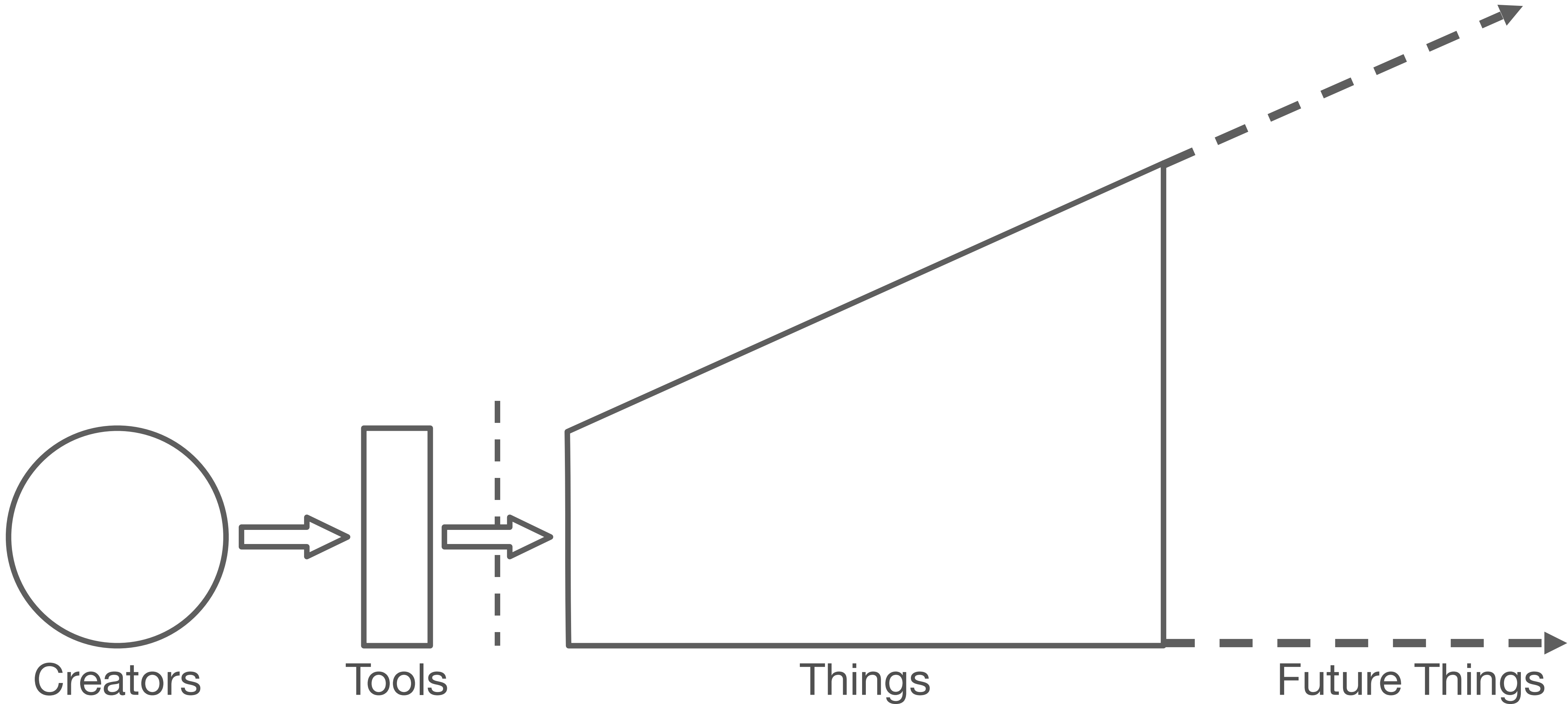




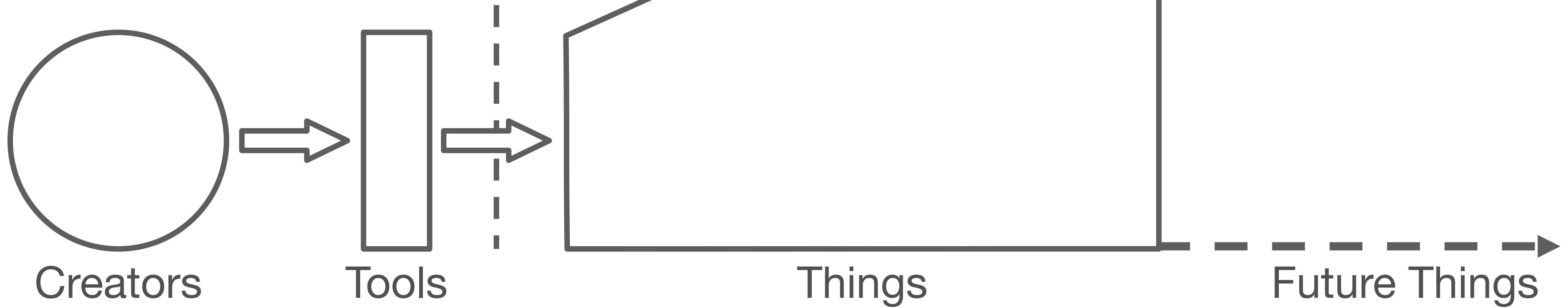
Creators





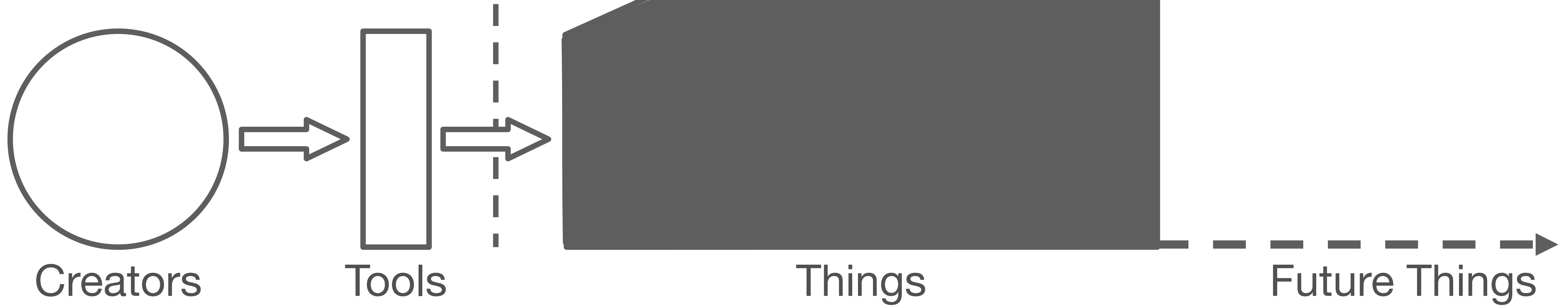


**But how much of this is
inaccessible?**



97-99%

Source: World Wide Web Consortium. "The WebAIM Million Report." 2019-2024



Who is responsible for making this accessible?

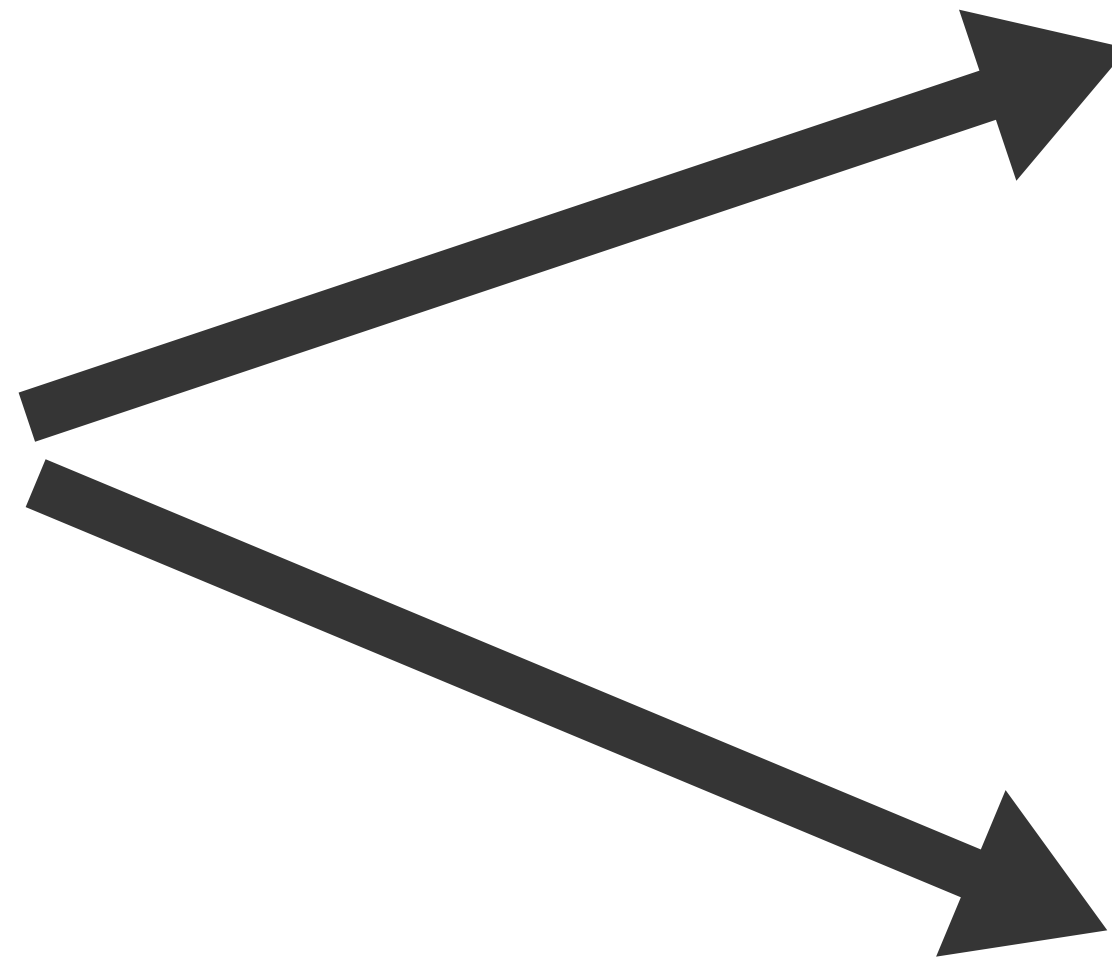
What about curbs in our cities?



Medicalizing framing: the body is the cause/location of disability (according to normative standards).



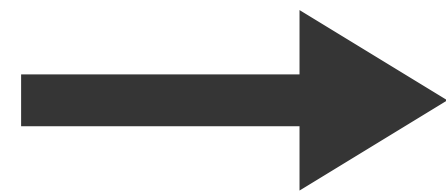
Augment or “cure” the body, the person typically bears the cost of access.



Social framing: The *curb* is the source/location where disability is produced (as a “barrier” to access).



We built barriers, so now we need to fix them.



But how do we *catch* barriers?

Listen to people with disabilities (PWD).

There are a lot of ways to listen:

1. Actually ask them!
2. Find where they are already speaking
3. Find where they have already spoken:
 - Research
 - Blog posts
 - Accessibility standards

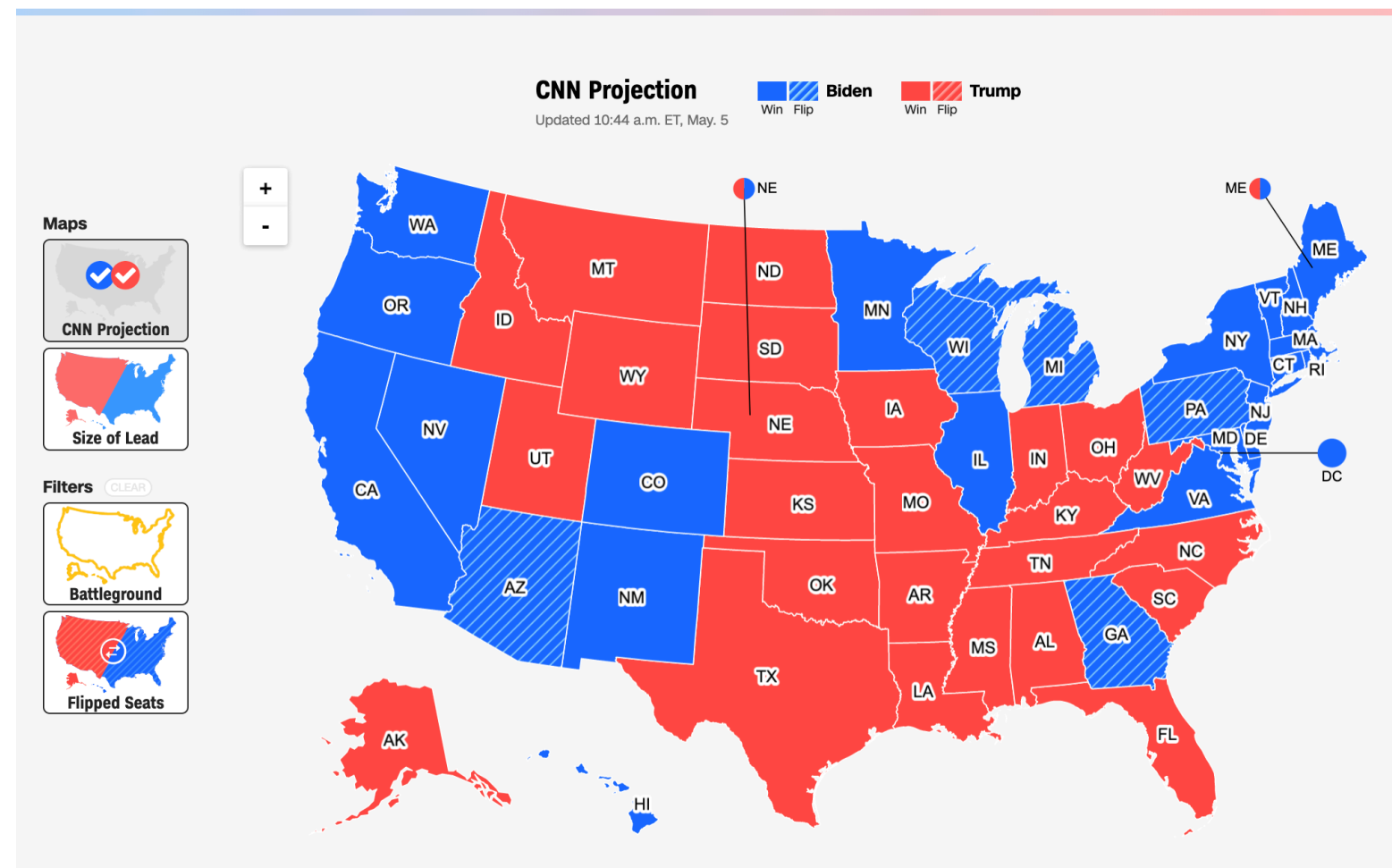
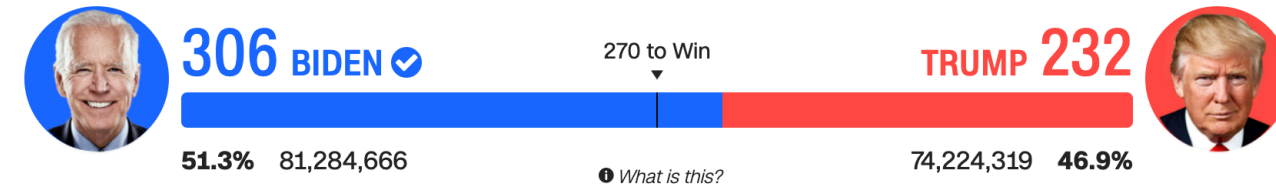
There are a lot of ways to listen:

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 - Research
 - Blog posts
 - **Accessibility standards**

PRESIDENTIAL RESULTS

Joe Biden wins election to be the 46th US President

Pennsylvania's 20 electoral votes put native son Joe Biden above the 270 needed to become the 46th President of the United States. Born in Scranton, the former vice president and longtime Delaware senator defeated Donald Trump, the first President to lose a reelection bid since George H.W. Bush in 1992.



Let's evaluate this map from CNN with Chartability.

STATE RESULTS

State	President	Electoral Votes	Projected Winner
Alabama	Trump	9	PROJECTED WINNER
Alaska	Trump	3	PROJECTED WINNER
Arizona	Biden	11	BATTLEGROUND

State	Candidate	%	Votes
Alabama	Trump	62.0%	1,441,170
	Biden	36.6%	849,624
Alaska	Trump	52.8%	189,951
	Biden	42.8%	153,778
Arizona	Biden	49.4%	1,672,143
	Trump	49.0%	1,661,686

Show More States

An acronym in web standards:

**P
O
U
R**

An acronym in web standards:

Perceivable

**O
U
R**

An acronym in web standards:

Perceivable

Operable

U

R

An acronym in web standards:

Perceivable

Operable

Understandable

R

The 4 pillars of accessible design:

Perceivable

Operable

Understandable

Robust

Perceivable
Operable
Understandable
Robust

Chartability's additions:

+

C

A

F

Perceivable
Operable
Understandable
Robust

Chartability's additions:

+

Compromising

A

F

Perceivable
Operable
Understandable
Robust

Chartability's additions:

+

Compromising

Assistive

F

Perceivable
Operable
Understandable
Robust

Chartability's additions:

+

Compromising
Assistive
Flexible



POUR+CAF

“I need to **pour a cup of coffee** to help me consider accessible design!”

Perceivable

Can someone perceive this in multiple ways? Is each way easy?

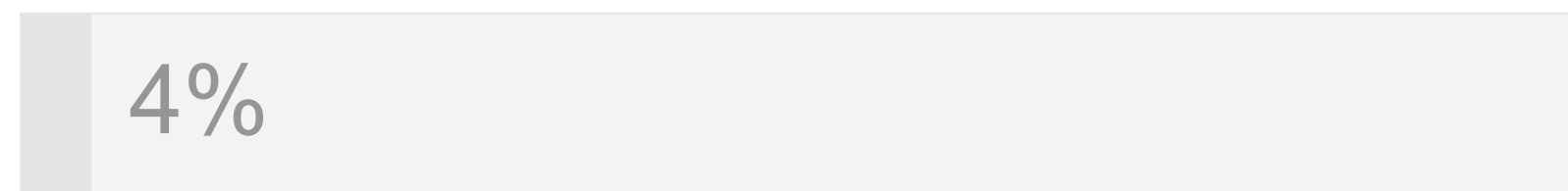
Perceivable Checklist:

1. High Contrast
2. Colorblind-Safe + Redundant Encoding
3. Alt Text

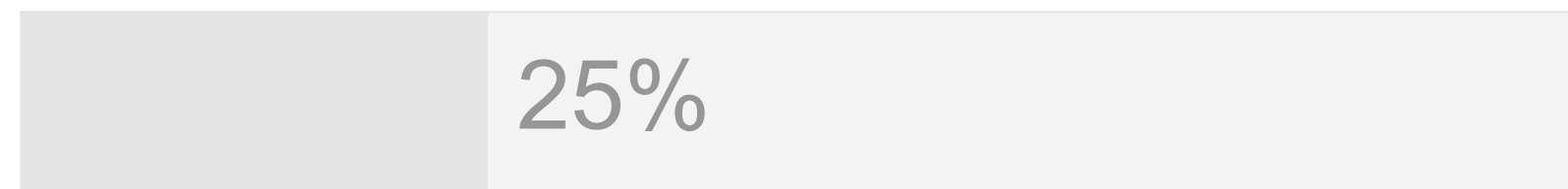
Design with high contrast

Colorblindness Disproportionately Overrepresented in A11y Resources

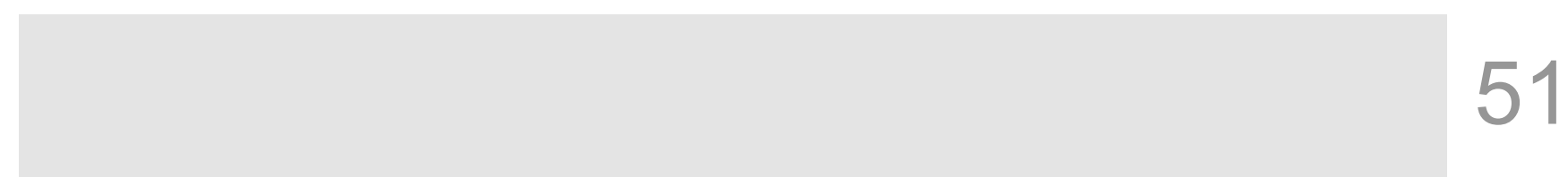
Colorblindness: % of People



Low Vision: % of People



Colorblindness: # of Resources



Low Vision: # of Resources



Colorblindness Disproportionately Overrepresented in A11y Resources

Colorblindness: % of People



Low Vision: % of People



Colorblindness: # of Resources



Low Vision: # of Resources



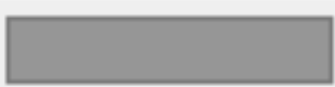

Use High Contrast Text



Text needs at least 4.5:1 contrast against its background.

Large text (bold and 16pt or larger) can be 3:1 or higher.

Contrast Checker

[Home](#) > [Resources](#) > Contrast Checker

Foreground Color
#969696 
Lightness 

Background Color
#FFFFFF 
Lightness 

Contrast Ratio
2.95:1
[permalink](#)

Normal Text

WCAG AA: **Fail**

WCAG AAA: **Fail**

The five boxing wizards jump quickly.

Large Text

WCAG AA: **Fail**

WCAG AAA: **Fail**

The five boxing wizards jump quickly.

Use High Contrast Geometries

Chart elements need at least 3:1 contrast against their background.

Contrast Checker

[Home](#) > [Resources](#) > Contrast Checker

Foreground Color

#E4E4E4

Lightness

Background Color

#F3F3F3

Lightness

Contrast Ratio

1.14:1

[permalink](#)

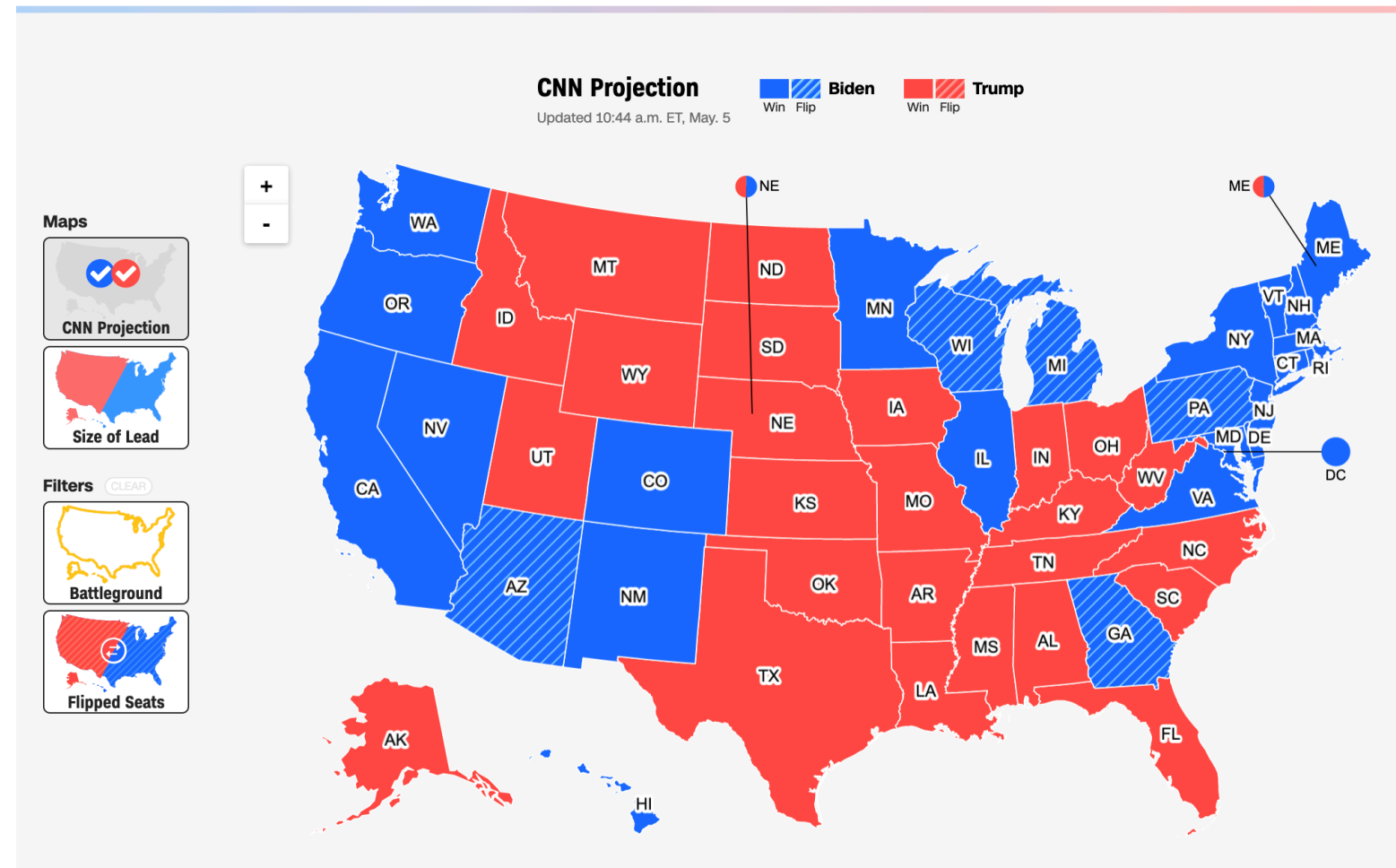
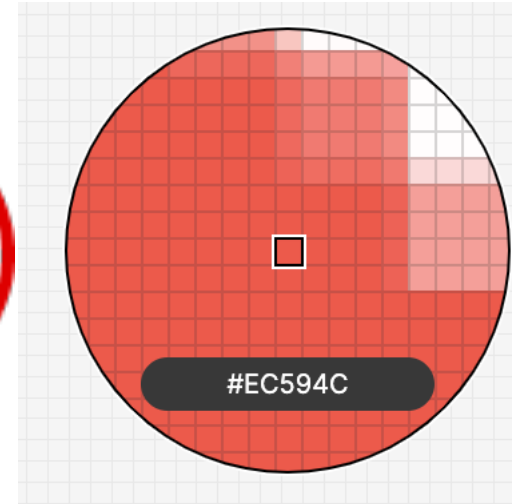
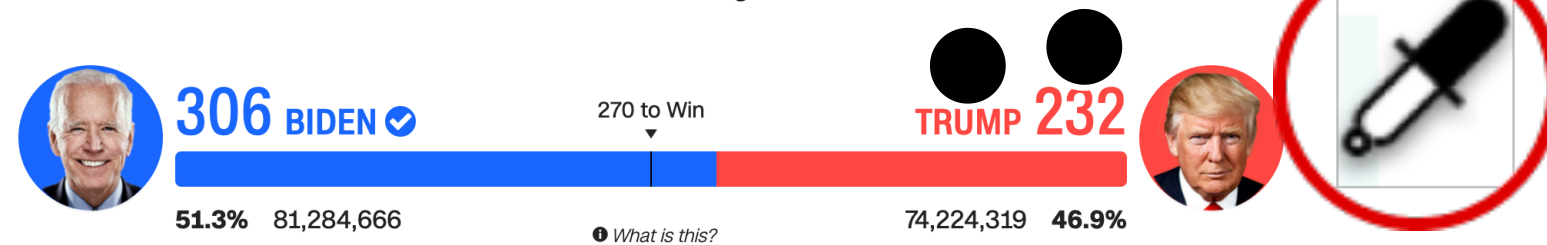
Graphical Objects and User Interface Components

WCAG AA: **Fail**

PRESIDENTIAL RESULTS

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Contrast Checker

[Home](#) > [Resources](#) > Contrast Checker

Foreground Color
#EC594C

Background Color
#FFFFFF

Lightness

Contrast Ratio: 3.44:1

Contrast Ratio
3.44:1

[permalink](#)

Normal Text

WCAG AA: **Fail**

WCAG AAA: **Fail**

The five boxing wizards jump quickly.

STATE RESULTS

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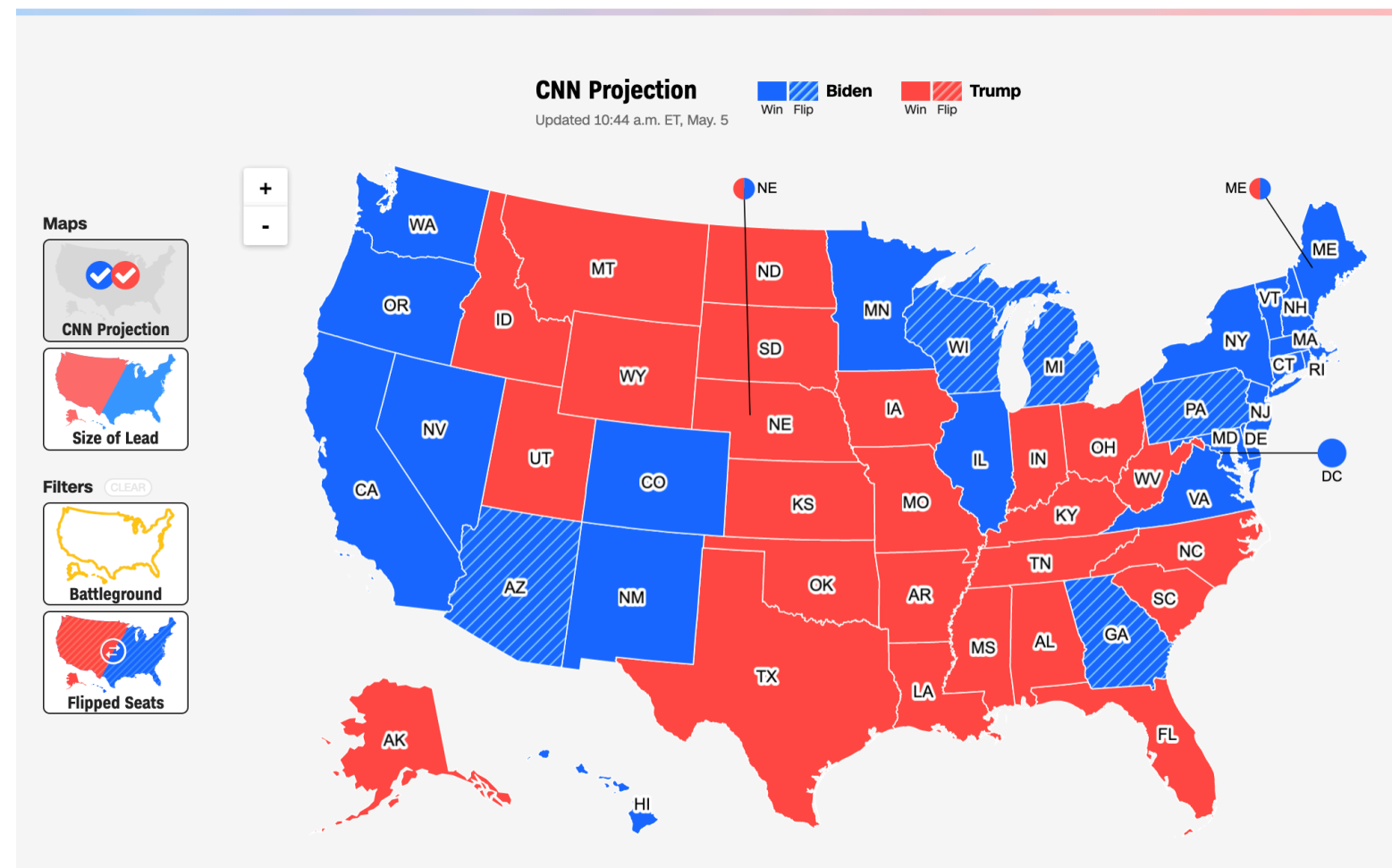
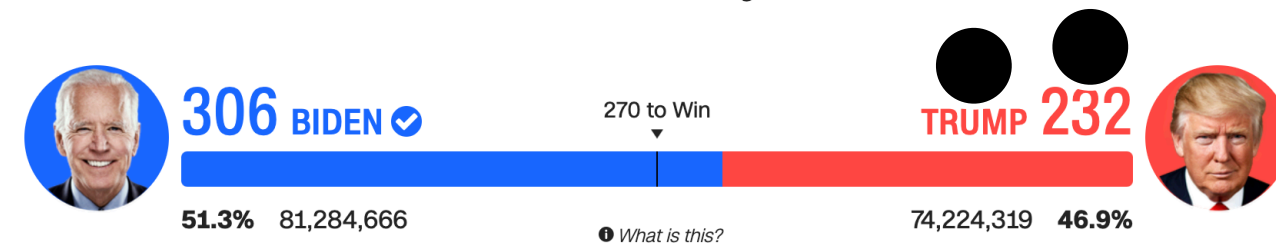
Each state card shows candidate names, percentages, and total votes.

Show More States

PRESIDENTIAL RESULTS

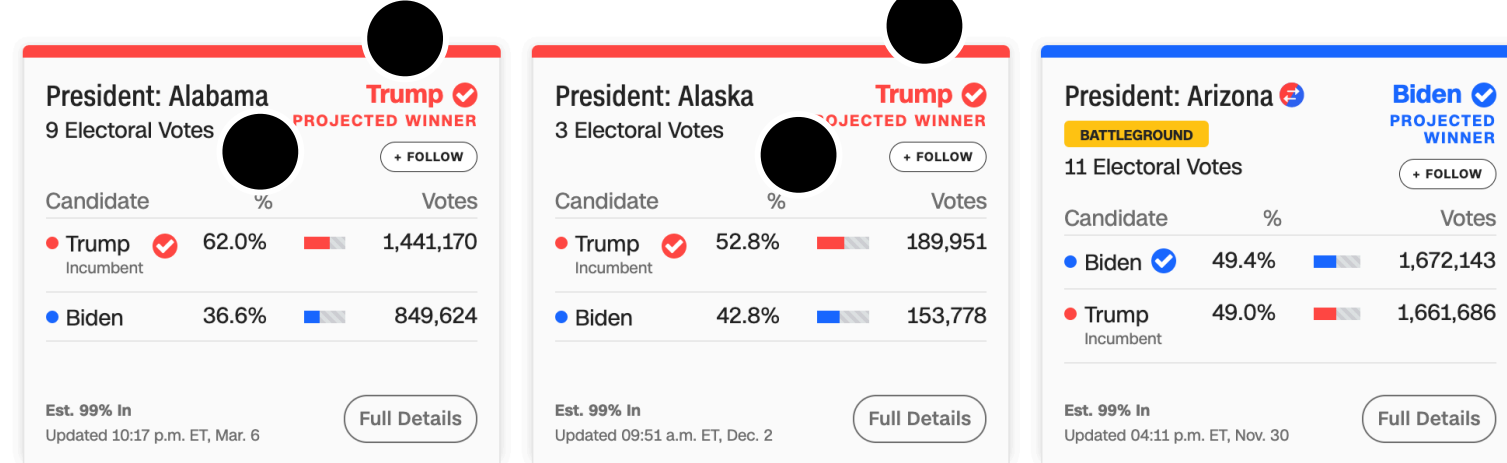
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6 instances of low contrast

STATE RESULTS



Show More States

Don't rely on color alone!

(Muth) <https://blog.datawrapper.de/colorblindness-part2/>



WHAT PEOPLE WITH NORMAL VISION SEE



WHAT GREEN-BLIND PEOPLE SEE
1% OF MEN

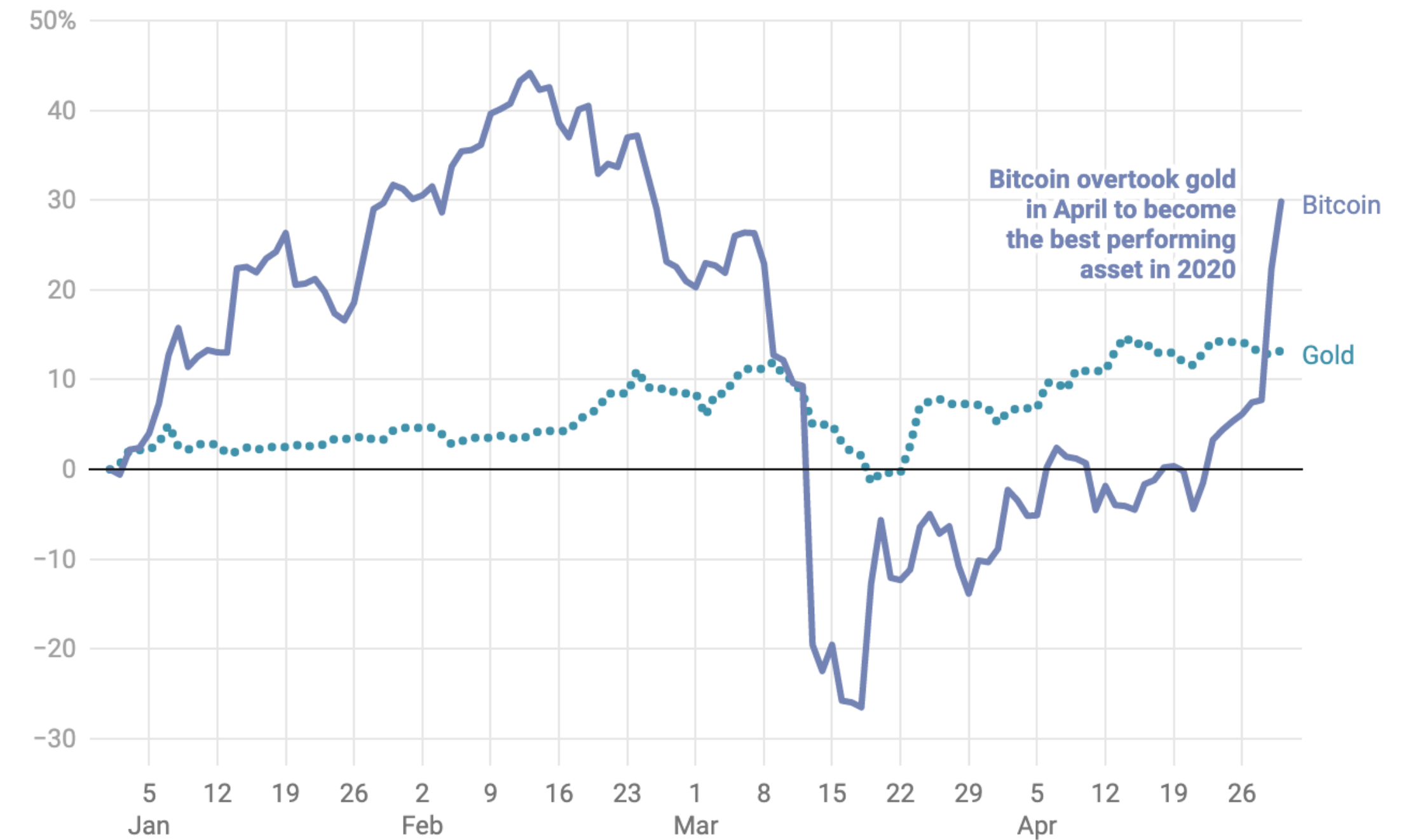
“Redundant encoding” is one strategy



WHAT PEOPLE WITH NORMAL VISION SEE



WHAT GREEN-BLIND PEOPLE SEE
1% OF MEN



Bitcoin and gold price change (%) between January and May 2020

Chart: Based on [Anthony Cuthbertson](#) • Source: [CoinMarketCap](#), [Nasdaq](#), [Gold Price](#) • [Get the data](#)

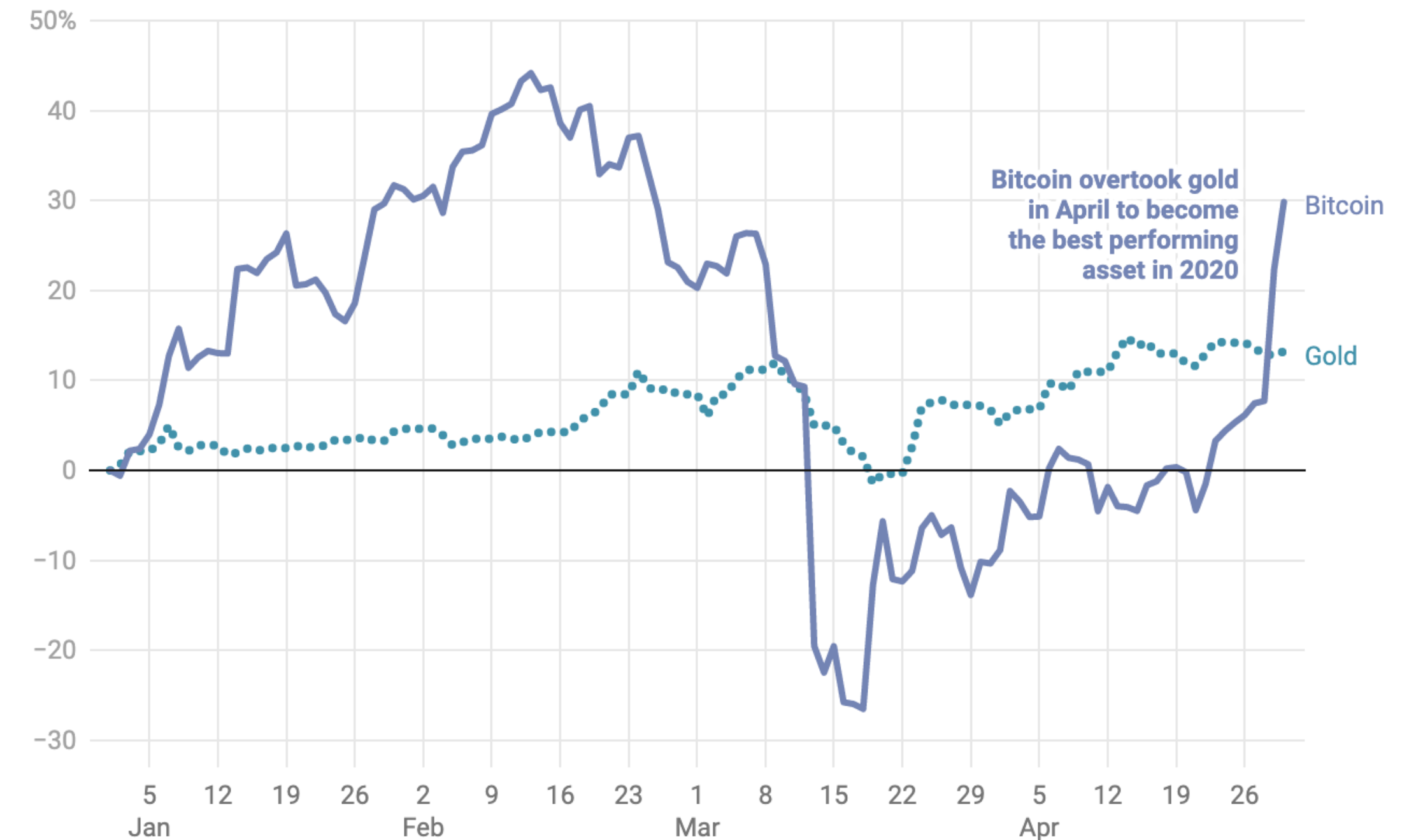
A note: “**Color-vision deficiency**” and “**colorblindness**” refer to the same thing, both terms are fine to use.



WHAT PEOPLE WITH NORMAL VISION SEE



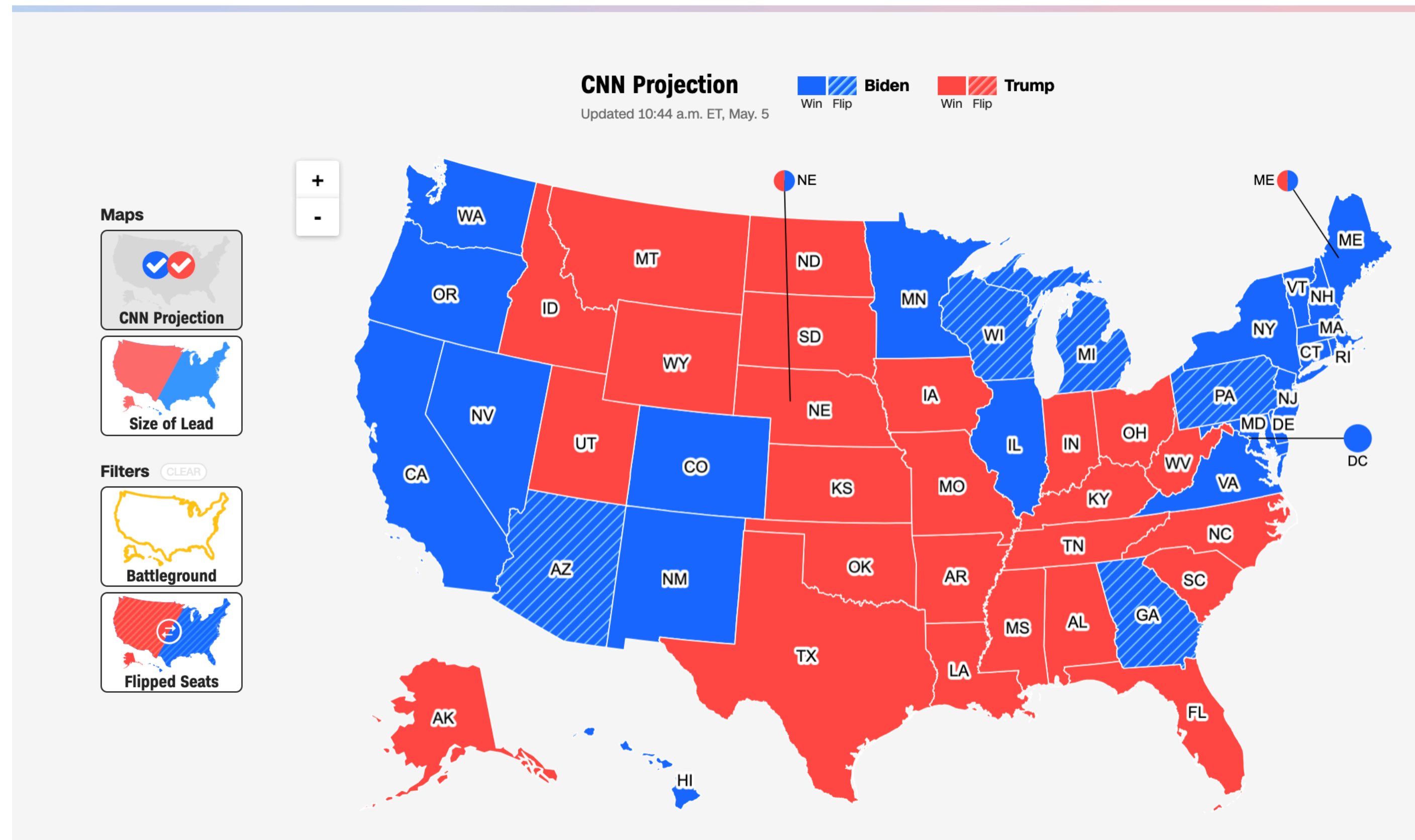
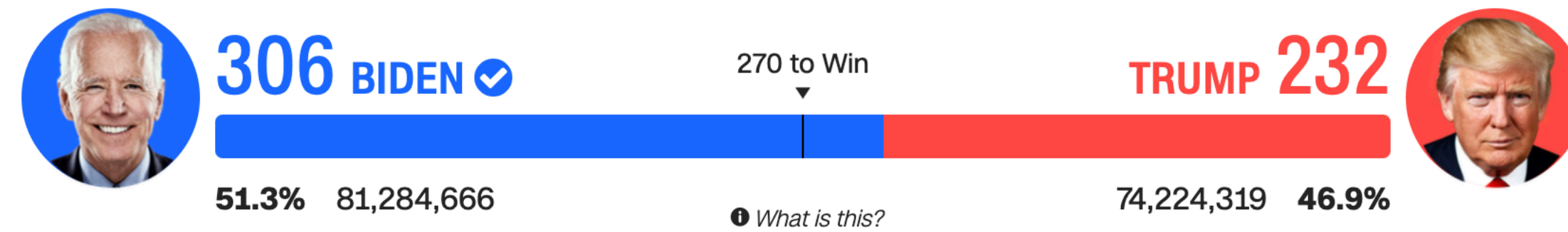
WHAT GREEN-BLIND PEOPLE SEE
1% OF MEN



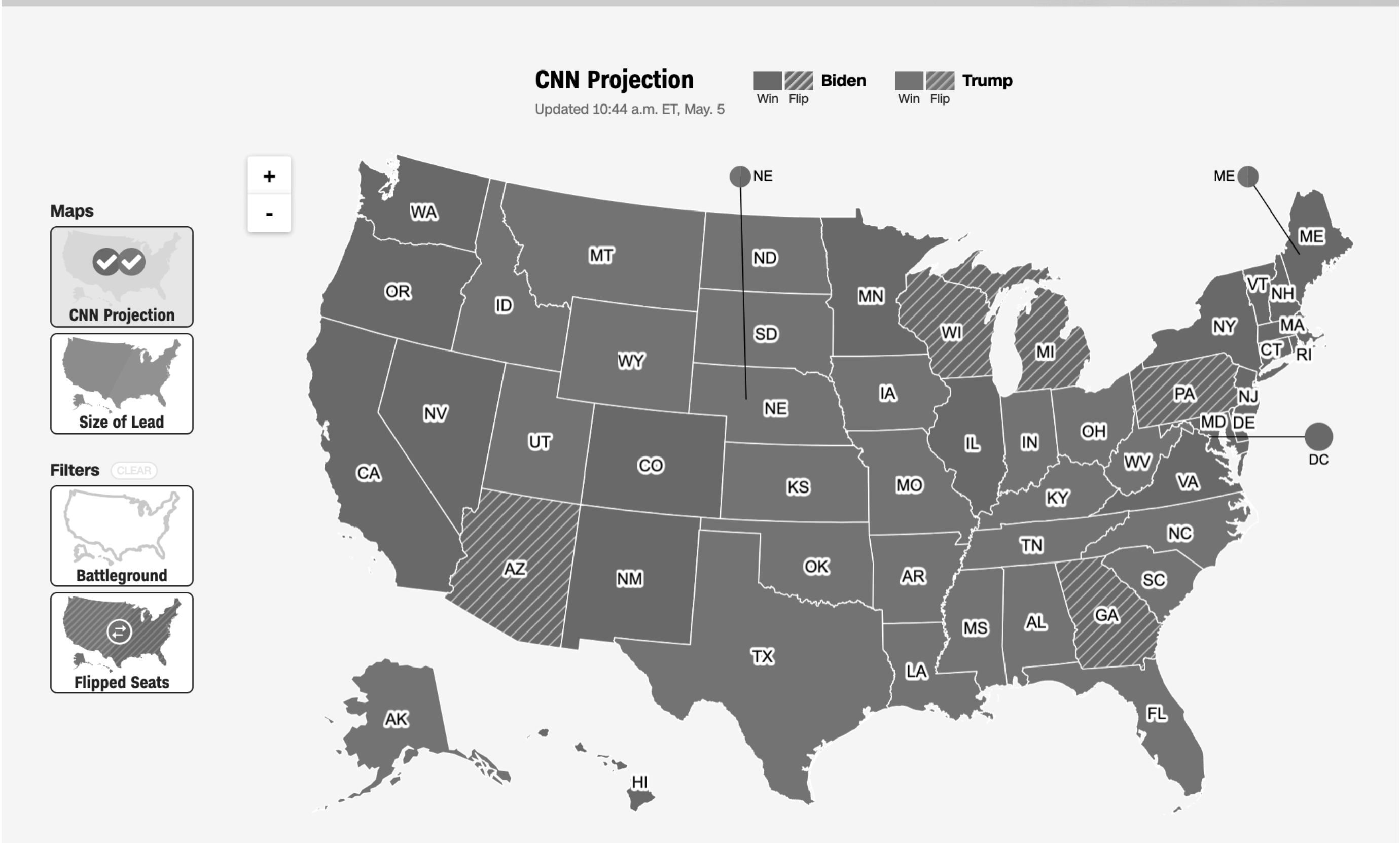
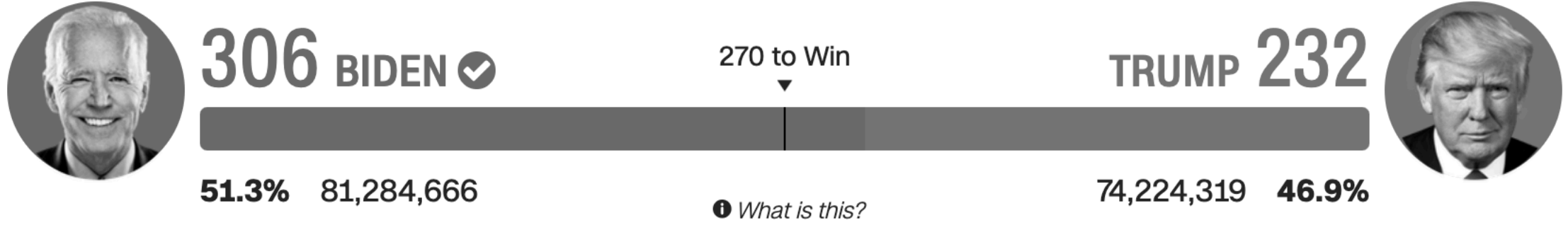
Bitcoin and gold price change (%) between January and May 2020

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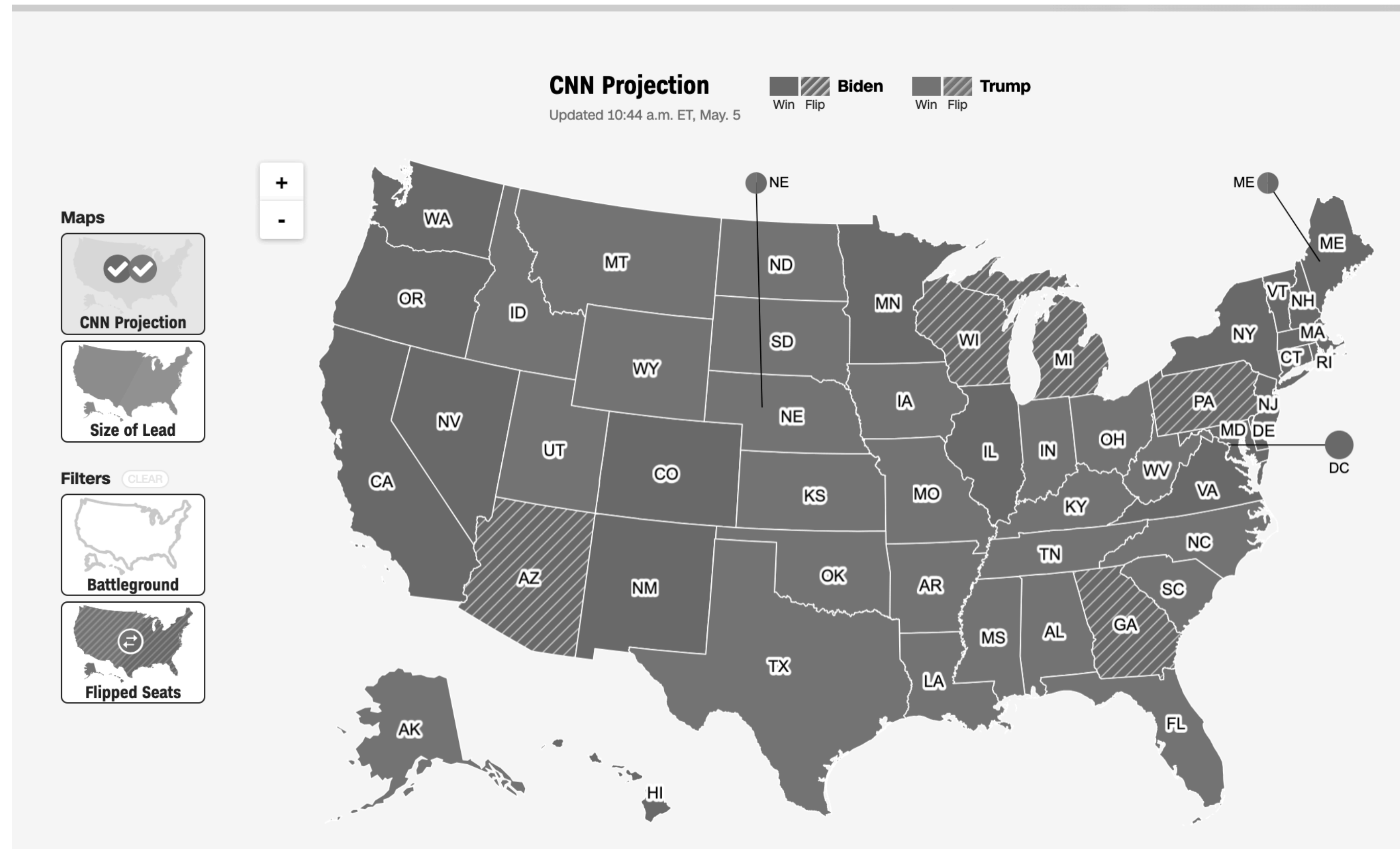
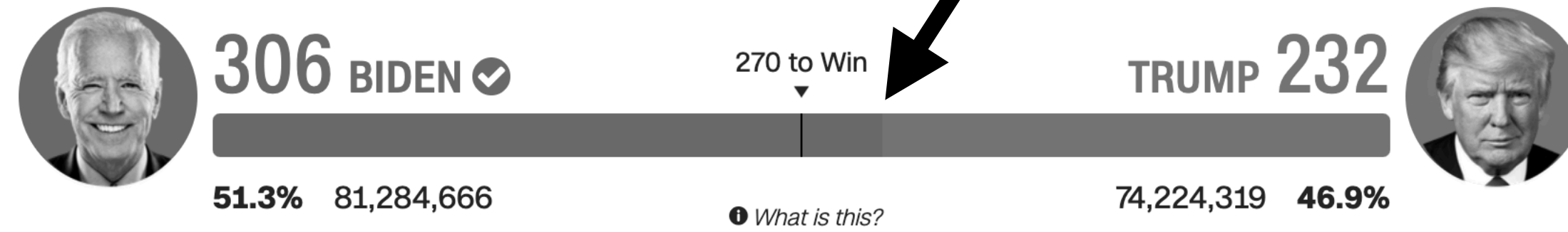
But sometimes you *can't* redundantly encode!



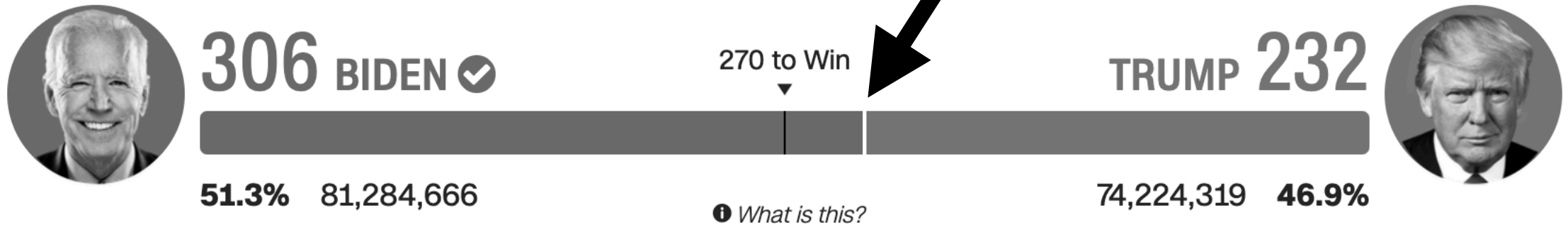
This map is trouble in greyscale



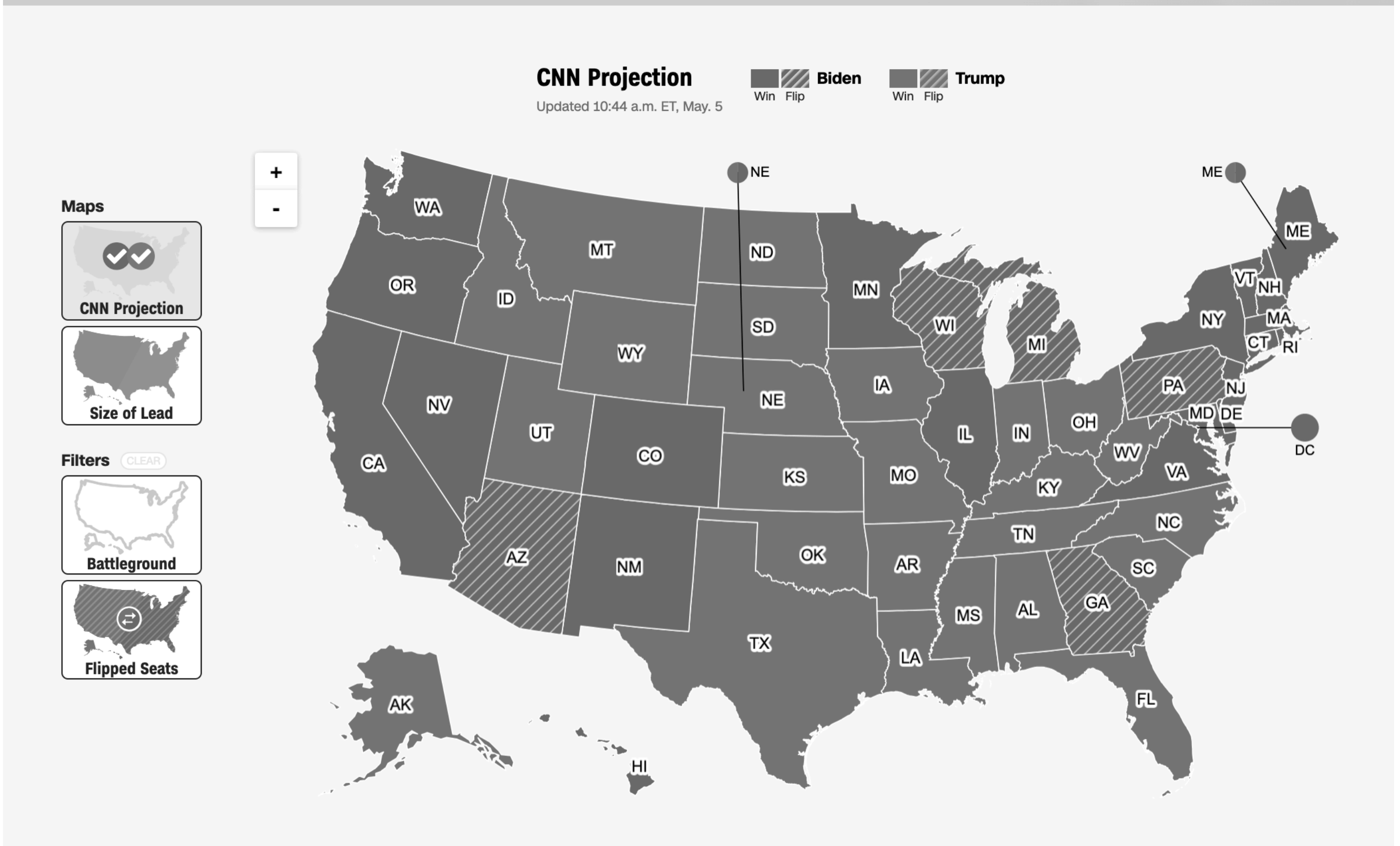
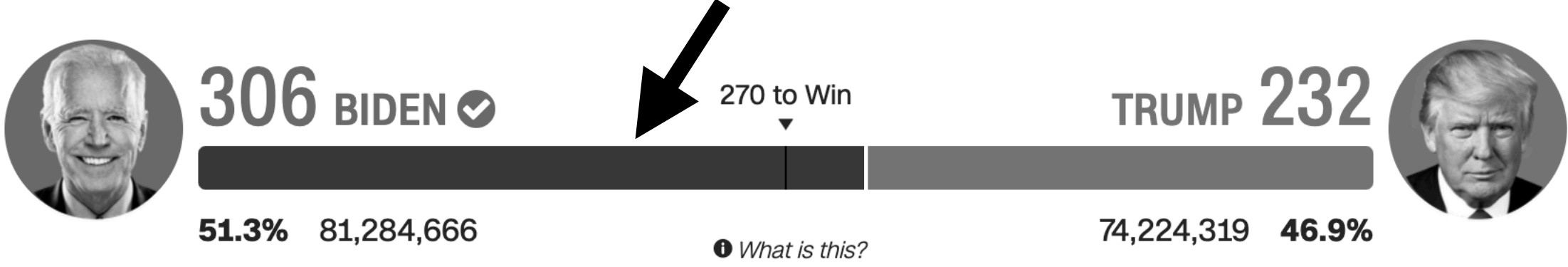
The division here matters!



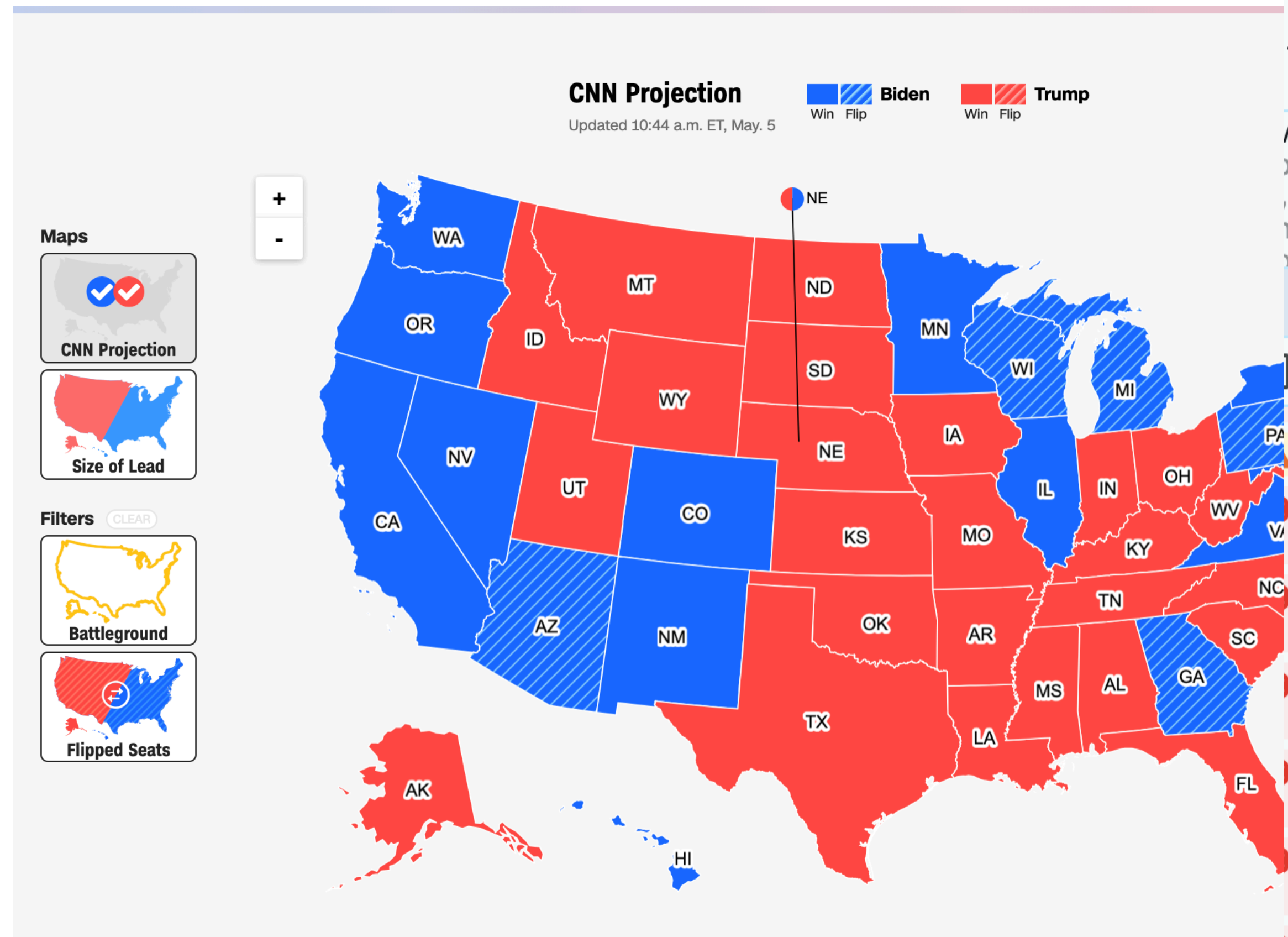
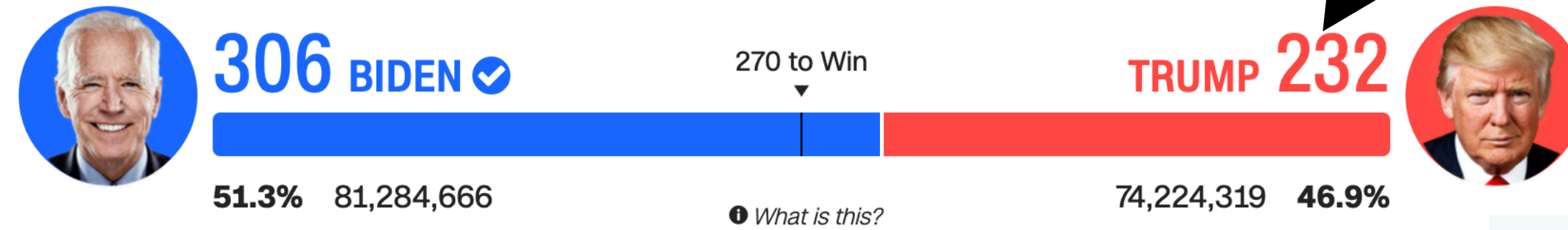
Maybe a small white divider, like the states?



Perhaps test a darker blue too?



What if we fix the contrast failures at the same time?



color: rgb(220 57 50);

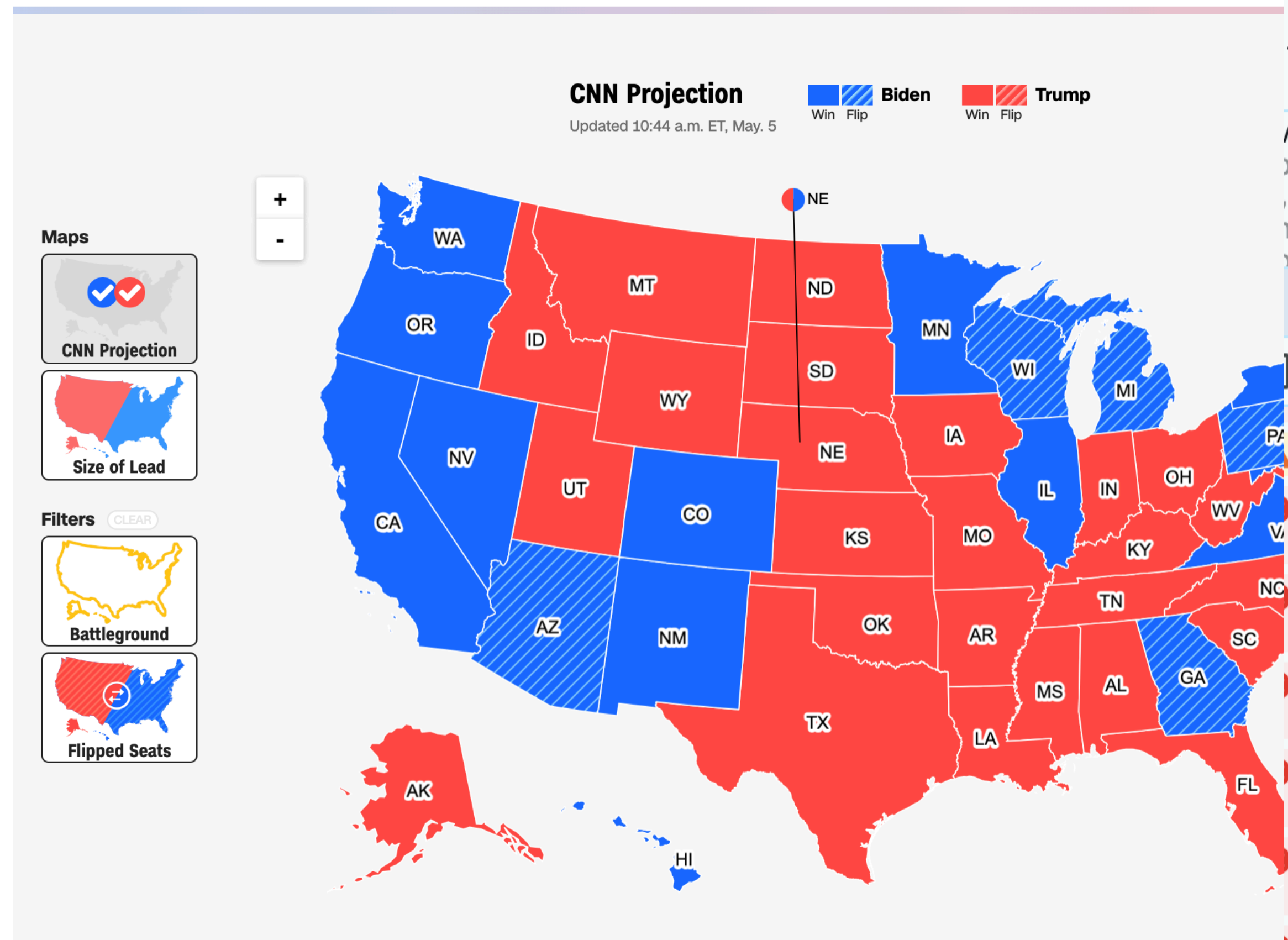
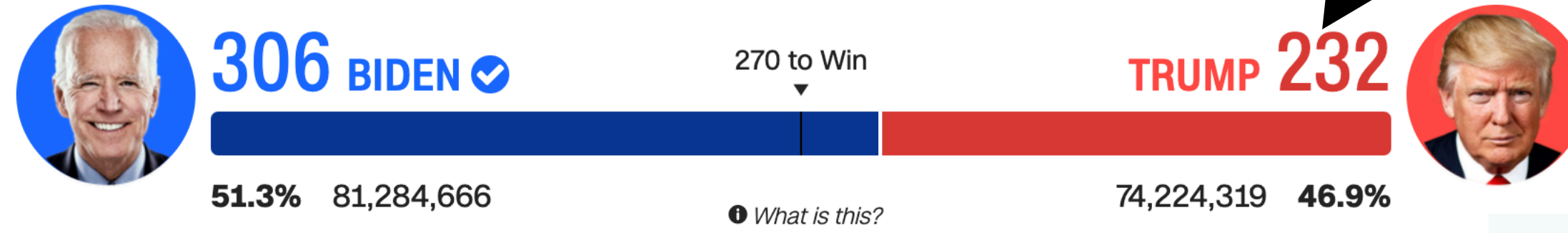
Contrast ratio 4.5

AA: 3.0 ✓

AAA: 4.5 ✓

Detailed description: An accessibility tool overlay is positioned over the right side of the map. It shows a color selection tool with a red circle and a color gradient bar. Below the color bar, the RGB values are displayed as 220, 57, 50. The tool also shows a contrast ratio of 4.5, which is above the AA (3.0) and AAA (4.5) thresholds, indicated by green checkmarks. There are several 'Failed net::' error messages visible in the background of the tool's interface.

This text now passes!



color: ■ rgb(220 57 50);

line height: 0.8x

Contrast ratio 4.5

AA: 3.0 ✓

AAA: 4.5 ✓

220 57 50 1

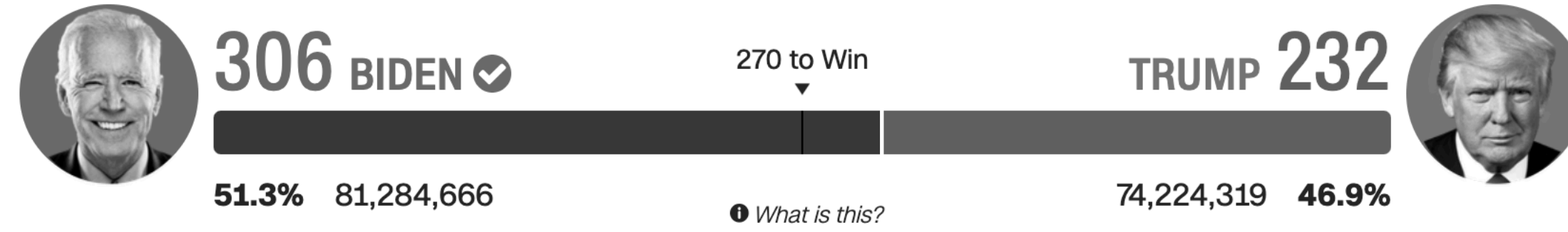
R G B A

Aa

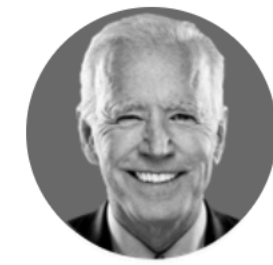
net::ERR_BLOCKED_BY_CLIENT

Detailed description: A semi-transparent overlay containing a color picker and accessibility checker. The color picker shows a red color with RGB values of 220, 57, 50 and an alpha of 1. The accessibility checker shows a contrast ratio of 4.5, which passes AA (3.0) and AAA (4.5) standards. The overlay also includes a grid of color swatches and a text input field with the text 'net::ERR_BLOCKED_BY_CLIENT'.

Let's check that greyscale again...



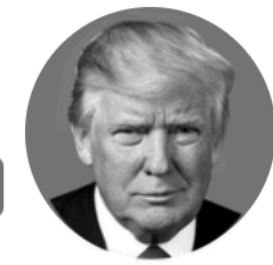
Before



306 BIDEN ✓

270 to Win
▼

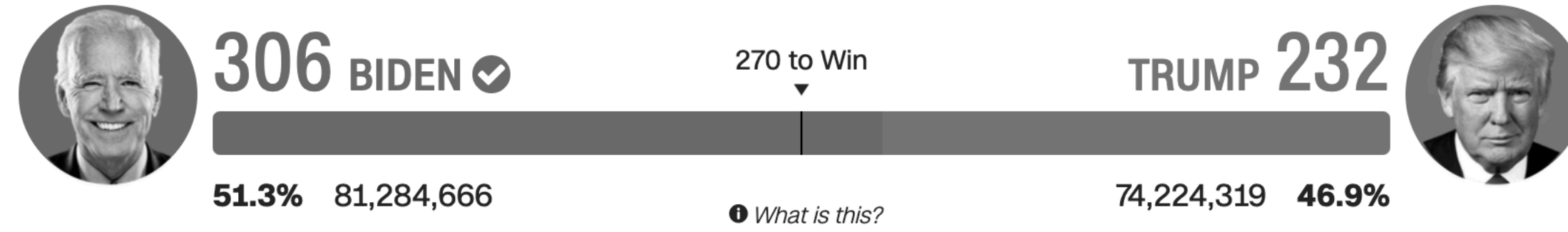
TRUMP **232**



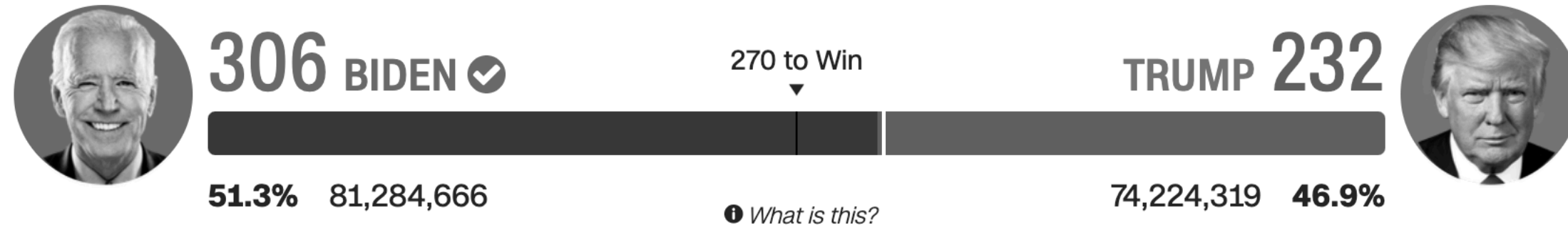
51.3% 81,284,666

[What is this?](#)

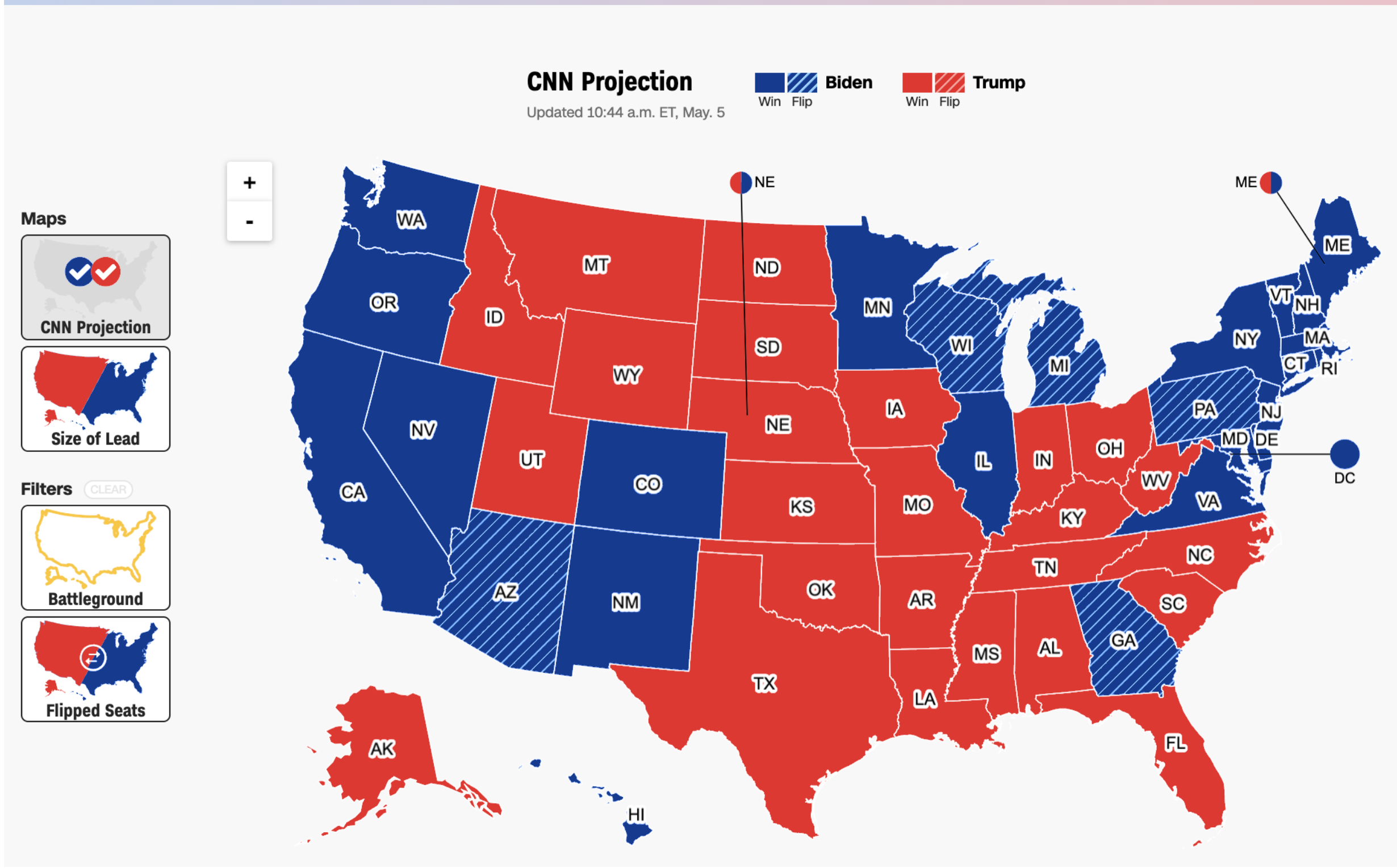
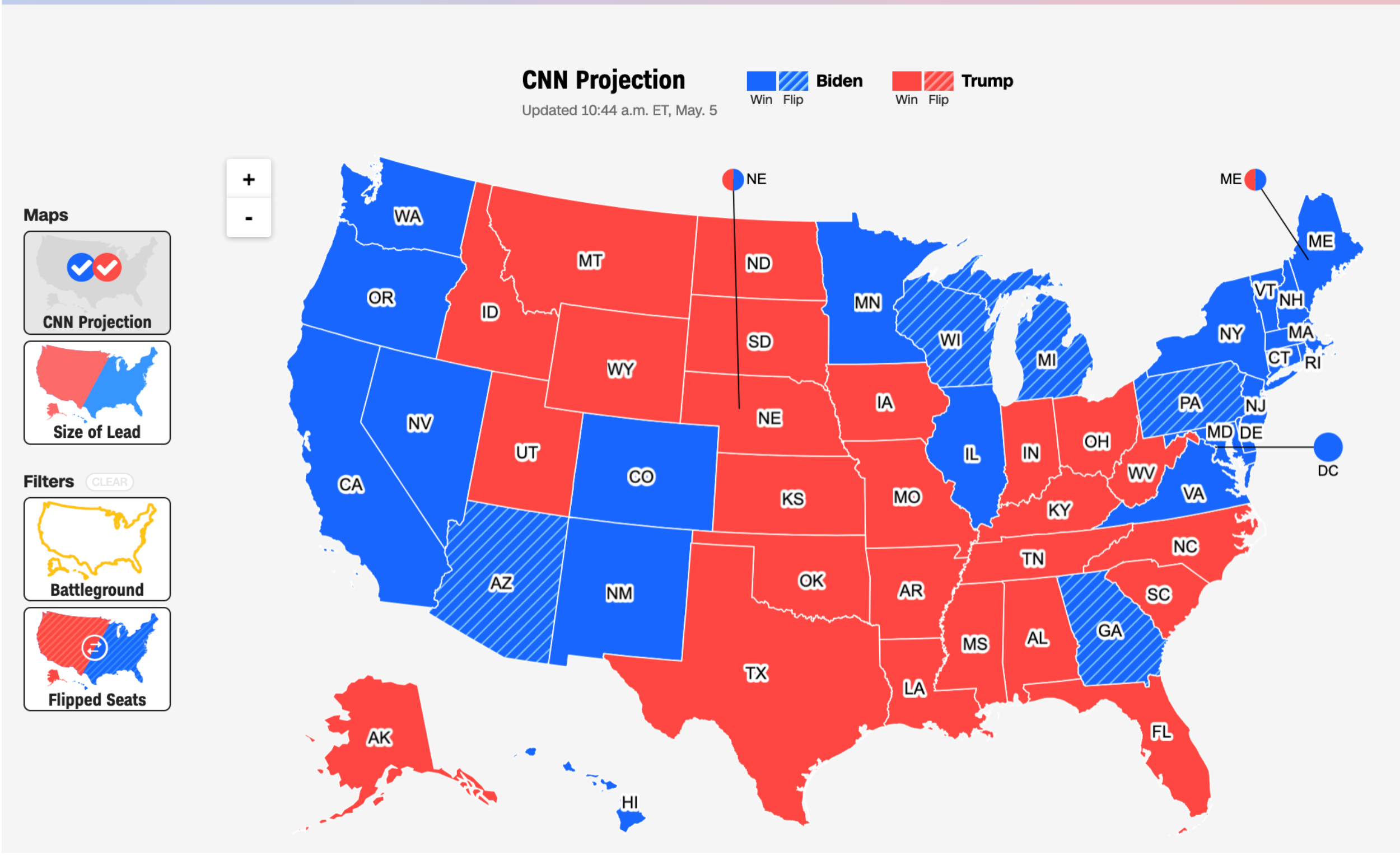
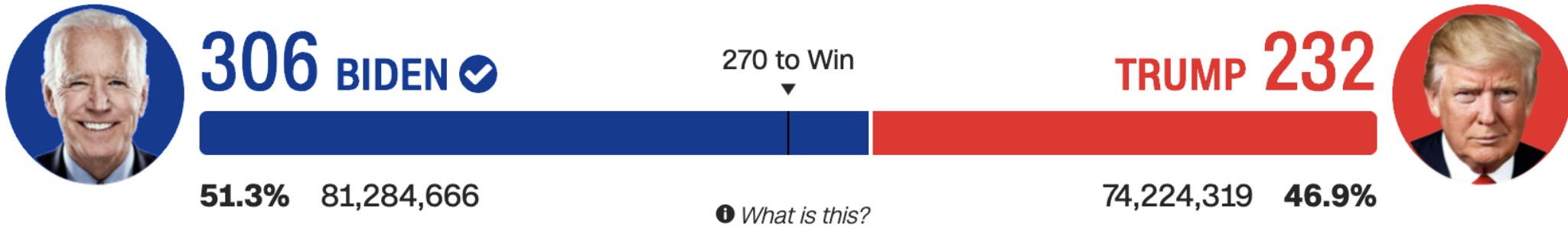
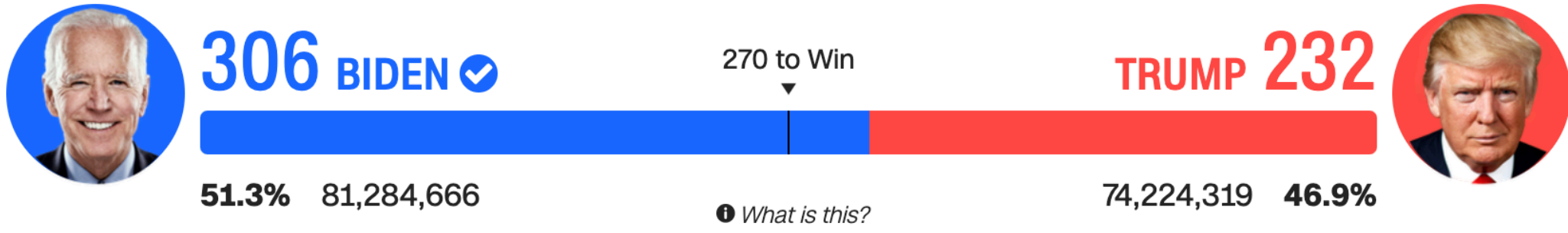
74,224,319 **46.9%**



And after!



Sufficient contrast can help folks differentiate



But what about more than 2 colors?



NOT IDEAL

Source: [Datawrapper](#)

But what about more than 2 colors?



Finding “pair” contrast gets really hard after 3+ colors...

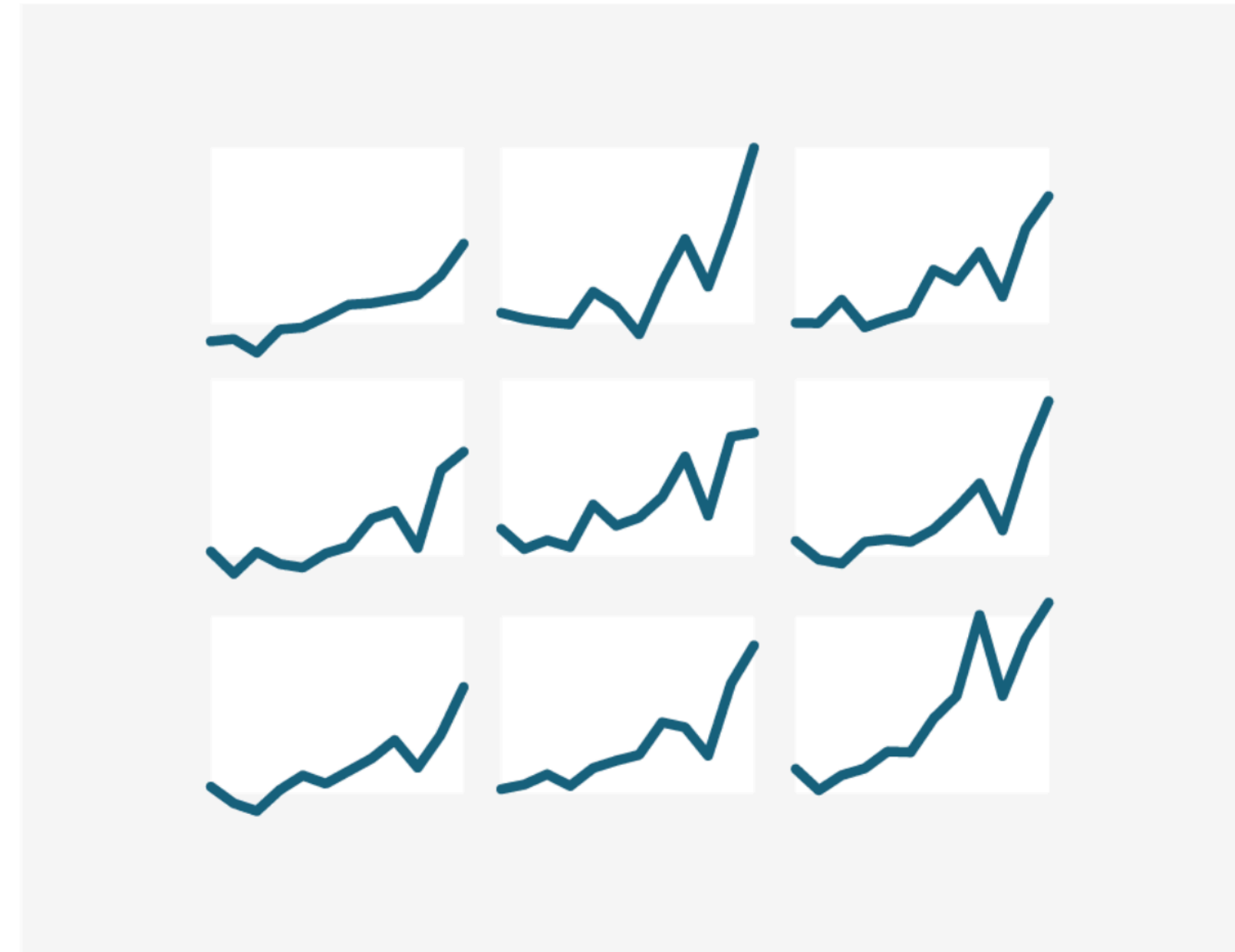
NOT IDEAL

Source: [Datawrapper](#)

Reduce your colors and redesign!



NOT IDEAL



BETTER

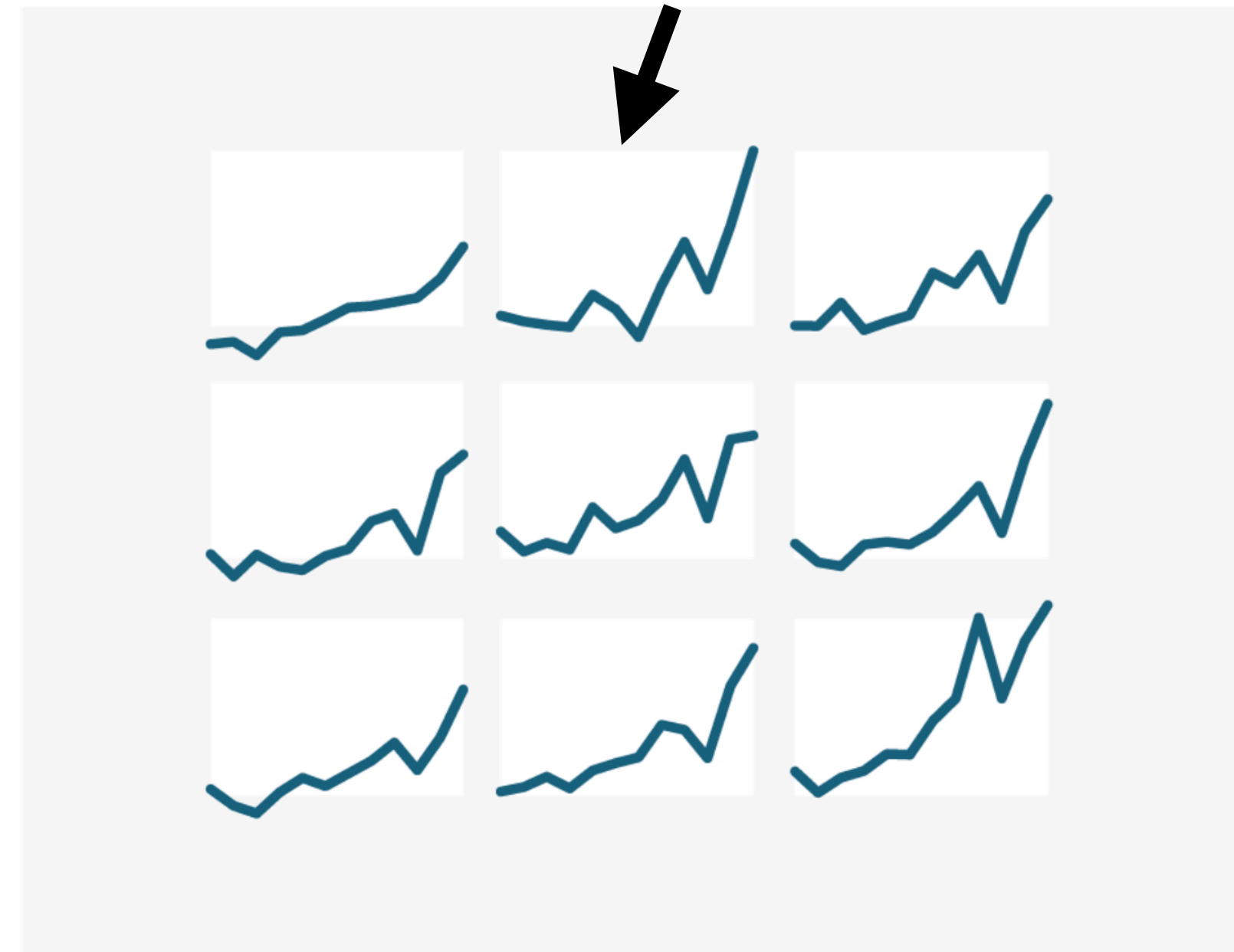
Source: [Datawrapper](#)

Reduce your colors and redesign!

Using “small multiples” is an easy, powerful technique



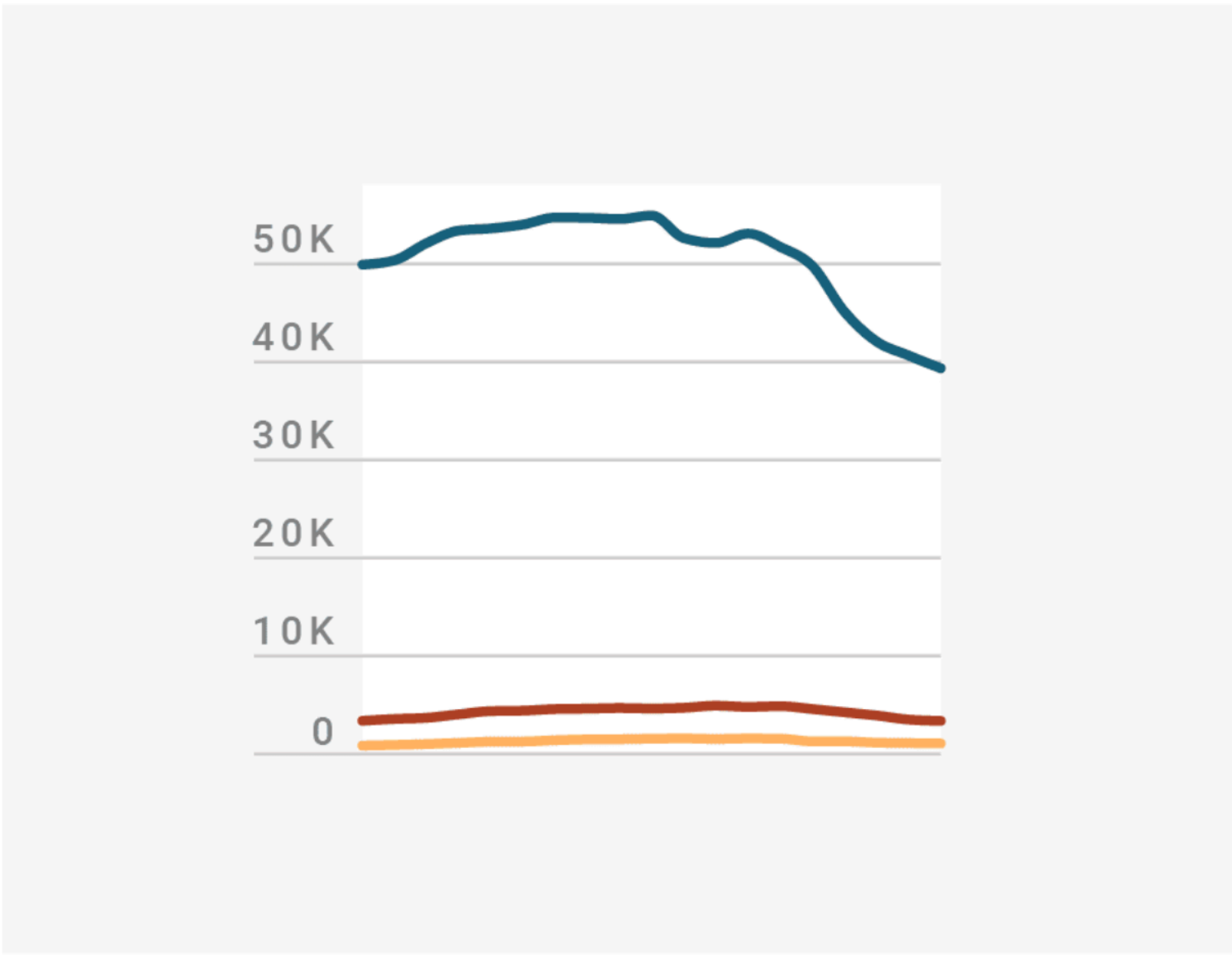
NOT IDEAL



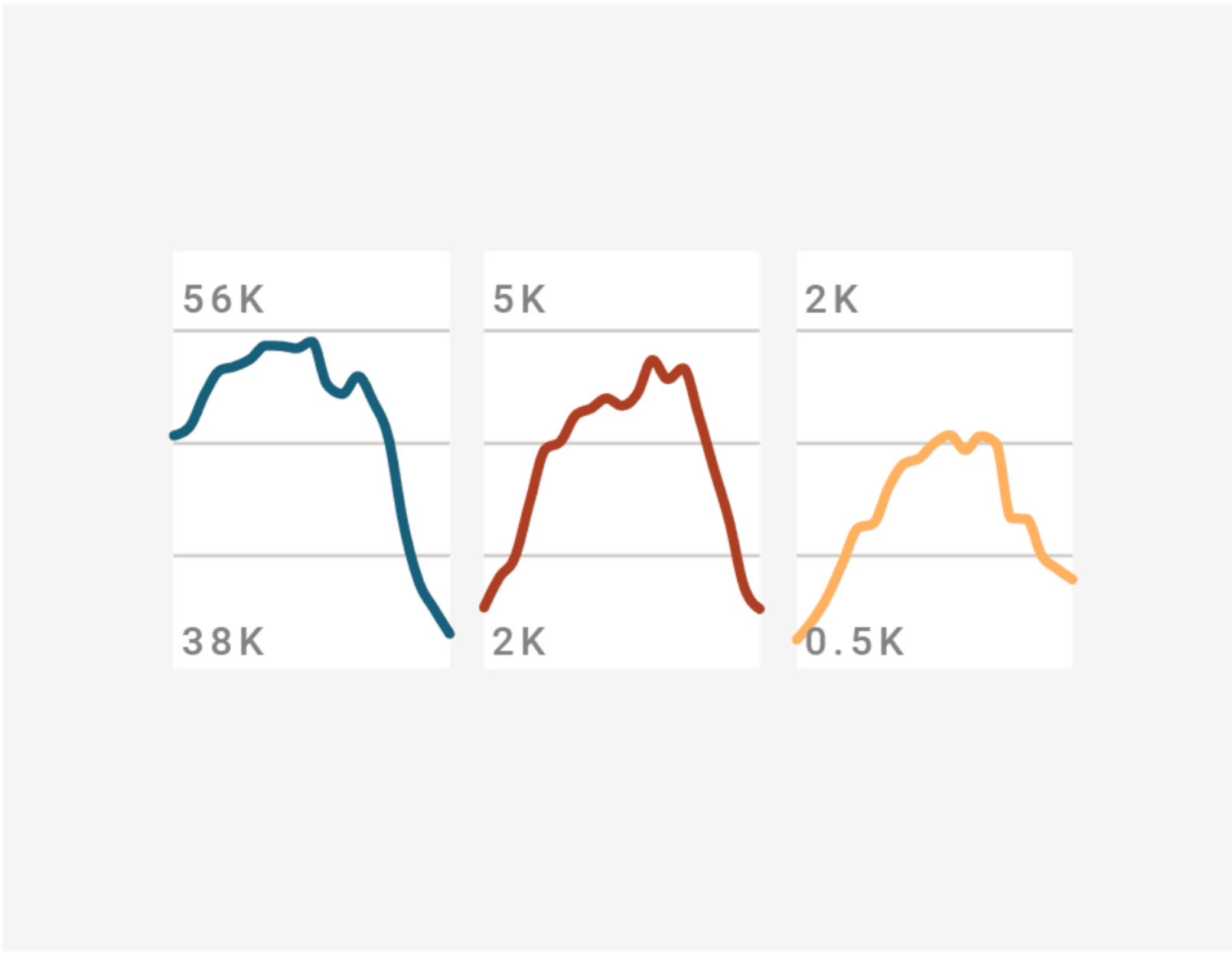
BETTER

Source: [Datawrapper](#)

Or simply separate your colors, if they matter



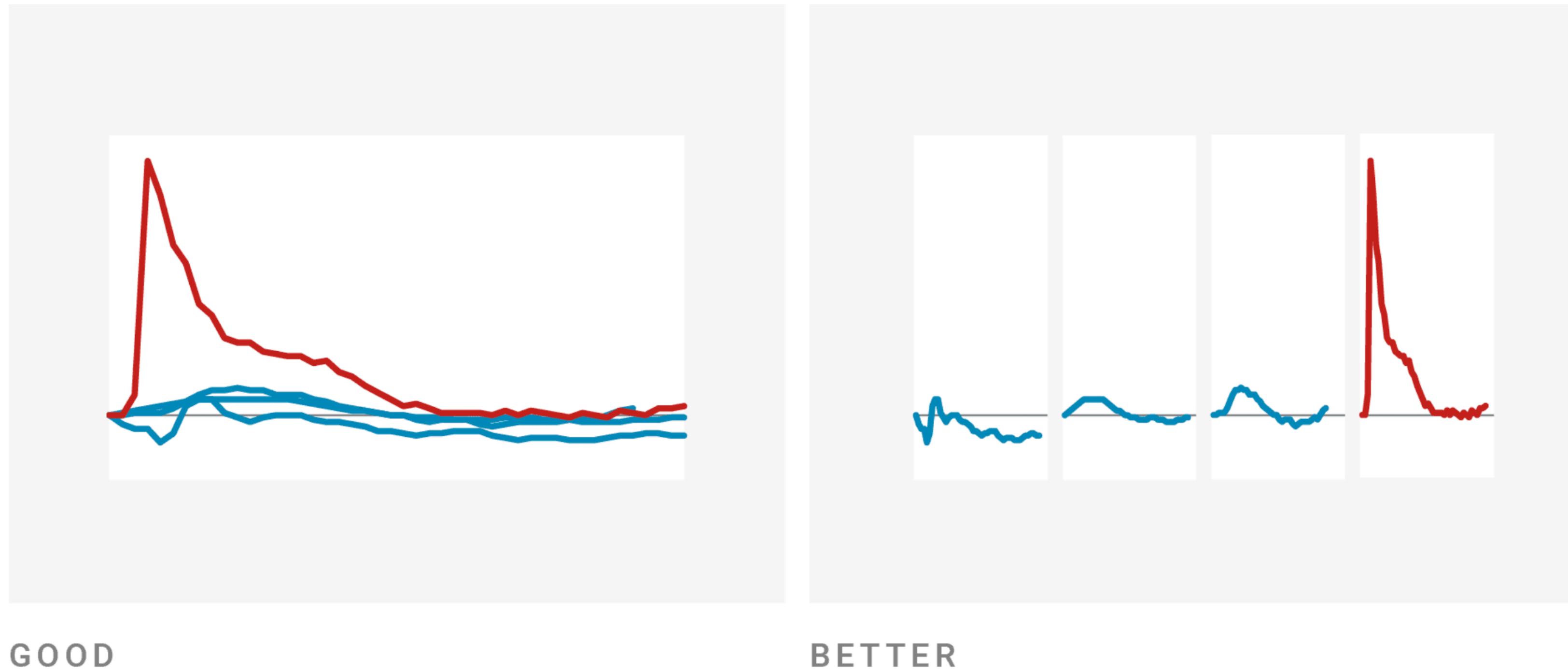
GOOD



ALSO GOOD

Source: [Datawrapper](#)

My favorite use of color is to pick just one for *emphasis*



Source: [Datawrapper](#)

Add alt text

There is great research on alt text, but the most important thing to know is that you should add it to every image you post online (including twitter), in a document, or presentation.

Guidance: <https://medium.com/nightingale/writing-alt-text-for-data-visualization-2a218ef43f81>

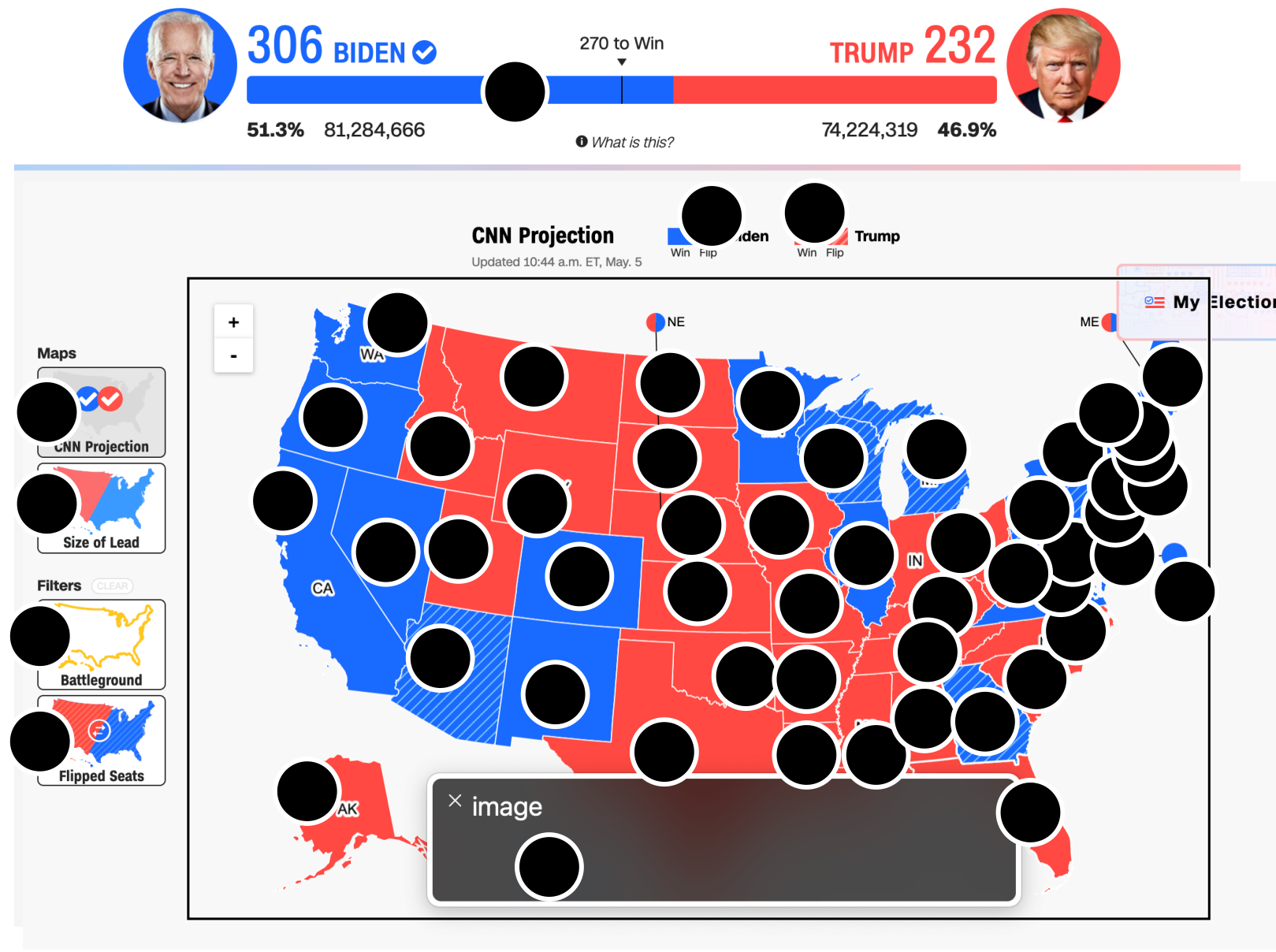
alt= "**Chart type** of **type of data**
where **reason for including chart**"

Include a **link to data source**
somewhere in the text

PRESIDENTIAL RESULTS

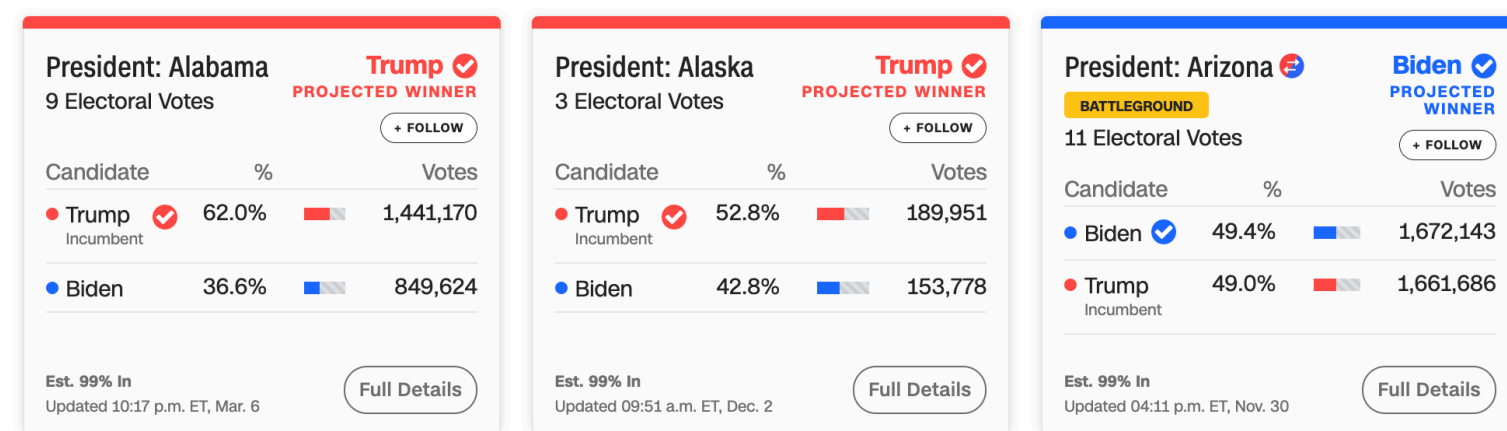
Joe Biden wins election to be the 46th US President

Pennsylvania's 20 electoral votes put native son Joe Biden above the 270 needed to become the 46th President of the United States. Born in Scranton, the former vice president and longtime Delaware senator defeated Donald Trump, the first President to lose a reelection bid since George H.W. Bush in 1992.



57 instances of
“Content is only visual”

STATE RESULTS

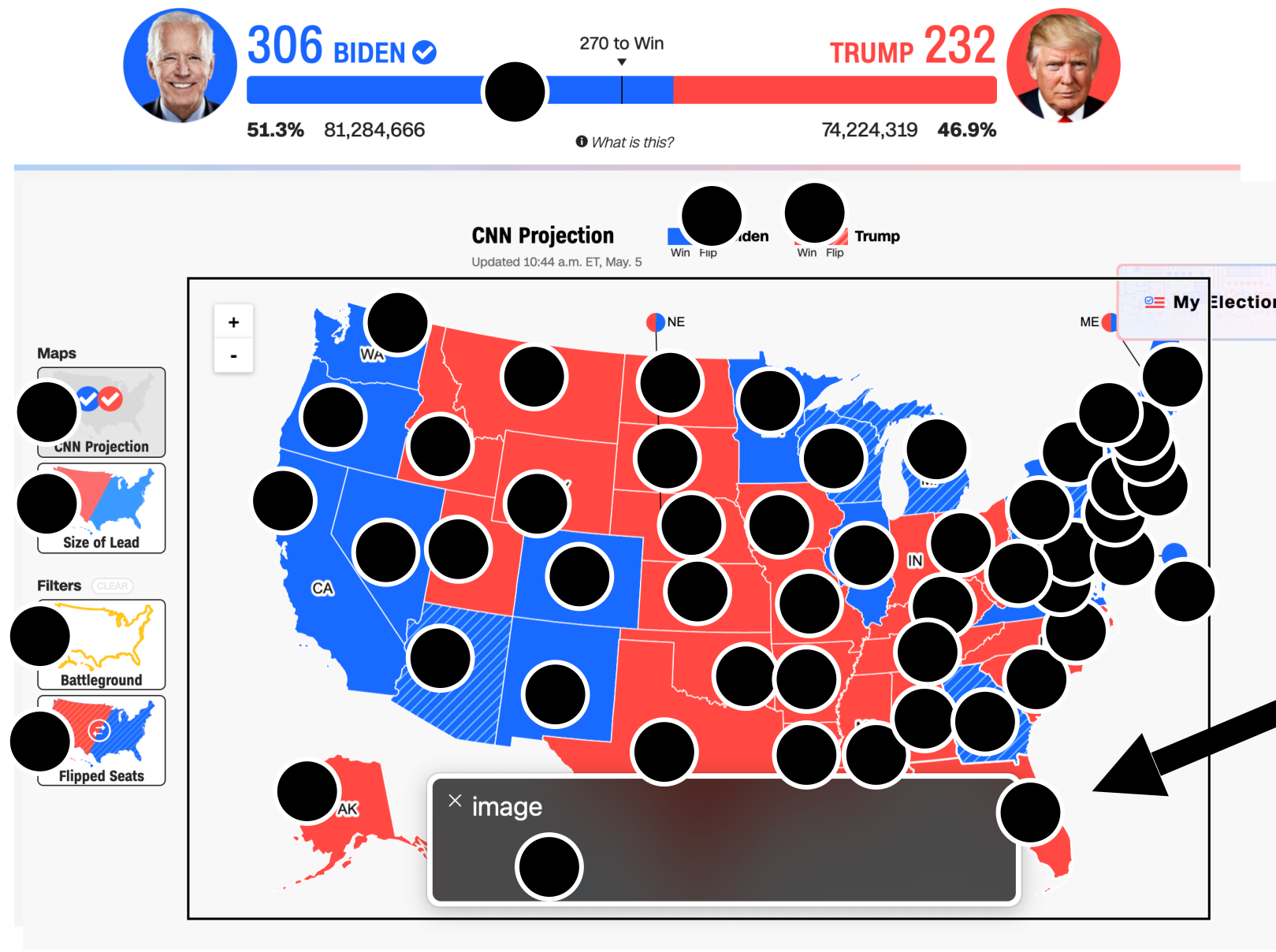


Show More States

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Each state should announce to screen readers what state it is and who won it, not “image!”

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Alaska	Trump	3	PROJECTED WINNER
Arizona	Biden	11	BATTLEGROUND

Candidate	%	Votes
Trump	62.0%	1,441,170
Biden	36.6%	849,624

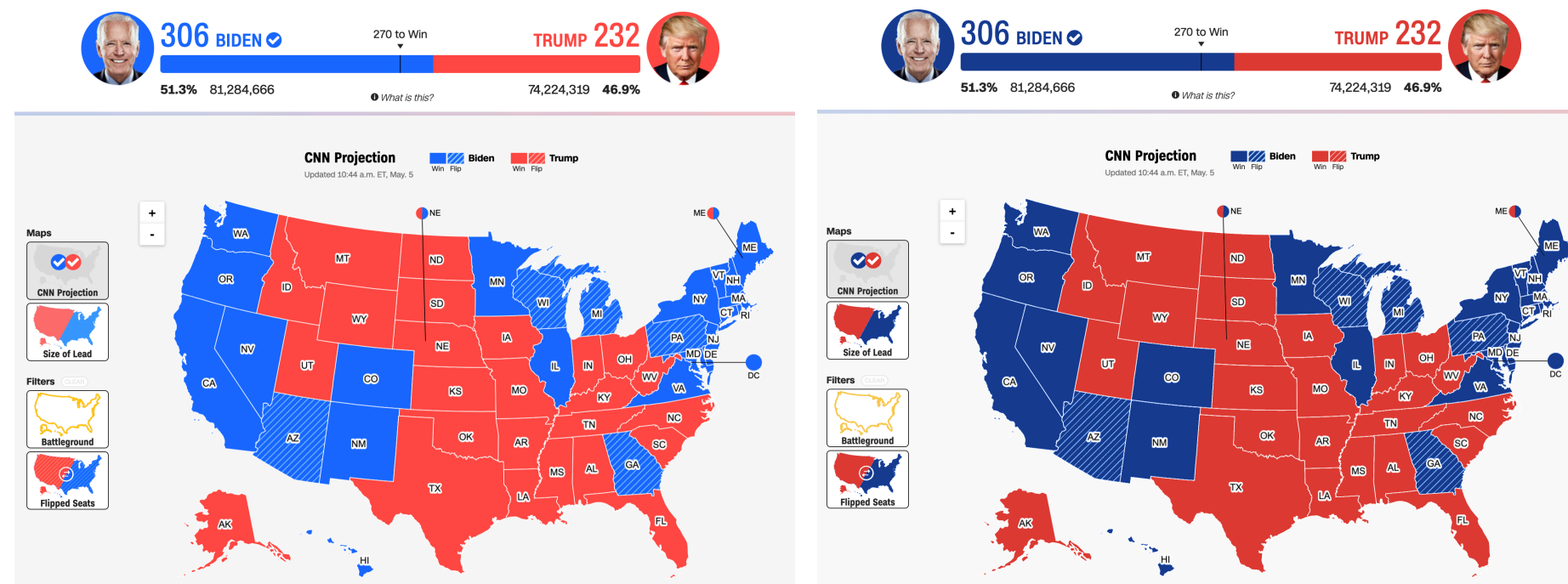
Est. 99% In
Updated 10:17 p.m. ET, Mar. 6

Full Details

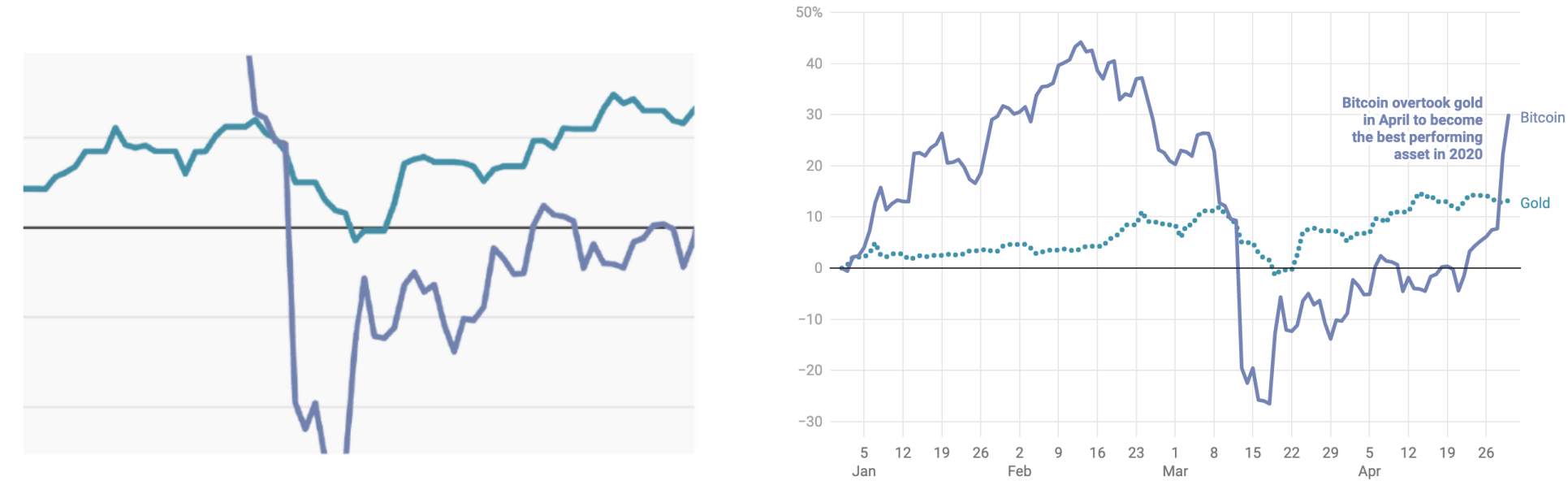
Show More States

Recap: Perceivability

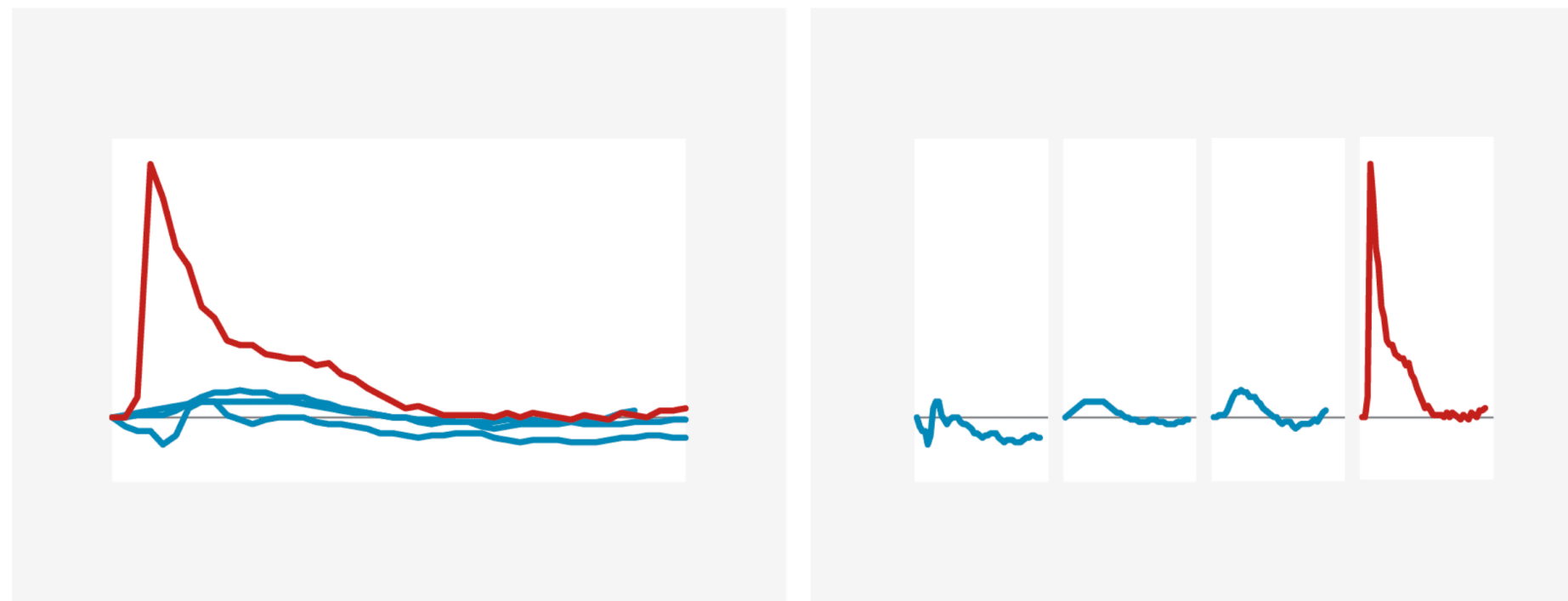
Use high contrast



Use redundant encoding



Reduce colors and crowding



Add alt text

alt= "Chart type of type of data where reason for including chart"

Include a link to data source somewhere in the text

Perceivable Evaluation Toolkit:

1. [Contrast Checker](#)
2. Safe color design
 - a. [CVD Checker](#)
 - b. [Redundant encoding design ideas](#)
 - c. [Small multiples design ideas](#)
3. [Alt Text](#)

Operable

Can someone operate this in multiple ways? Is each way easy?

Operable Checklist:

1. Mouse
2. Keyboard-only
3. Screen Reader

Many assistive input technologies “navigate”



A person in a wheelchair operating an old computer using a desk-mounted sip and puff device called the POSSUM.

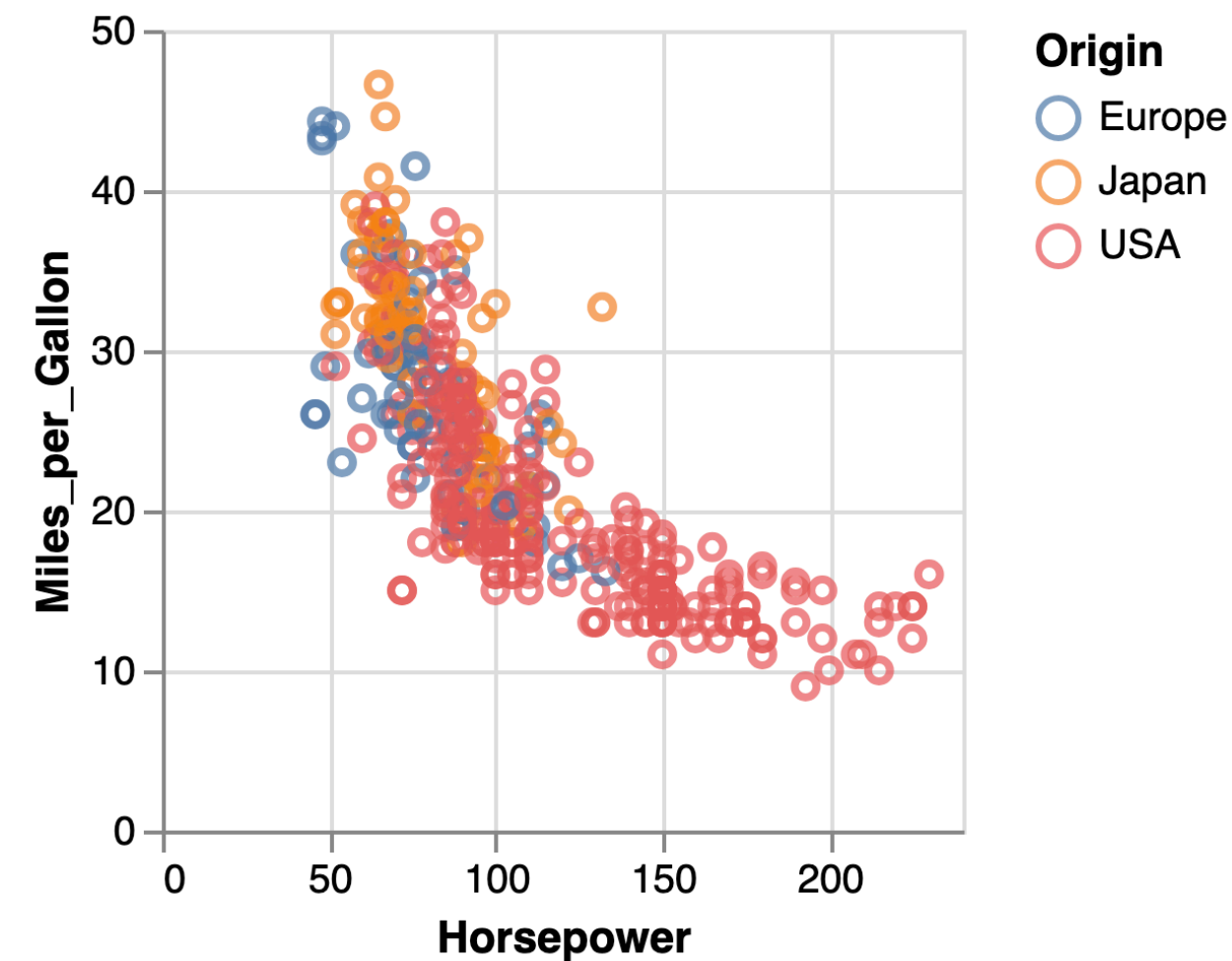
Image credit: [Wikipedia](#), Public Domain, 1960. Photographer: Possum Ltd.

Why “keyboard-only?”

Some things work for screen readers but not for keyboard-only users!

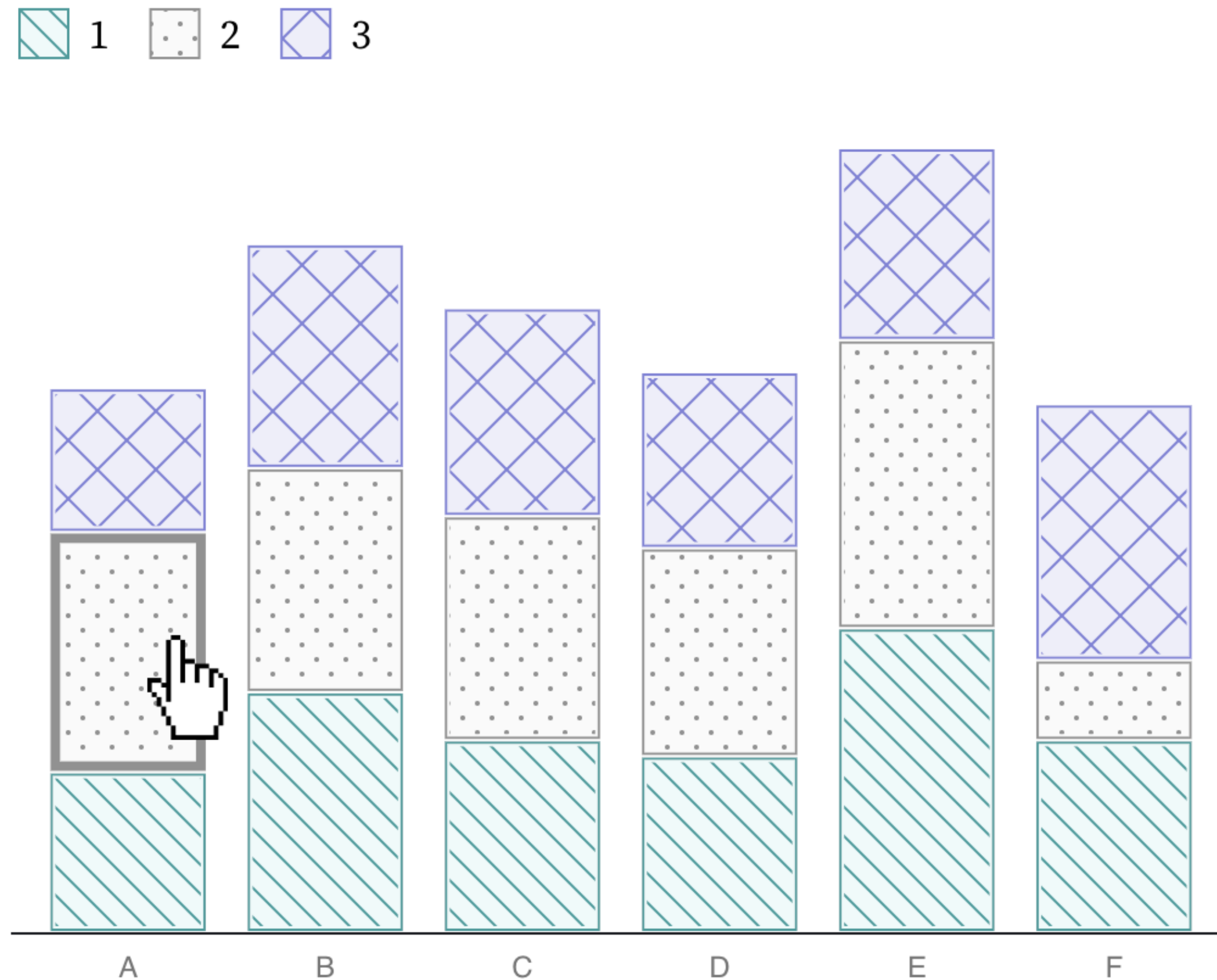
Scatterplot with External Links and Tooltips

A scatterplot showing horsepower and miles per gallons that opens a Google search for the car that you click on.



https://vega.github.io/vega-lite/examples/point_href.html

Ensure Keyboard Access (if interactive)



Status: Category 2 of Building A has been selected.

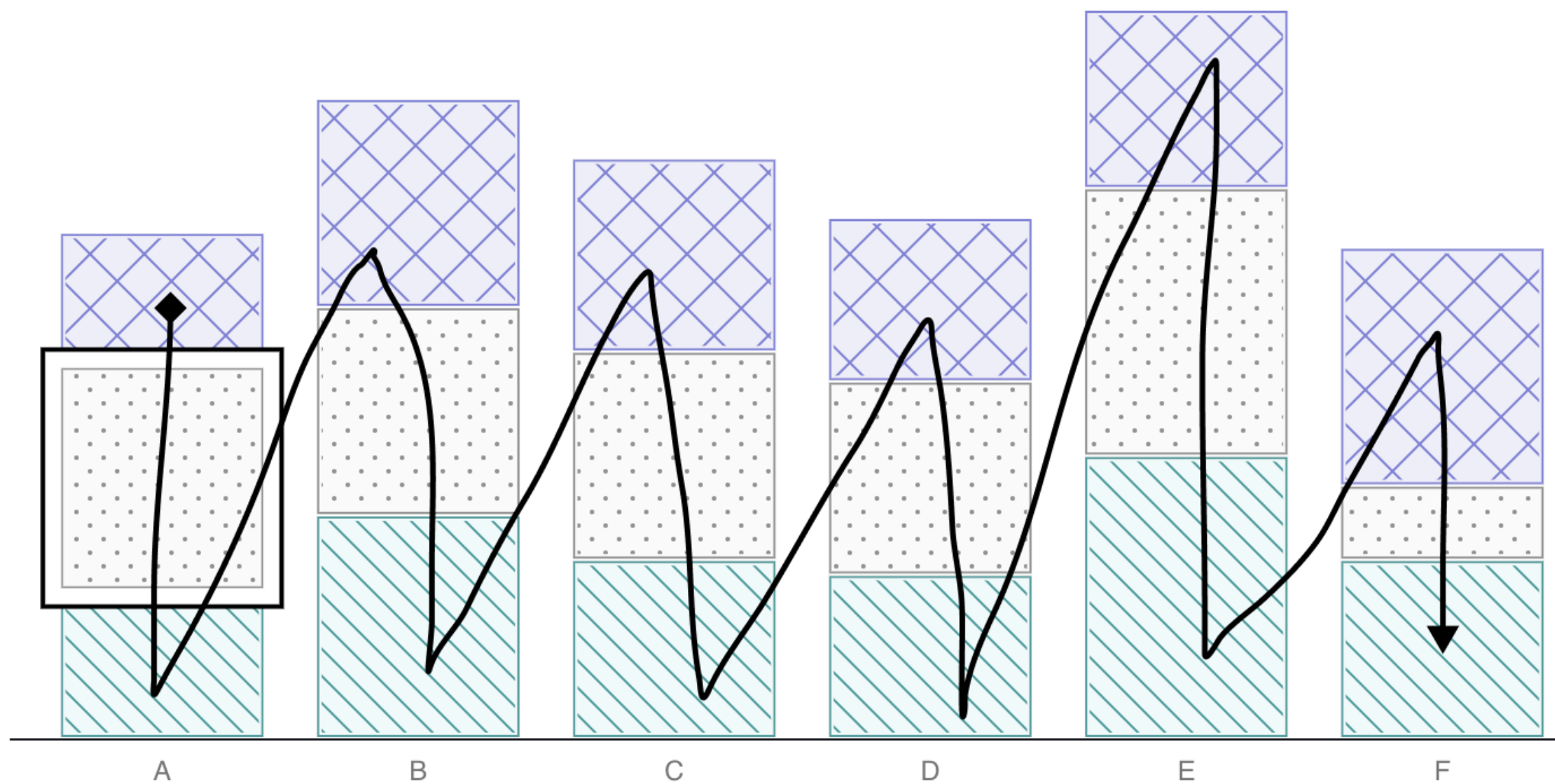
Products In Building A that belong to Category 2*

Product Name	Count in Stock
Product A	147
Product C	88
Product M	69

**This table has been populated by the selection in the preceding chart.*

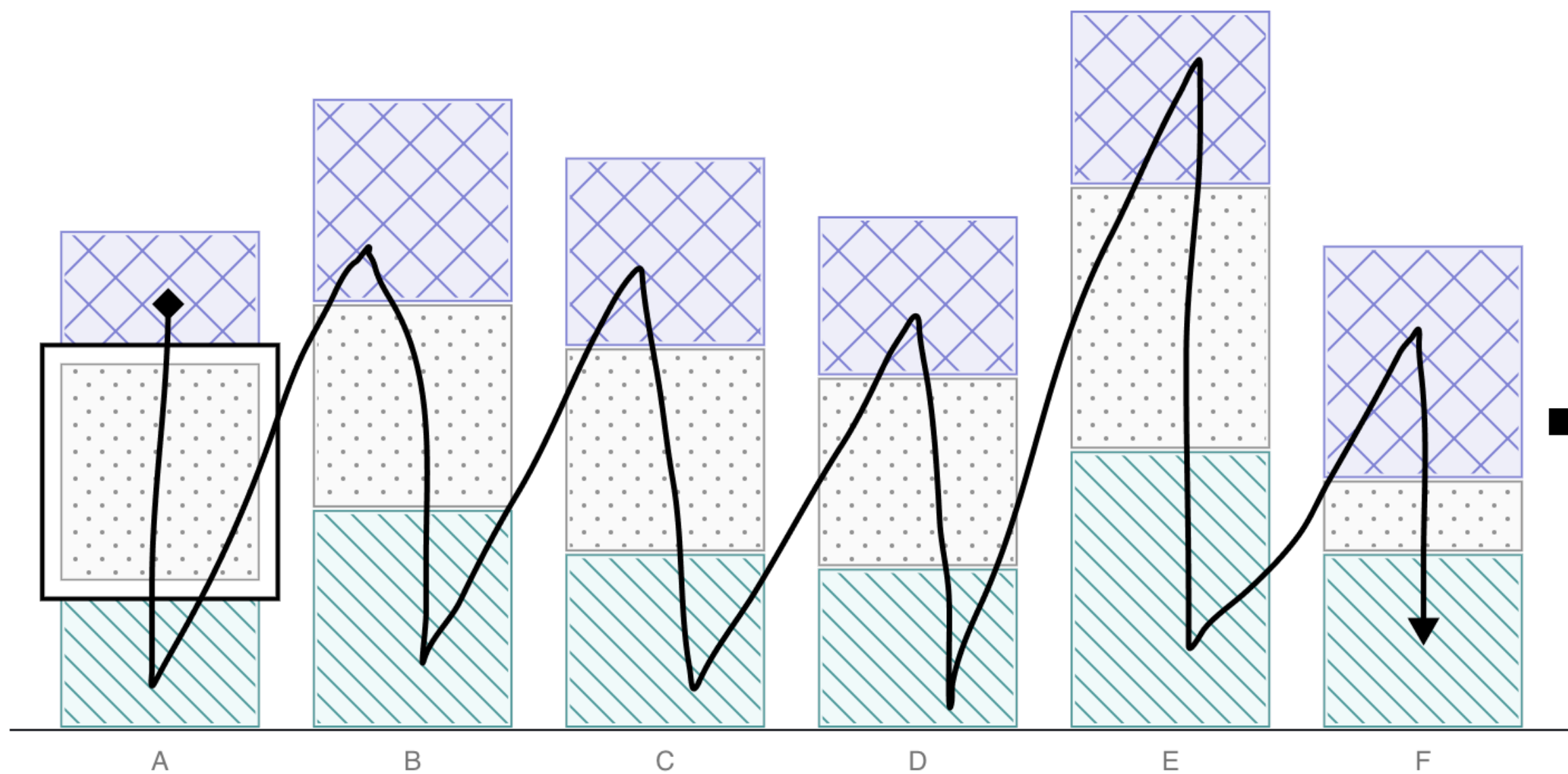
How does someone move around? By default, it is as elements are rendered:

1 2 3

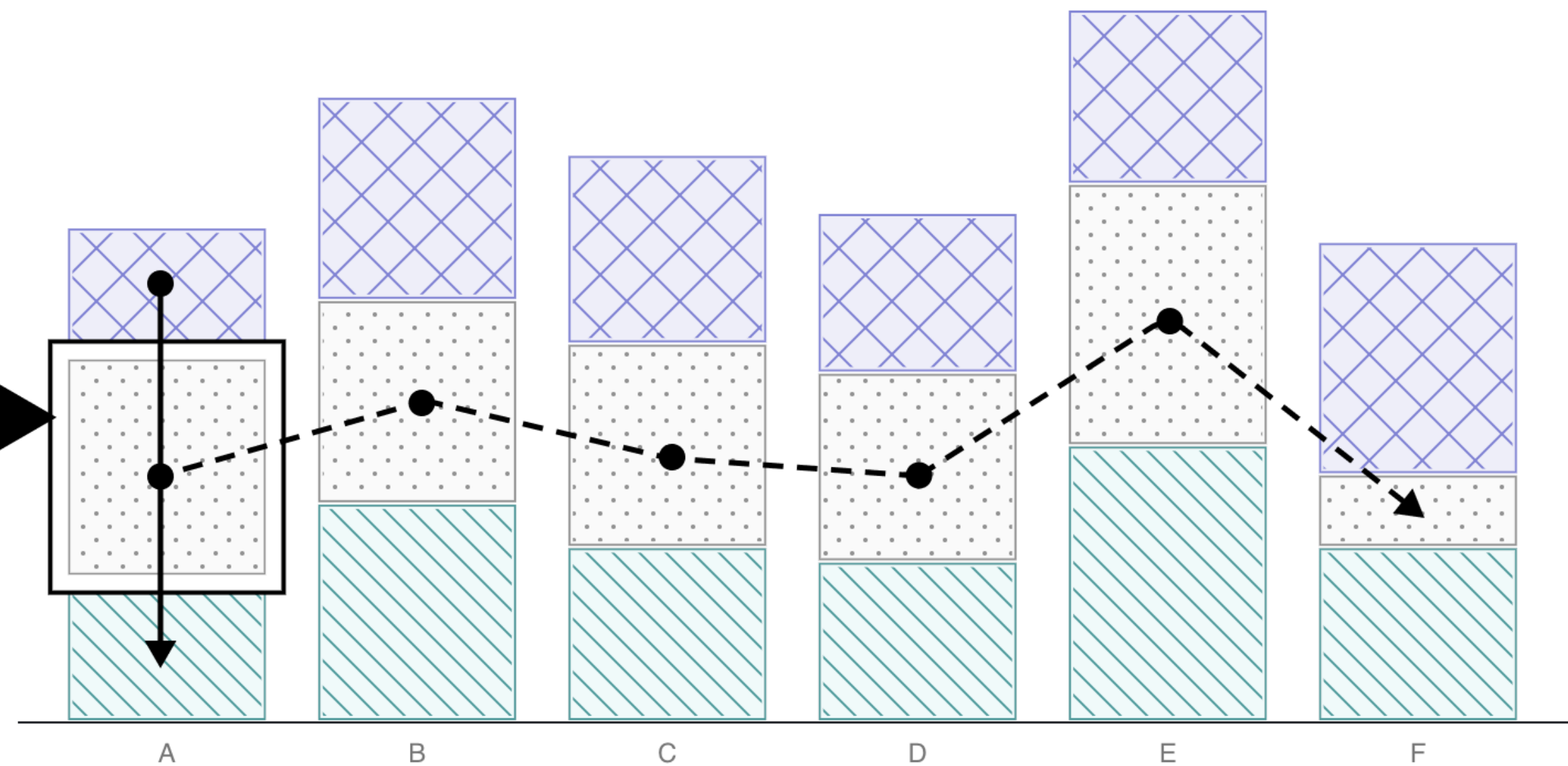


Consider more flexible movement when data *exploration* matters

1 2 3

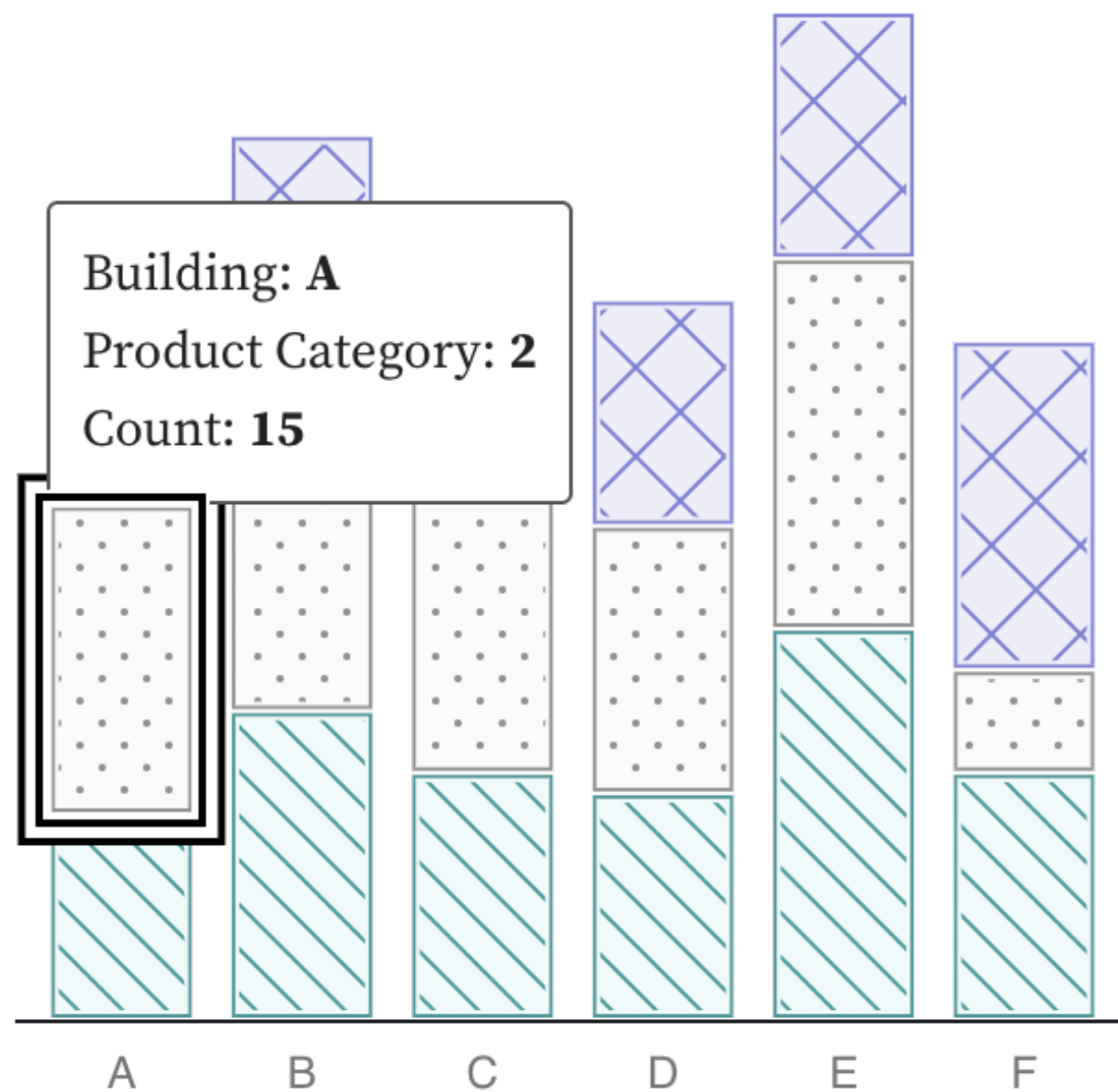


1 2 3



Alt text should communicate operability

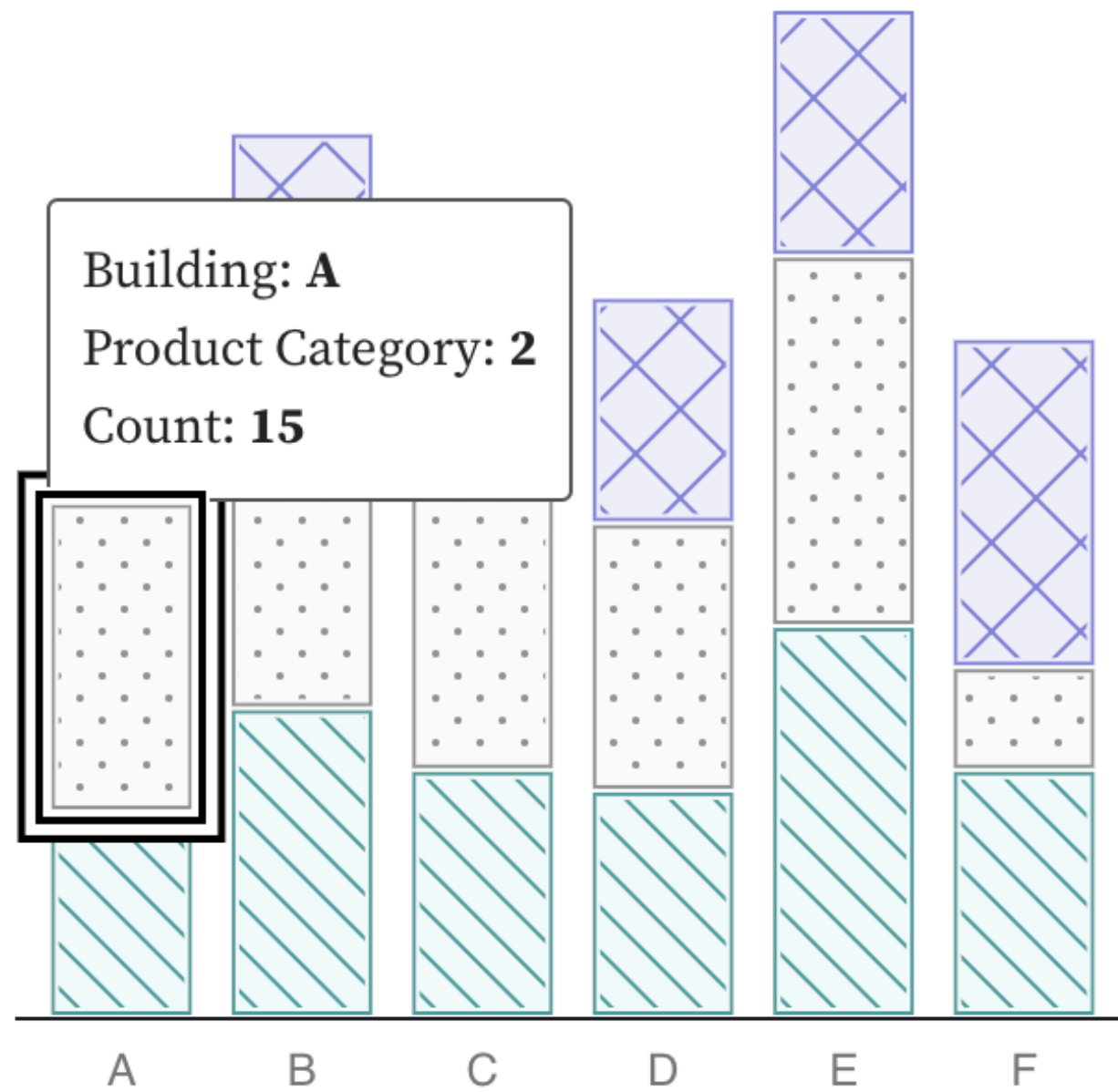
1 2 3



× Building A. Product Category 2.
Count 15. Bar 2 of 3. Image.

Semantics matter

1 2 3

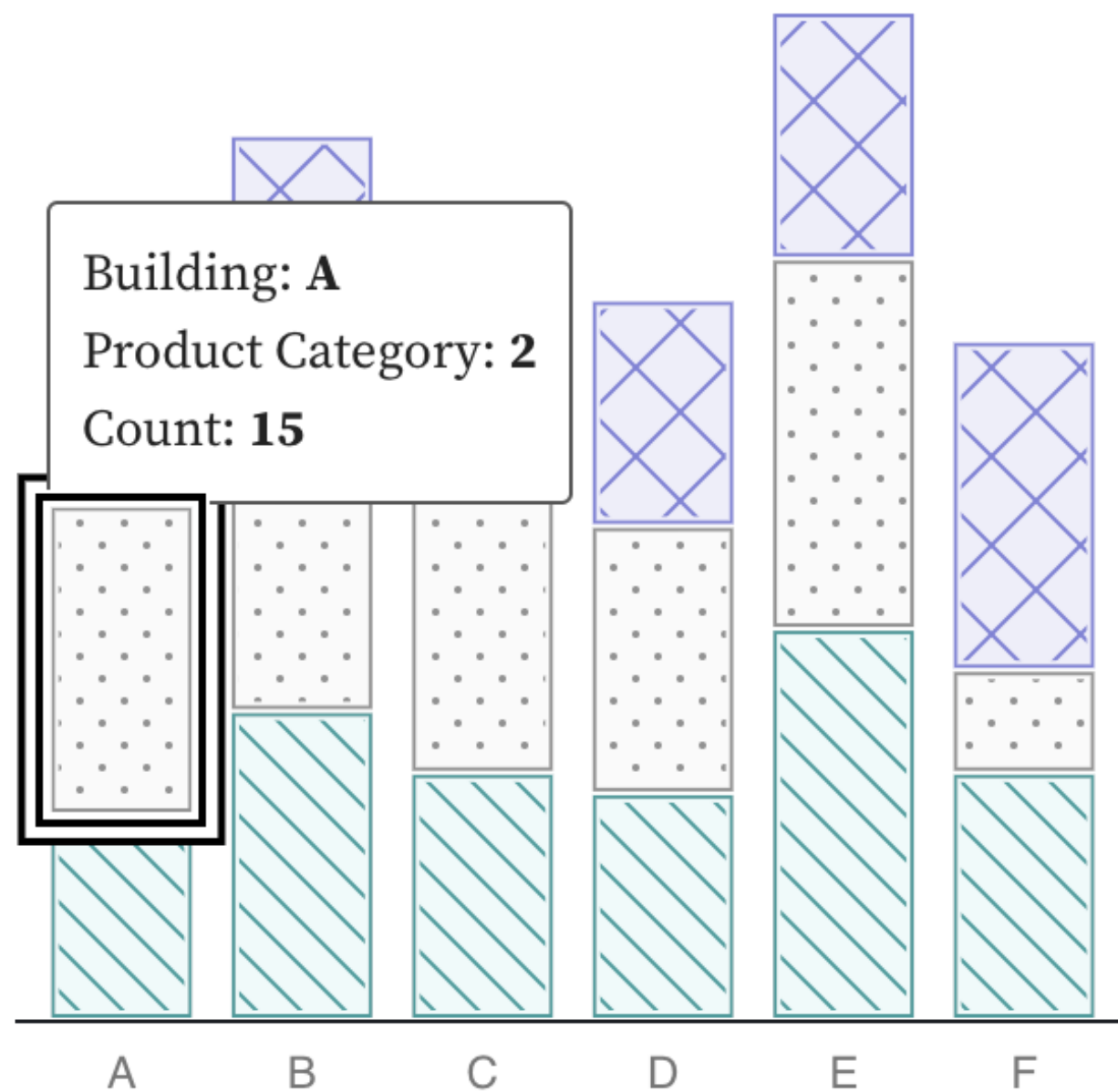


× Building A. Product Category 2.
Count 15. Bar 2 of 3. Image.

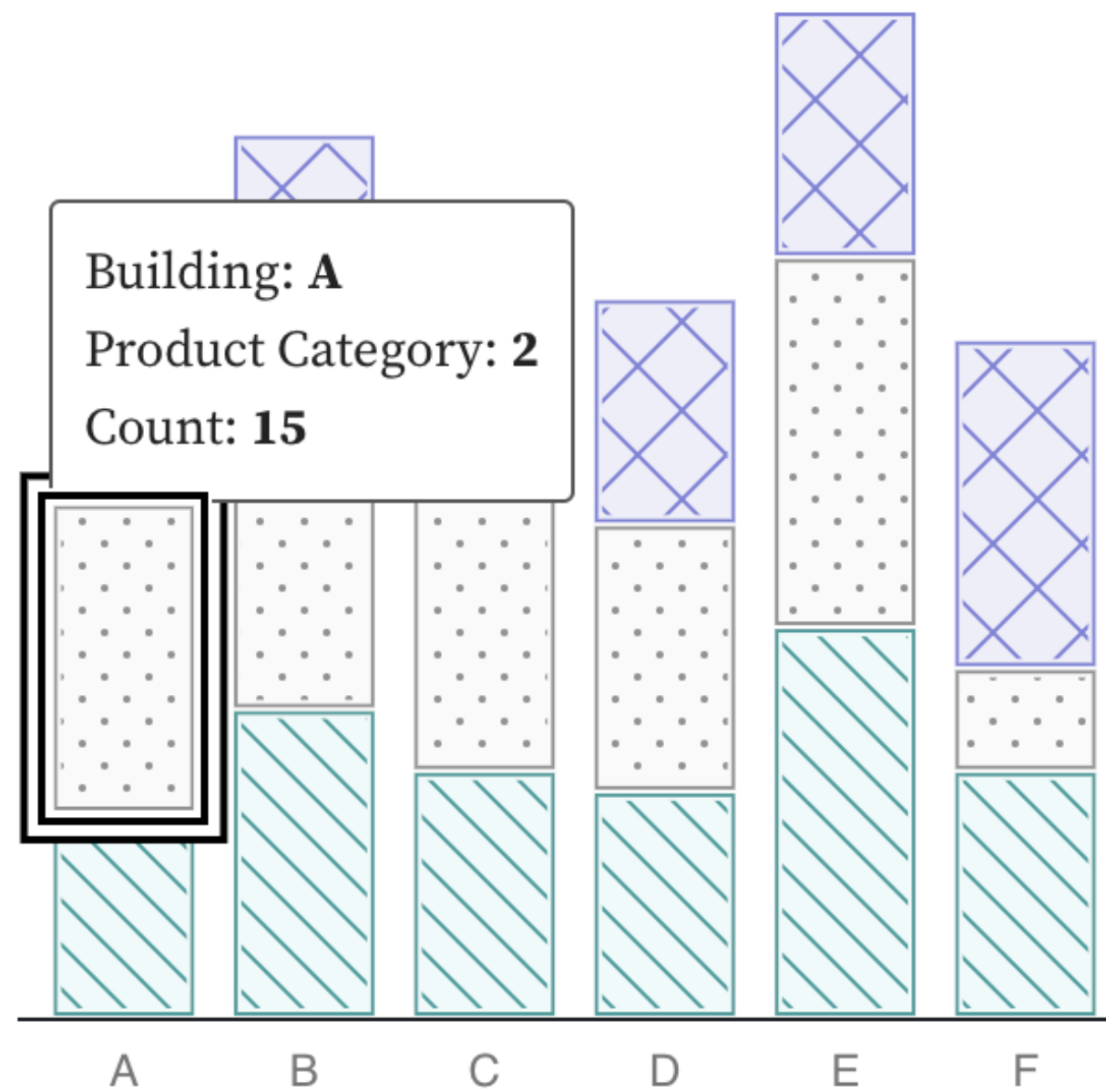
“Image” doesn’t signal
interactivity!

“Aria” states and roles are standardized

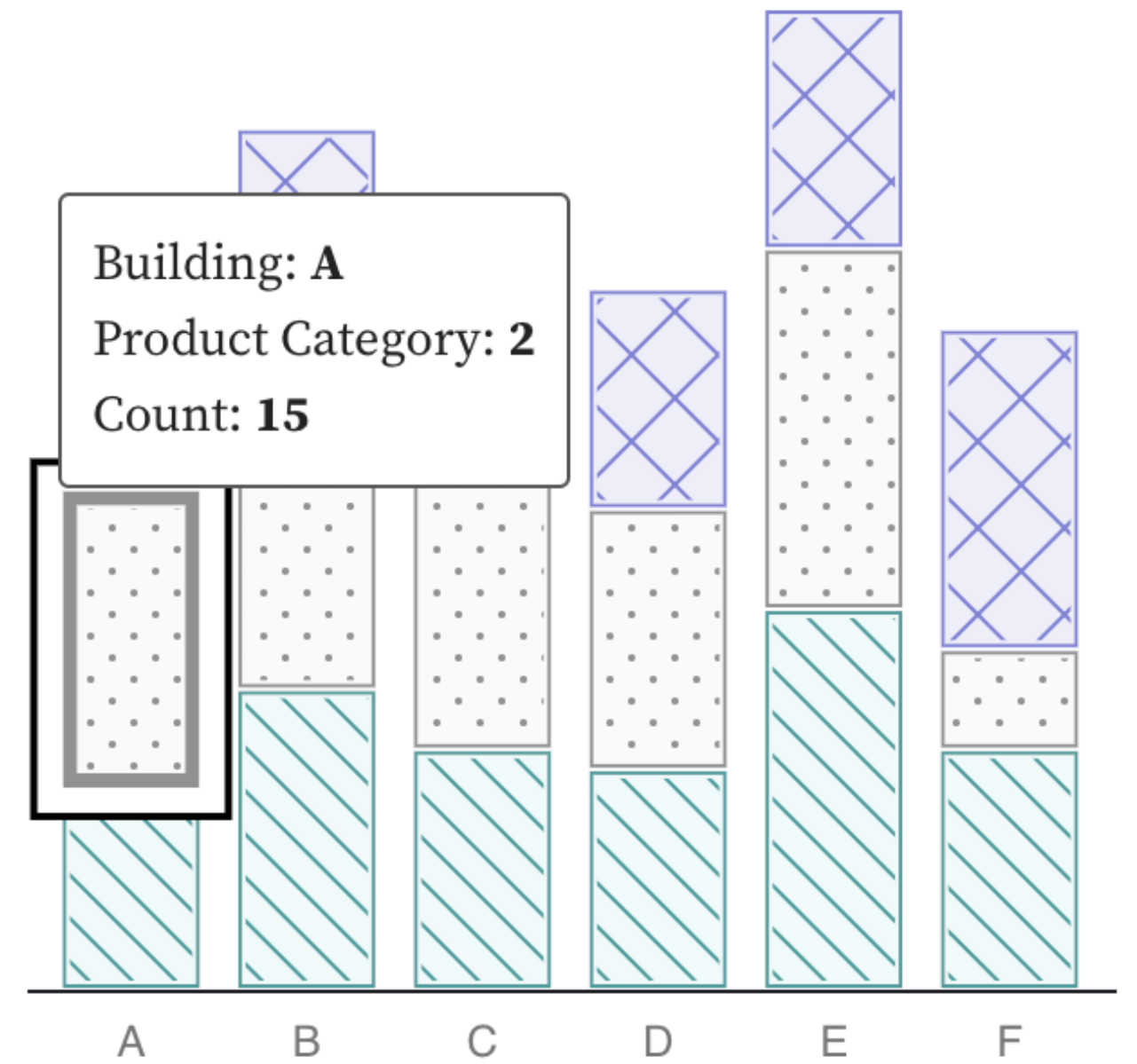
1 2 3



1 2 3



1 2 3



× Building A. Product Category 2. Count 15. Bar 2 of 3. Image.

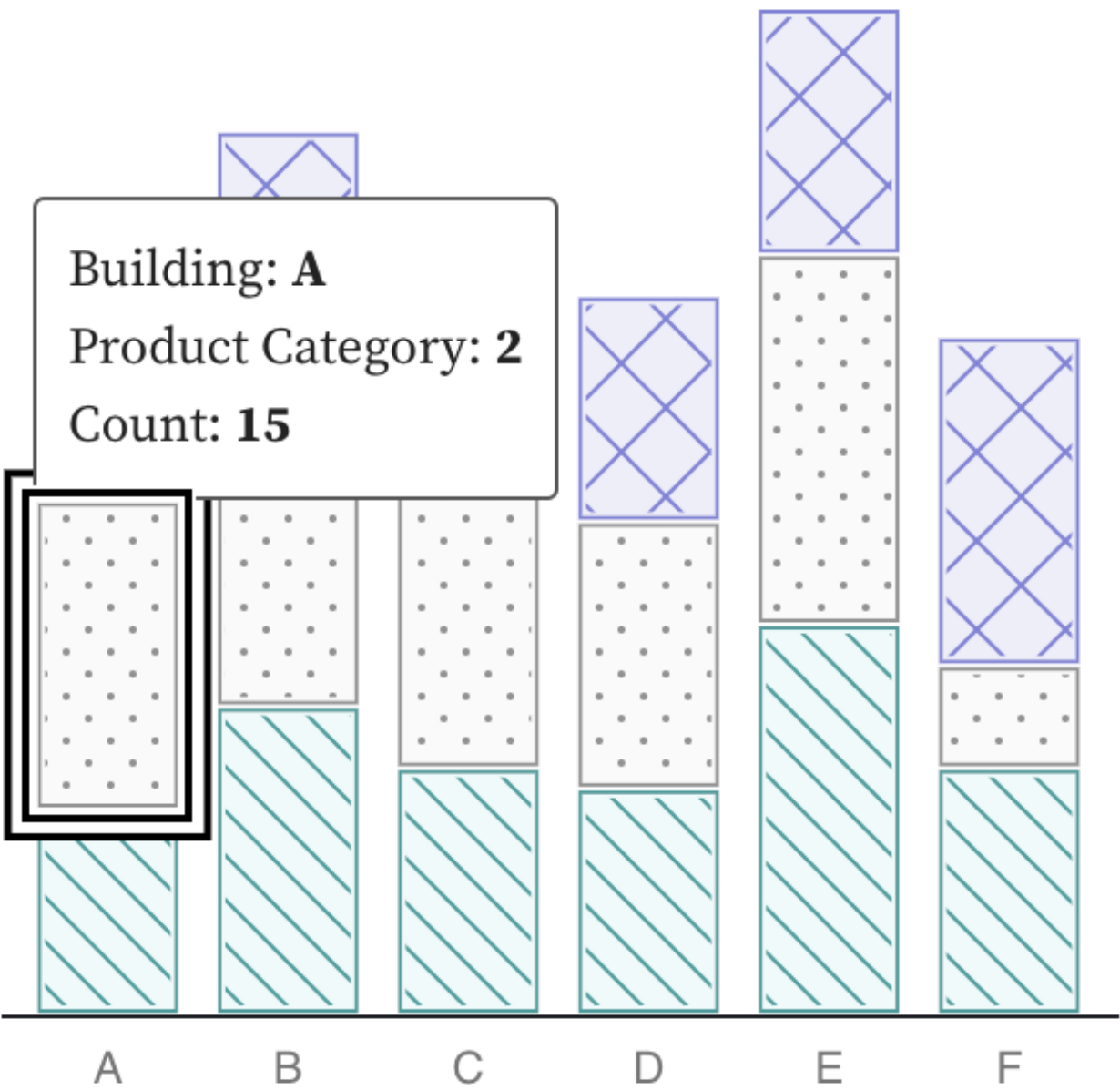
× Building A. Product Category 2. Count 15. Bar 2 of 3., toggle button

× selected, Building A. Product Category 2. Count 15. Bar 2 of 3., toggle button

Communicating operability should be visual too

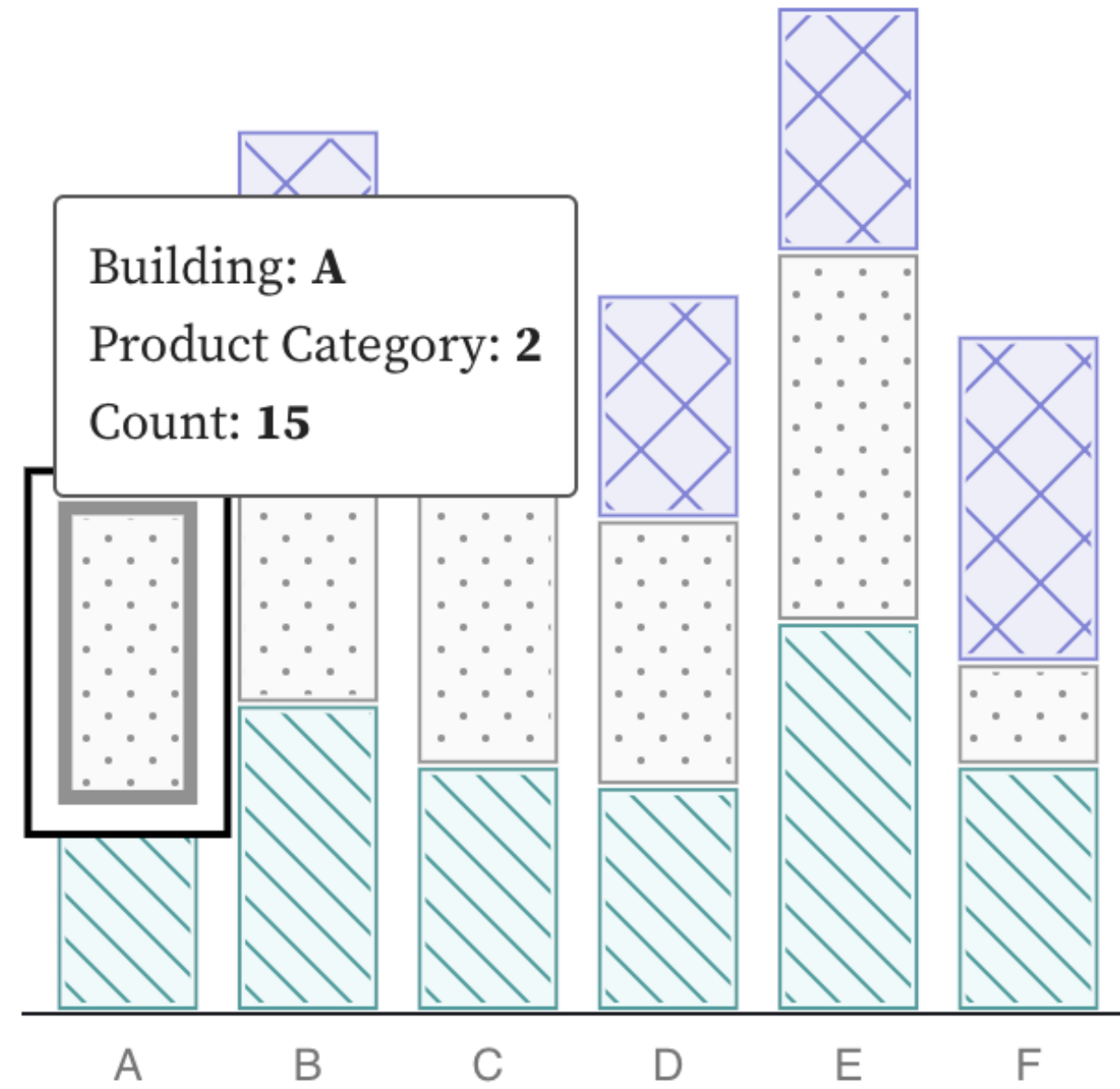
Hovered/focused

1 2 3



Selected

1 2 3

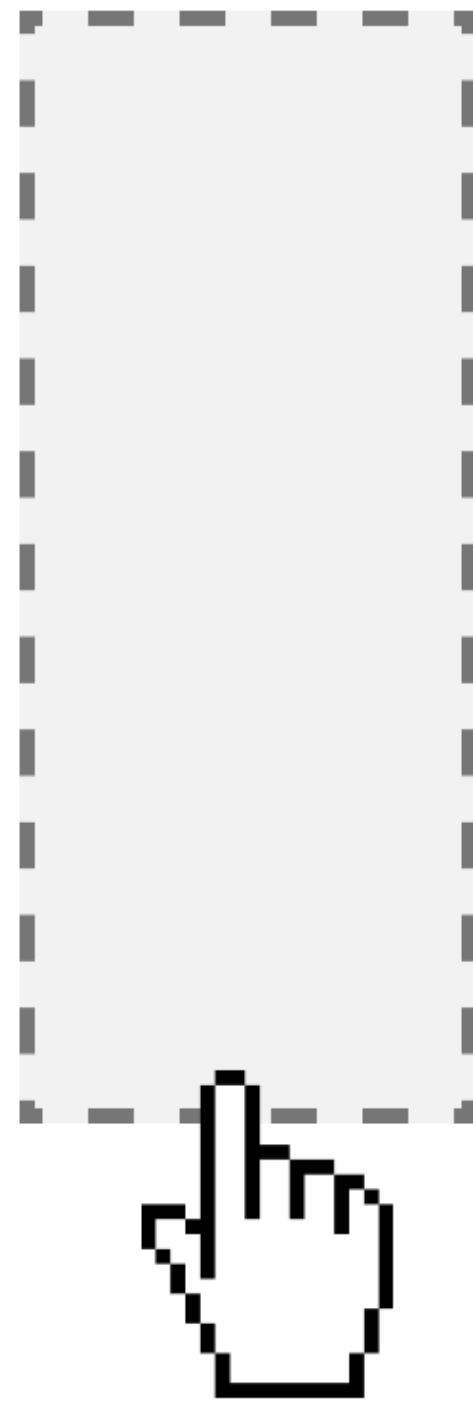


Design your own interaction styling

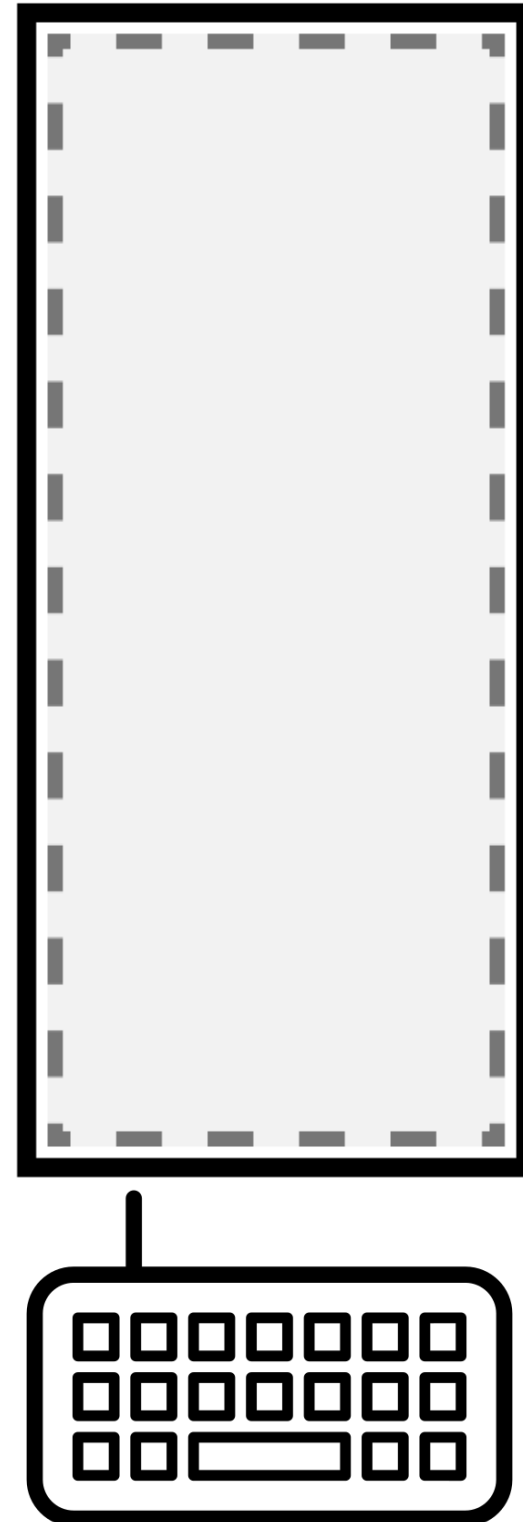
Default



Hovered



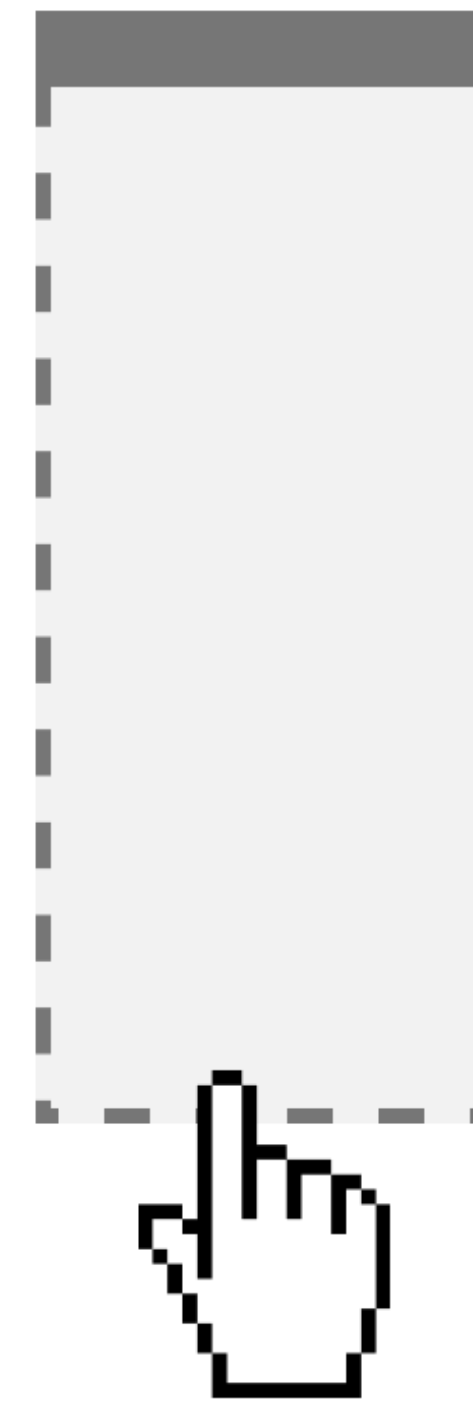
Focused



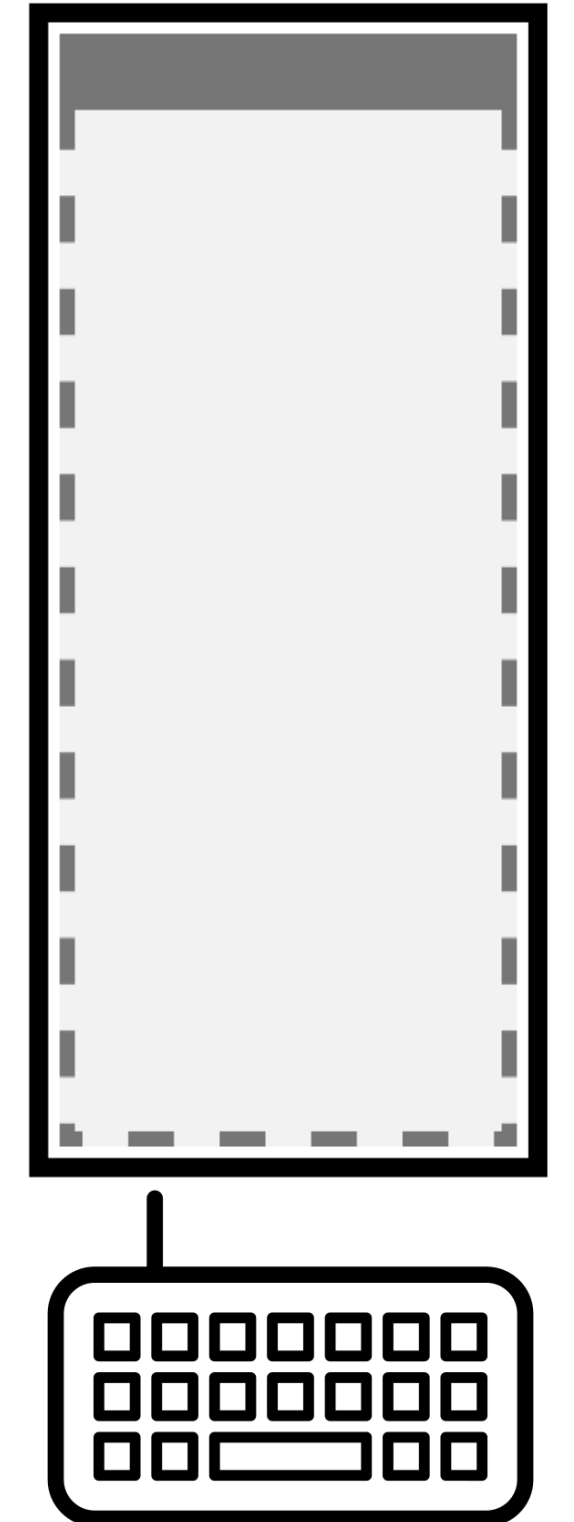
Selected



**Hovered +
Selected**



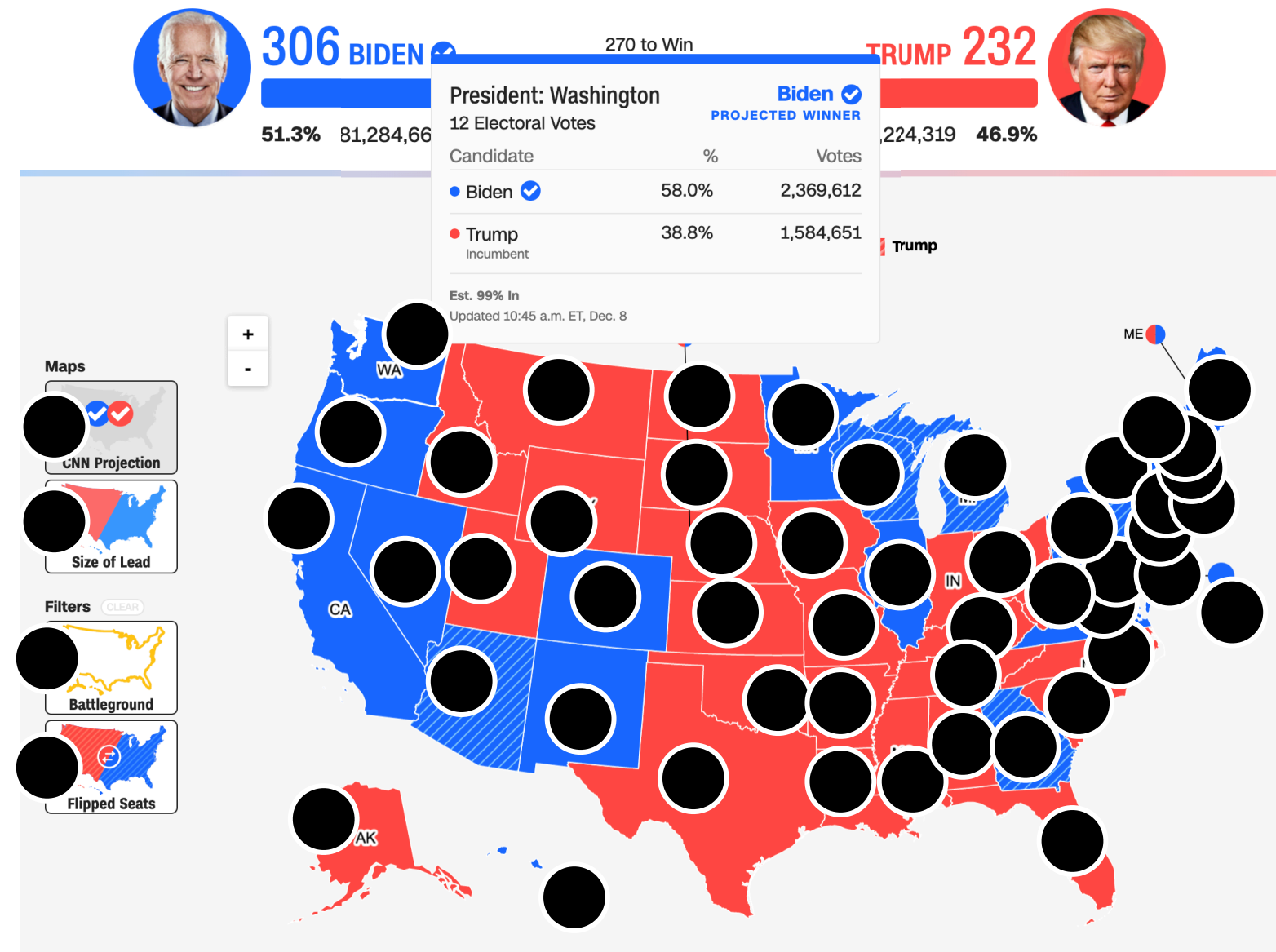
**Focused +
Selected**



PRESIDENTIAL RESULTS

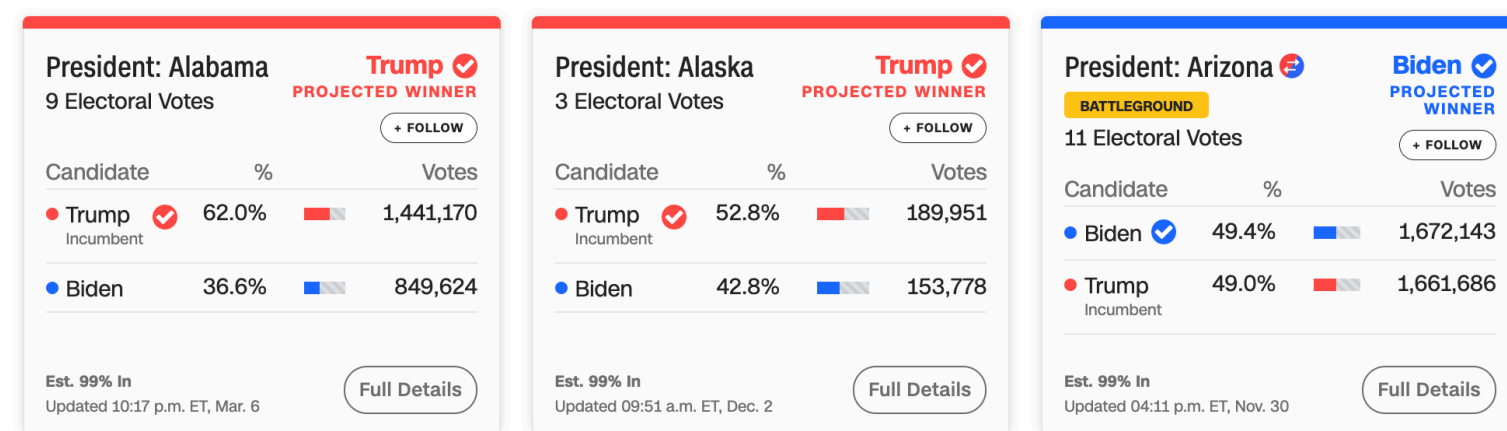
Joe Biden wins election to be the 46th US President

Pennsylvania's 20 electoral votes put native son Joe Biden above the 270 needed to become the 46th President of the United States. Born in Scranton, the former vice president and longtime Delaware senator defeated Donald Trump, the first President to lose a reelection bid since George H.W. Bush in 1992.



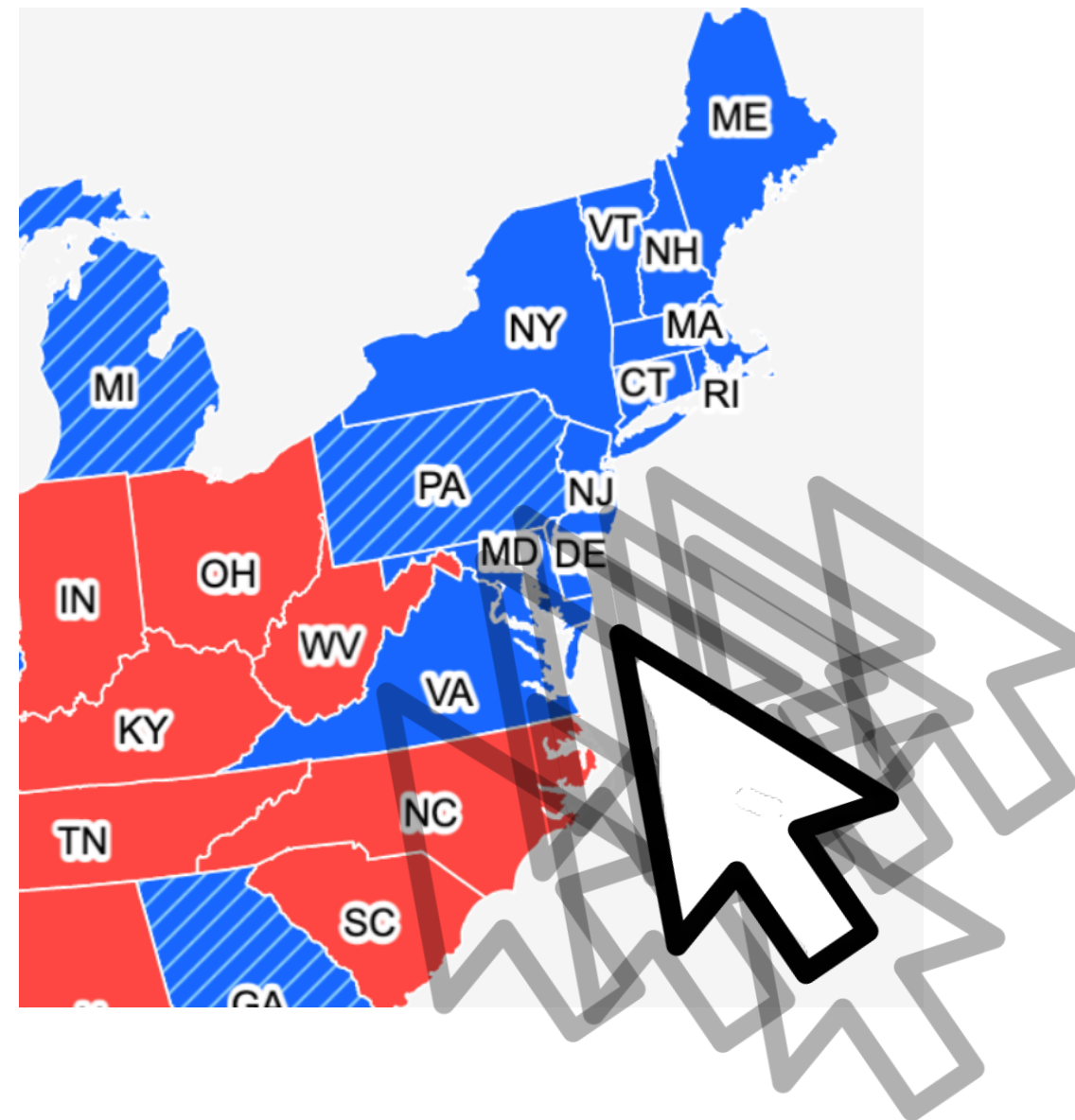
54 instances of “only one input type”

STATE RESULTS



Show More States

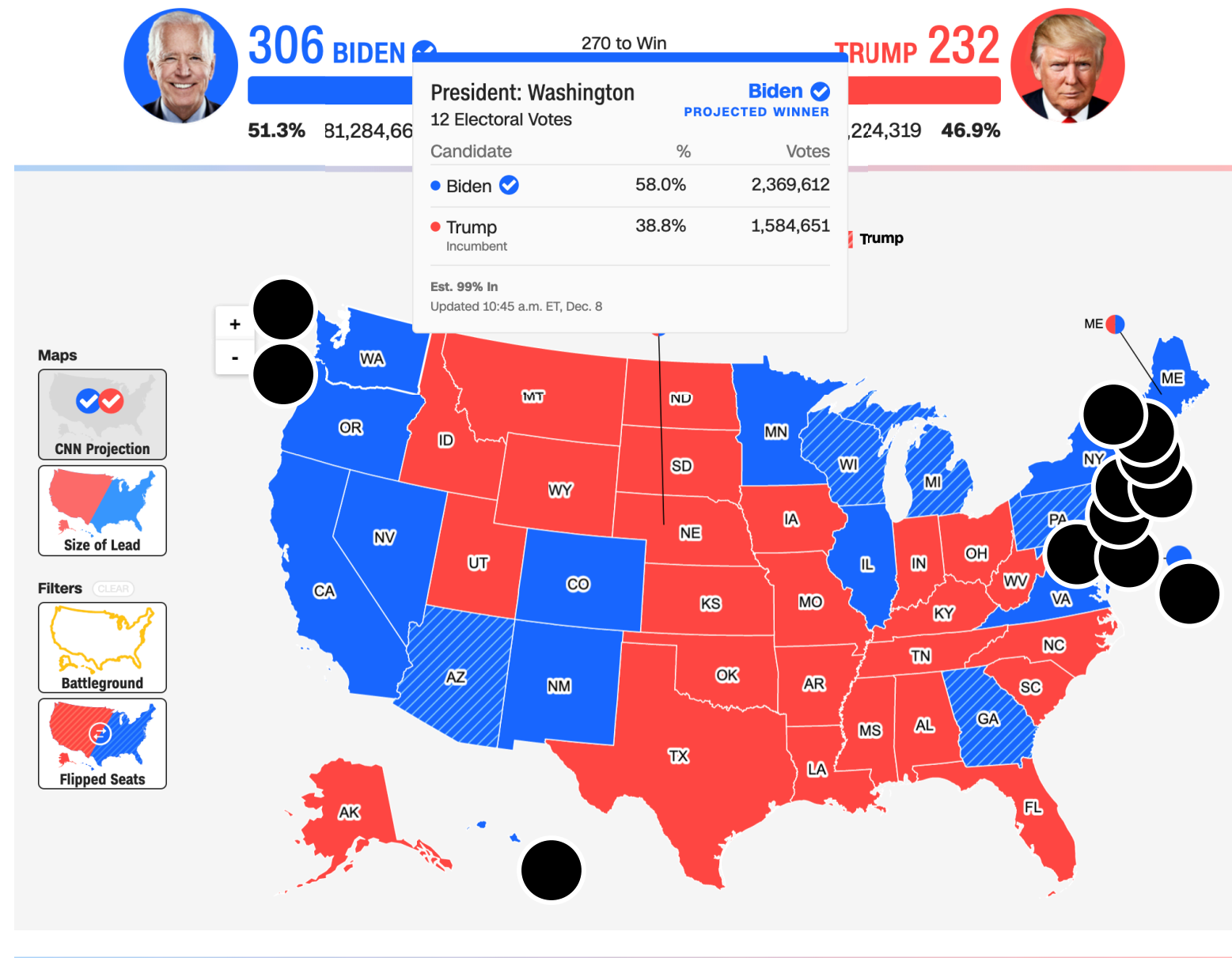
Expecting users to hover on something tiny is an accessibility design failure



PRESIDENTIAL RESULTS

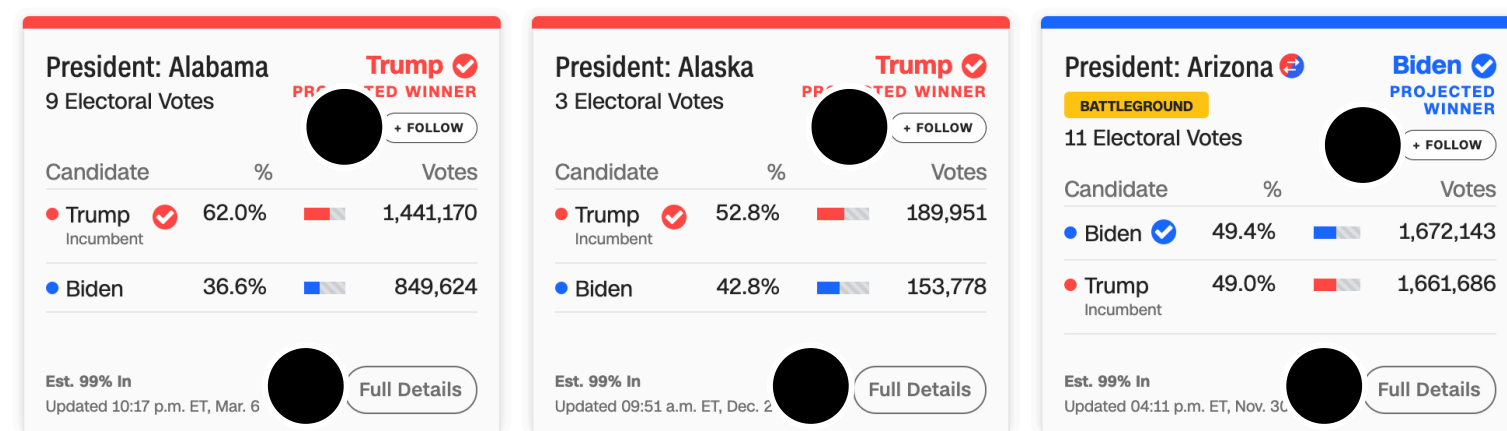
Joe Biden wins election to be the 46th US President

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18 instances of “target pointer size is too small”

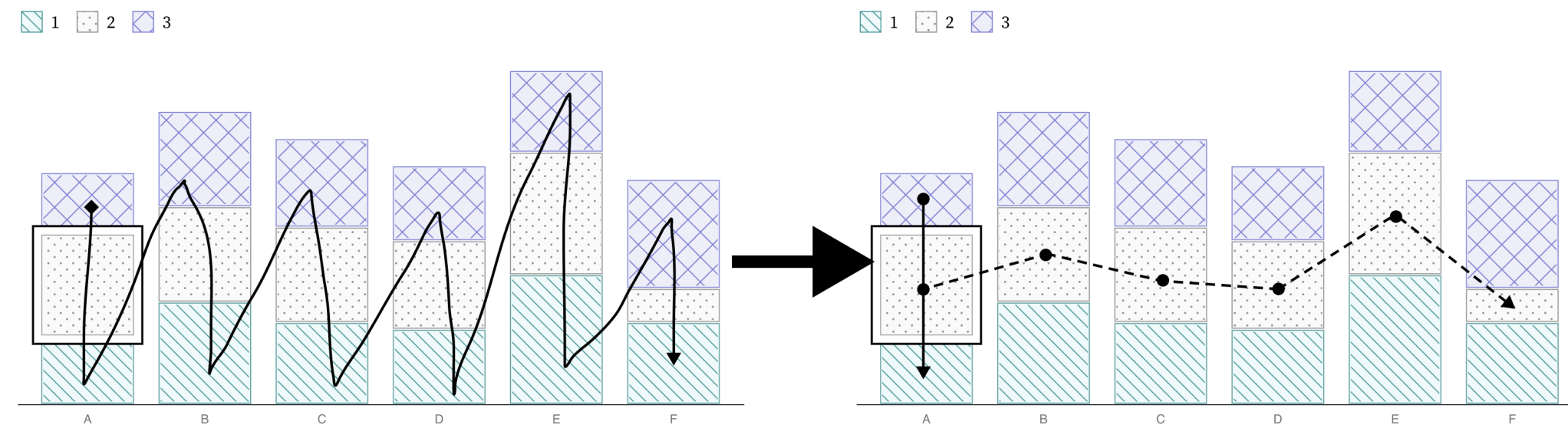
STATE RESULTS



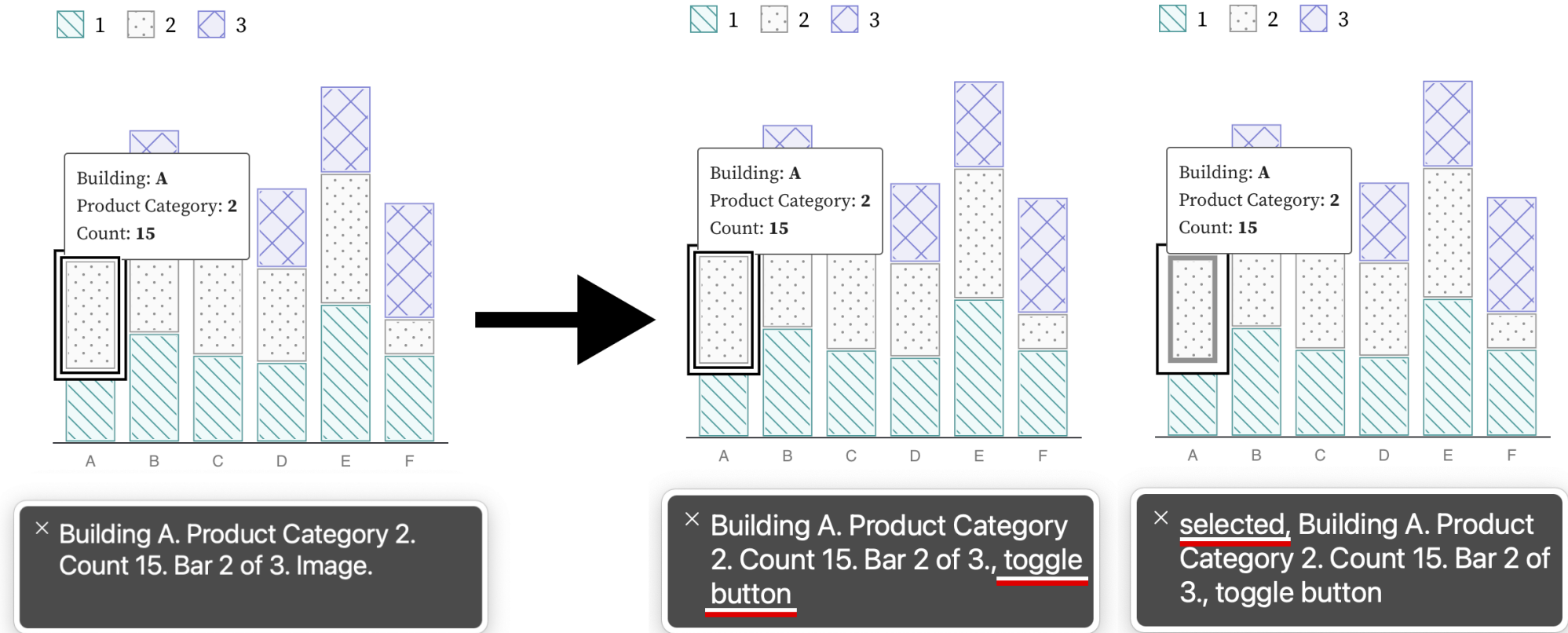
Show More States

Recap: Operability

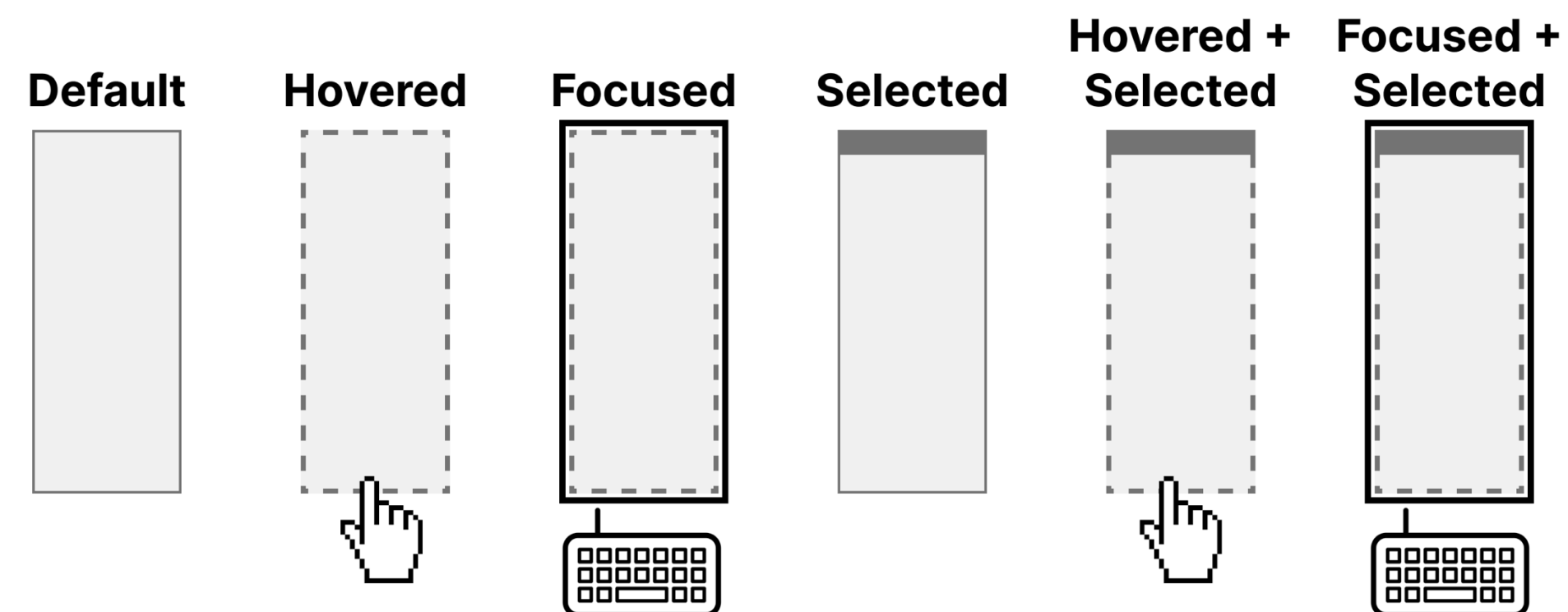
Consider how someone navigates



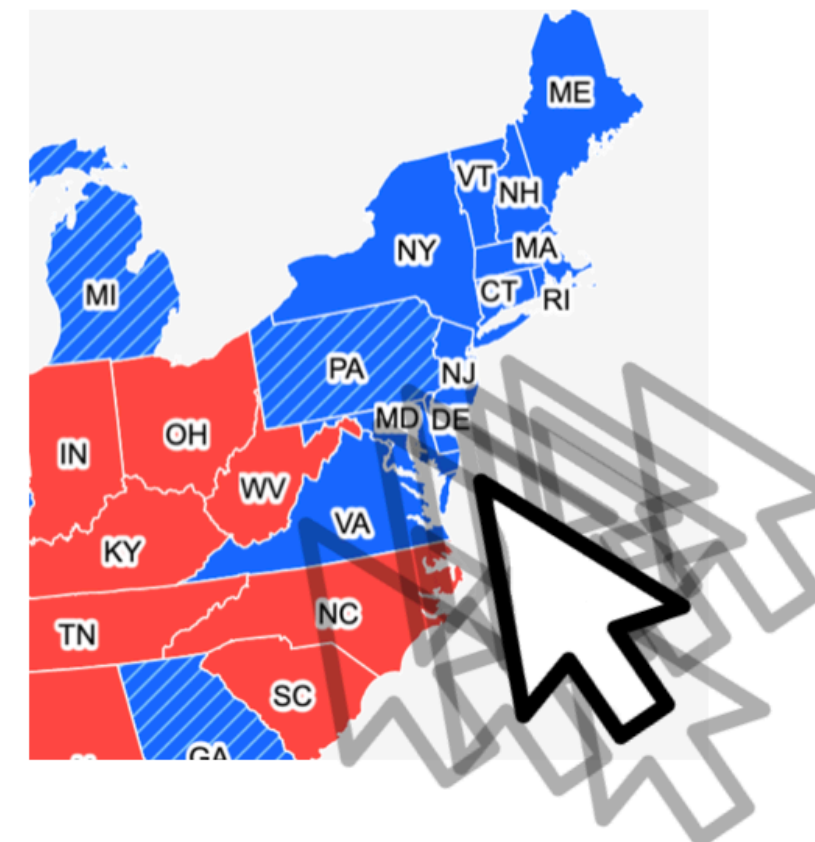
Describe the functionality of elements



Communicate interaction state visually



Improve the size of interaction areas



Operable Evaluation Toolkit:

- 1. Use your mouse:** can it do something meaningful? (tooltip, click event, etc) If so:
 - a. Test using a **keyboard-only**: can you navigate *and* use keyboard activation (spacebar/enter) on the visualization?
 - b. Test using a **screen reader**: Can you use a screen reader to navigate and use keyboard activation on the visualization?
- 2. Check sizes:** can a mouse *easily* interact with this?

Understandable

Can someone understand this in multiple ways? Is each way easy?

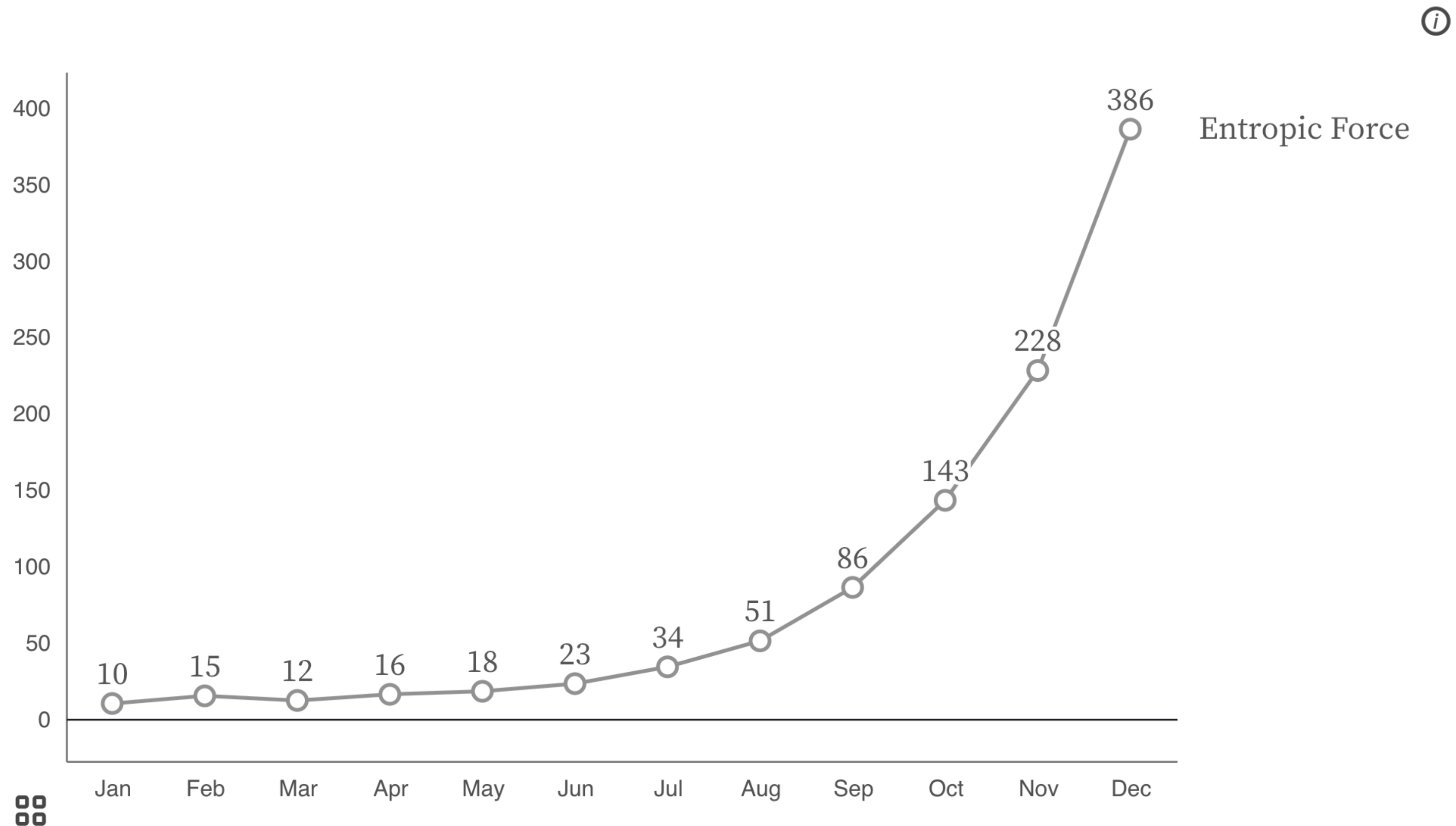
Understandable Checklist:

1. Descriptive title, summary, or caption
2. Data table or data download
3. Reading level

Non-descriptive titles are inaccessible

Entropic Force

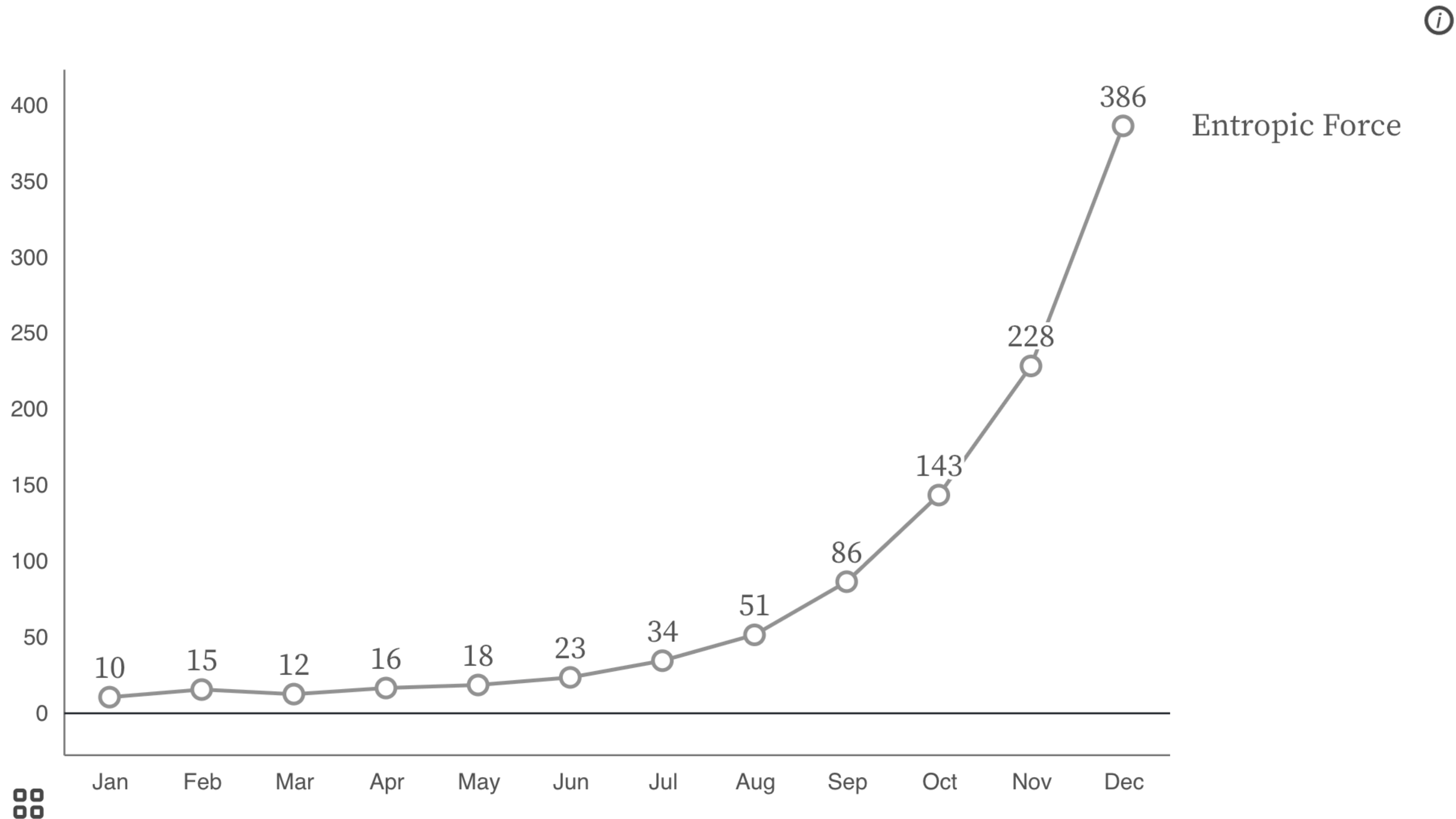
In EF units (non-normalized)



Descriptive titles have summaries/takeaways

Entropic Force has Increased Exponentially

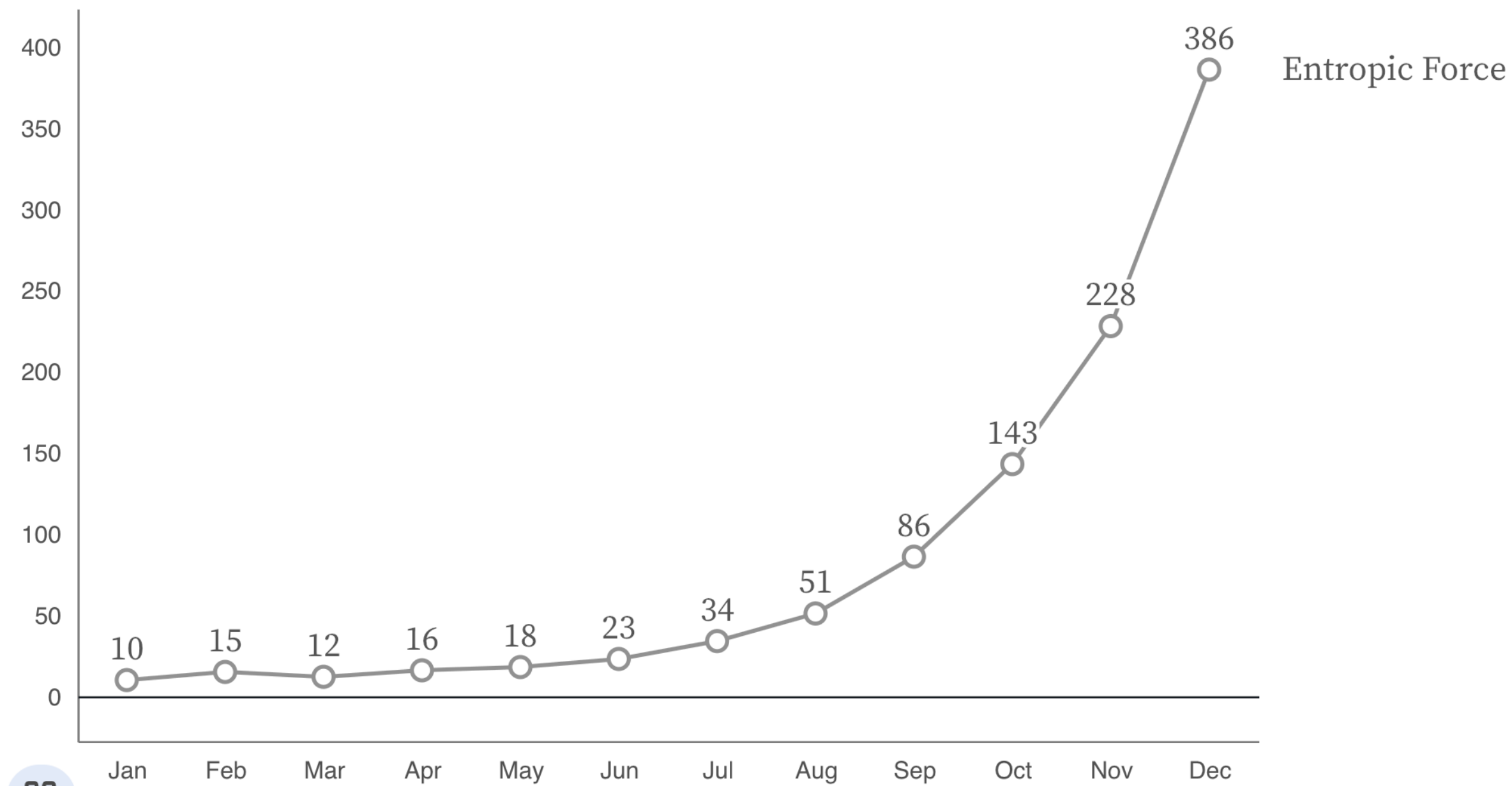
Measured in EF units (non-normalized)



All charts should have data available!

Entropic Force has Increased Exponentially

Measured in EF units (non-normalized)



Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Line	Date	Value	Note
Entropic Force	Jan	10	Lowest Value
Entropic Force	Feb	15	
Entropic Force	Mar	12	
Entropic Force	Apr	16	
Entropic Force	May	18	
Entropic Force	Jun	23	
Entropic Force	Jul	34	
Entropic Force	Aug	51	
Entropic Force	Sep	86	
Entropic Force	Oct	143	
Entropic Force	Nov	228	
Entropic Force	Dec	386	Highest Value

Technical language is often overkill

Measured in EF units (non-normalized). EF units are valuable for catching egregious oversimulation in models that use randomized data decimation techniques. This particular evaluation findings demonstrate that the randomization models are significantly overproducing entropy in our latest force simulations.

Hemingway *Editor*

Readability

Post-graduate

Poor. Aim for 14.

Words: 39

Show More ▾

1 adverb. Aim for 0 or fewer.

0 uses of passive voice. Nice work.

1 phrase has a simpler alternative.

0 of 3 sentences are hard to read.

2 of 3 sentences are very hard to read.

Keep summaries as non-technical as possible

If the topic is technical, provide a “plain language” summary somewhere close by that is easy to find (either in the same location or with by providing a link).

Measured in EF units (non-normalized). EF units are valuable for catching egregious over-simulation in models that use randomized data decimation techniques. This particular evaluation findings demonstrate that the randomization models are significantly over-producing entropy in our latest force simulations.

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Show More ▾

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1 phrase has a simpler alternative.

0 of 3 sentences are hard to read.

2 of 3 sentences are very hard to read.

Measured in EF units (non-normalized). These units are helpful for catching bad data loss when we remove our data at random. We are producing too much entropic force in our latest models.

Hemingway
Editor

Readability

Grade 6

Good

Words: **32**

Show More ▾

0 adverbs. Well done.

0 uses of passive voice. Nice work.

0 phrases have simpler alternatives.

0 of 3 sentences are hard to read.

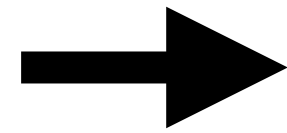
0 of 3 sentences are very hard to read.

Recap: Understandability

Use concise, descriptive titles

Entropic Force

In EF units (non-normalized)



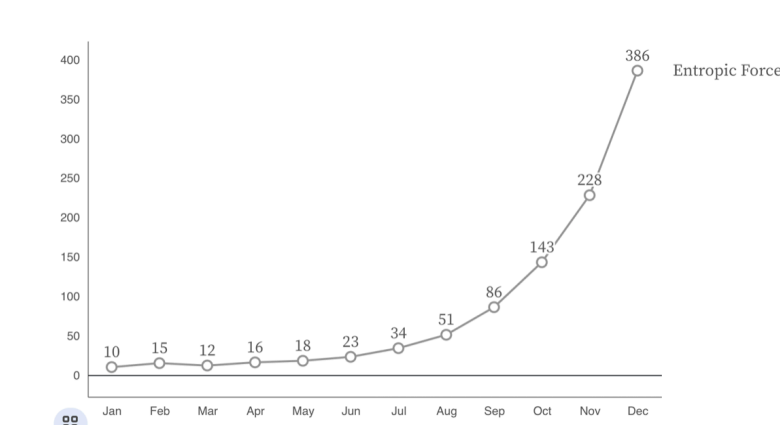
Entropic Force has Increased Exponentially

Measured in EF units (non-normalized)

Add easy-to-access data or tables

Entropic Force has Increased Exponentially

Measured in EF units (non-normalized)



Line	Date	Value	Note
Entropic Force	Jan	10	Lowest Value
Entropic Force	Feb	15	
Entropic Force	Mar	12	
Entropic Force	Apr	16	
Entropic Force	May	18	
Entropic Force	Jun	23	
Entropic Force	Jul	34	
Entropic Force	Aug	51	
Entropic Force	Sep	86	
Entropic Force	Oct	143	
Entropic Force	Nov	228	
Entropic Force	Dec	386	Highest Value

Simplify your language

Measured in EF units (non-normalized). EF units are valuable for catching egregious oversimulation in models that use randomized data decimation techniques. This particular evaluation findings demonstrate that the randomization models are significantly over-producing entropy in our latest force simulations.

Hemingway Editor

Readability

Post-graduate

Poor. Aim for 14.

Words: 39

Show More

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Measured in EF units (non-normalized). These units are helpful for catching bad data loss when we remove our data at random. We are producing too much entropic force in our latest models.

Hemingway Editor

Readability

Grade 6

Good

Words: 32

Show More

0 adverbs. Well done.

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0 of 3 sentences are very hard to read.

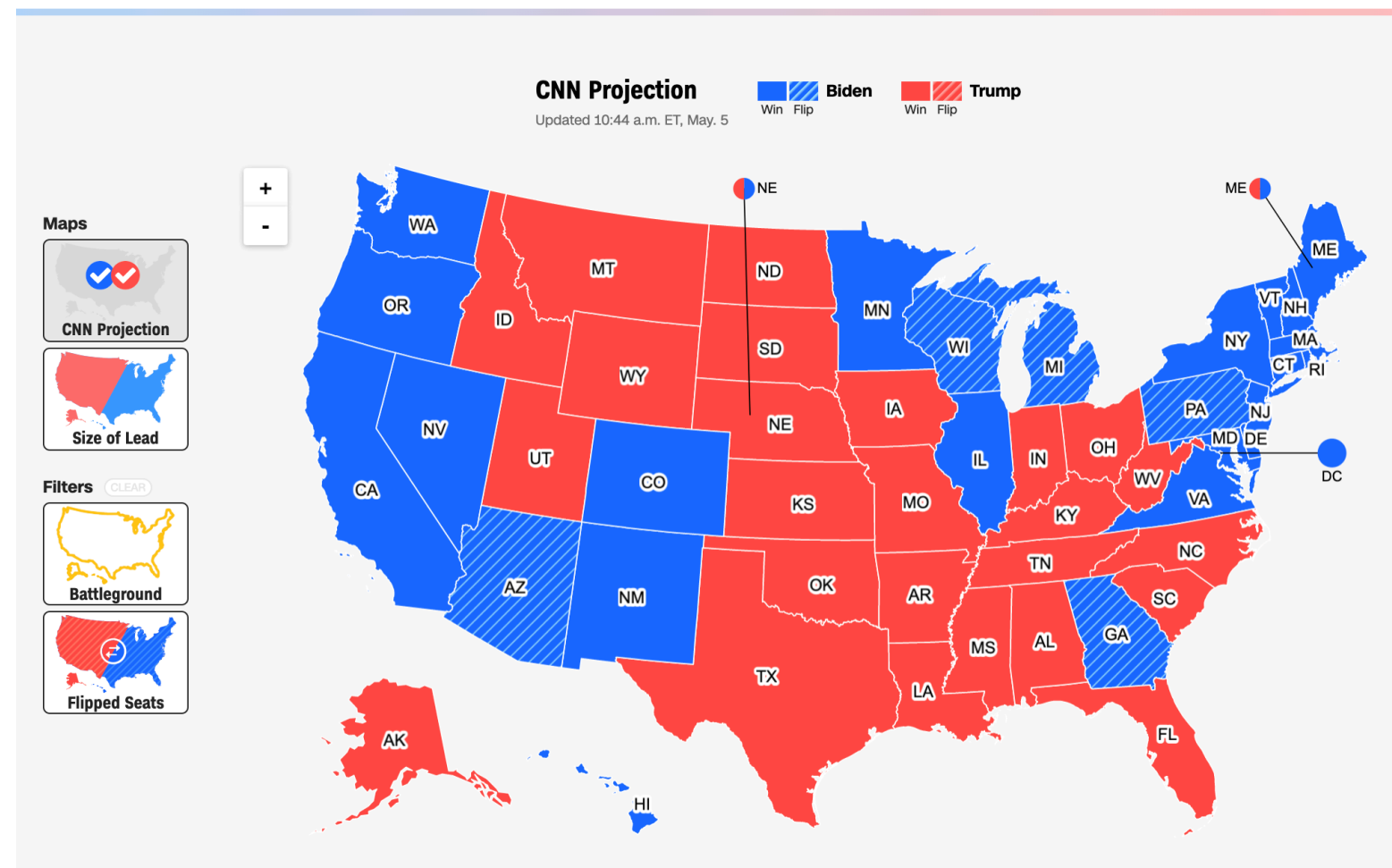
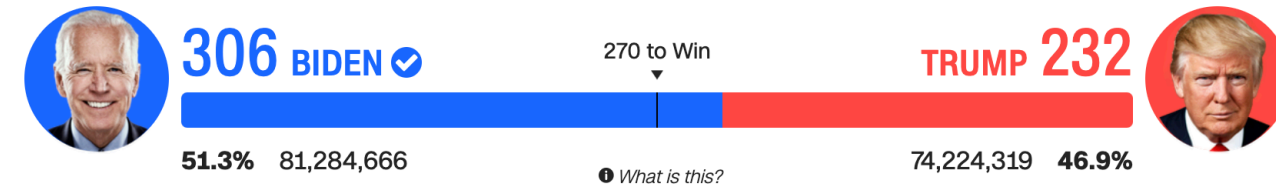
Understandable Evaluation Toolkit:

1. Is there a [descriptive title](#), summary, or caption?
2. Is there an [accessible table](#) or downloadable data file provided?
3. Is the descriptive text supporting the visualization presented at [a reading level at grade 9](#) or below?

PRESIDENTIAL RESULTS

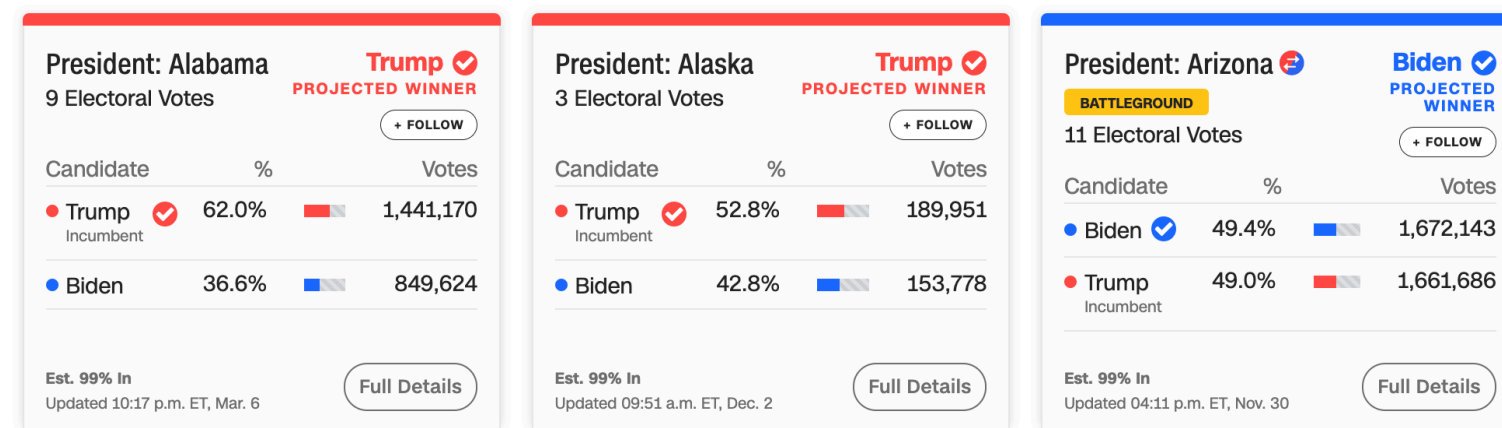
Joe Biden wins election to be the 46th US President

Pennsylvania's 20 electoral votes put native son Joe Biden above the 270 needed to become the 46th President of the United States. Born in Scranton, the former vice president and longtime Delaware senator defeated Donald Trump, the first President to lose a reelection bid since George H.W. Bush in 1992.



Continue this for: Robust, Compromising, Assistive, and Flexible

STATE RESULTS



Show More States

978 access failures found in ~60 minutes.

Perceivable:

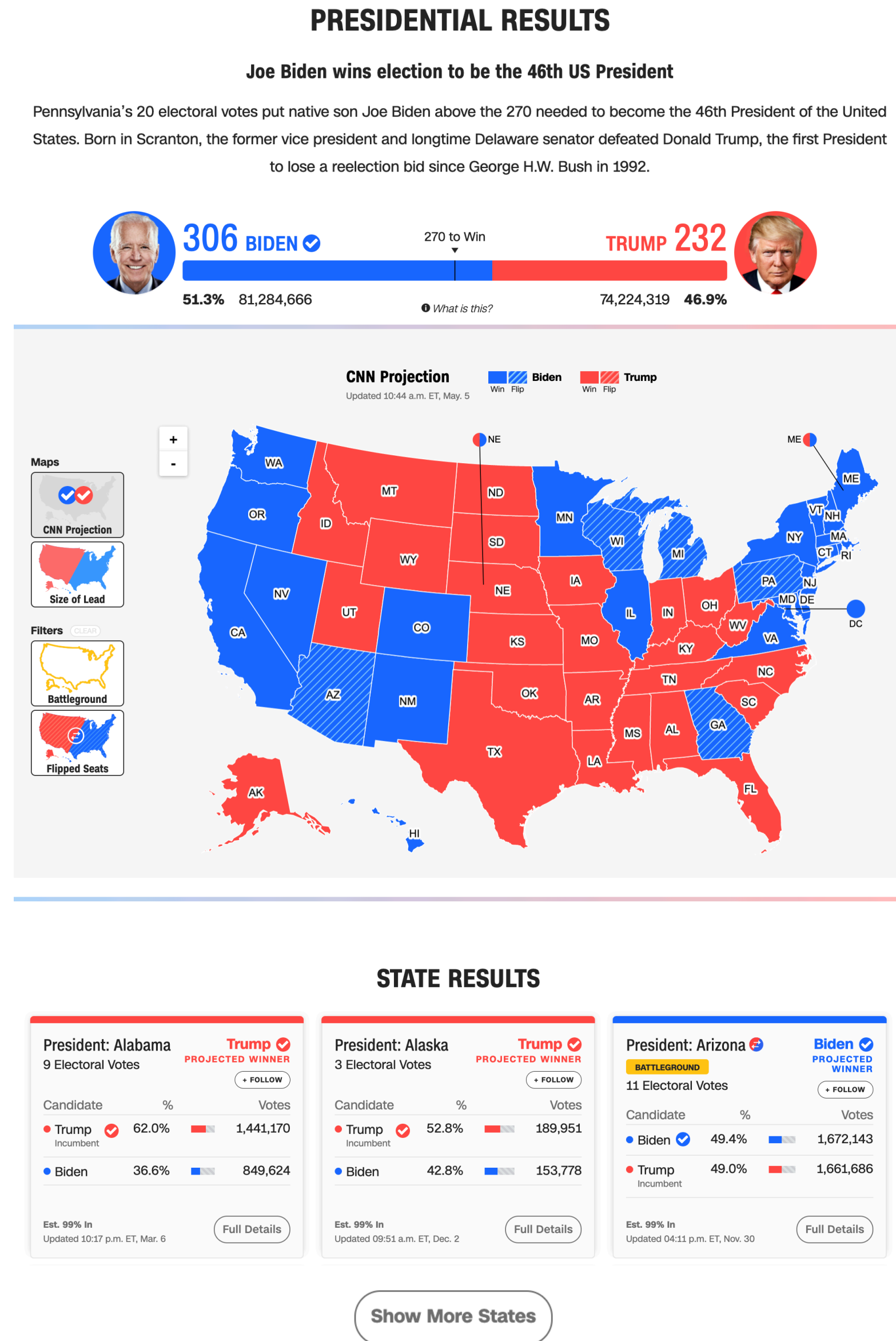
- 6 – Low contrast
- 57 - Content is only visual
- 50 - Color alone is used
- 3 - Meaningful elements can be distinguished

Operable:

- 54 - Interaction modality only has one input type
- 58 - No interaction cues or instructions
- 5 - Low contrast on interactive elements
- 4 - Keyboard focus indicator missing
- 4 - Complex actions have no alternative
- 18 - Target pointer interaction is too small

Understandable:

- 4 - Interactive context is not clear
- 6 - Metrics or variables are undefined



Robust:

- 275 - Does not conform to standards
- 82 - Semantically invalid
- 12 - Fragile technology support

Compromising:

- 54 - Information can only be reached through single process
- 61 - Information cannot be navigated according to narrative or structure

Assistive:

- 101 - Navigation and interaction is tedious

Flexible:

- 2 - User style change not respected
- 121 - User text adjustments are not respected
- 1 - Scrolling experiences cannot be adjusted or opted out of
- Contrast and textures cannot be adjusted

My work

Past:

[Visa Chart Components](#), a library of charts

[Chartability](#), a set of guidelines

Latest:

[Data Navigator!](#)

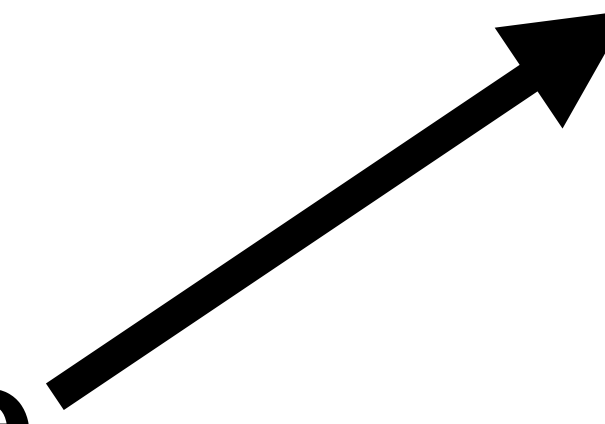
Current:

(secret project)

2024

frank.computer

★ Slides here



Accessibility and Visualization

An introduction.



Frank Elavsky



Human-
Computer
Interaction
Institute



hcii.cmu.edu, axle-lab.com, dig.cmu.edu