

2024

frank.computer

Accessibility and Visualization

An introduction.



Frank Elavsky



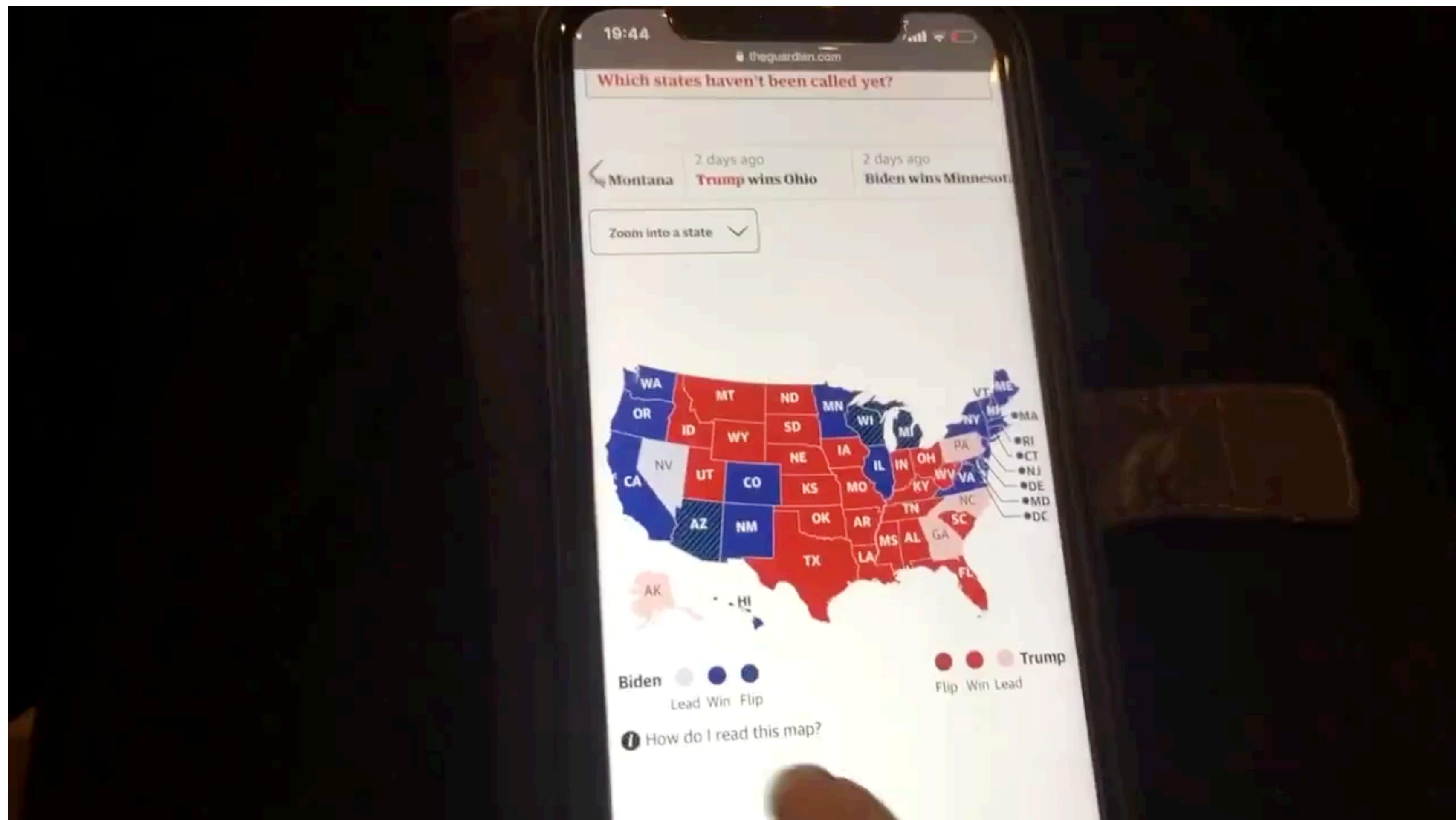
Human-
Computer
Interaction
Institute



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

What is an inaccessible experience like?

Credit: Sarah Fossheim [on twitter](#)



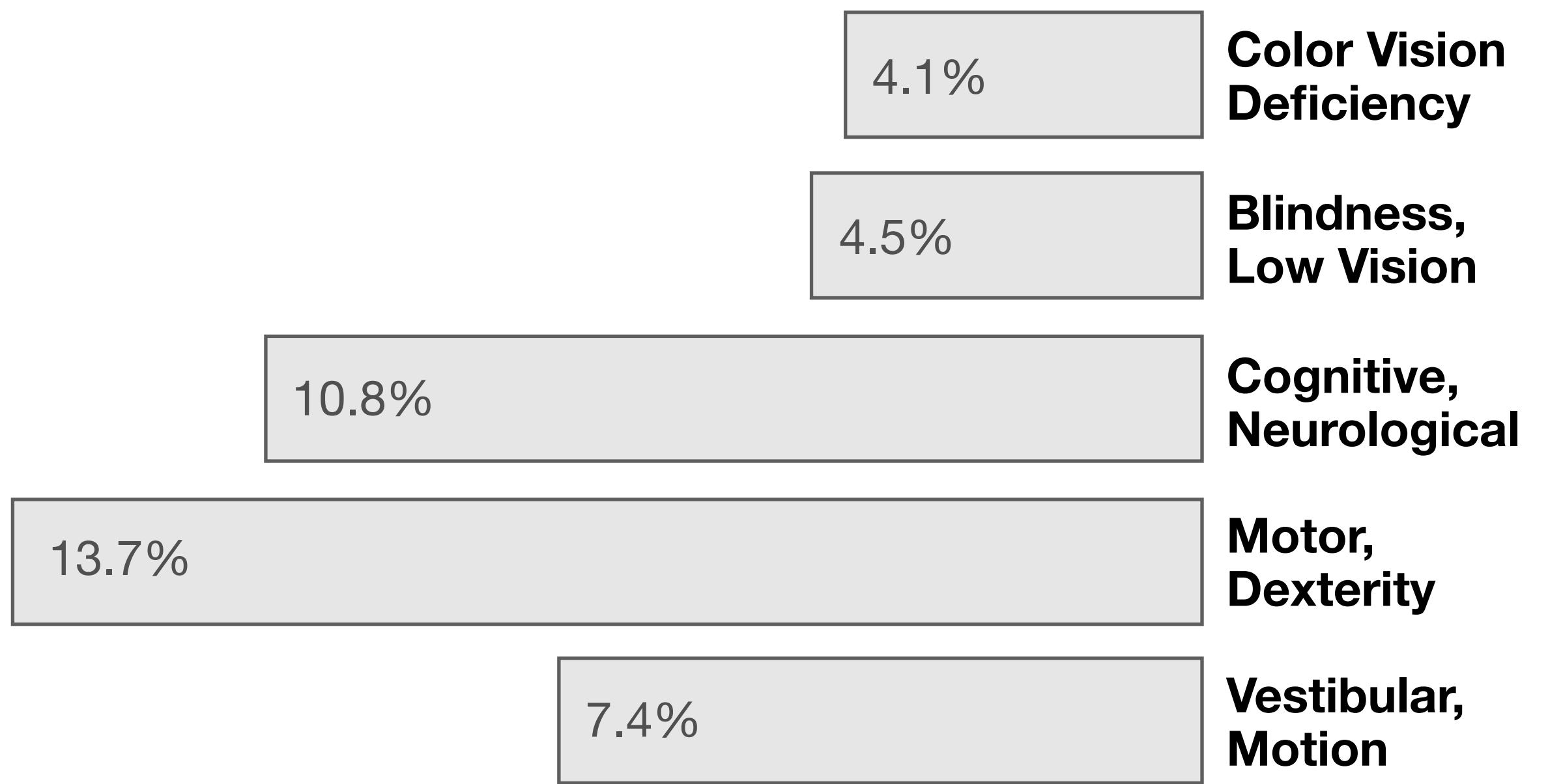
Access is a human right

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

It is the morally and ethically correct thing to do.

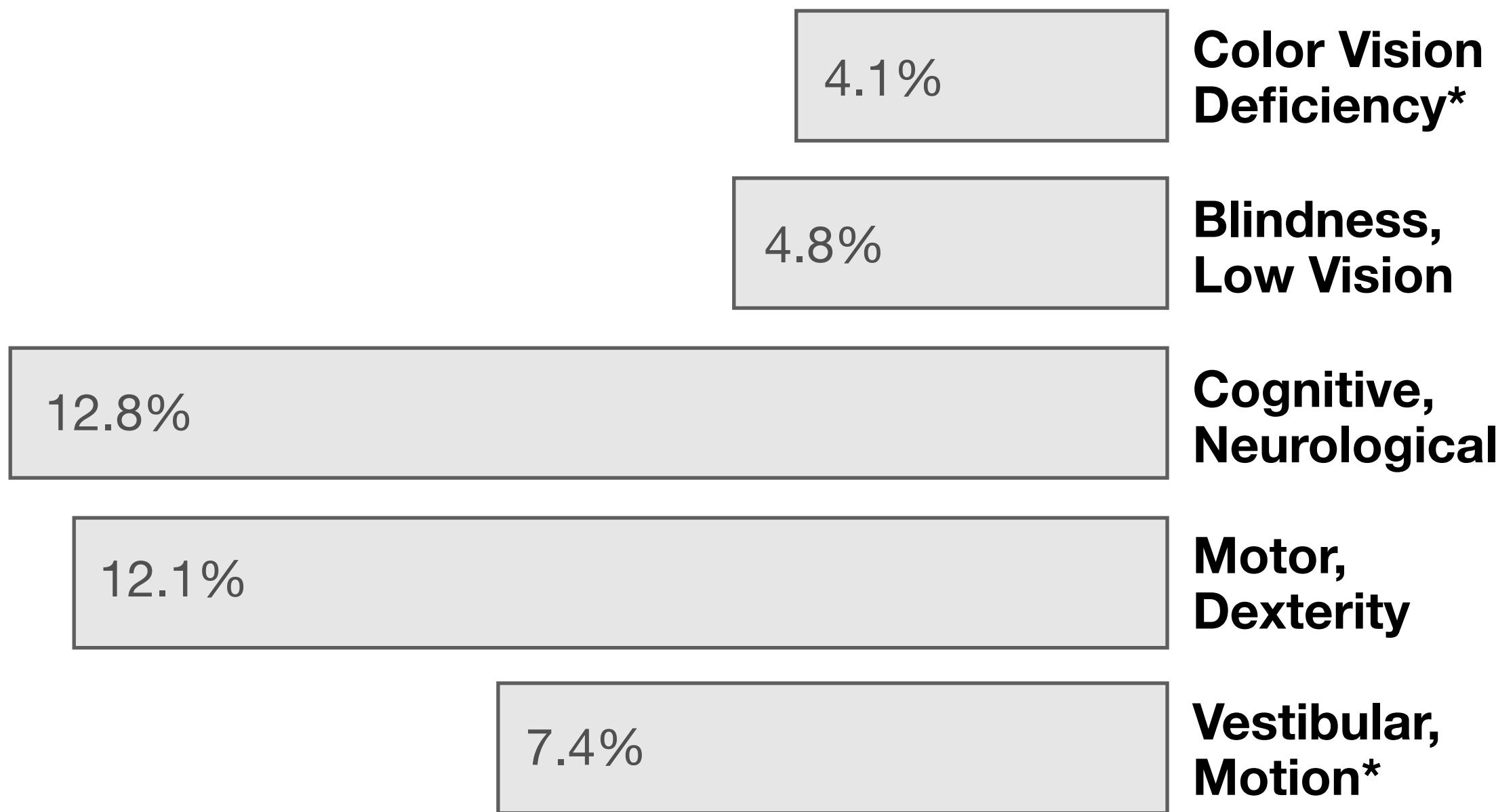


UN CRPD Article 9: Accessibility, UN CRPD Article 10: Right to Life



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

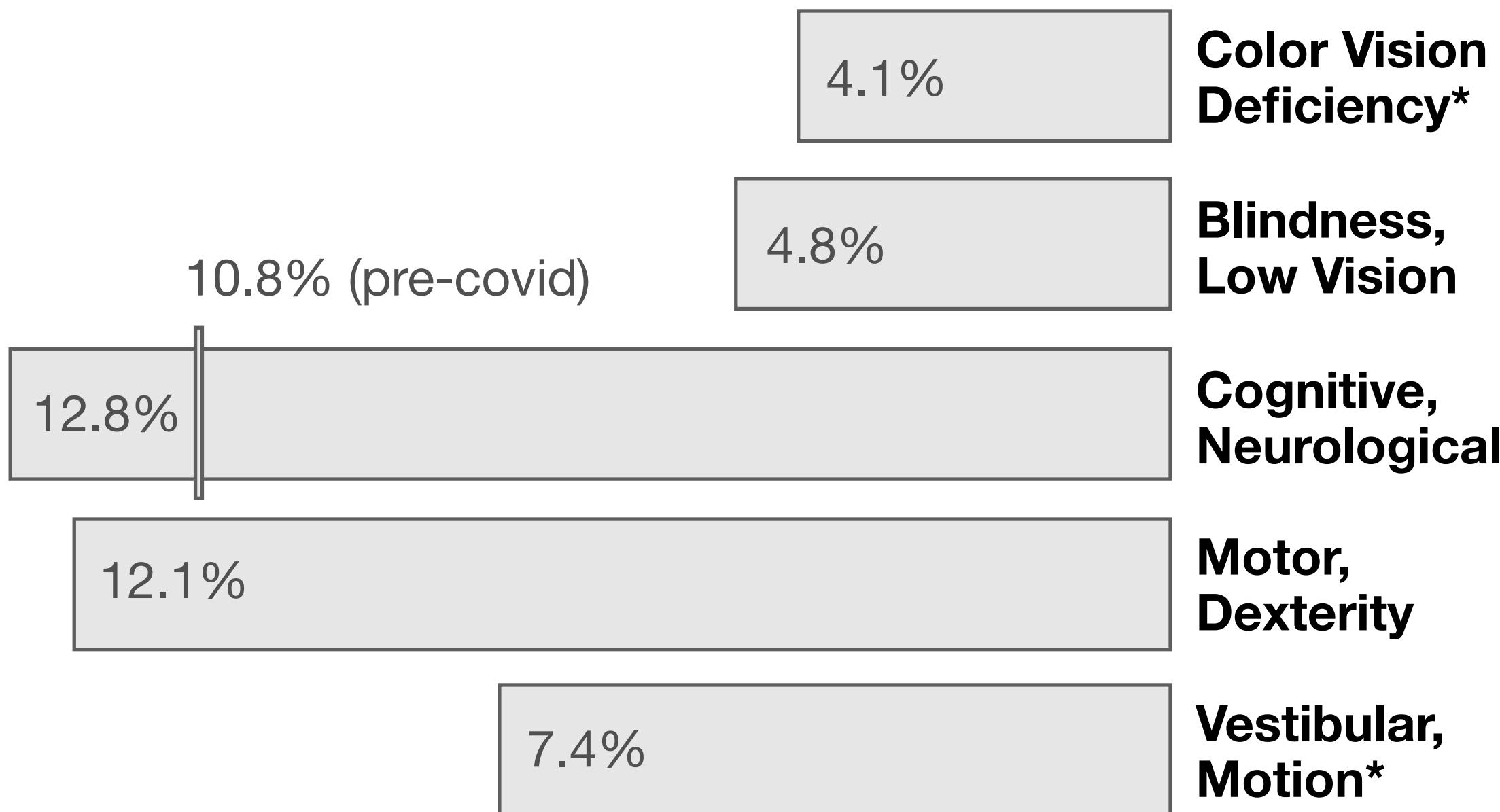
~26% of people living in the United States self-report living with a disability that affects their daily life (2017)



Centers for Disease Control and Prevention. Disability and Health Data System (DHDS). 2023. Available from: <http://dhds.cdc.gov>

*No new data

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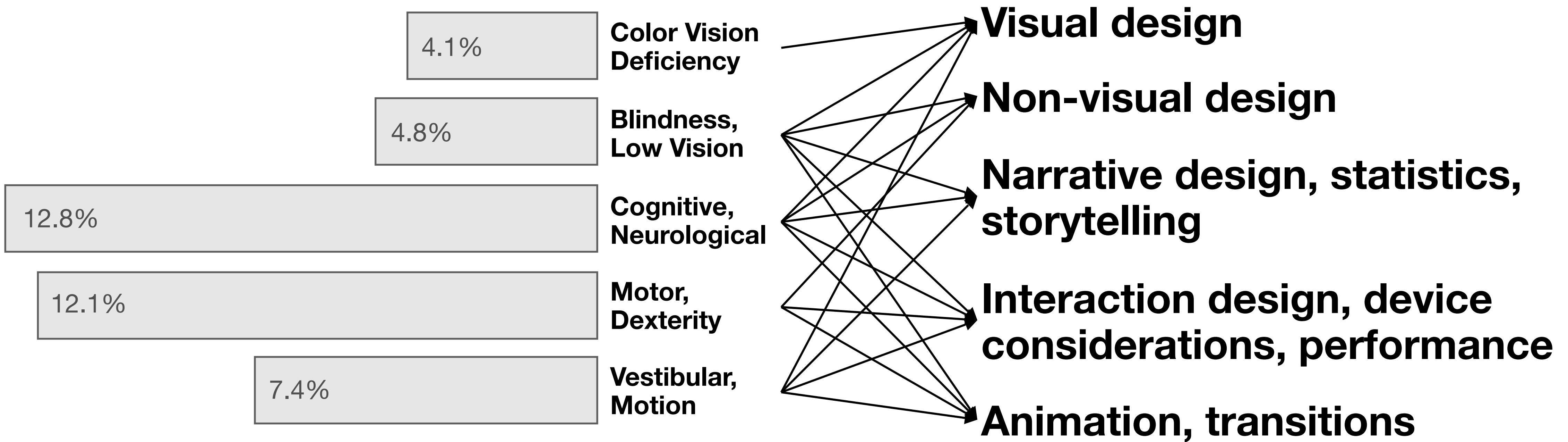


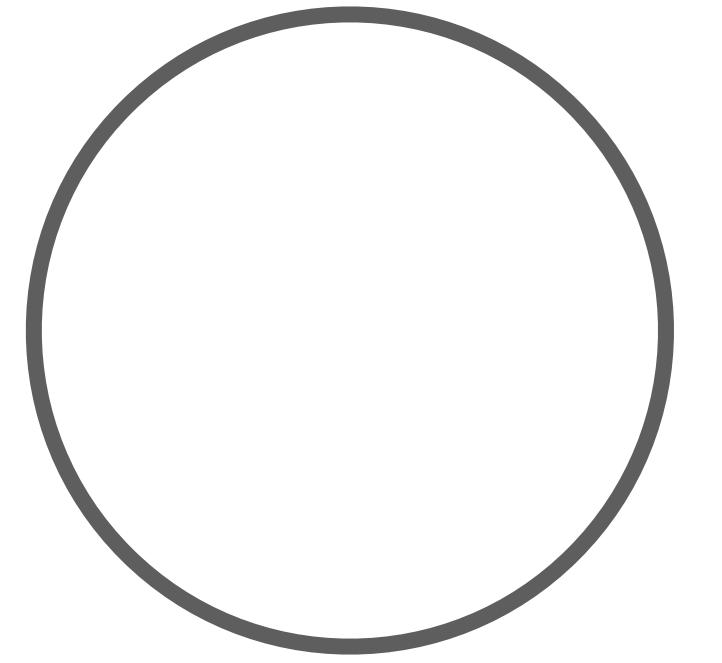
Cognitive disability is on the rise

Centers for Disease Control and Prevention. Disability and Health Data System (DHDS). 2023. Available from: <http://dhds.cdc.gov>

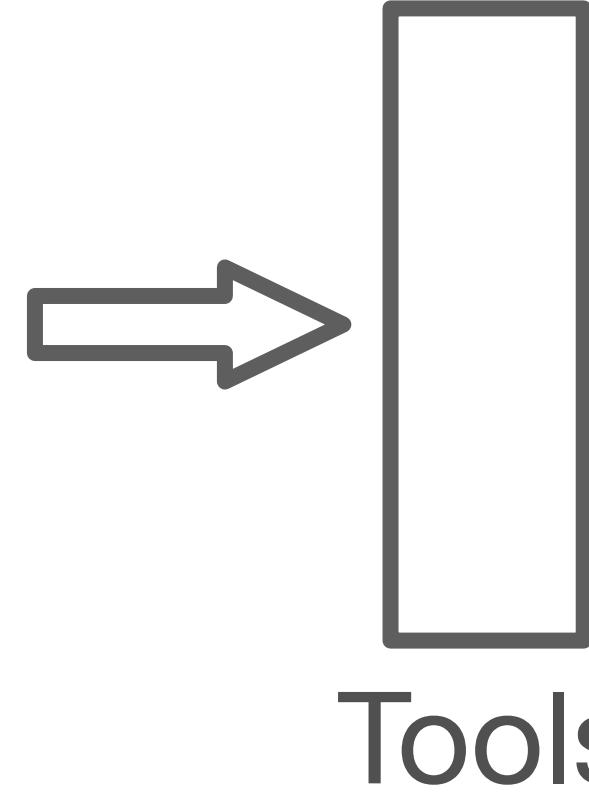
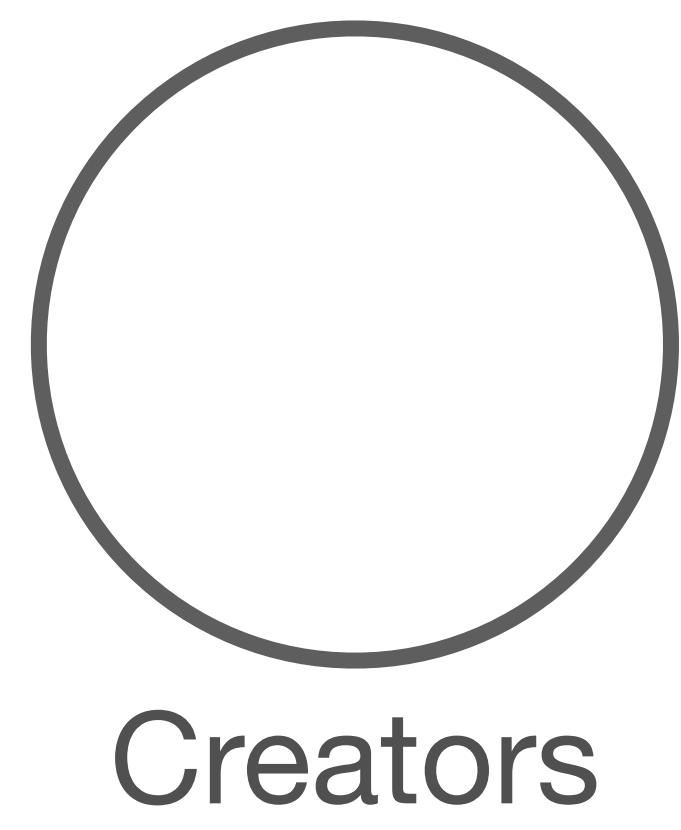
*No new data

Accessibility affects every aspect of visualization work

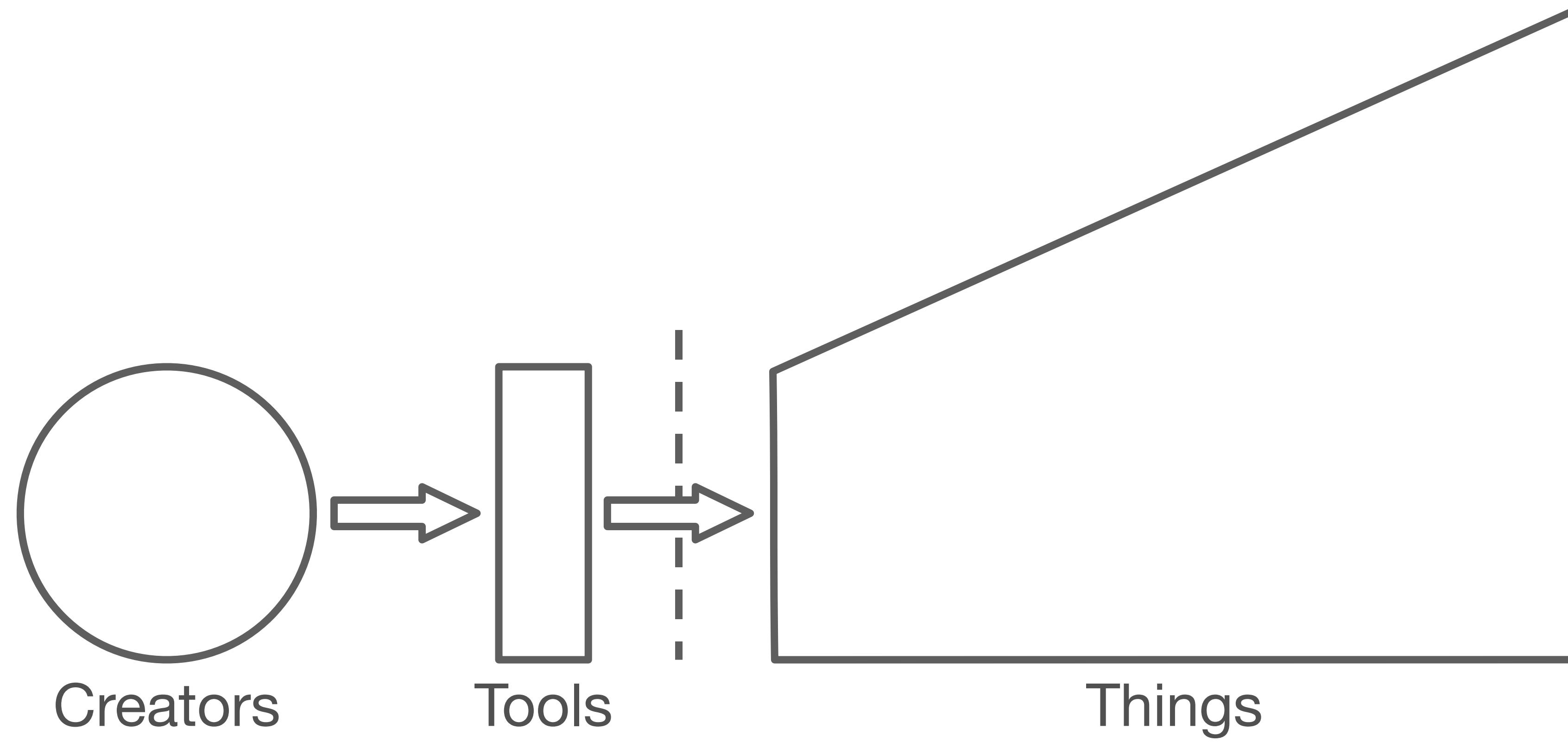


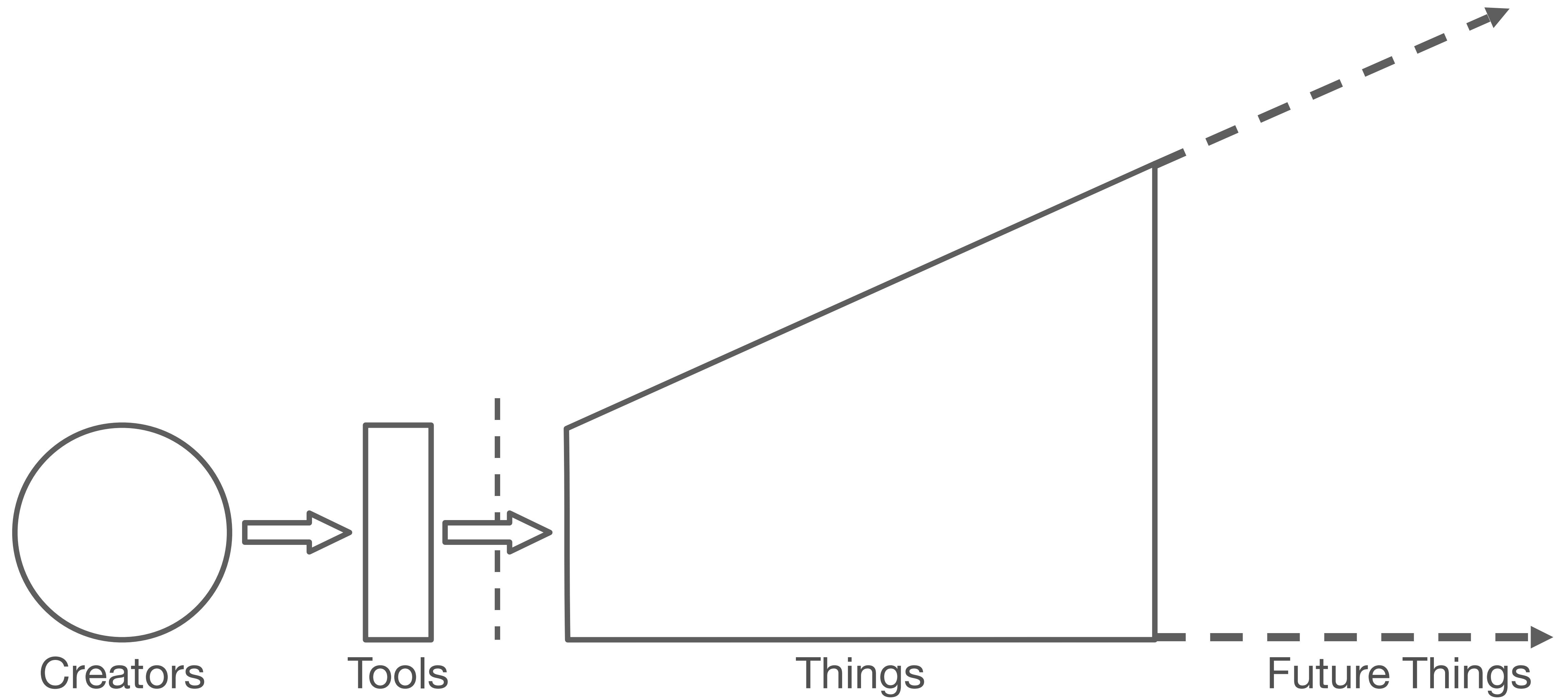


Creators

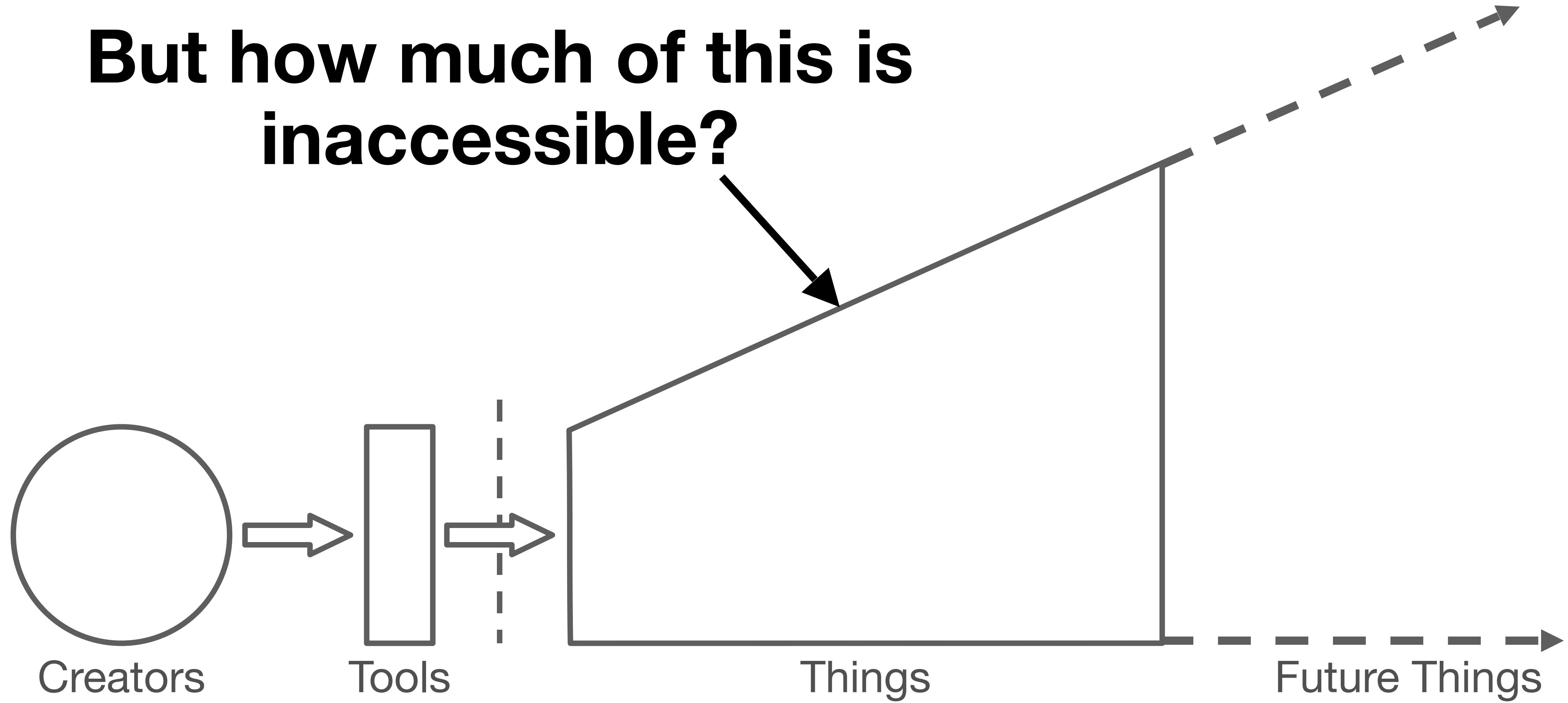


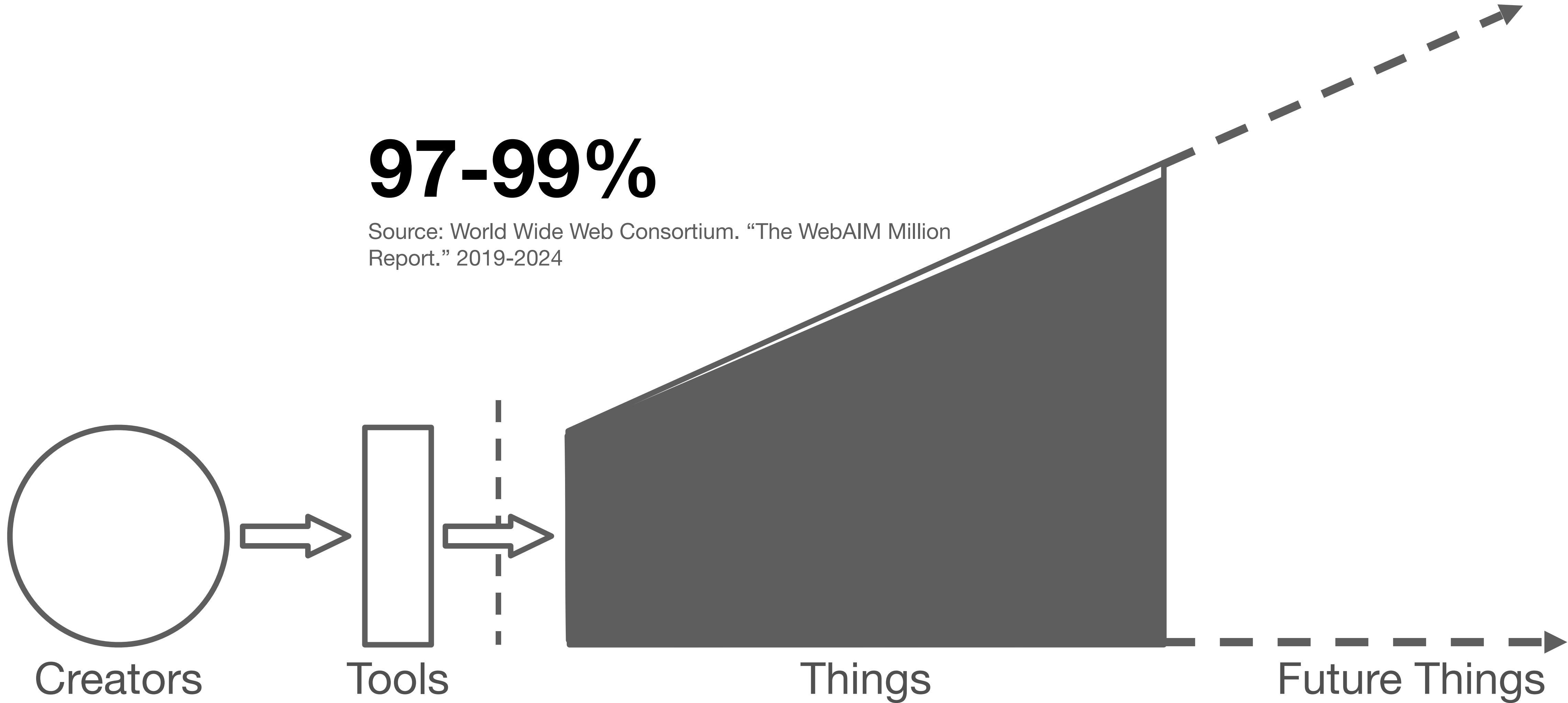
Tools





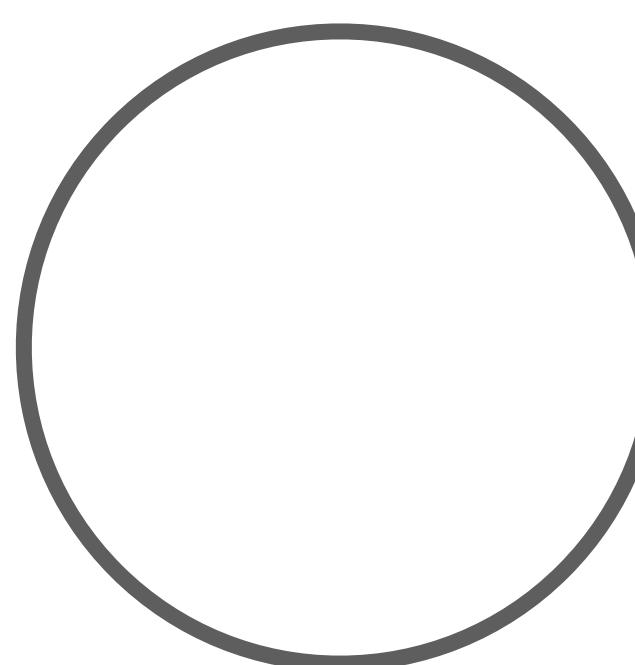
But how much of this is inaccessible?



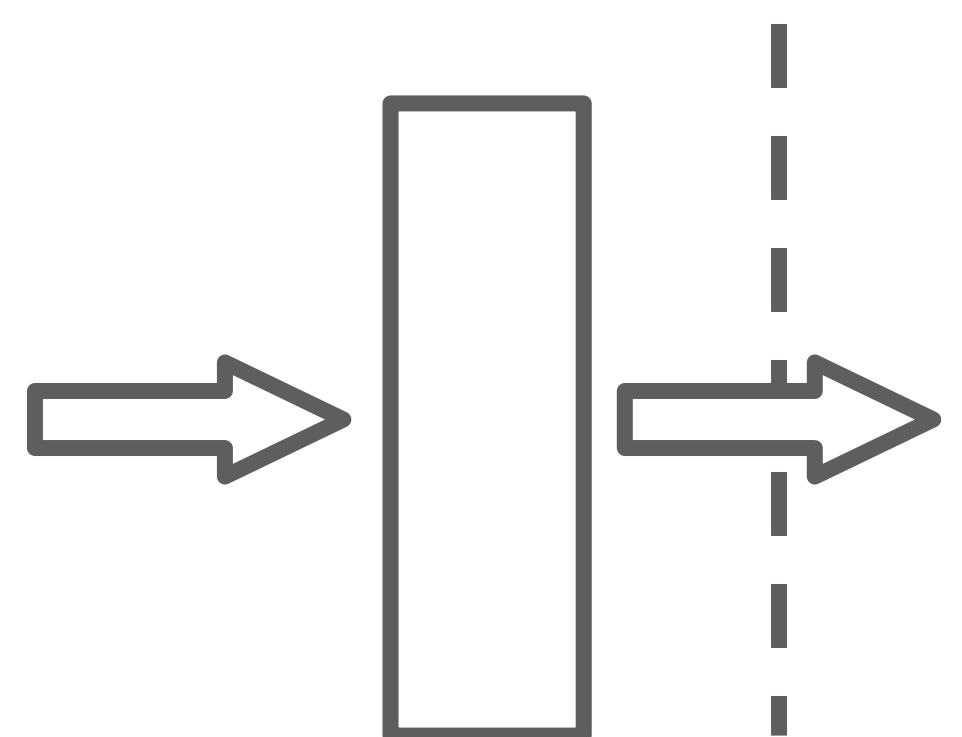


97-99%

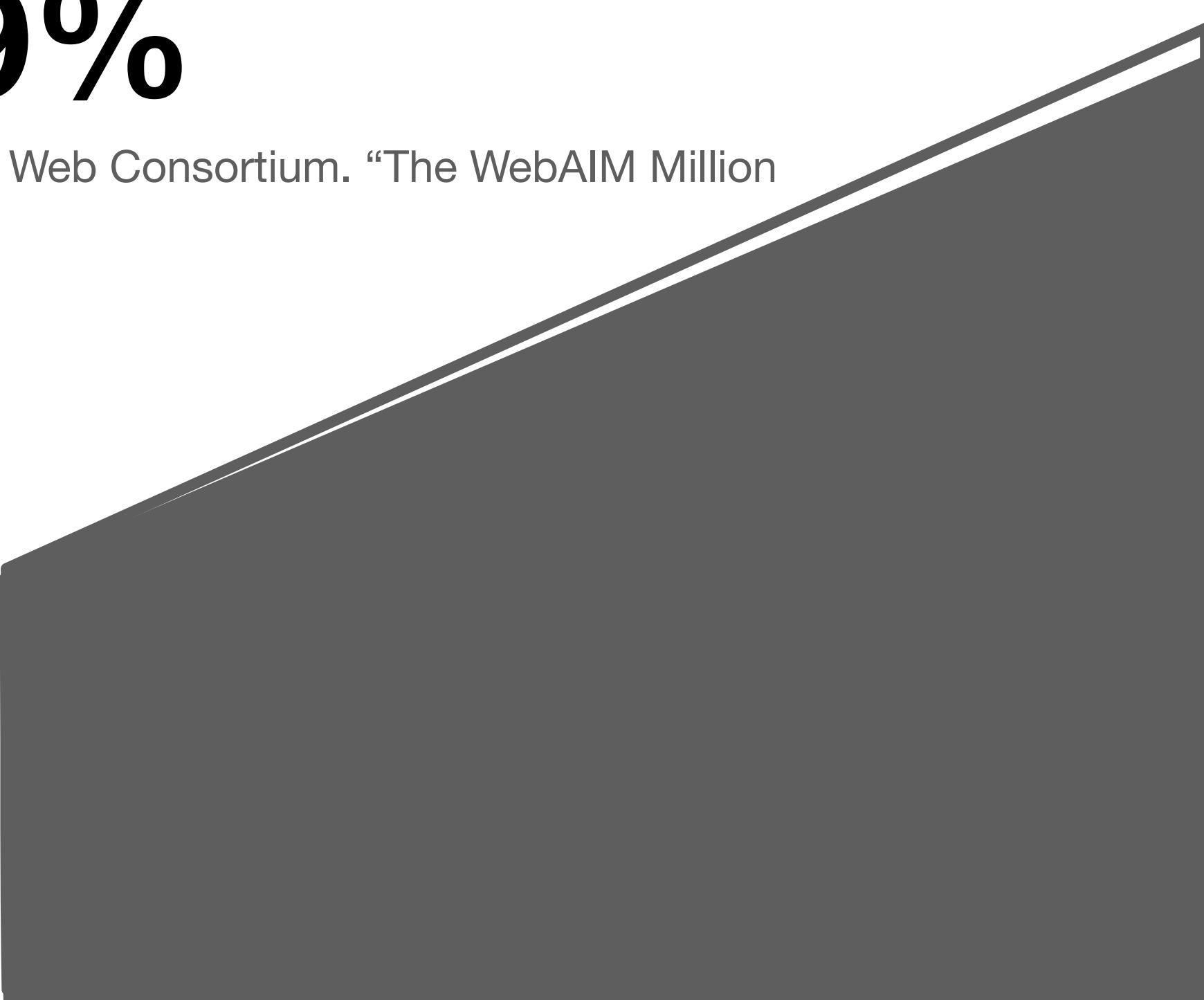
Source: World Wide Web Consortium. "The WebAIM Million Report." 2019-2024



Creators



Tools



Things

Future Things

Who is responsible for making this accessible?

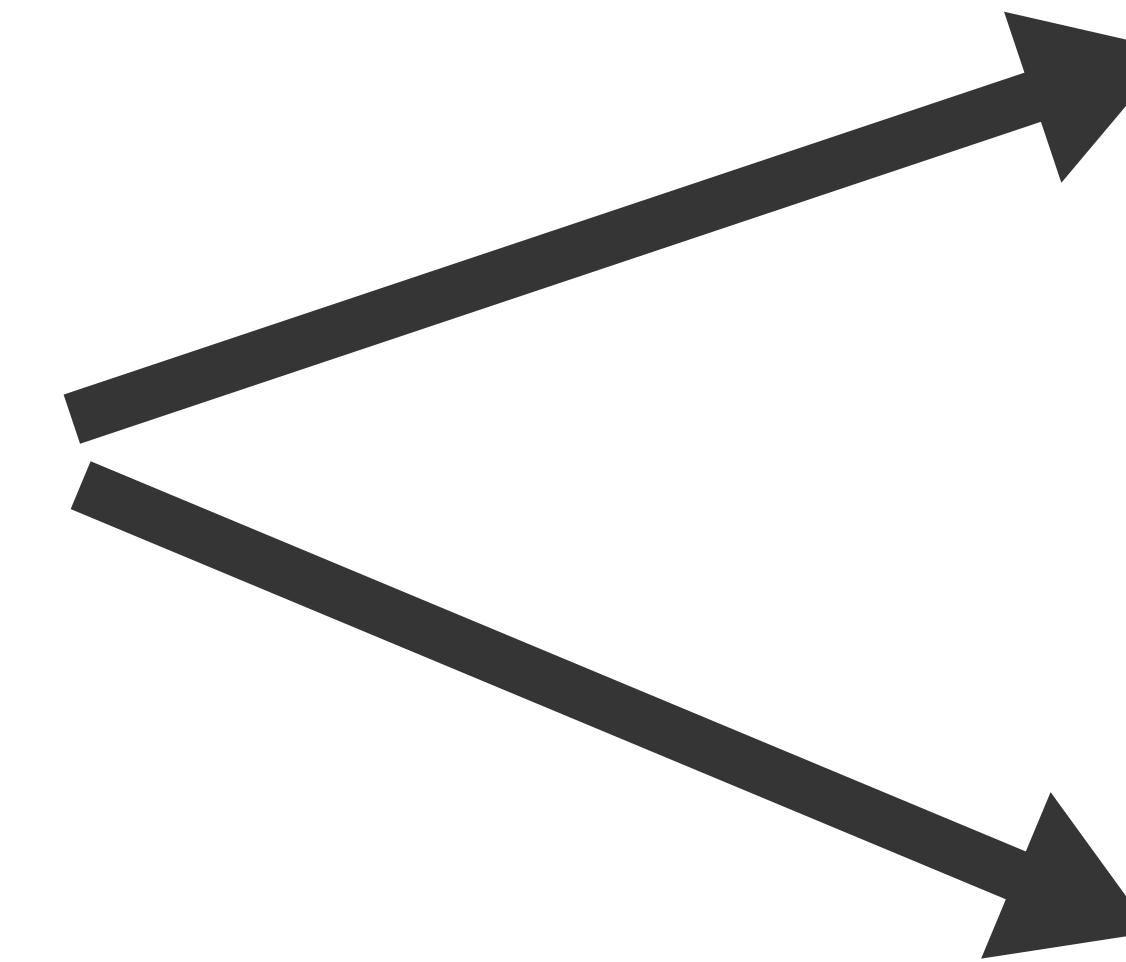
What about curbs in our cities?



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



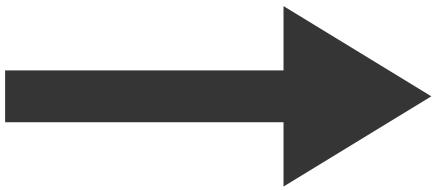
Augment or “cure” the body, the person typically bears the cost of access.



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

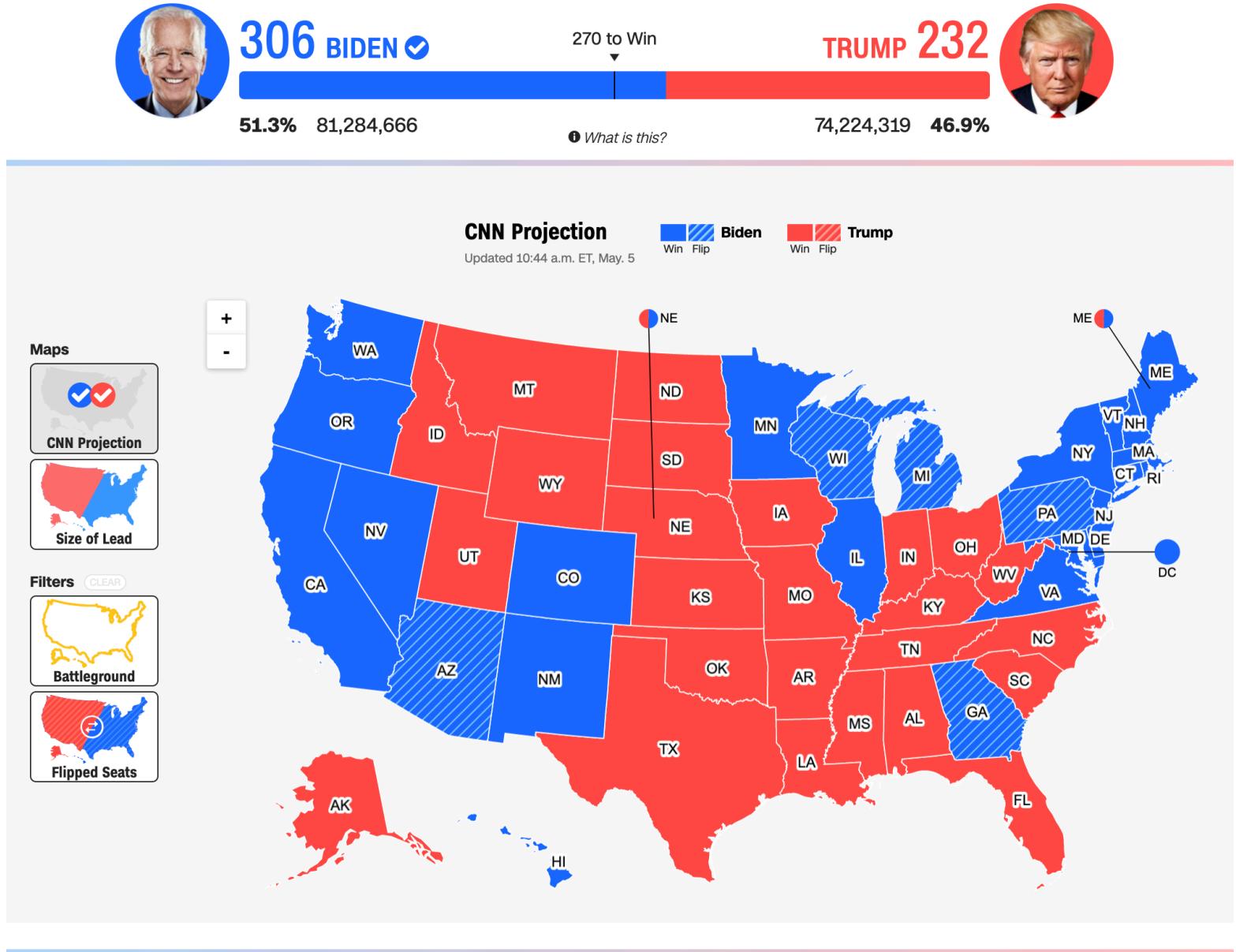
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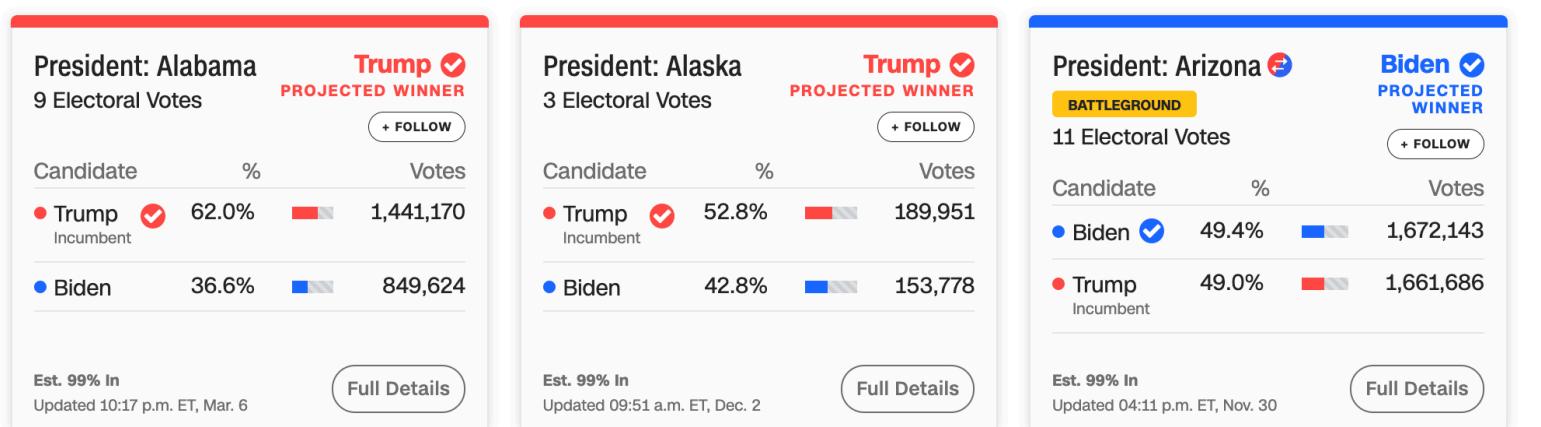
PRESIDENTIAL RESULTS

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.



STATE RESULTS



Show More States

Let's evaluate this map from CNN with Chartability.

An acronym in web standards:

P
O
U
R

An acronym in web standards:

Perceivable
Ousable
Relevant

An acronym in web standards:

Perceivable
Operable
U
R

An acronym in web standards:

Perceivable
Operable
Ununderstandable
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:

+

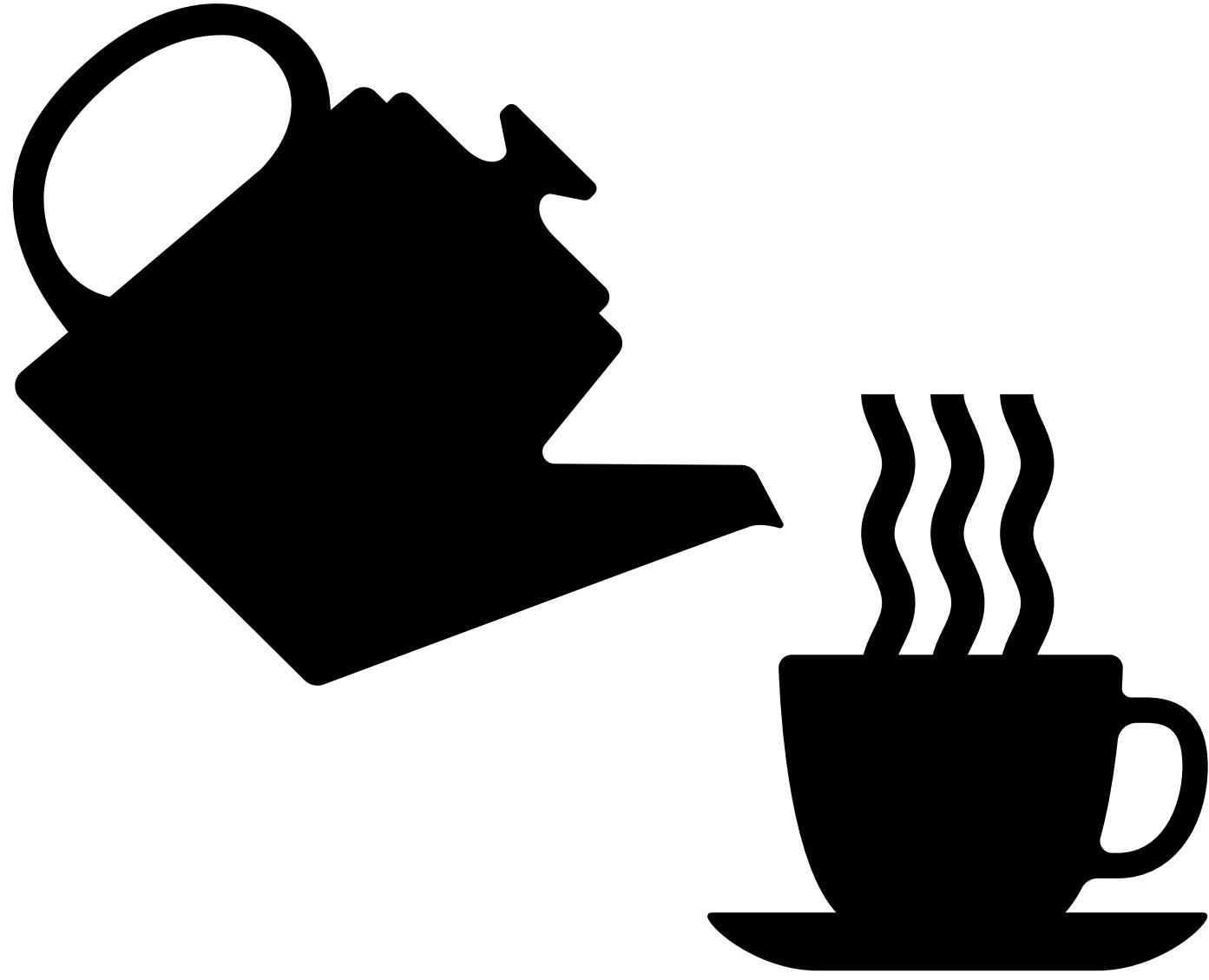
**Compromising
Assistive
F**

**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?

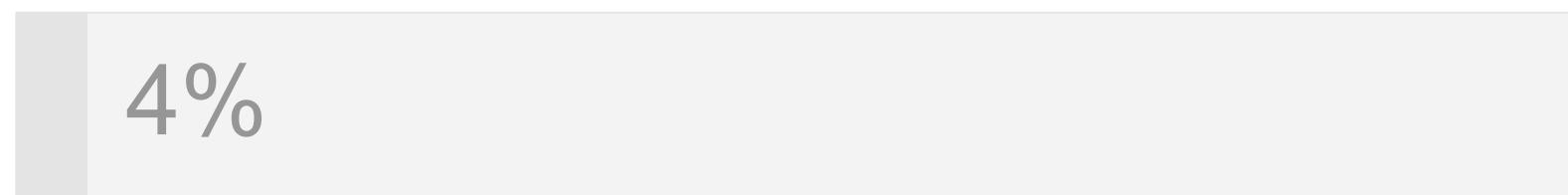
Perceivable Checklist:

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

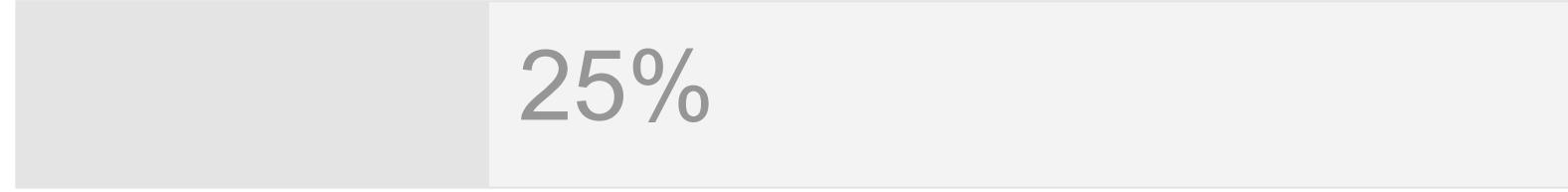
Design with high contrast

Colorblindness Disproportionately Overrepresented in A11y Resources

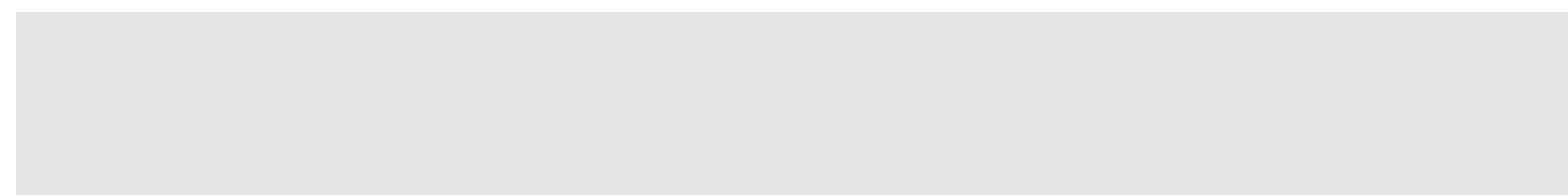
Colorblindness: % of People



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



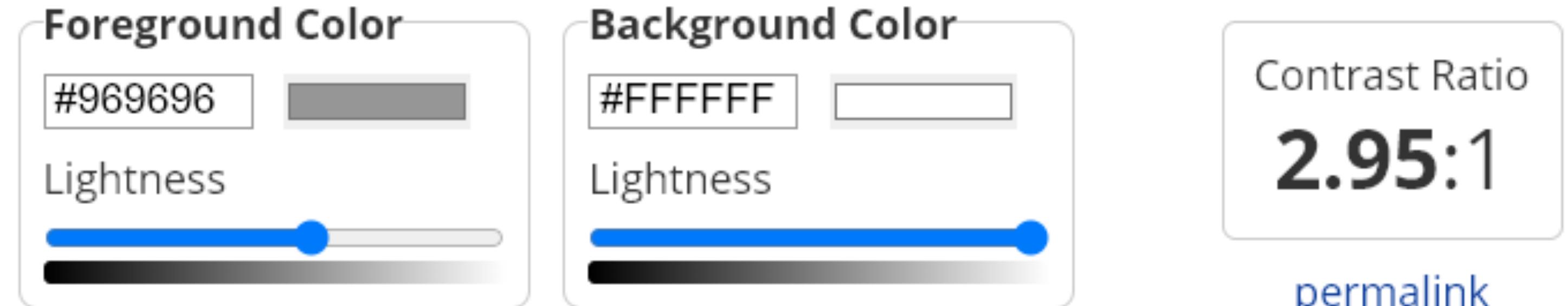
Use High Contrast Text

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



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

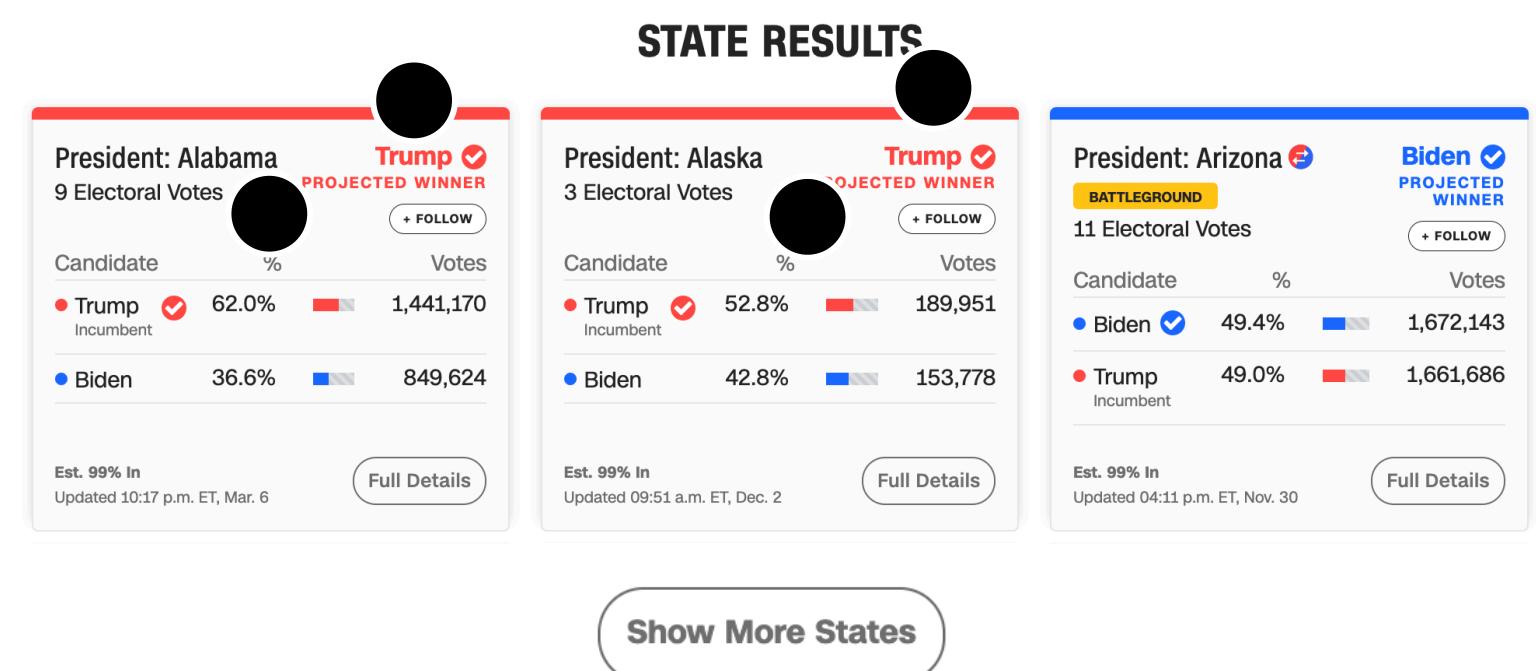
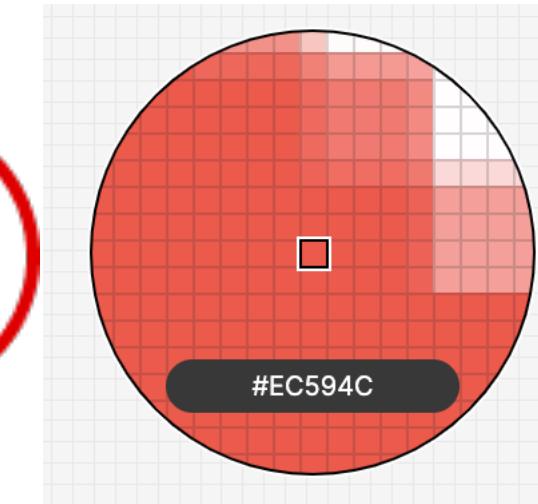
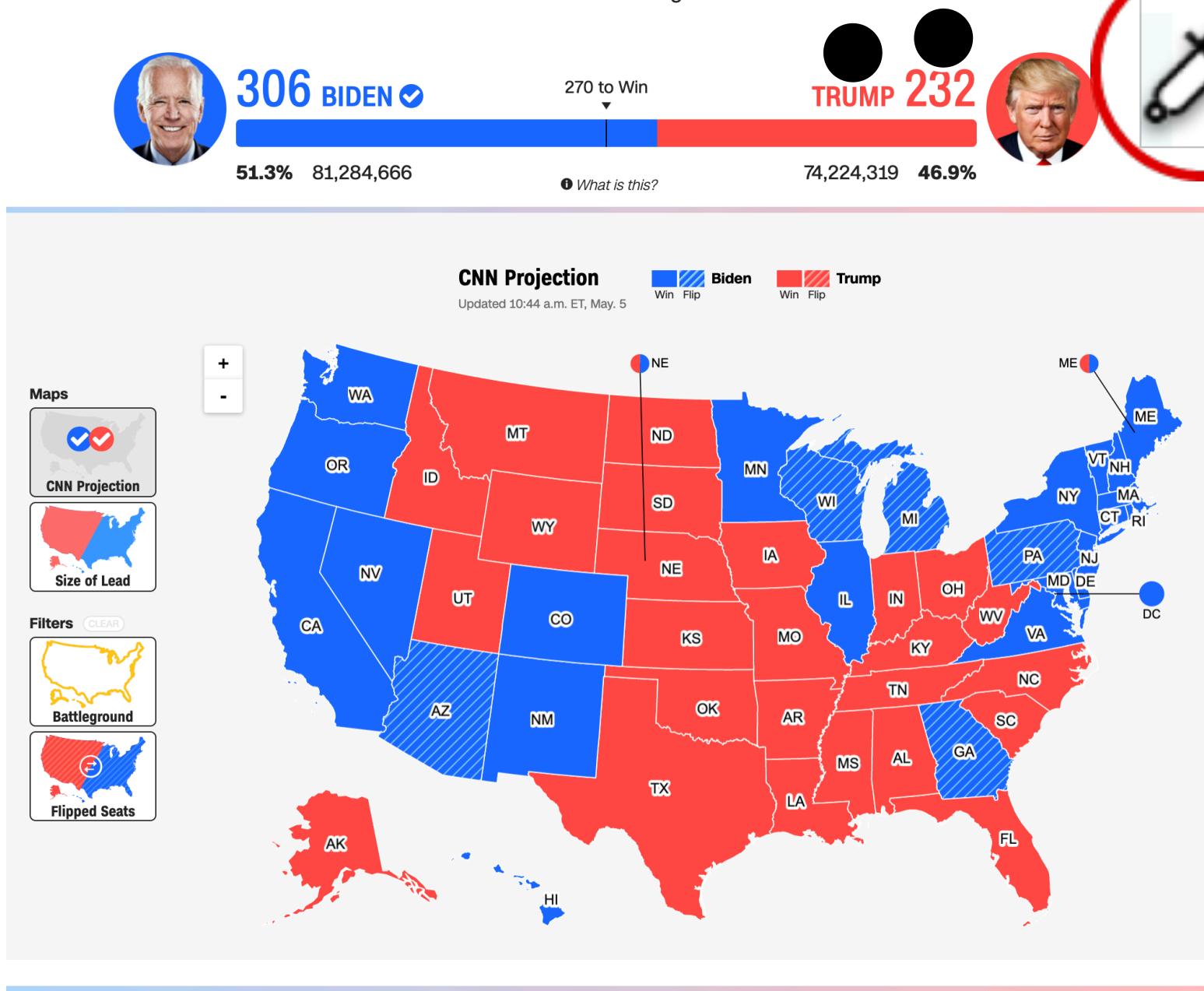
WCAG AA: **Fail**



PRESIDENTIAL RESULTS

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.



Contrast Checker

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

Foreground Color

#EC594C



Lightness

Background Color

Background Color

#FFFFFF

Lightness

Contrast Ratio

3.44:1

[permalink](#)

Normal Text

WCAG AA: **Fail**

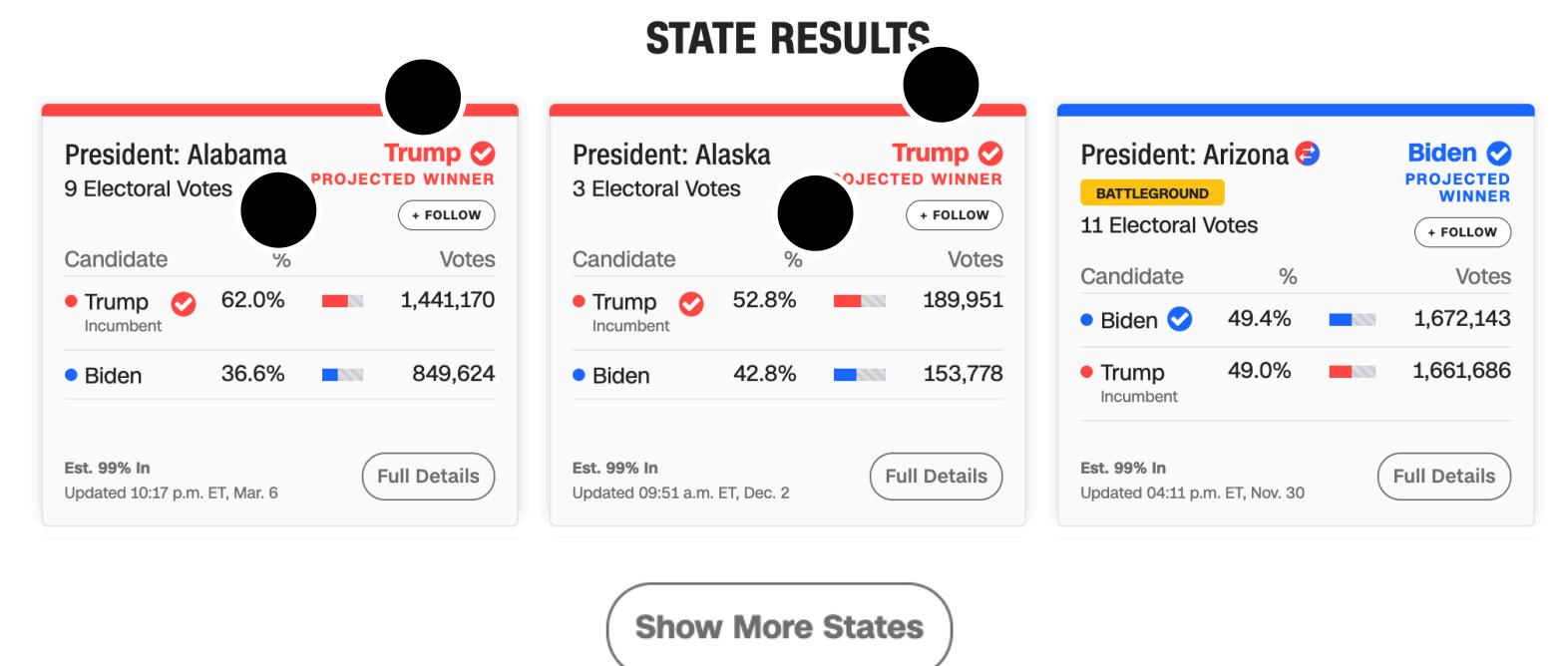
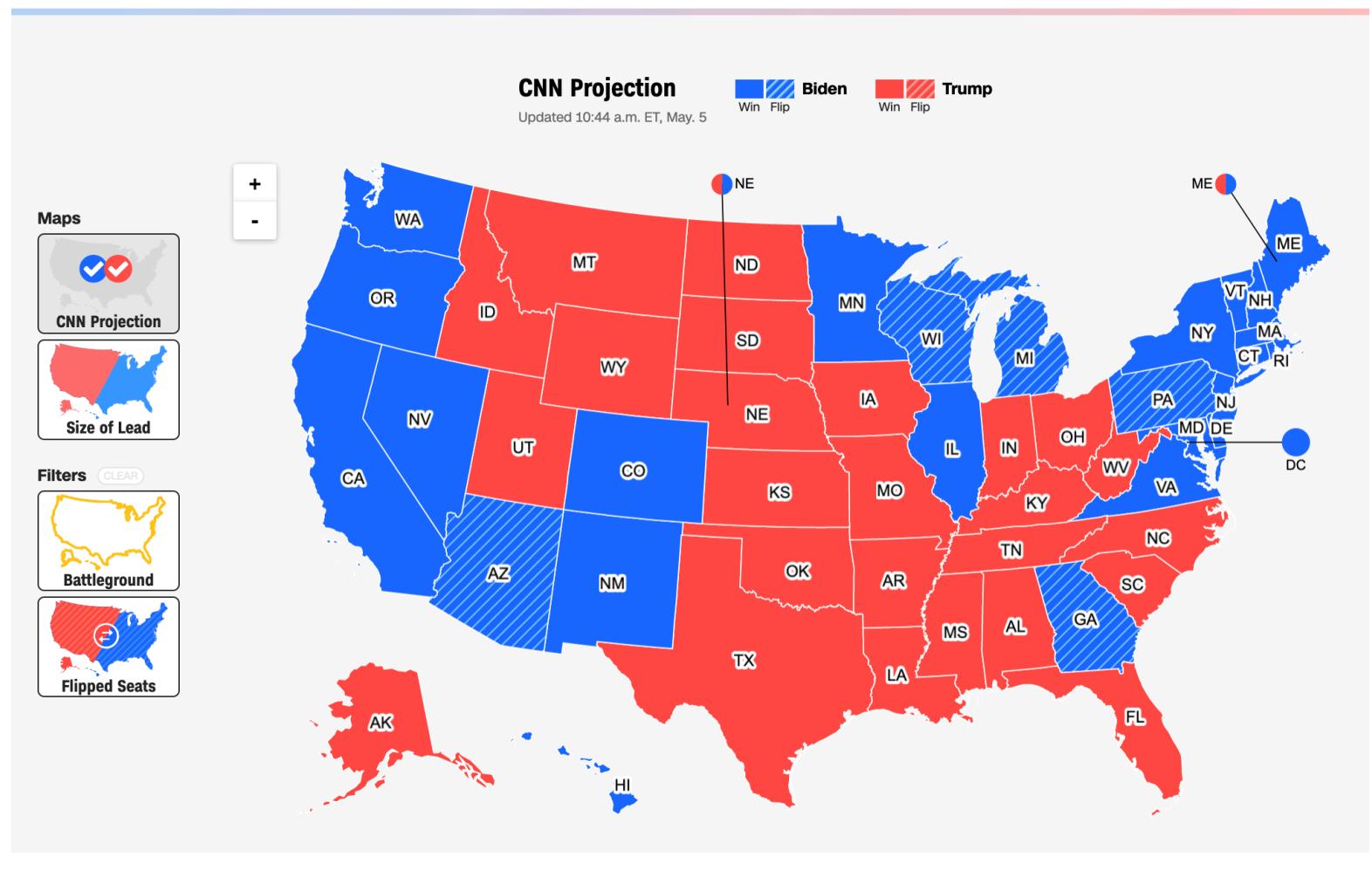
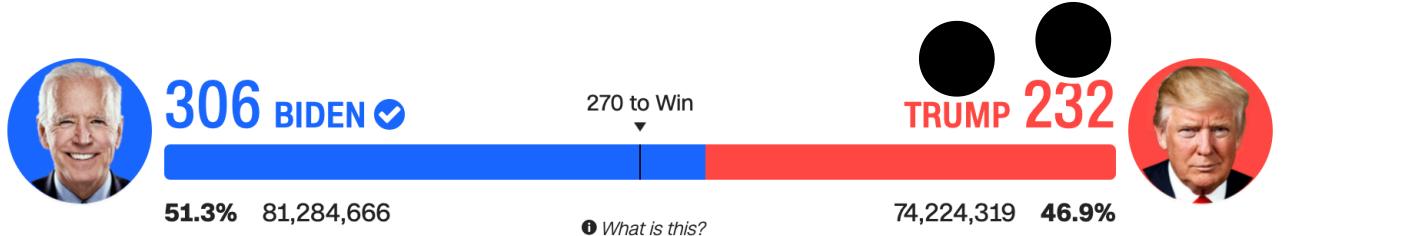
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The five boxing wizards jump quickly.

PRESIDENTIAL RESULTS

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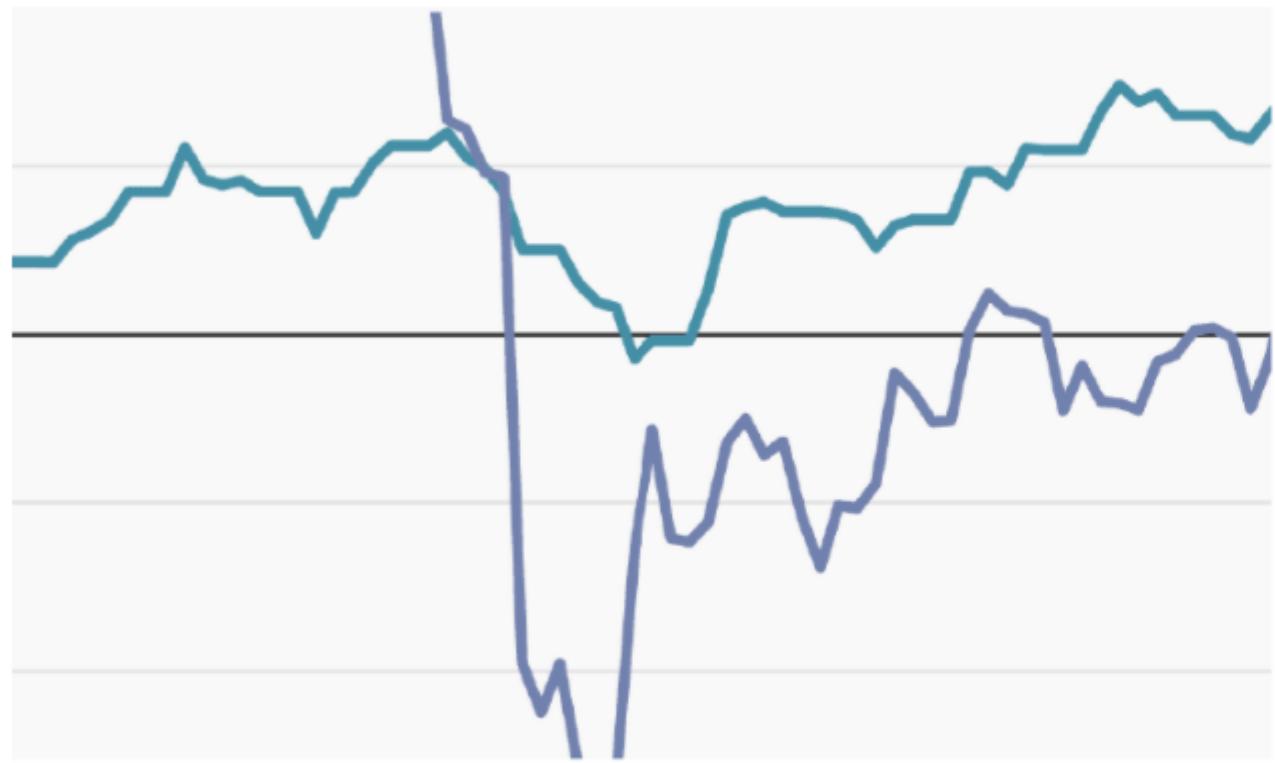
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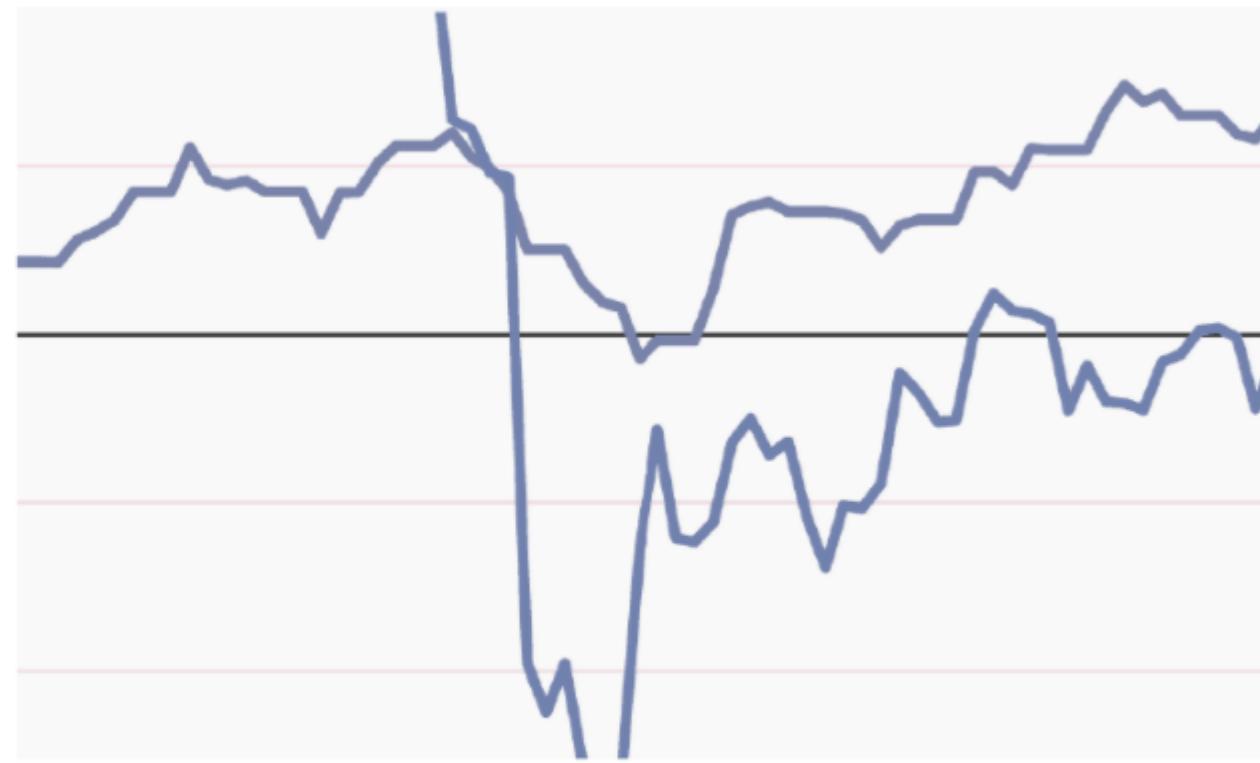
6 instances of low contrast

Don't rely on color alone!

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

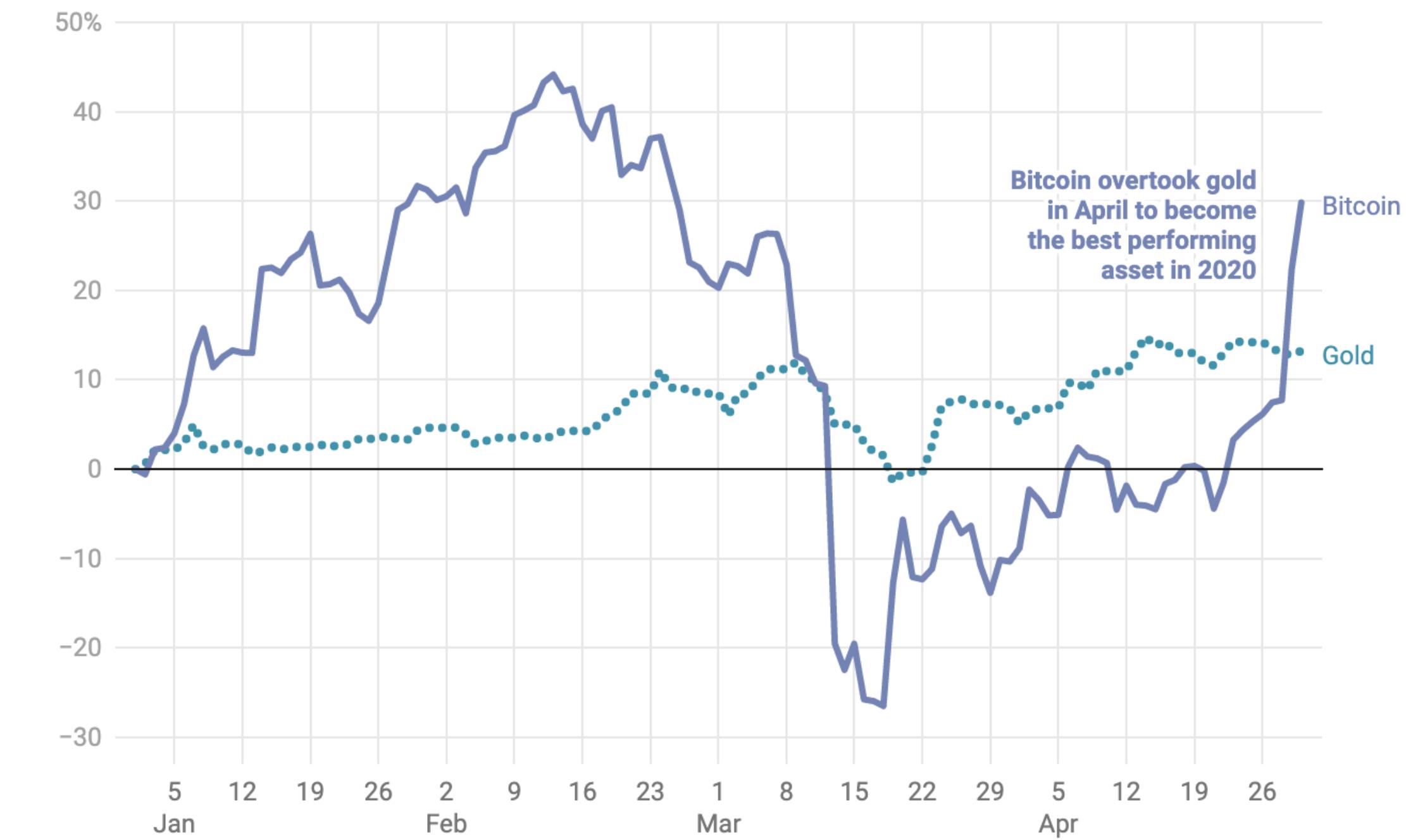
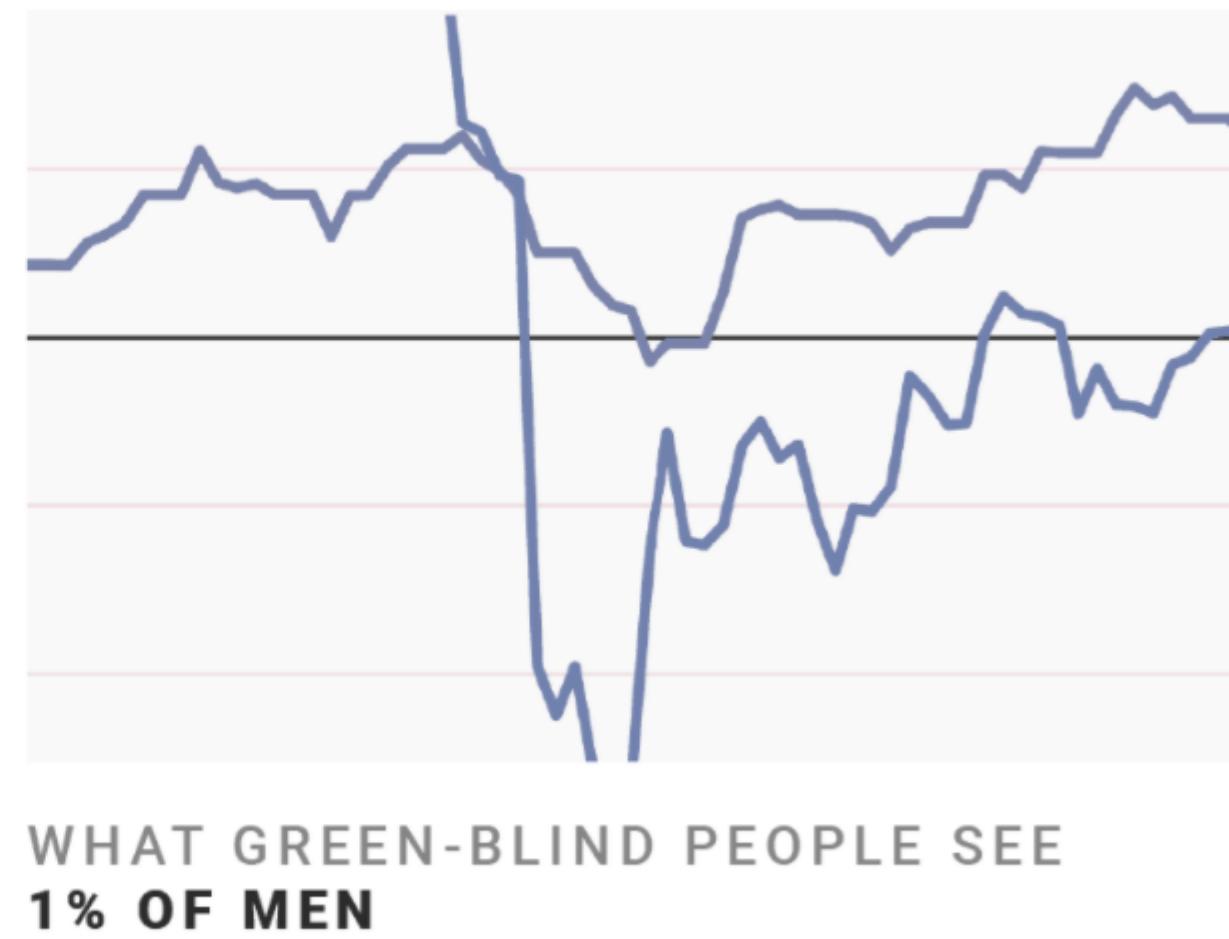
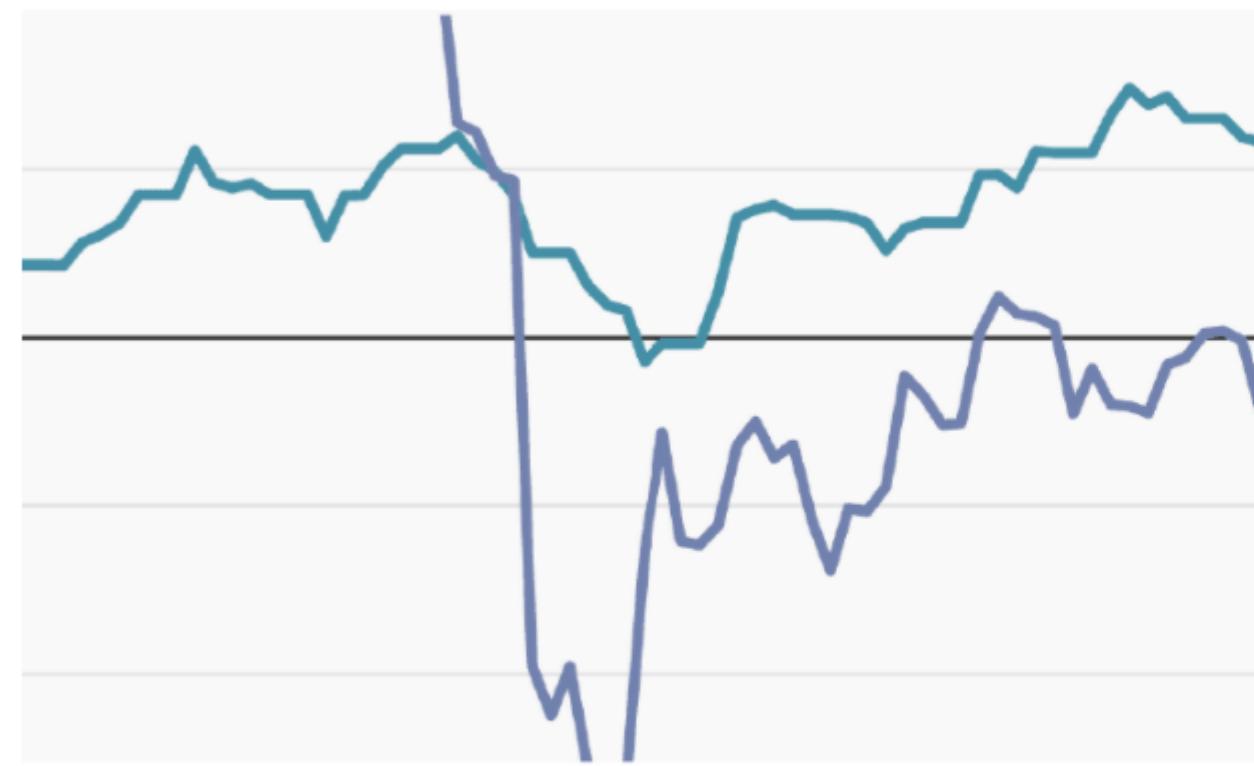


WHAT PEOPLE WITH NORMAL
VISION SEE



WHAT GREEN-BLIND PEOPLE SEE
1% OF MEN

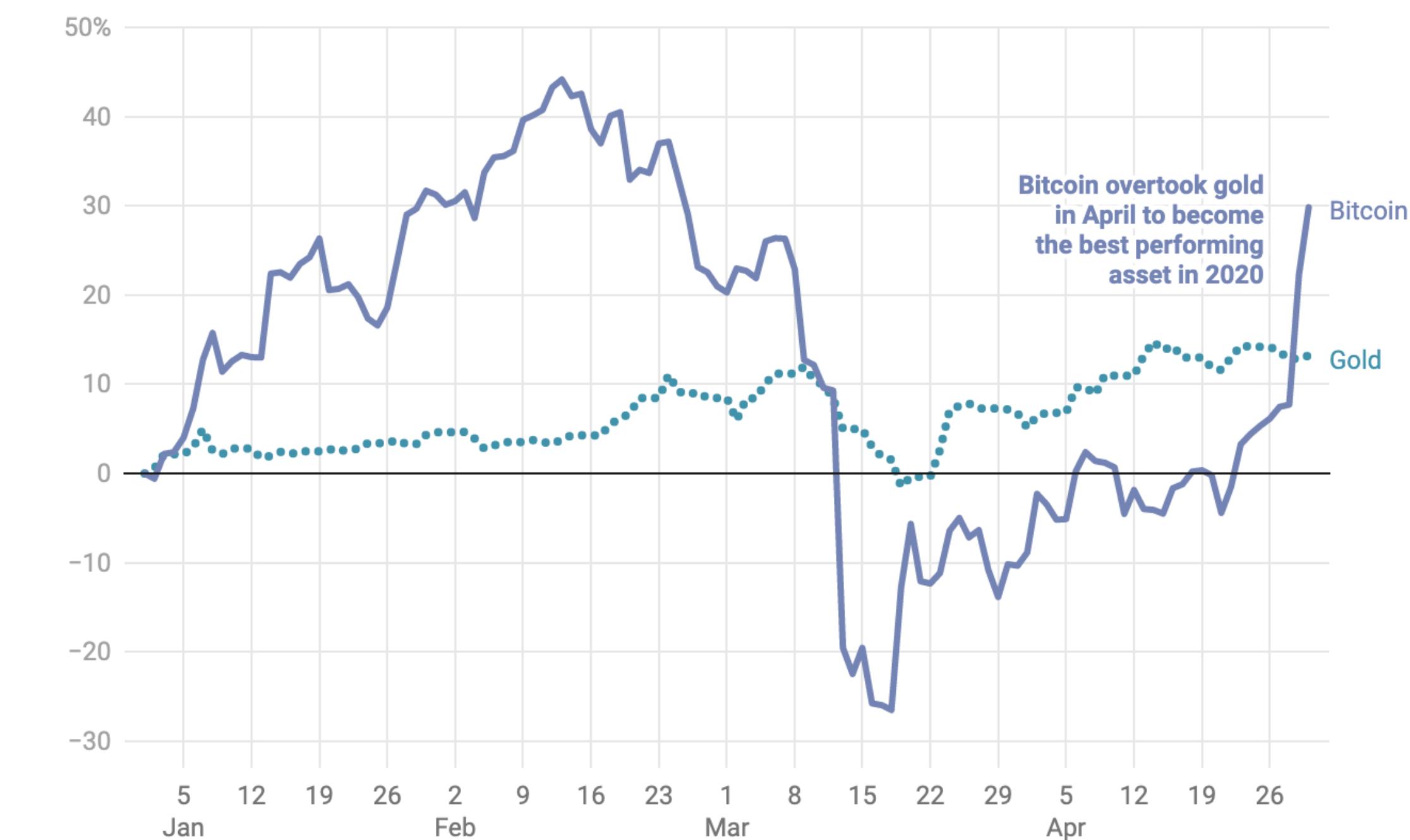
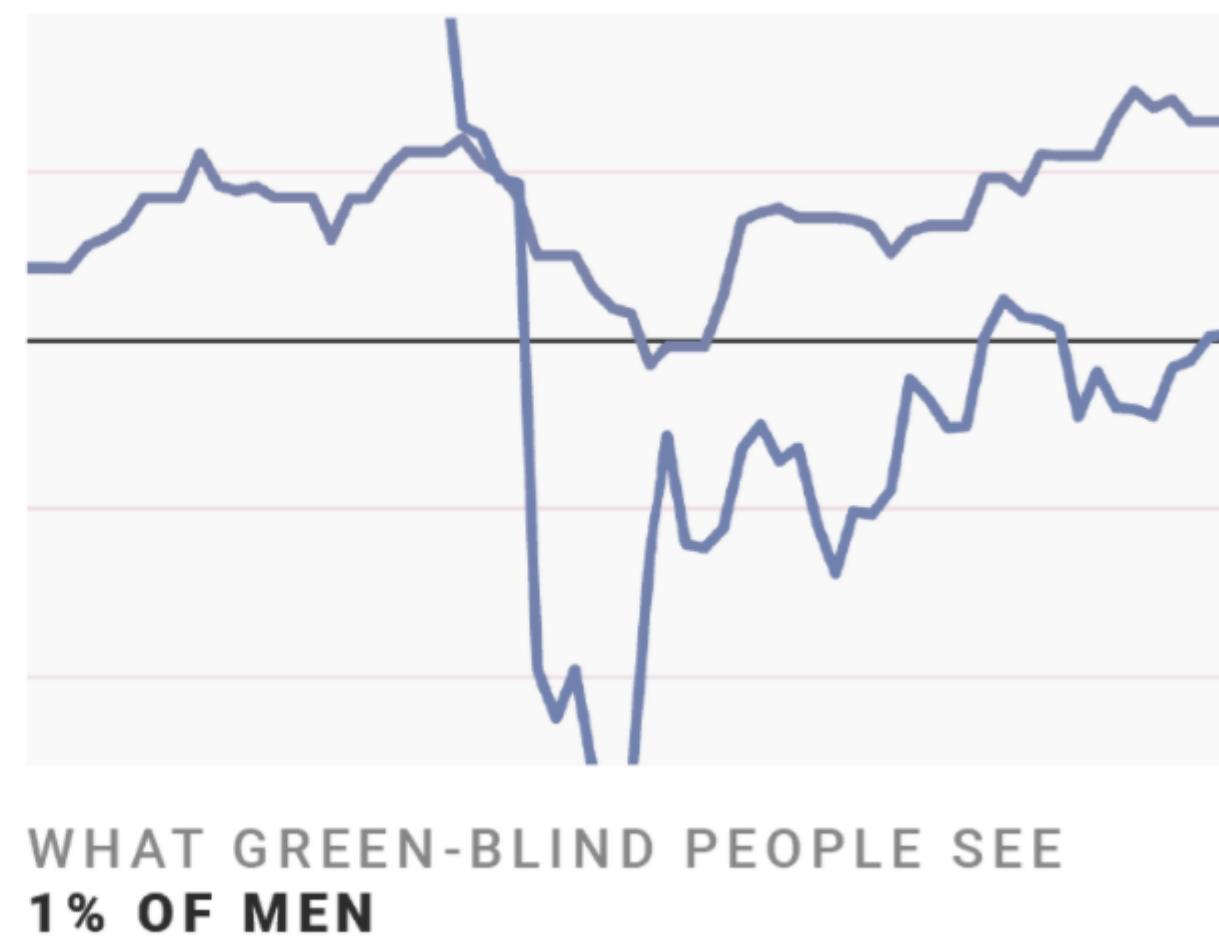
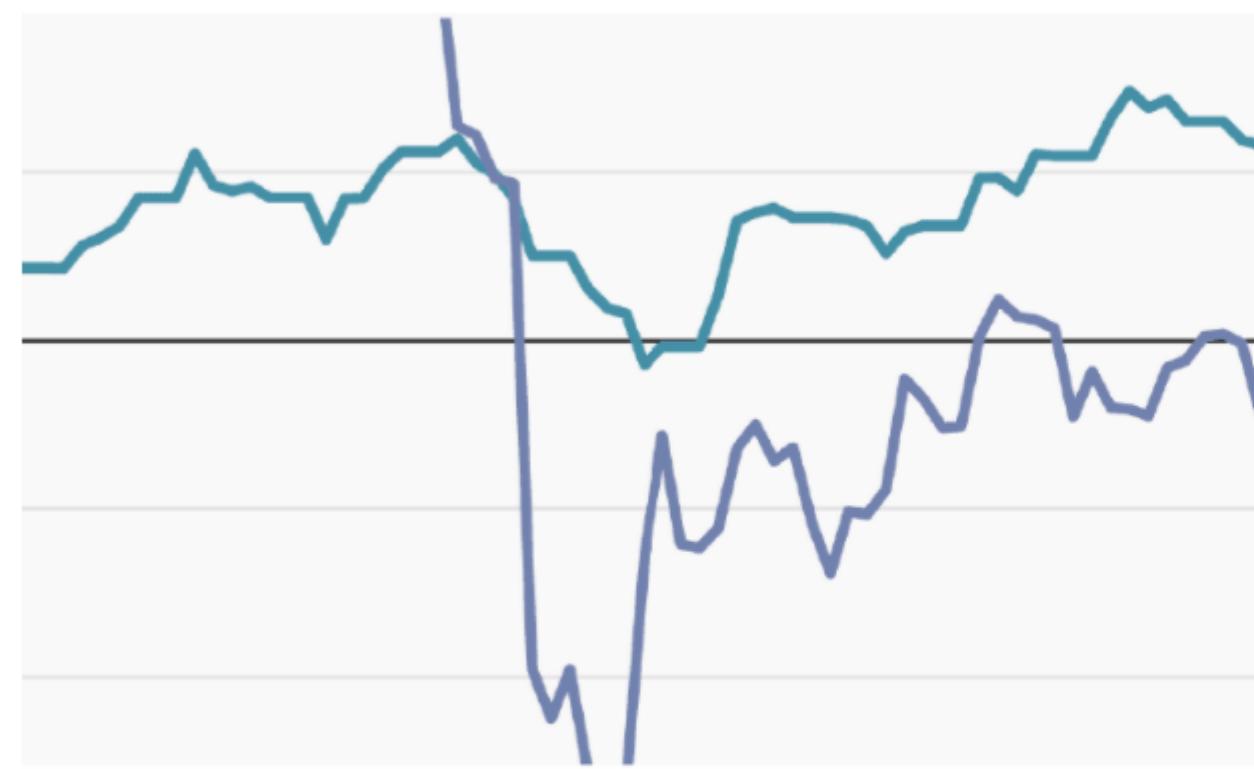
“Redundant encoding” is one strategy



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

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

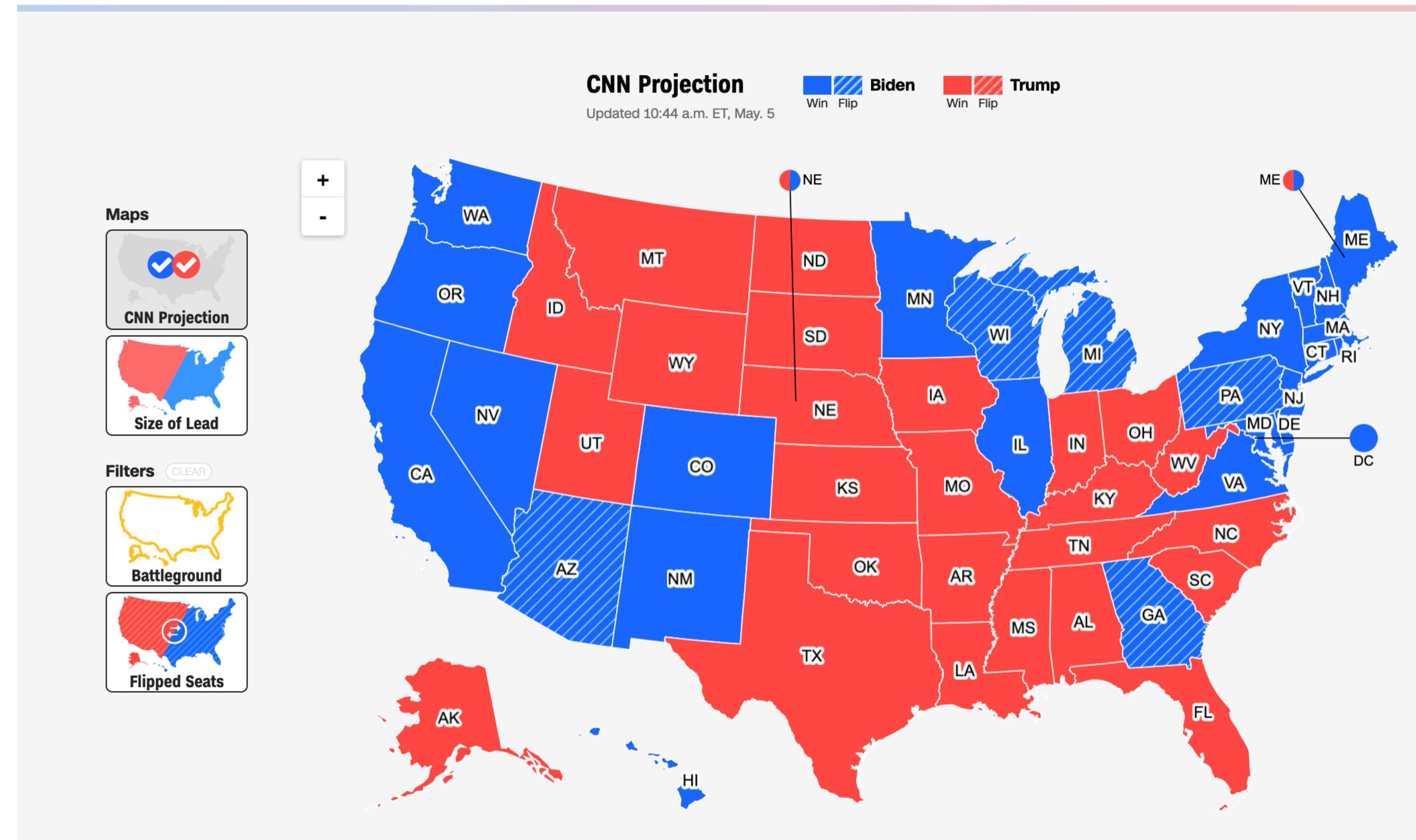
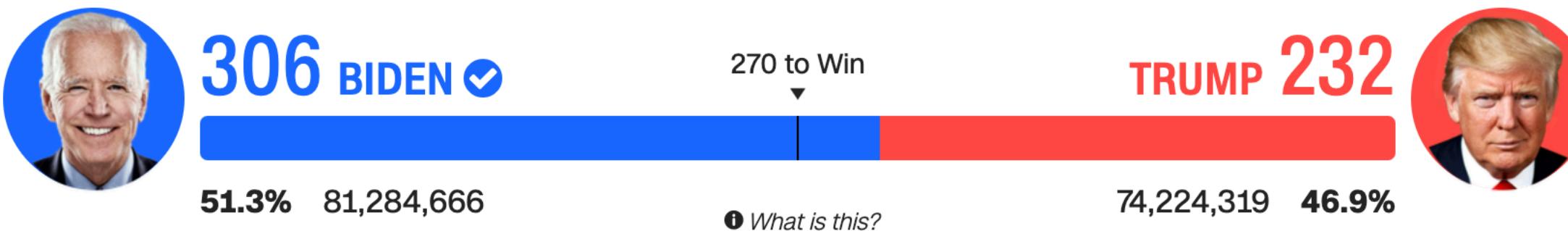
A note: “Color-vision deficiency” and “colorblindness” refer to the same thing, both terms are fine to use.



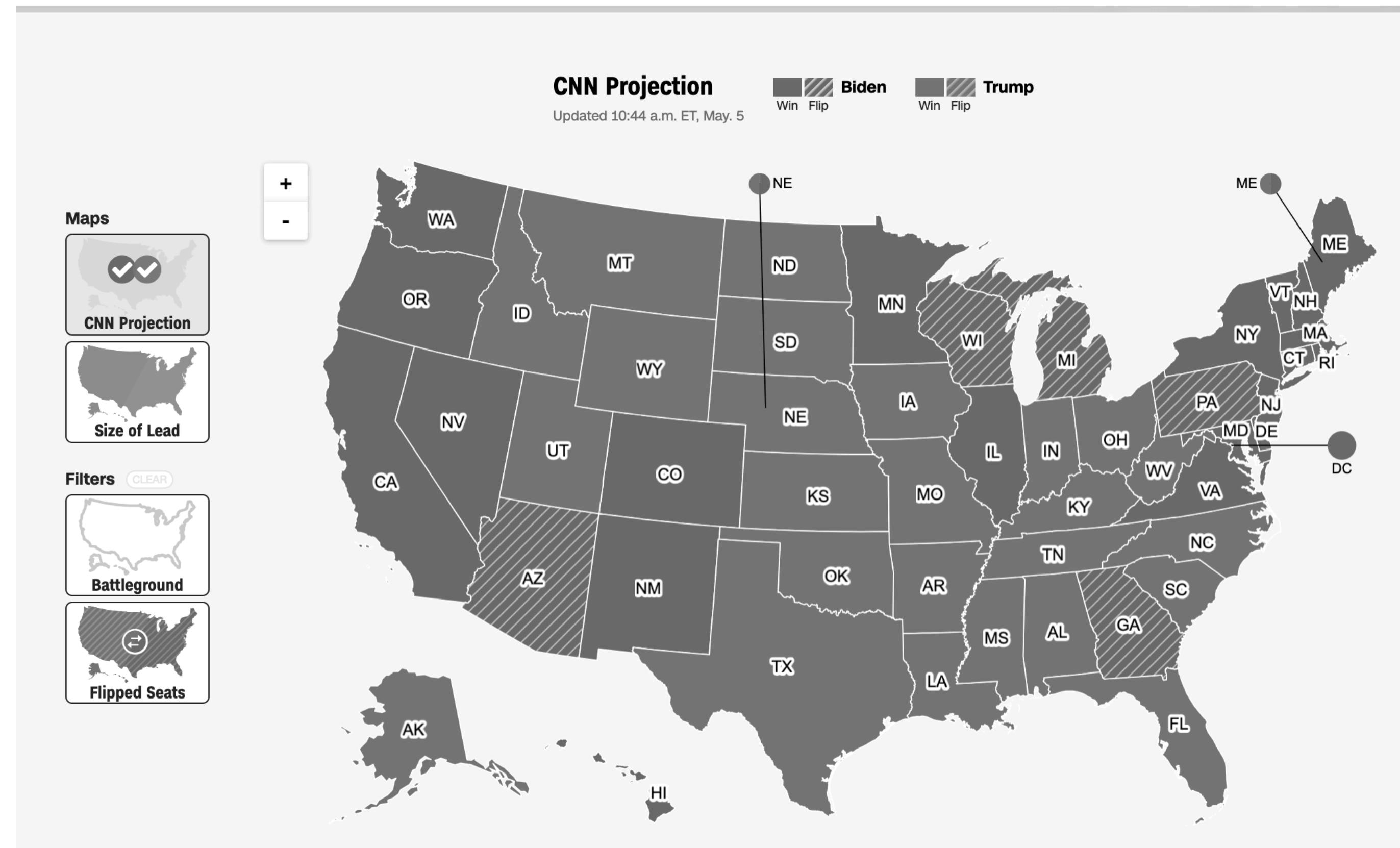
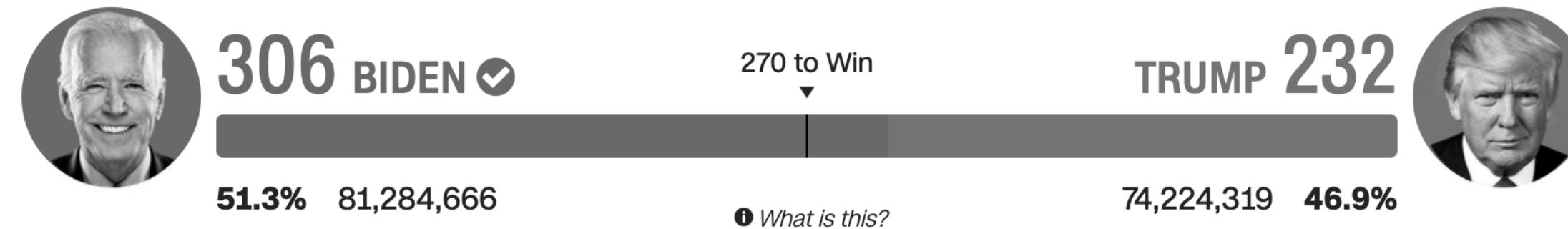
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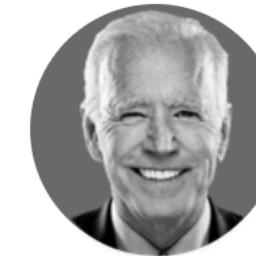
But sometimes you *can't* redundantly encode!



This map is trouble in greyscale



The division here matters!



306 BIDEN ✓

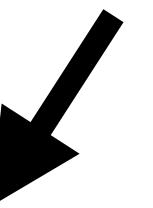
51.3% 81,284,666



232 TRUMP

74,224,319 46.9%

270 to Win



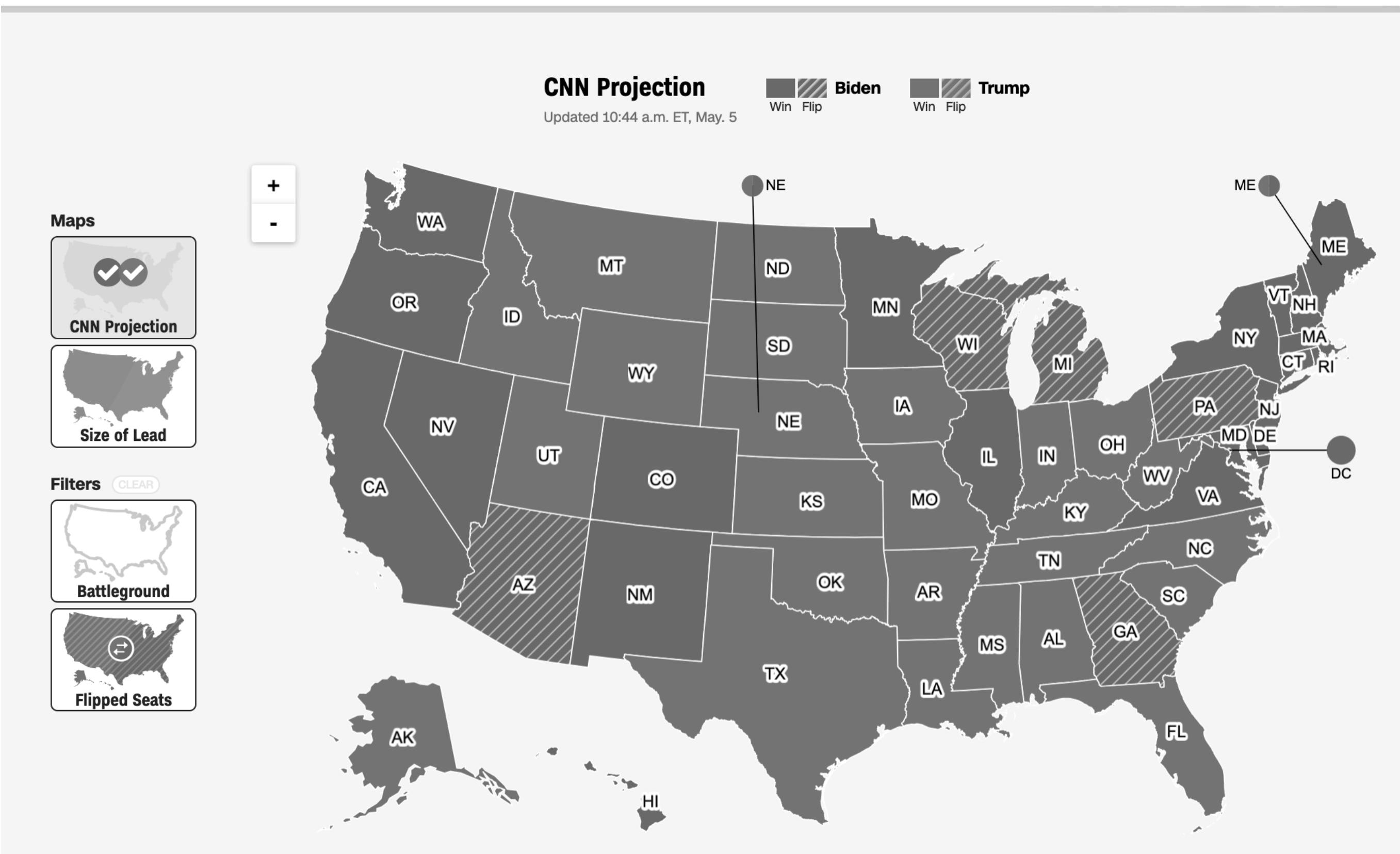
270 to Win

CNN Projection

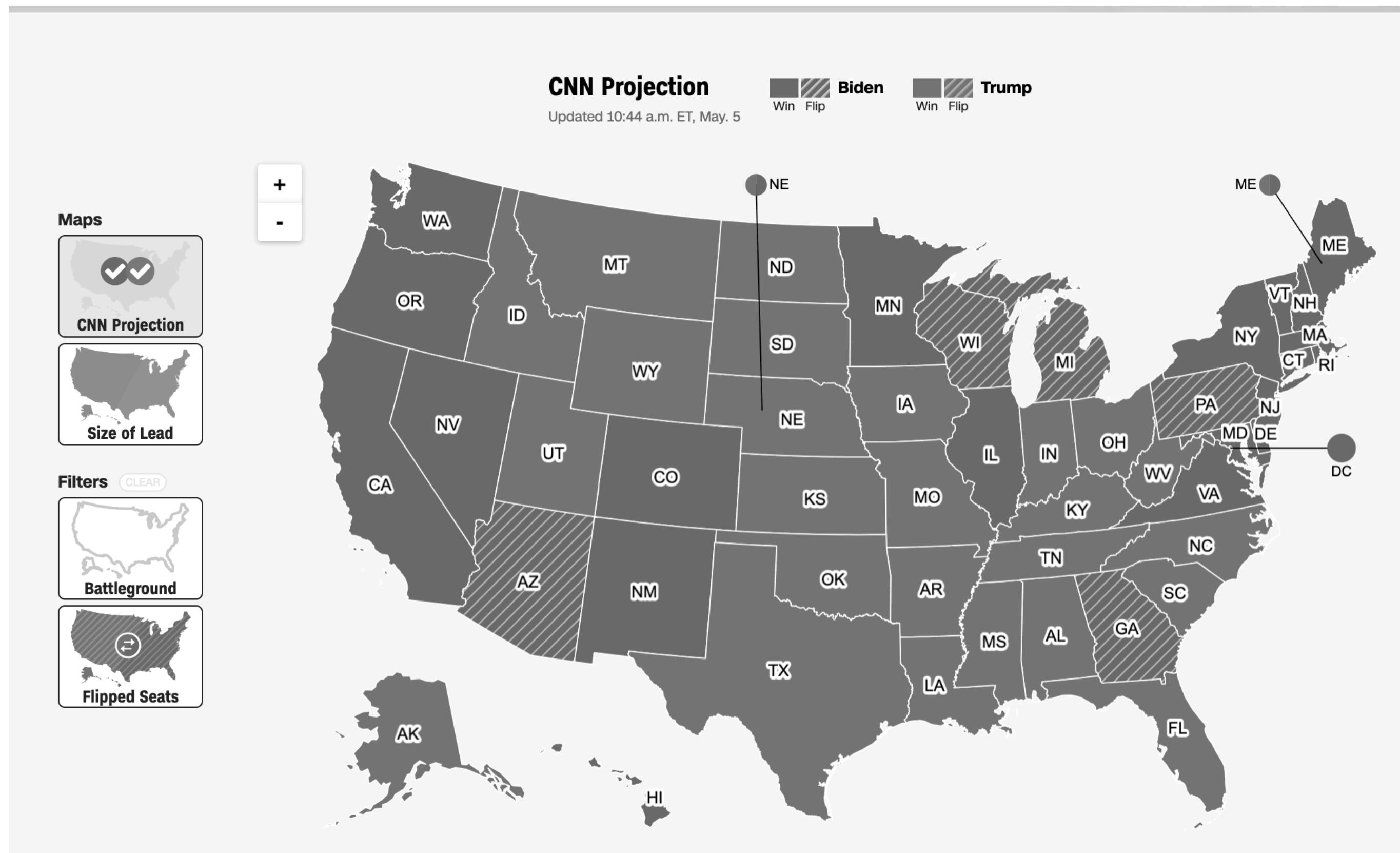
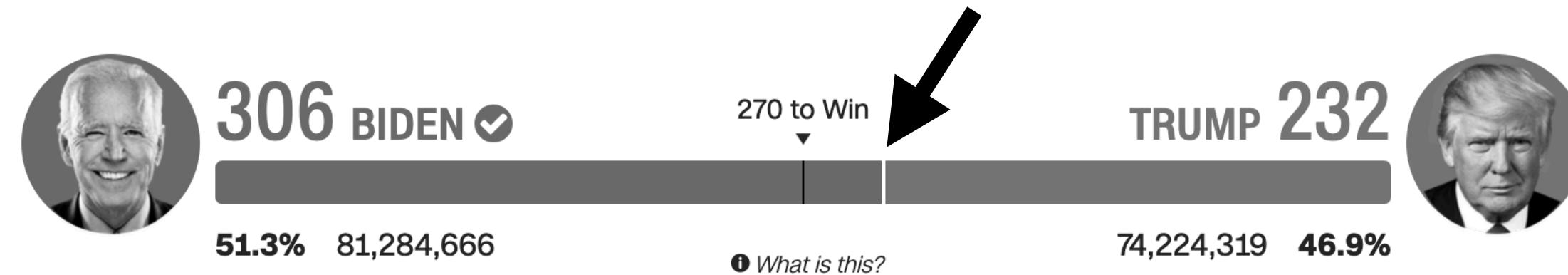
Updated 10:44 a.m. ET, May 5

Biden
Win Flip

Trump
Win Flip



Maybe a small white divider, like the states?



Perhaps test a darker blue too?



306 BIDEN ✓

51.3% 81,284,666



270 to Win



232 TRUMP

74,224,319 46.9%

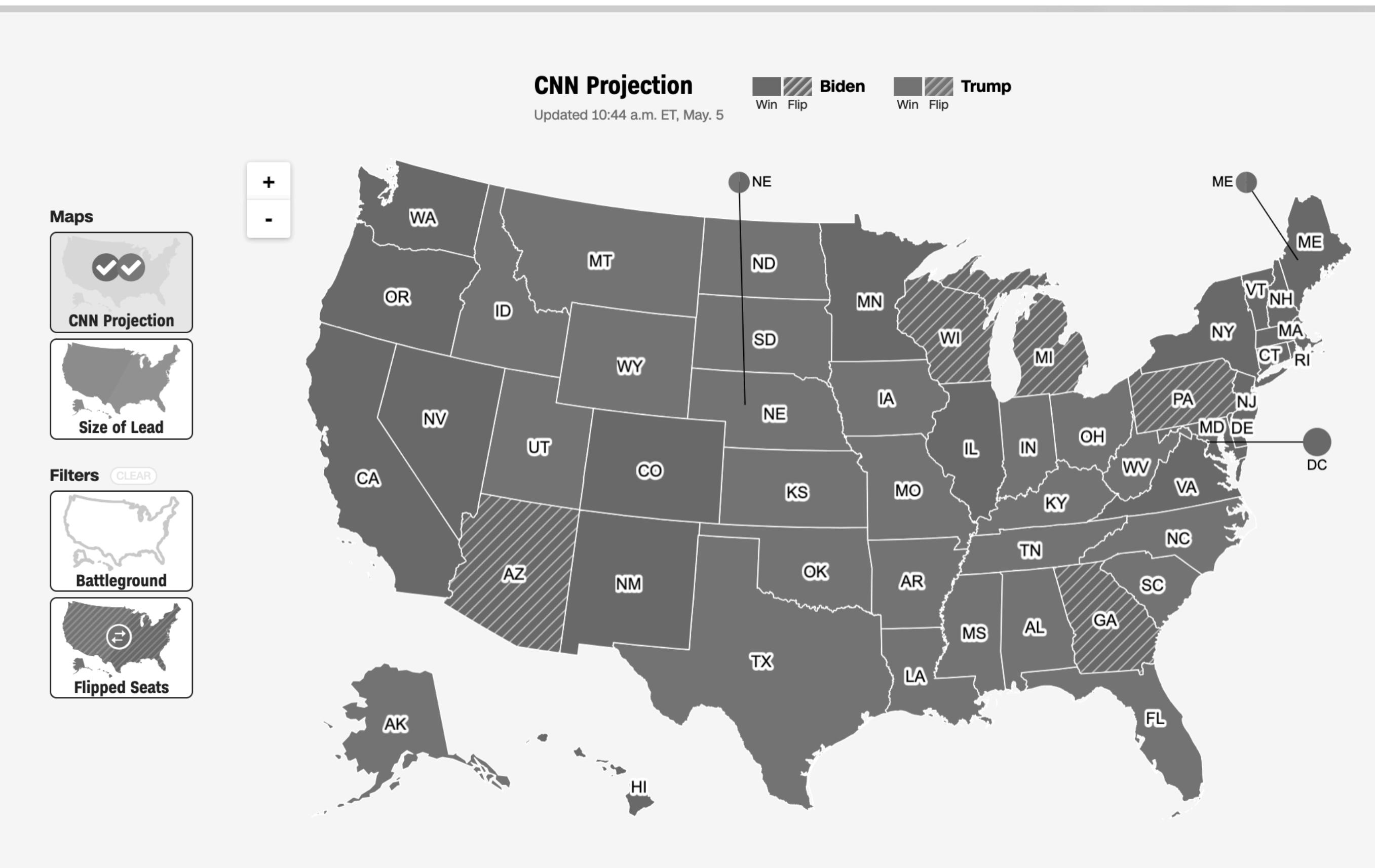
ⓘ What is this?

CNN Projection

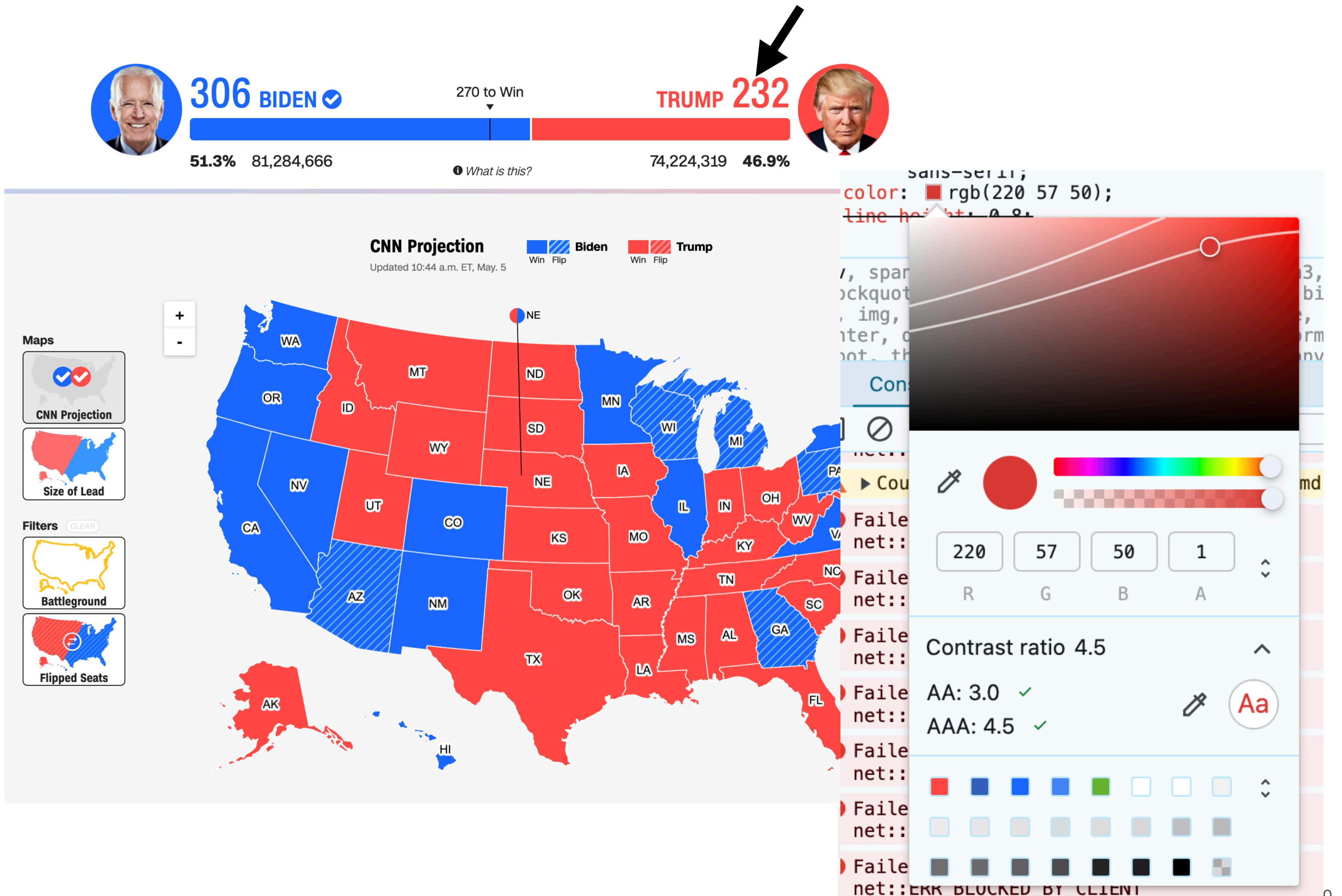
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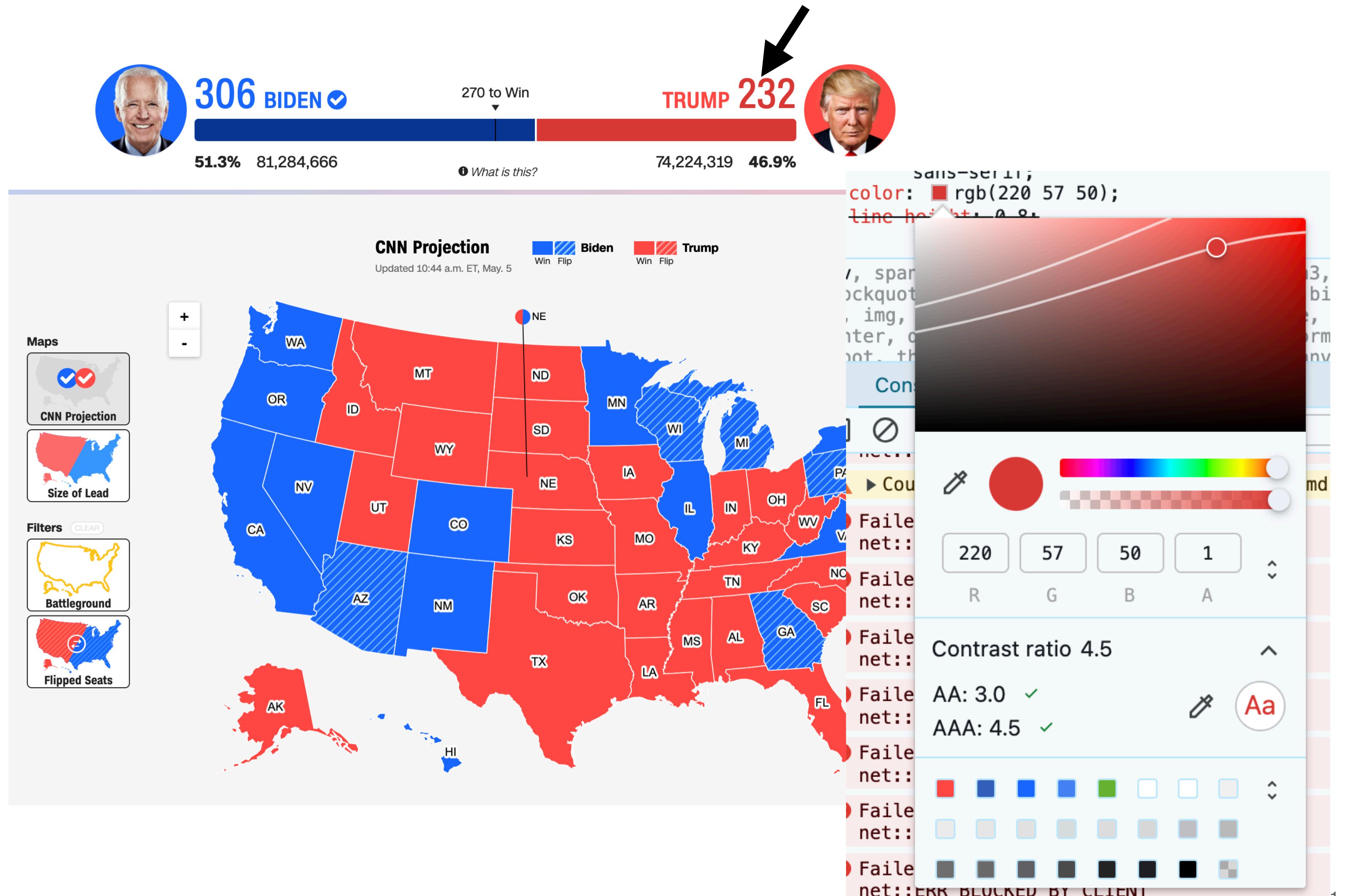
Trump
Win Flip



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



This text now passes!



Let's check that greyscale again...



Before



306 BIDEN ✓

51.3% 81,284,666

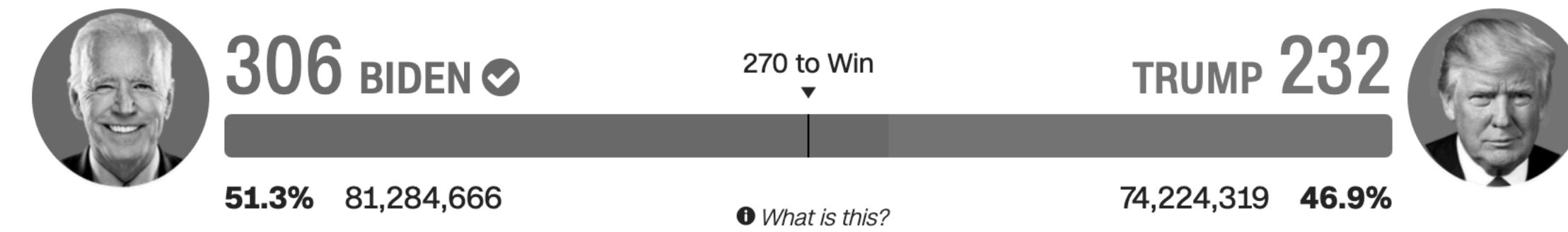
270 to Win



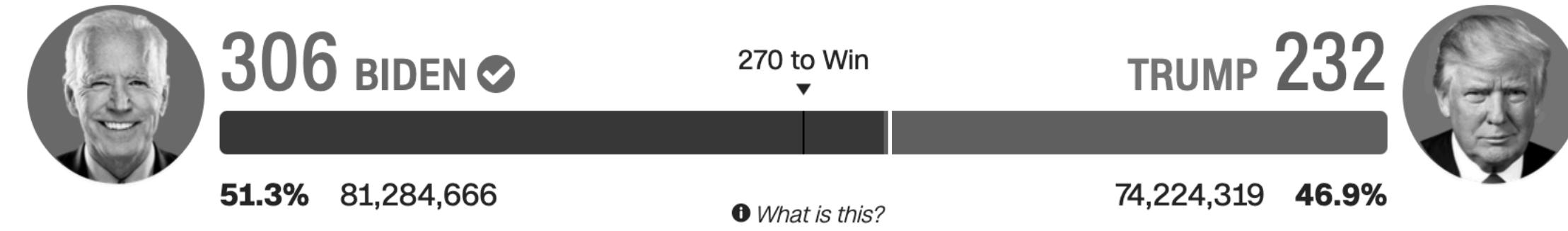
TRUMP 232

74,224,319 **46.9%**

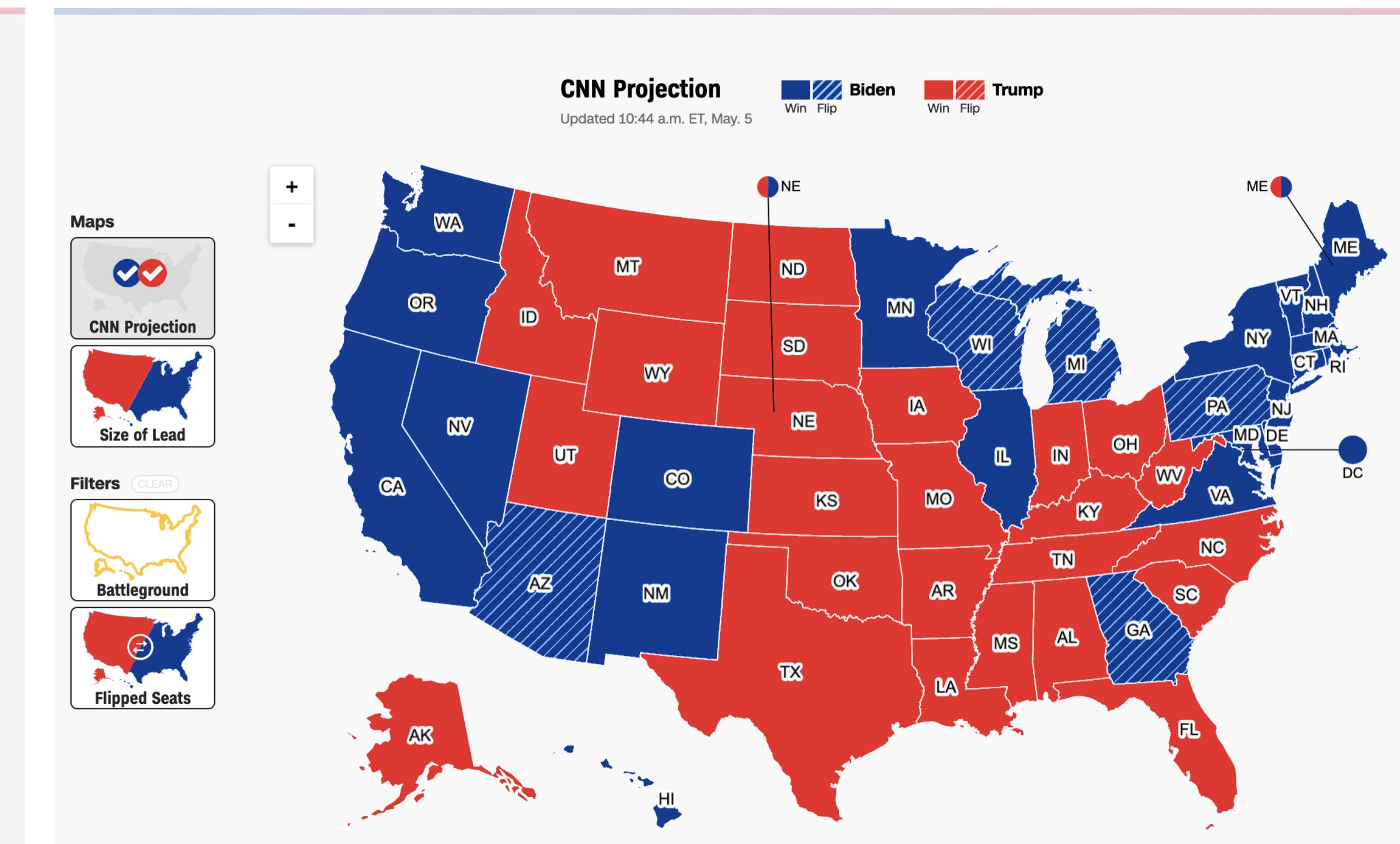
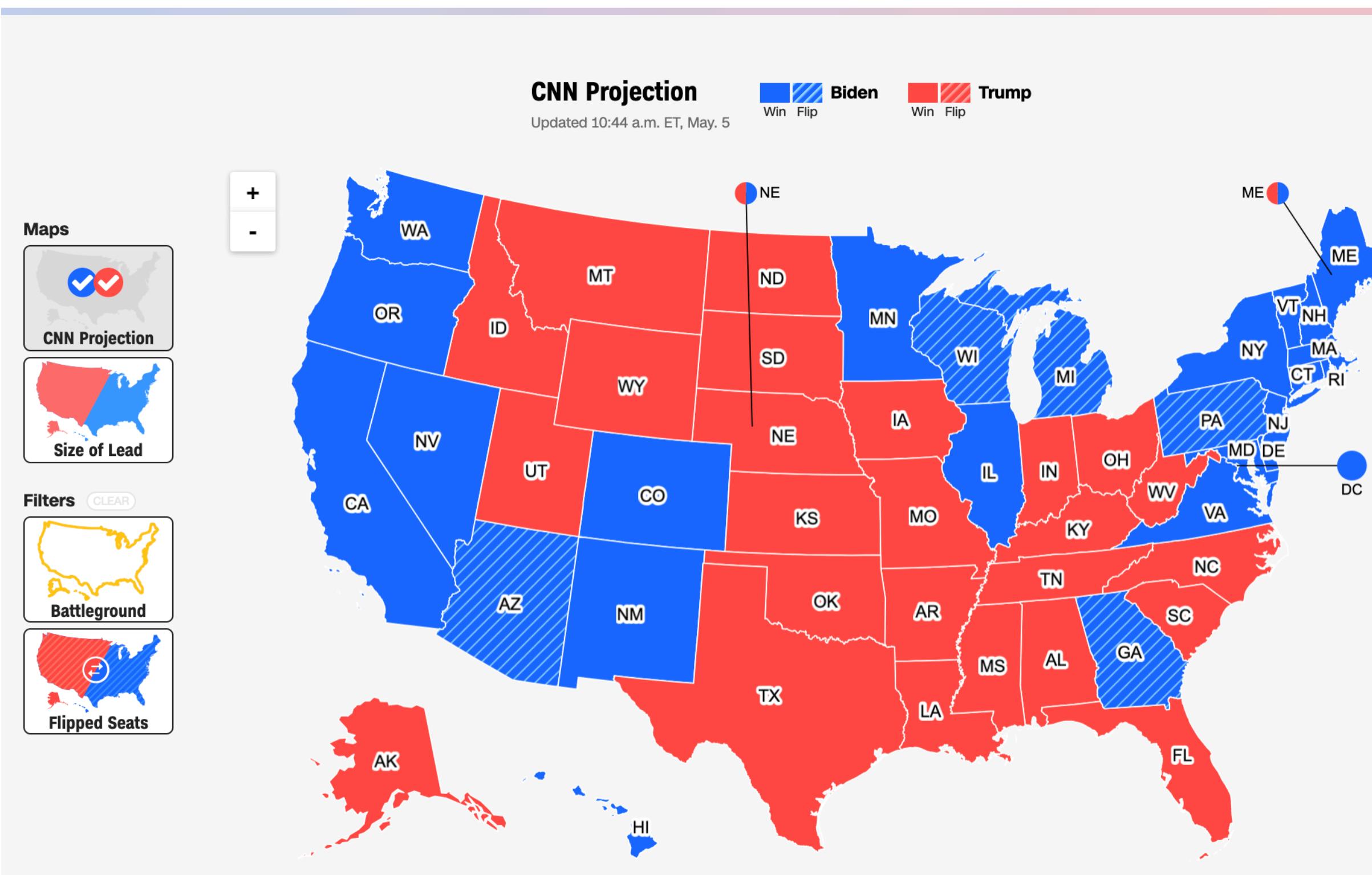
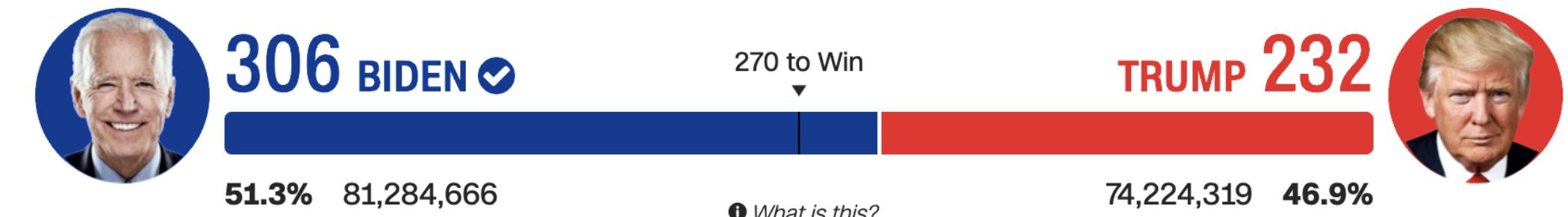
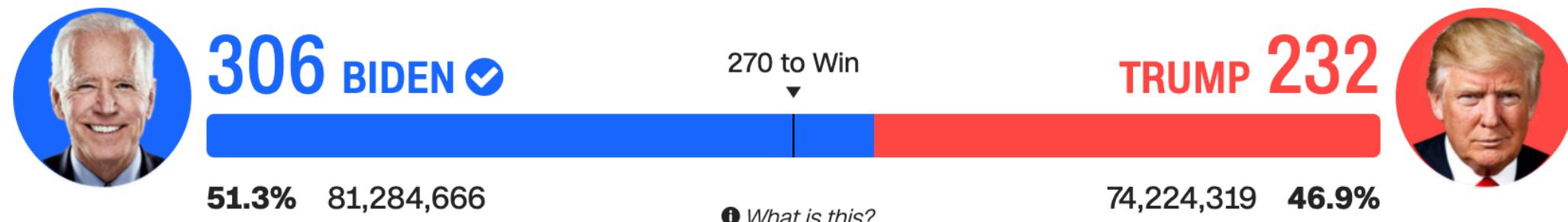
ⓘ What is this?



And after!



Sufficient contrast can help folks differentiate



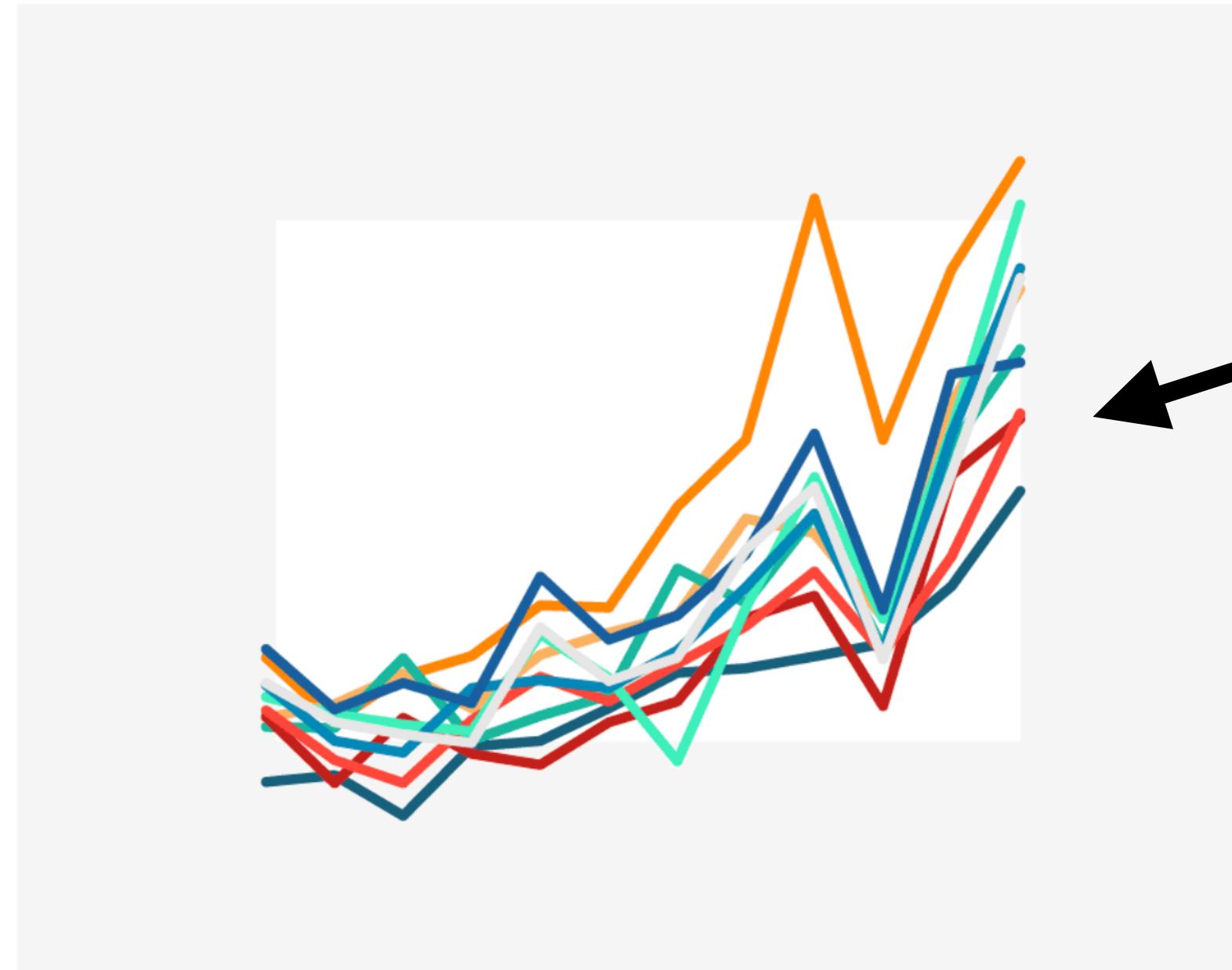
But what about more than 2 colors?



NOT IDEAL

Source: [Datawrapper](#)

But what about more than 2 colors?



NOT IDEAL

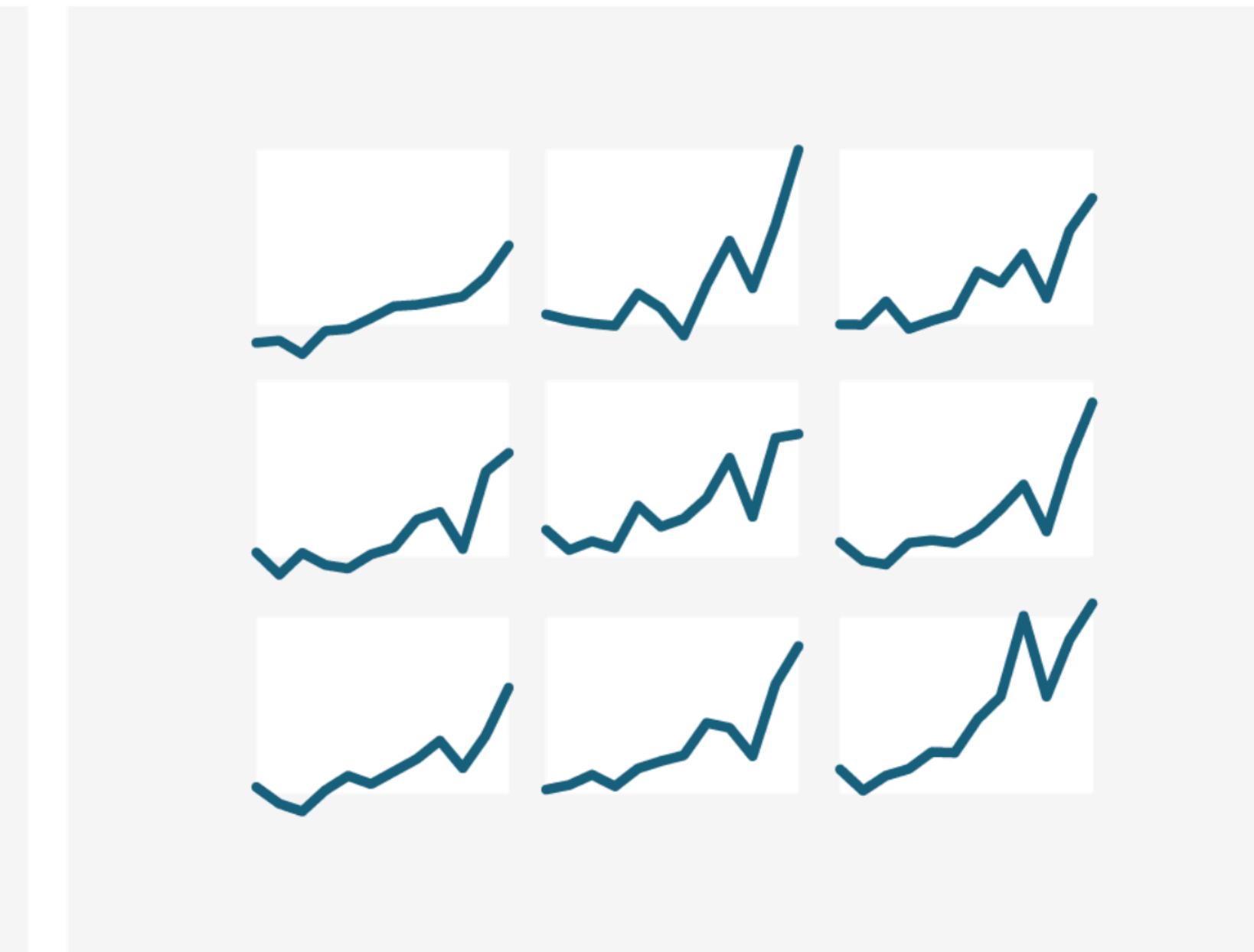
Finding “pair” contrast gets
really hard after 3+ colors...

Source: [Datawrapper](#)

Reduce your colors and redesign!



NOT IDEAL



BETTER

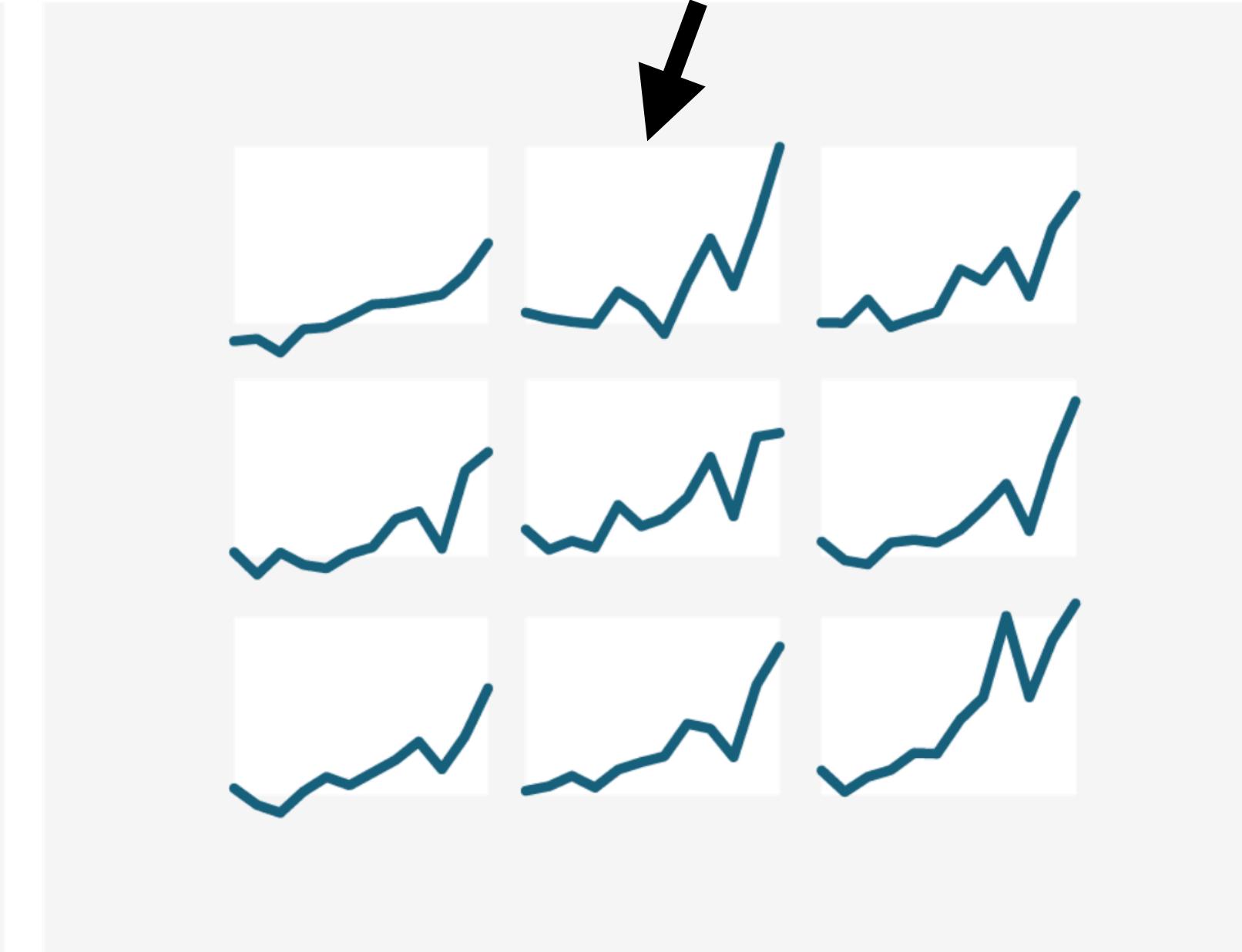
Source: [Datawrapper](#)

Reduce your colors and redesign!

Using “small multiples” is an easy, powerful technique



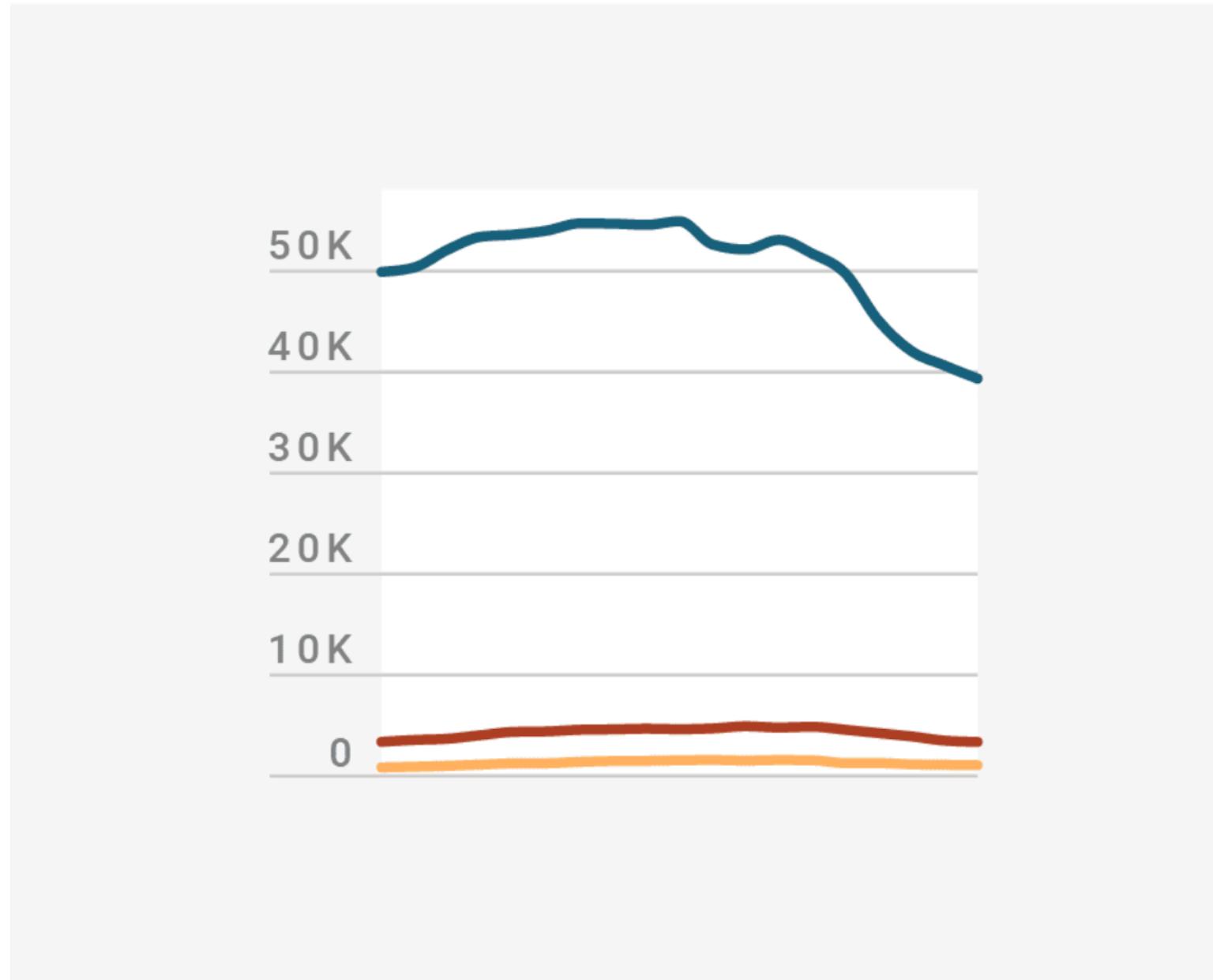
NOT IDEAL



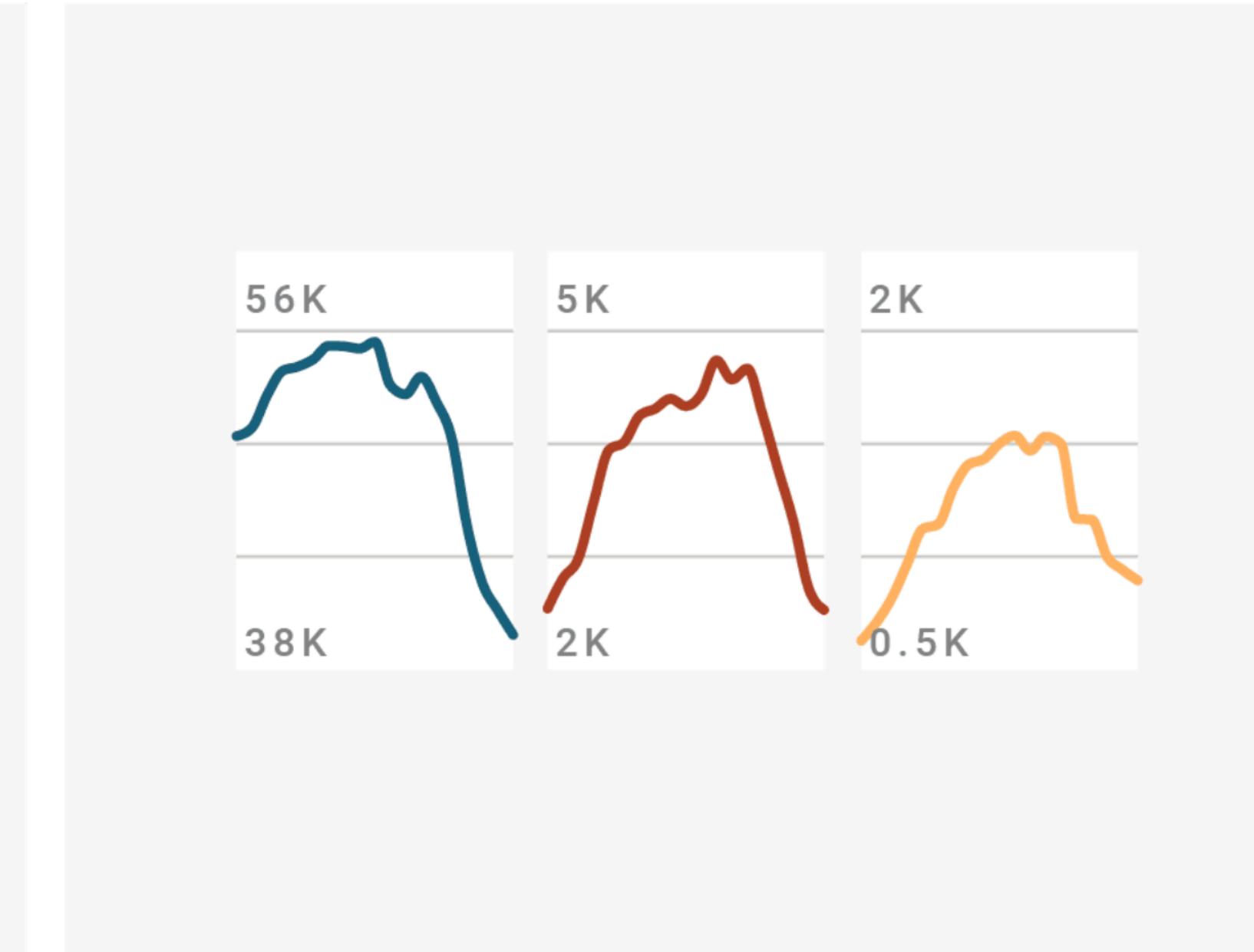
BETTER

Source: [Datawrapper](#)

Or simply separate your colors, if they matter



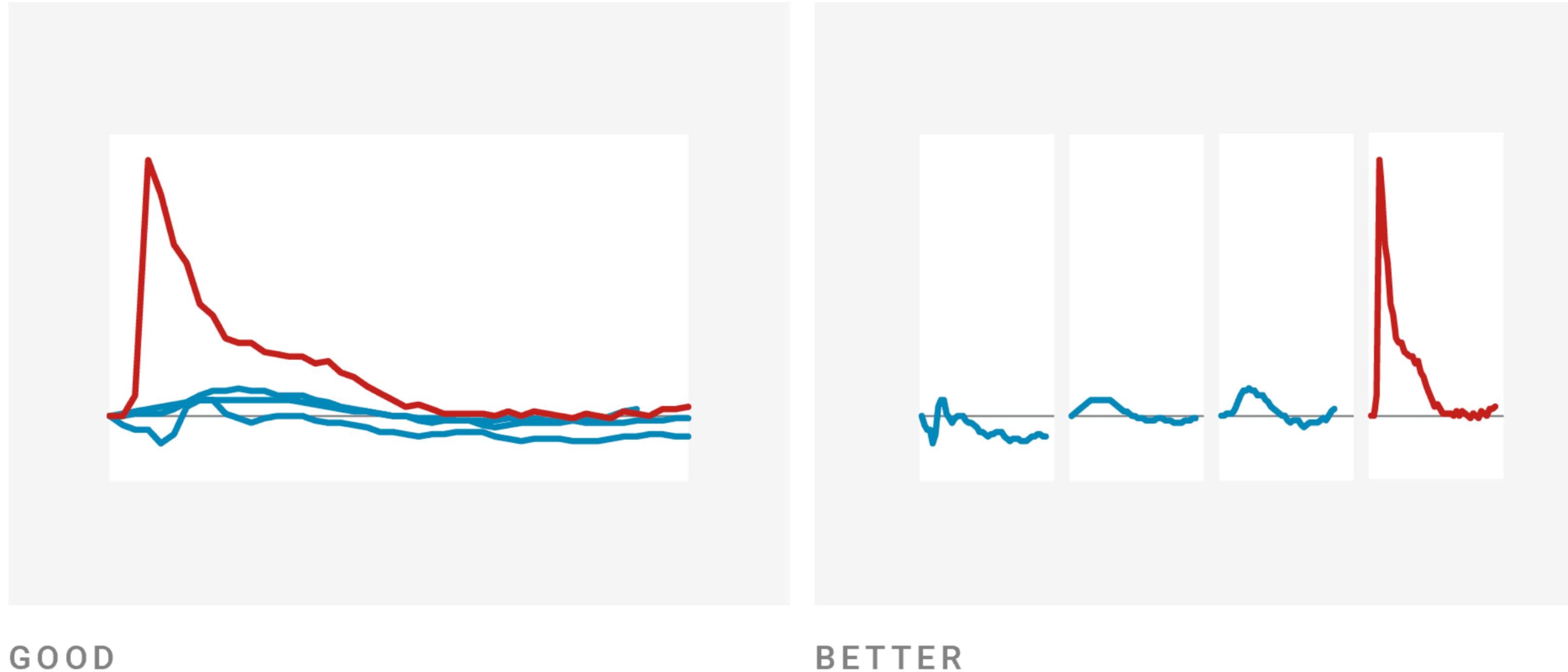
GOOD



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>

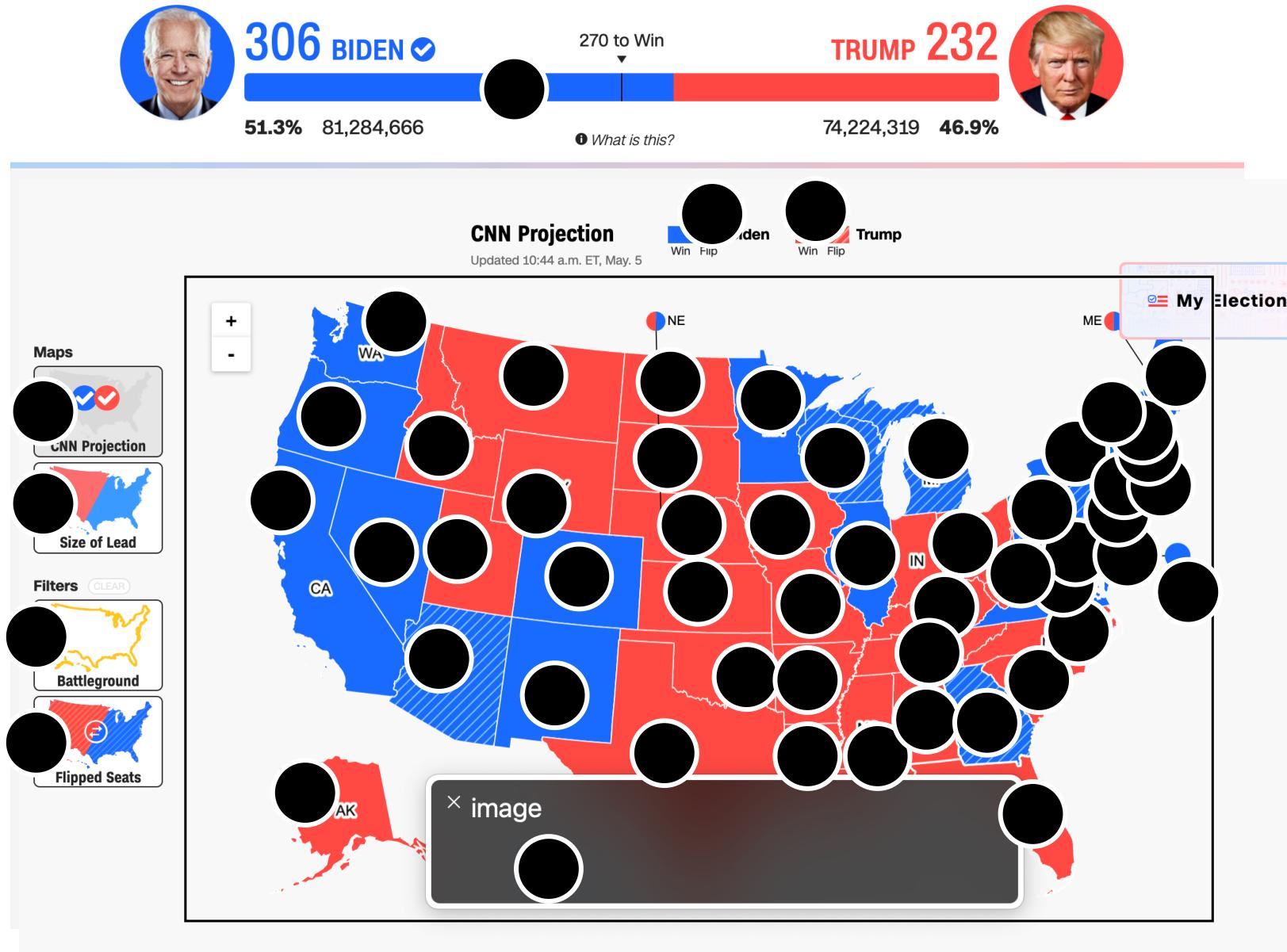
alt= "**Chart type** of **type of data**
where **reason for including chart**"

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

PRESIDENTIAL RESULTS

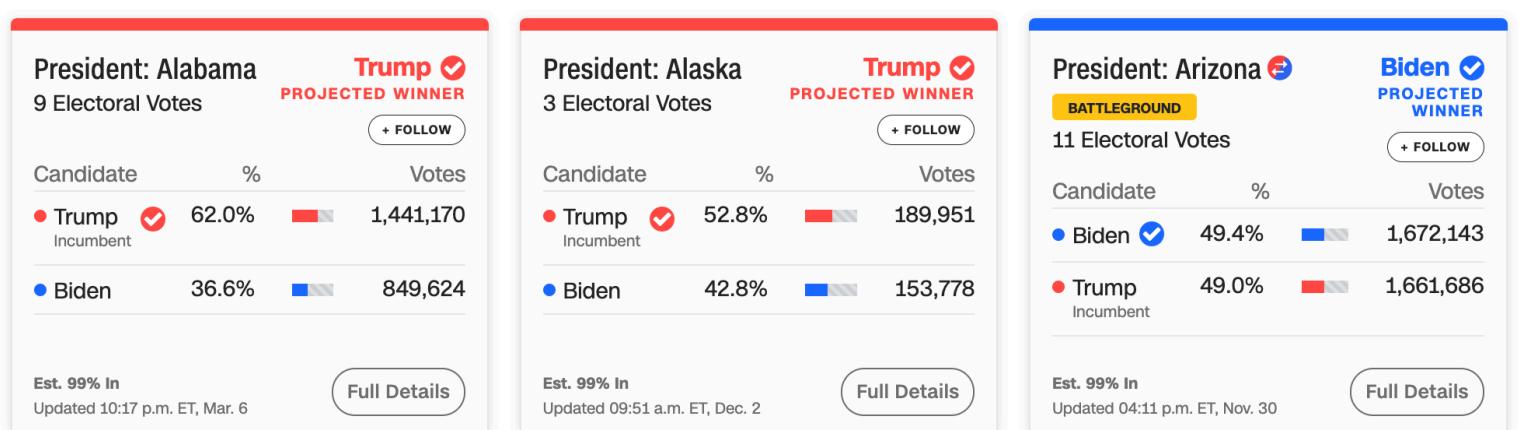
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57 instances of
“Content is only visual”

STATE RESULTS

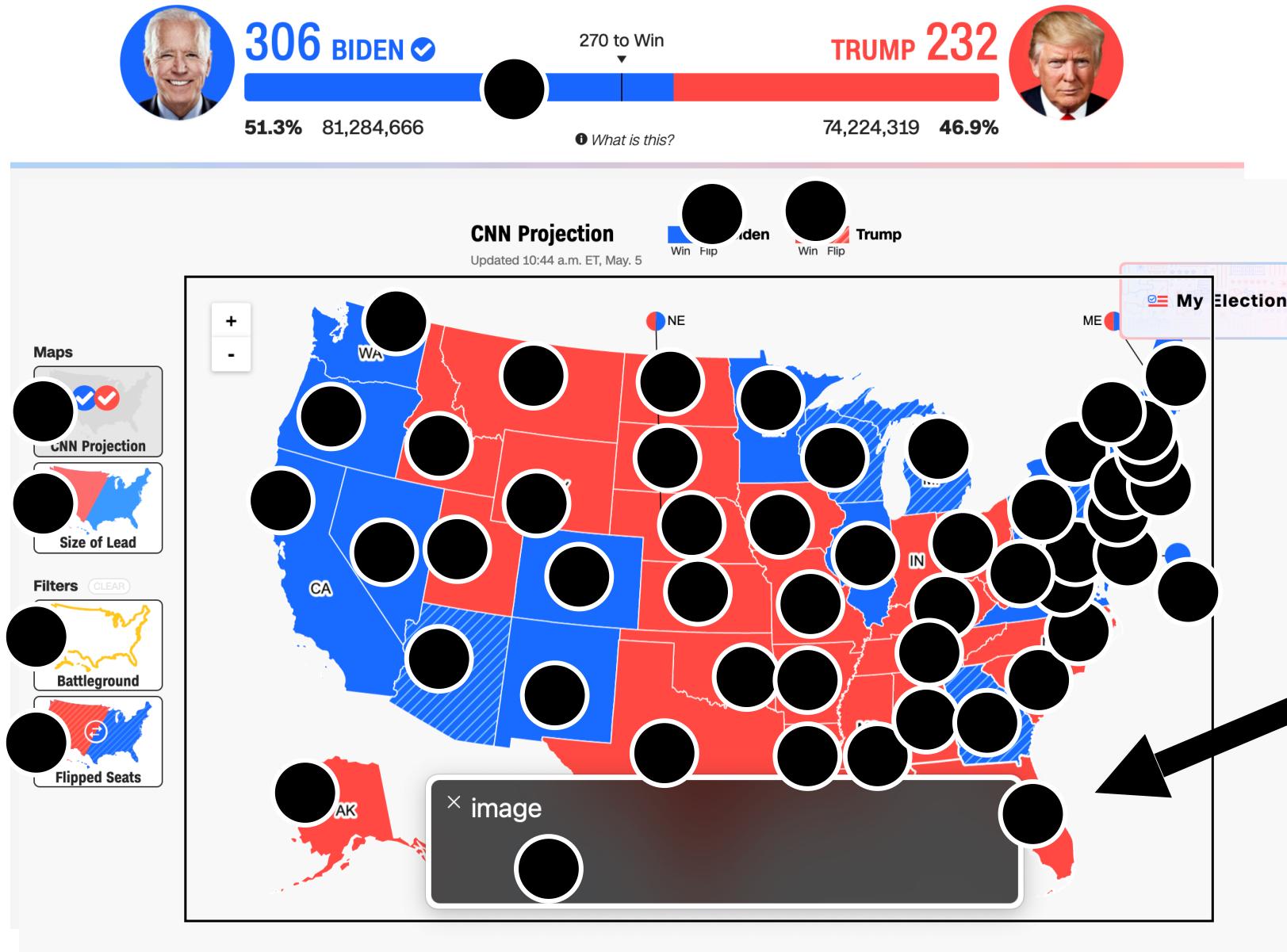


Show More States

PRESIDENTIAL RESULTS

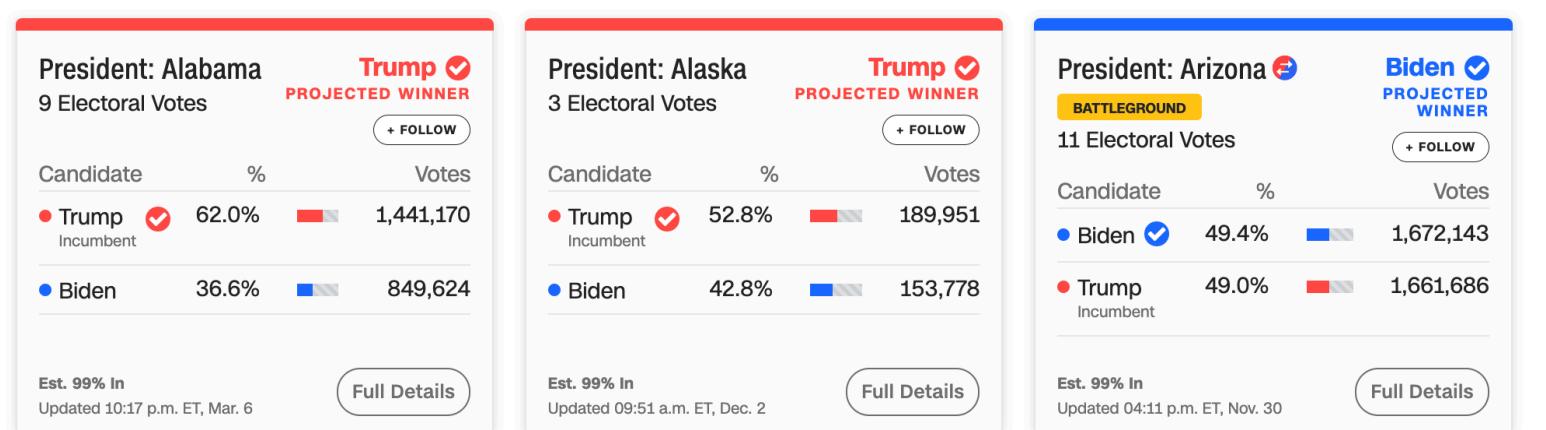
Joe Biden wins election to be the 46th US President

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.



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

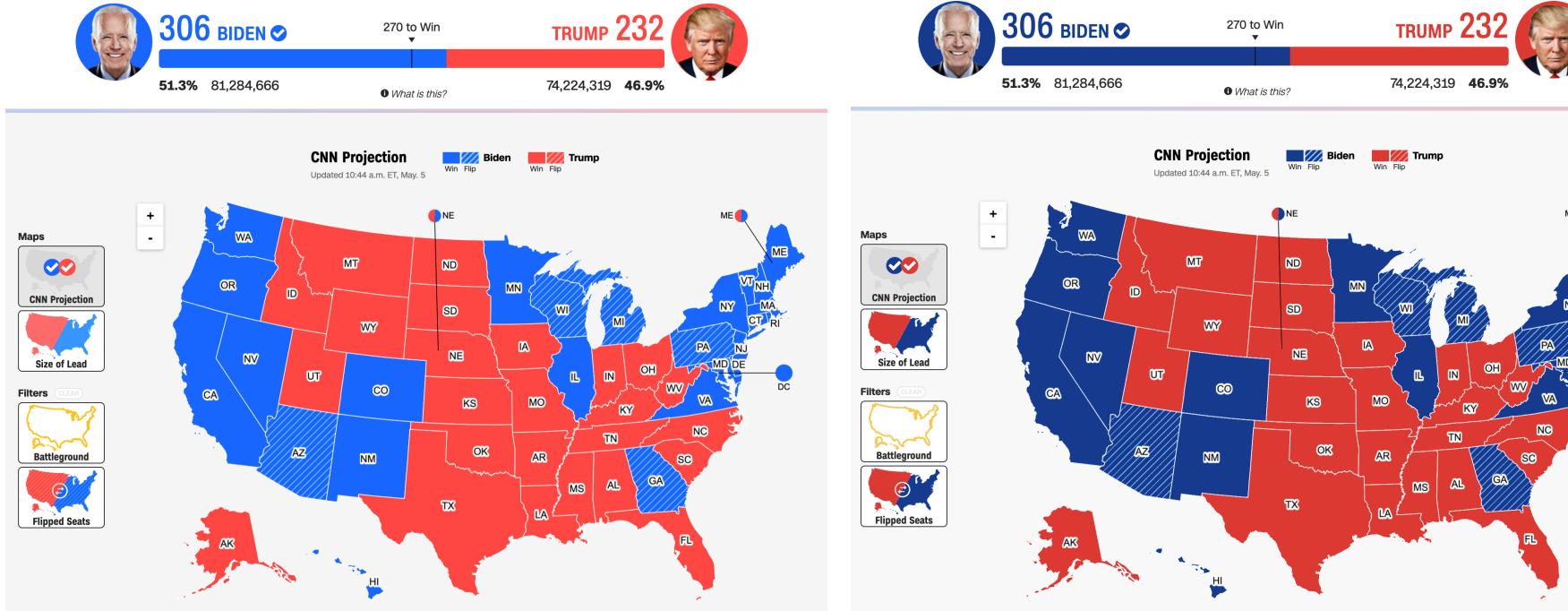
STATE RESULTS



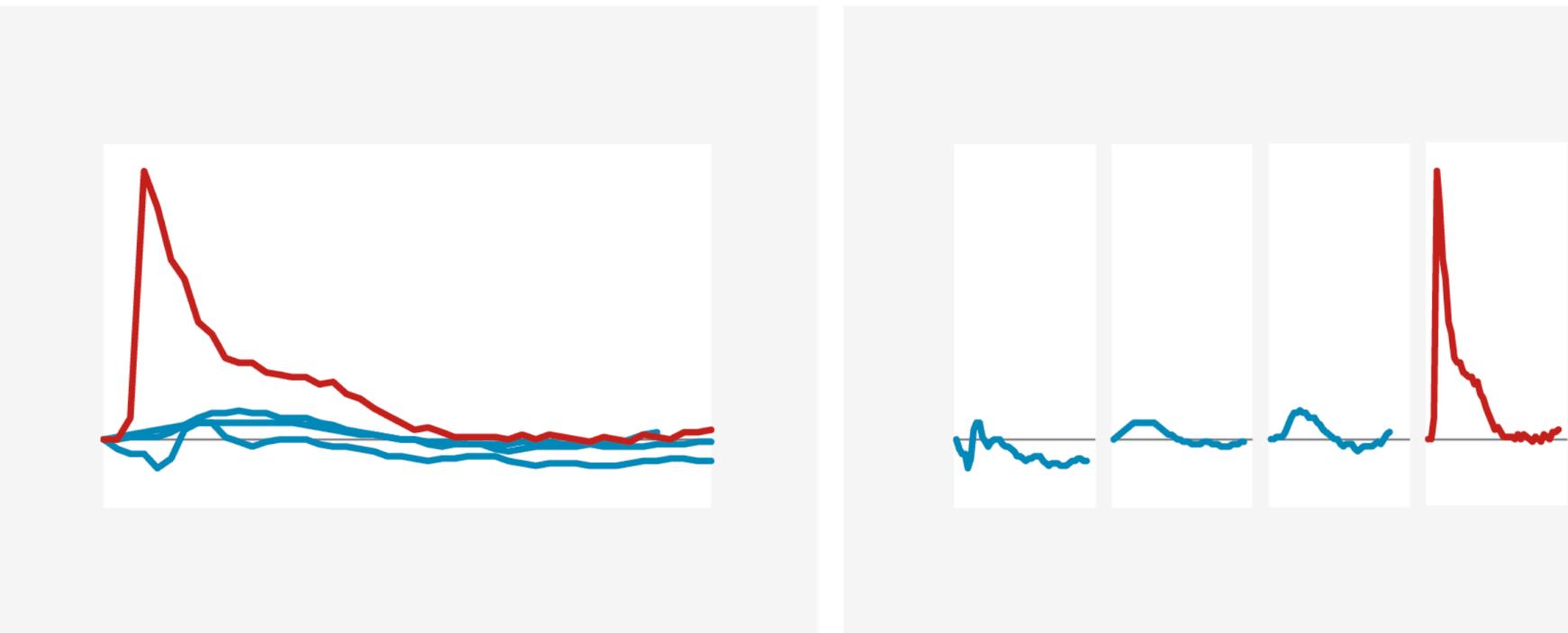
Show More States

Recap: Perceivability

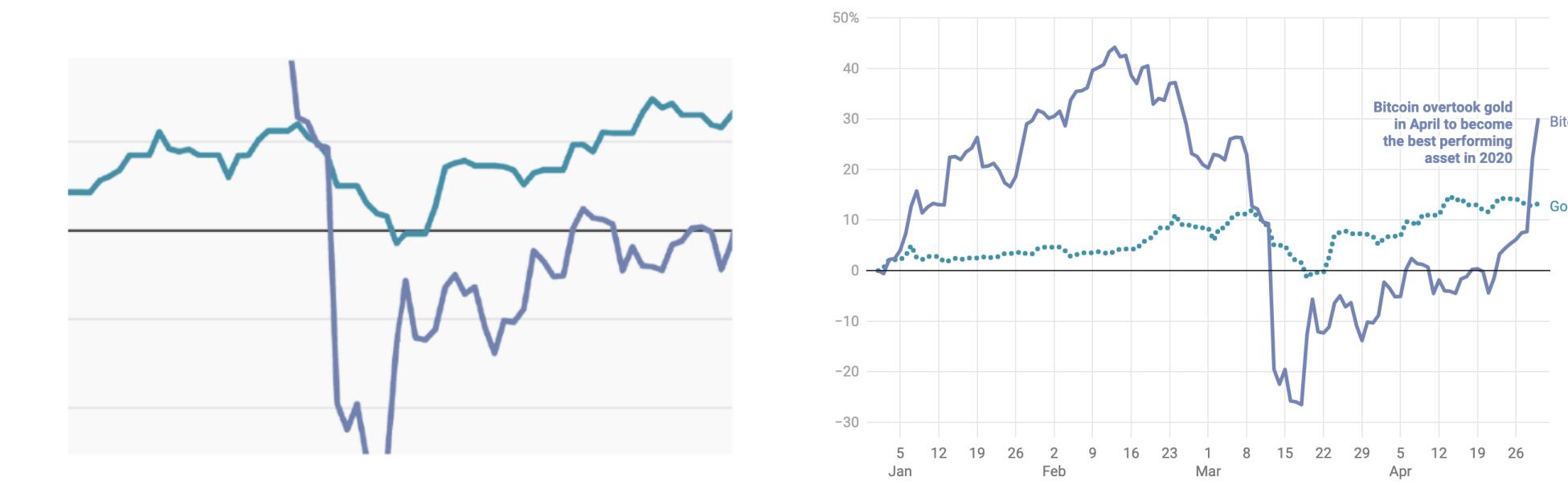
Use high contrast



Reduce colors and crowding



Use redundant encoding



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.

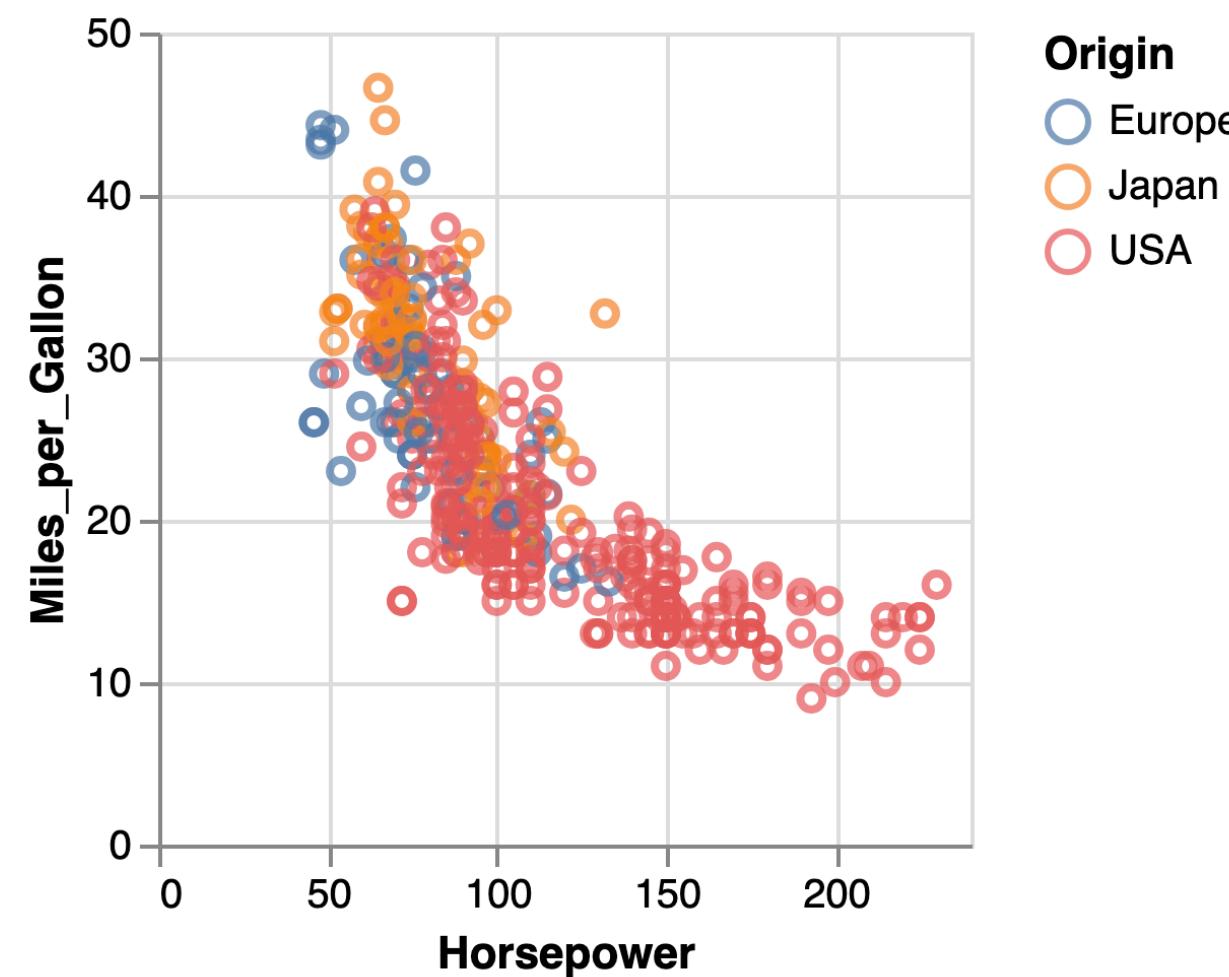
Image credit: [Wikipedia](#), Public Domain, 1960. Photographer: Possum Ltd.

Why “keyboard-only?”

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

Scatterplot with External Links and Tooltips

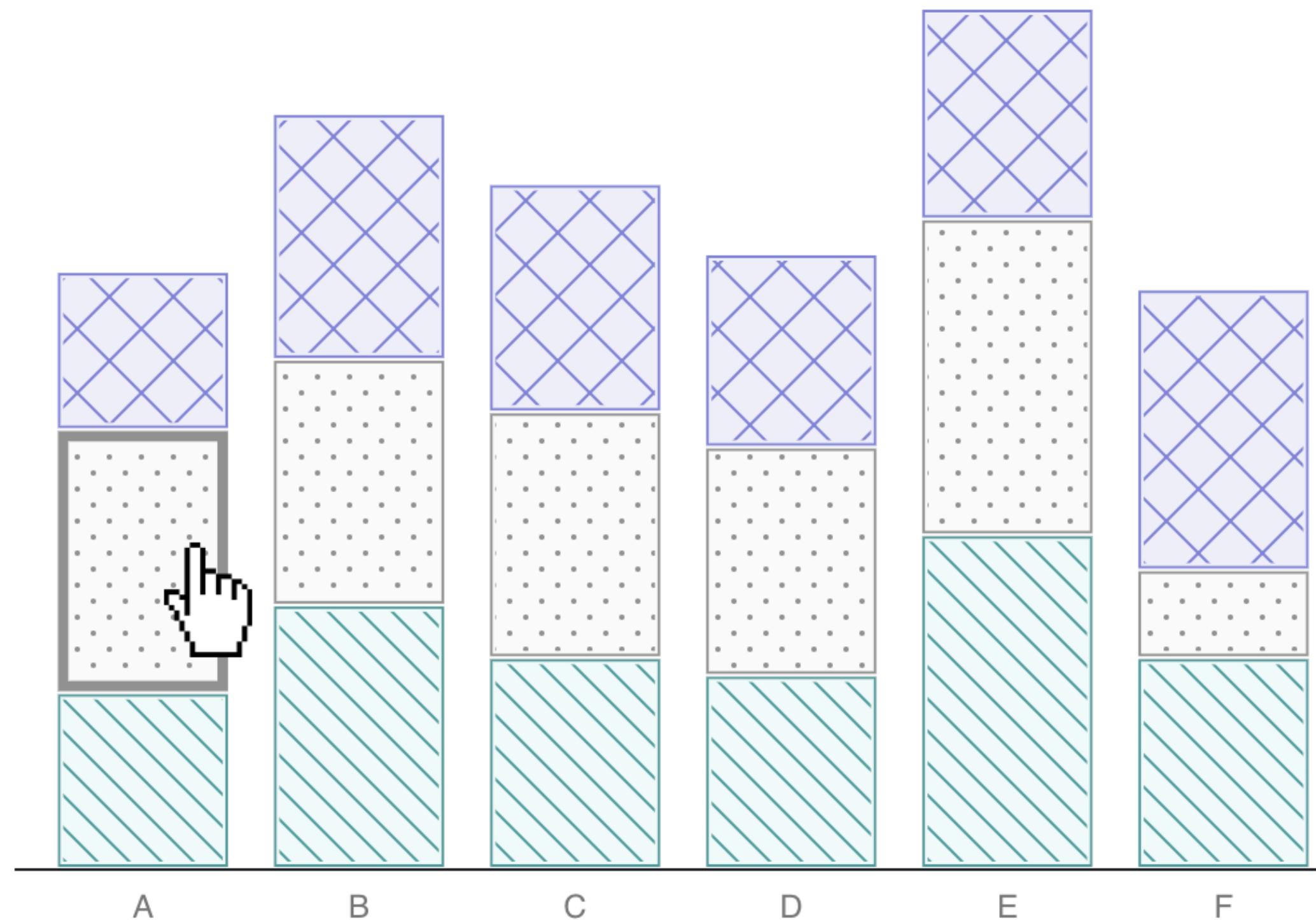
A scatterplot showing horsepower and miles per gallons that opens a Google search for the car that you click on.



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

Ensure Keyboard Access (if interactive)

1 2 3



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
-----------	-----

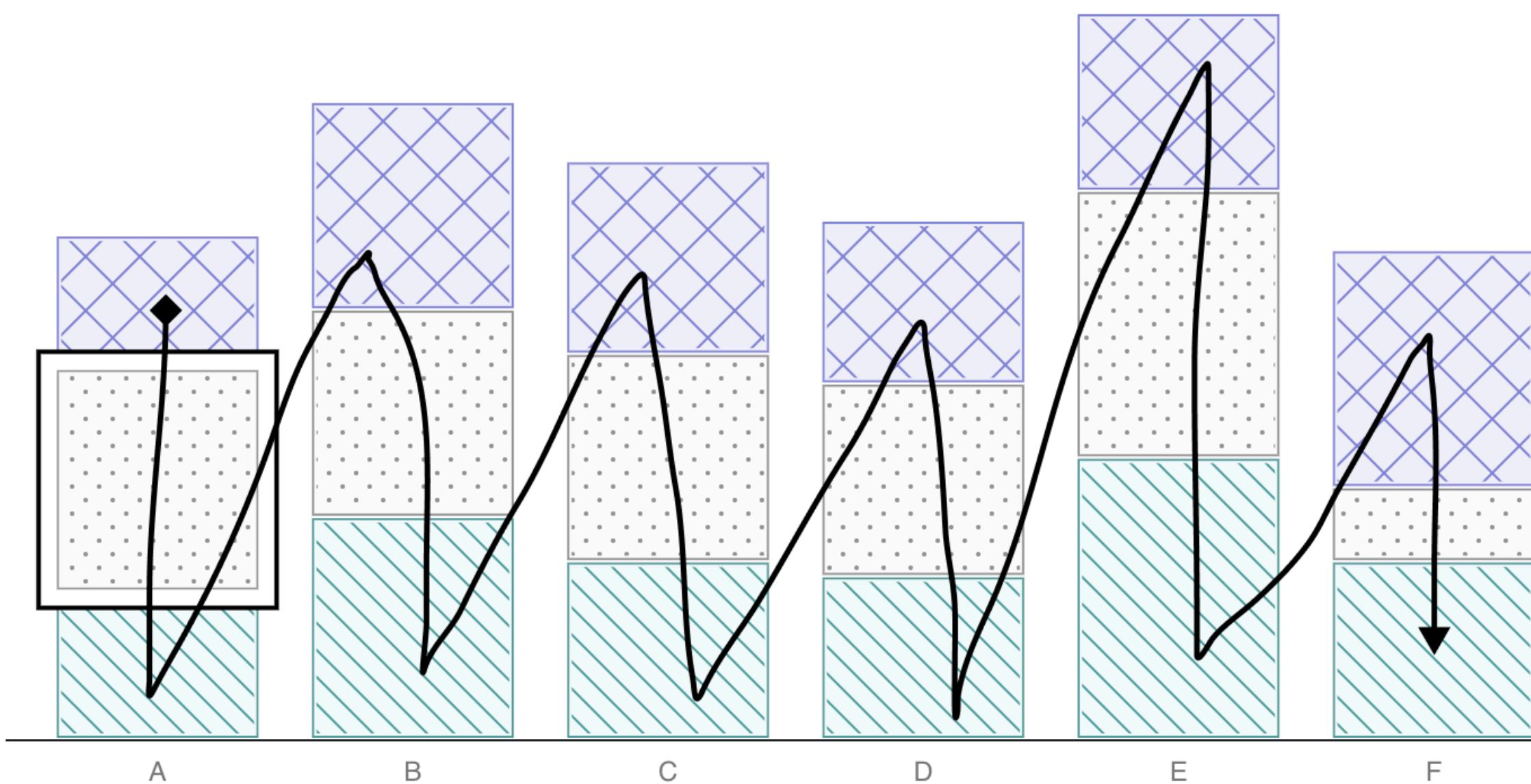
Product C	88
-----------	----

Product M	69
-----------	----

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

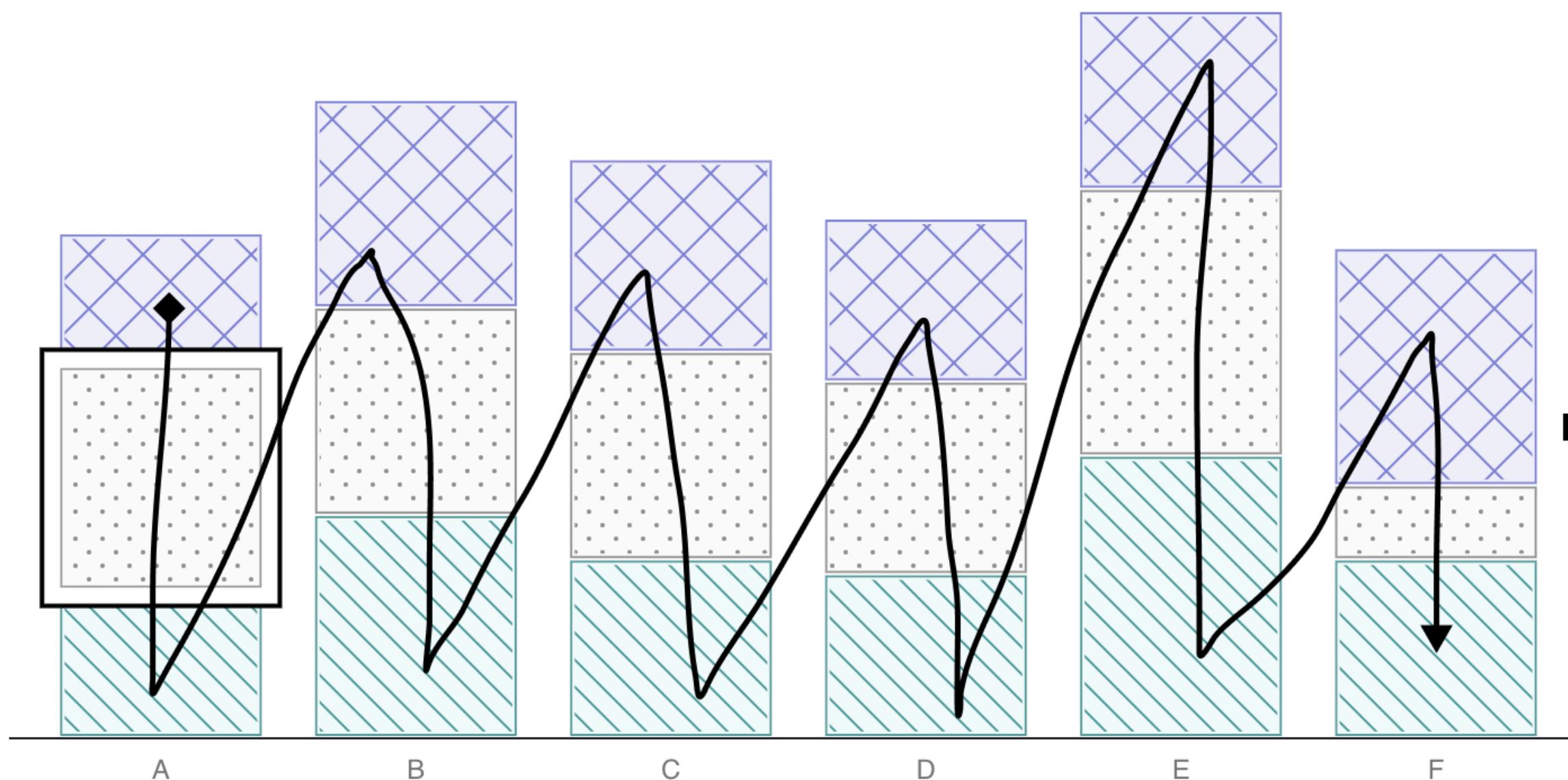
How does someone move around? By default, it is as elements are rendered:

1 2 3

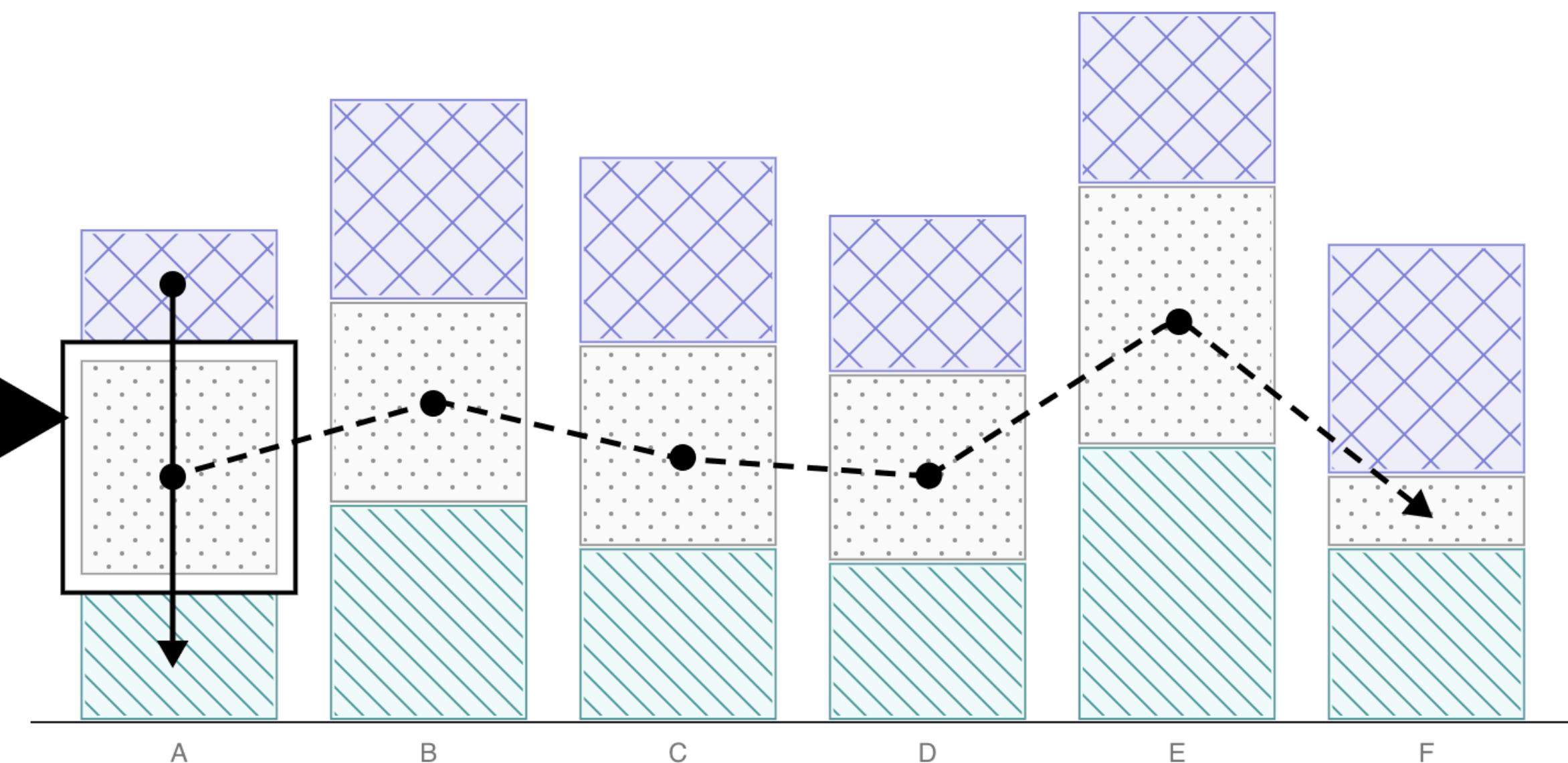


Consider more flexible movement when data exploration matters

1 2 3

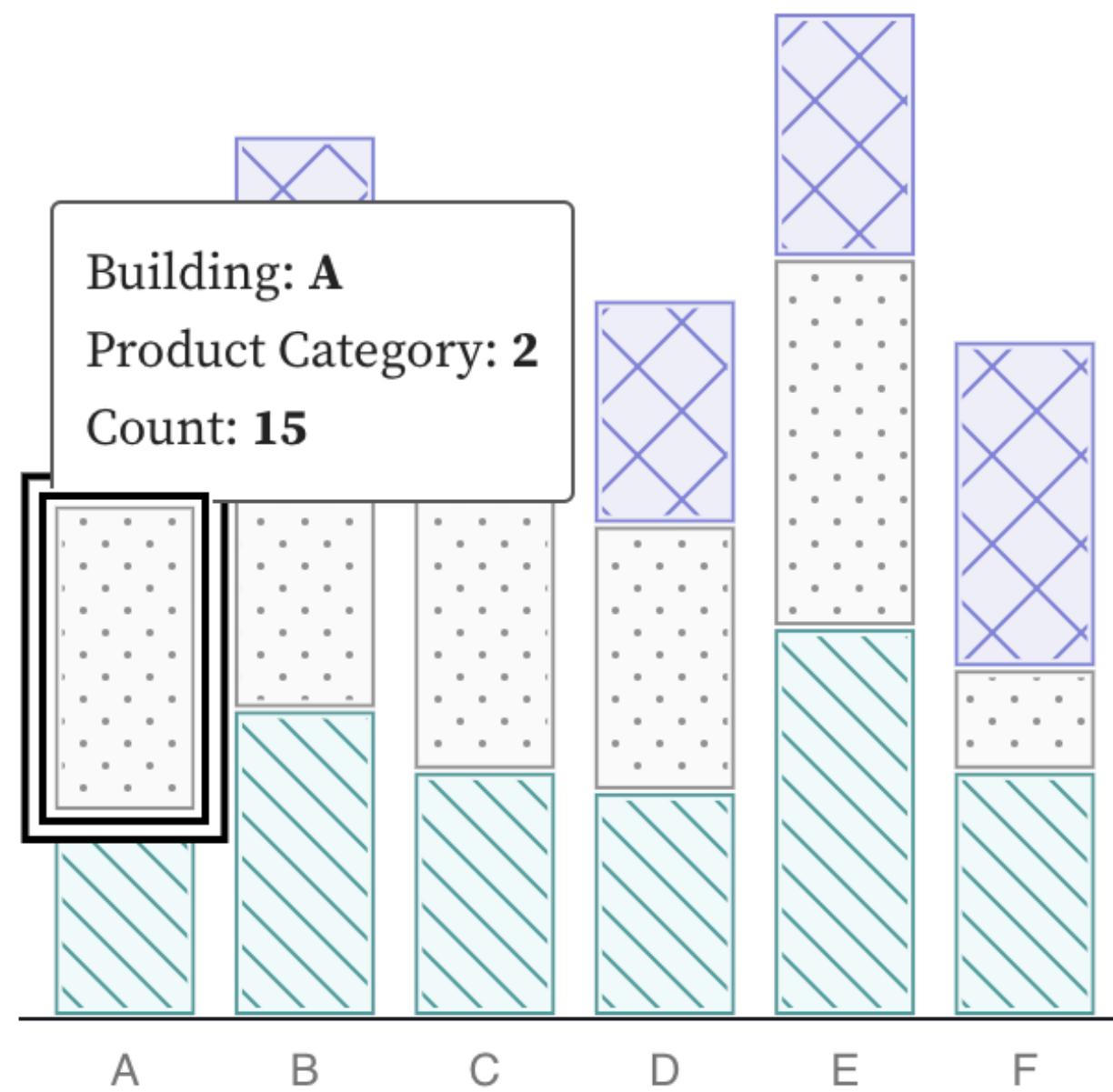


1 2 3



Alt text should communicate operability

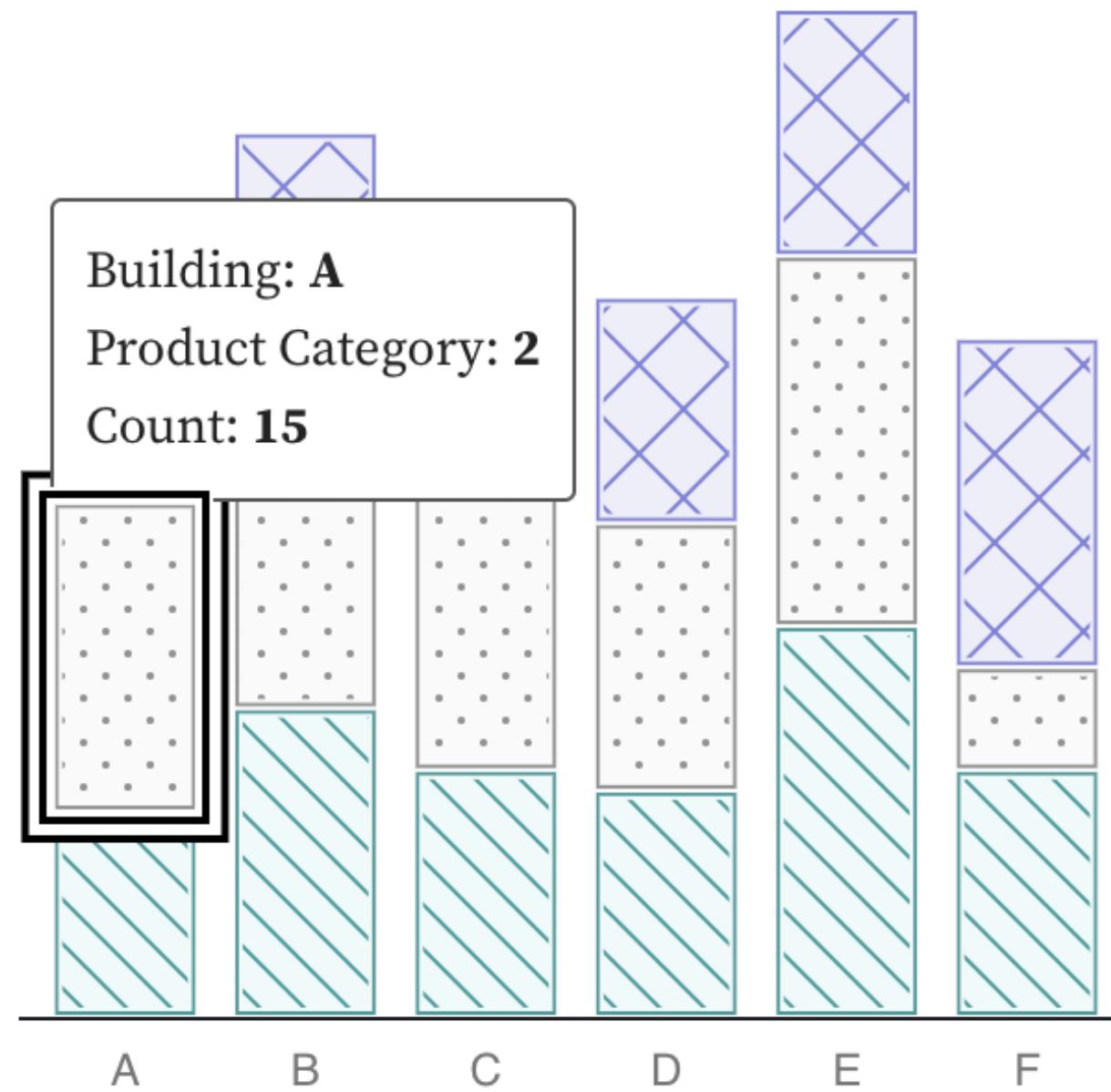
1 2 3



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

Semantics matter

1 2 3

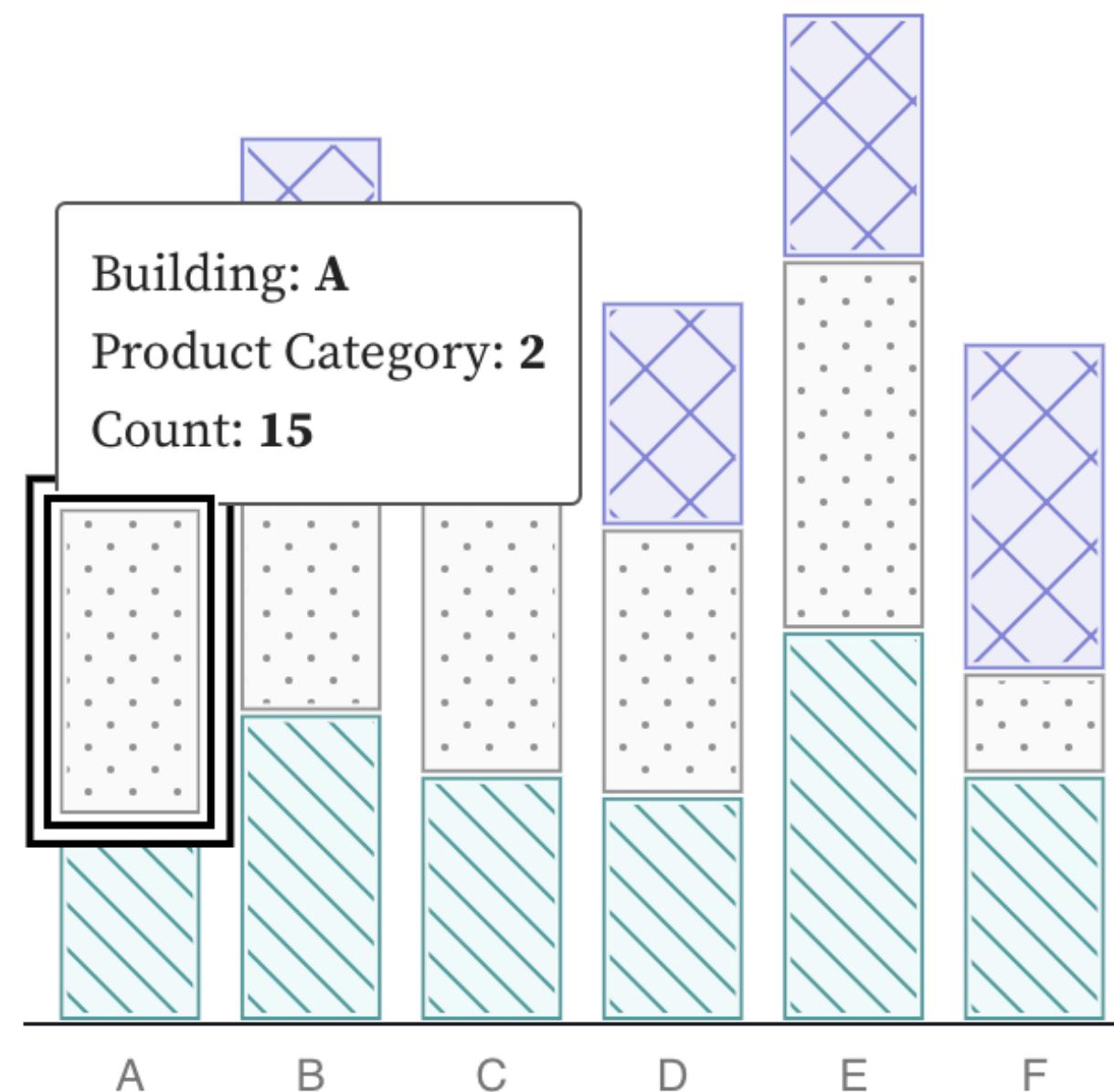


“Image” doesn’t signal interactivity!

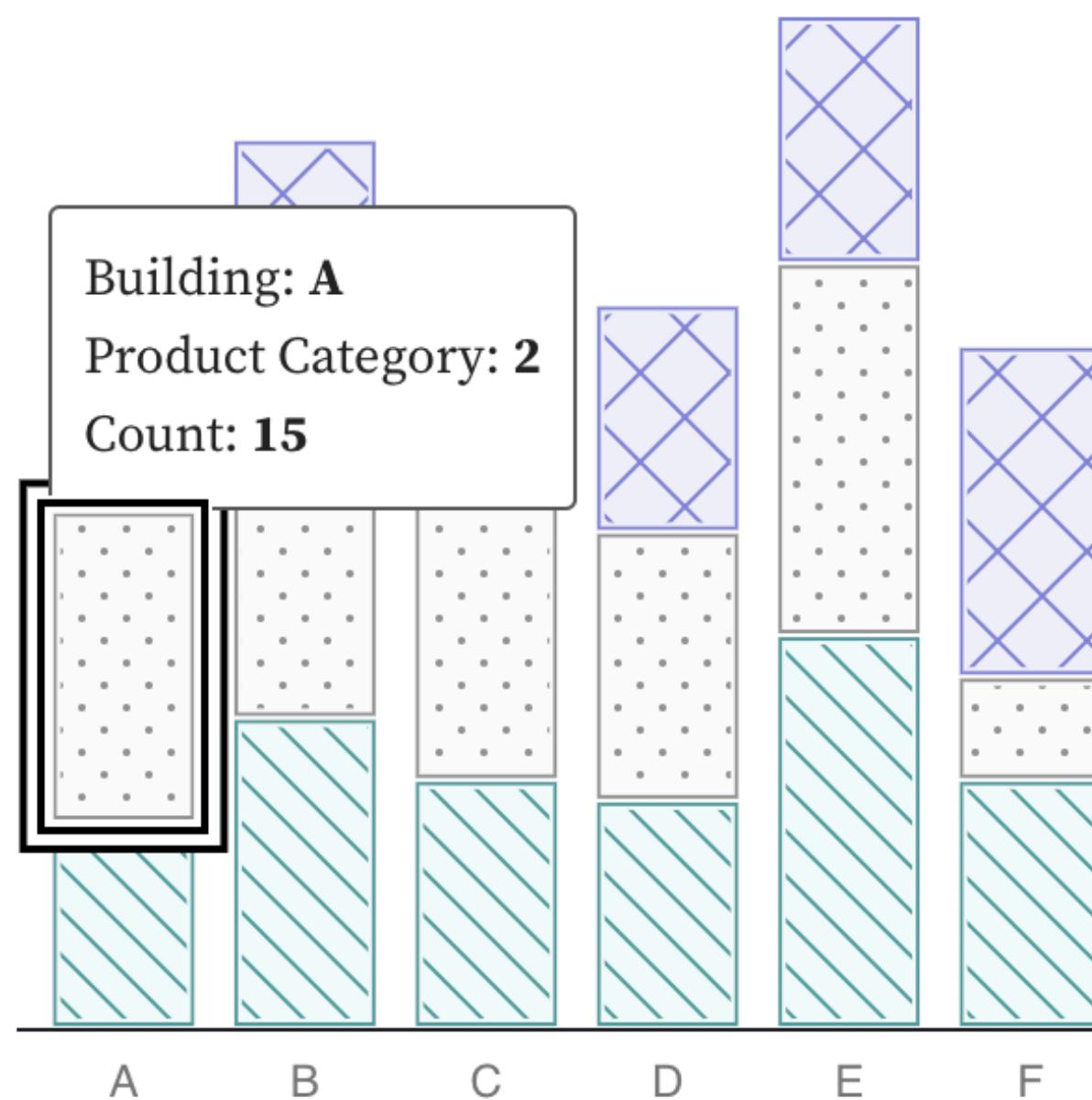
✗ Building A. Product Category 2.
Count 15. Bar 2 of 3. Image.

“Aria” states and roles are standardized

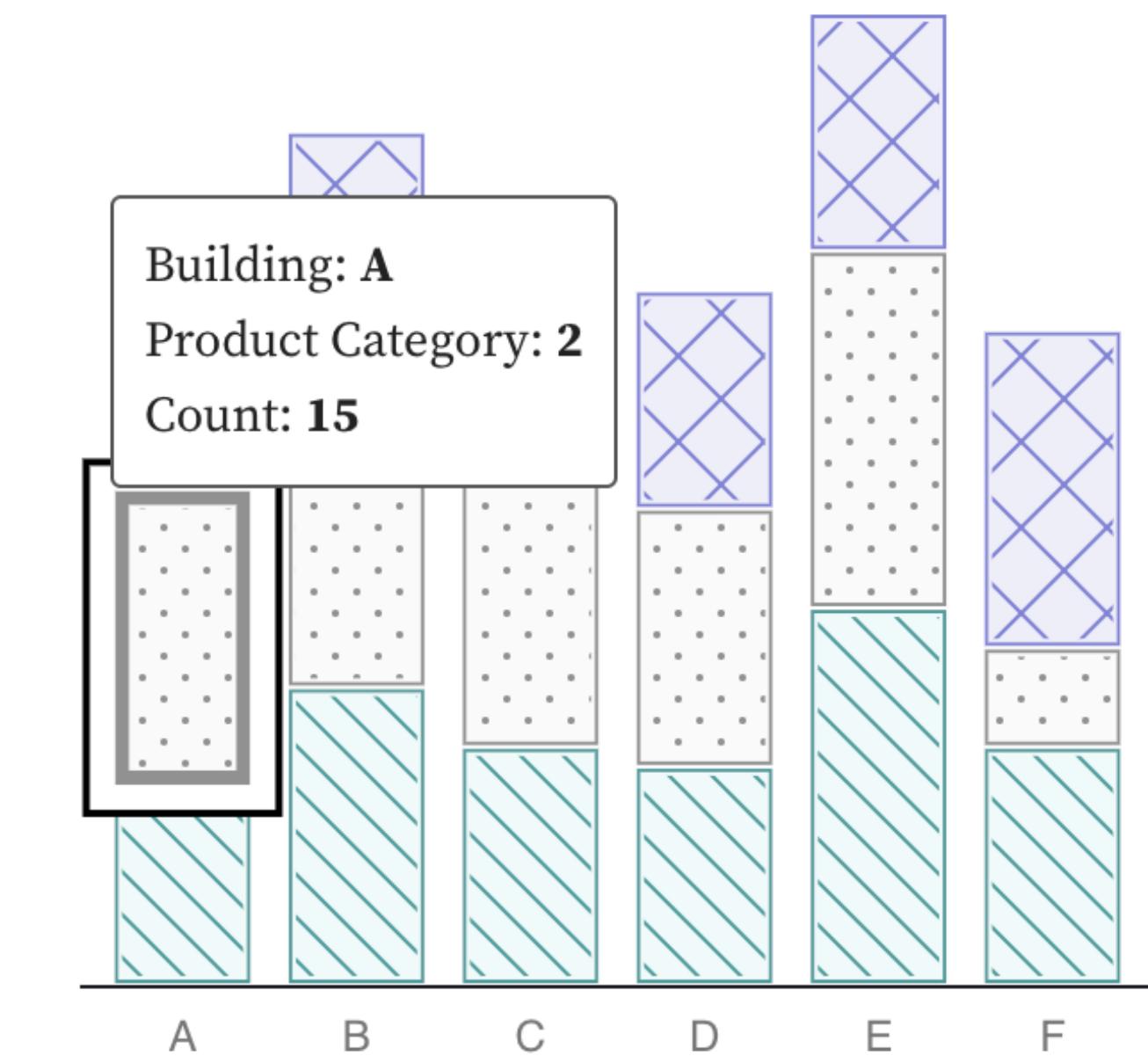
1 2 3



1 2 3



1 2 3



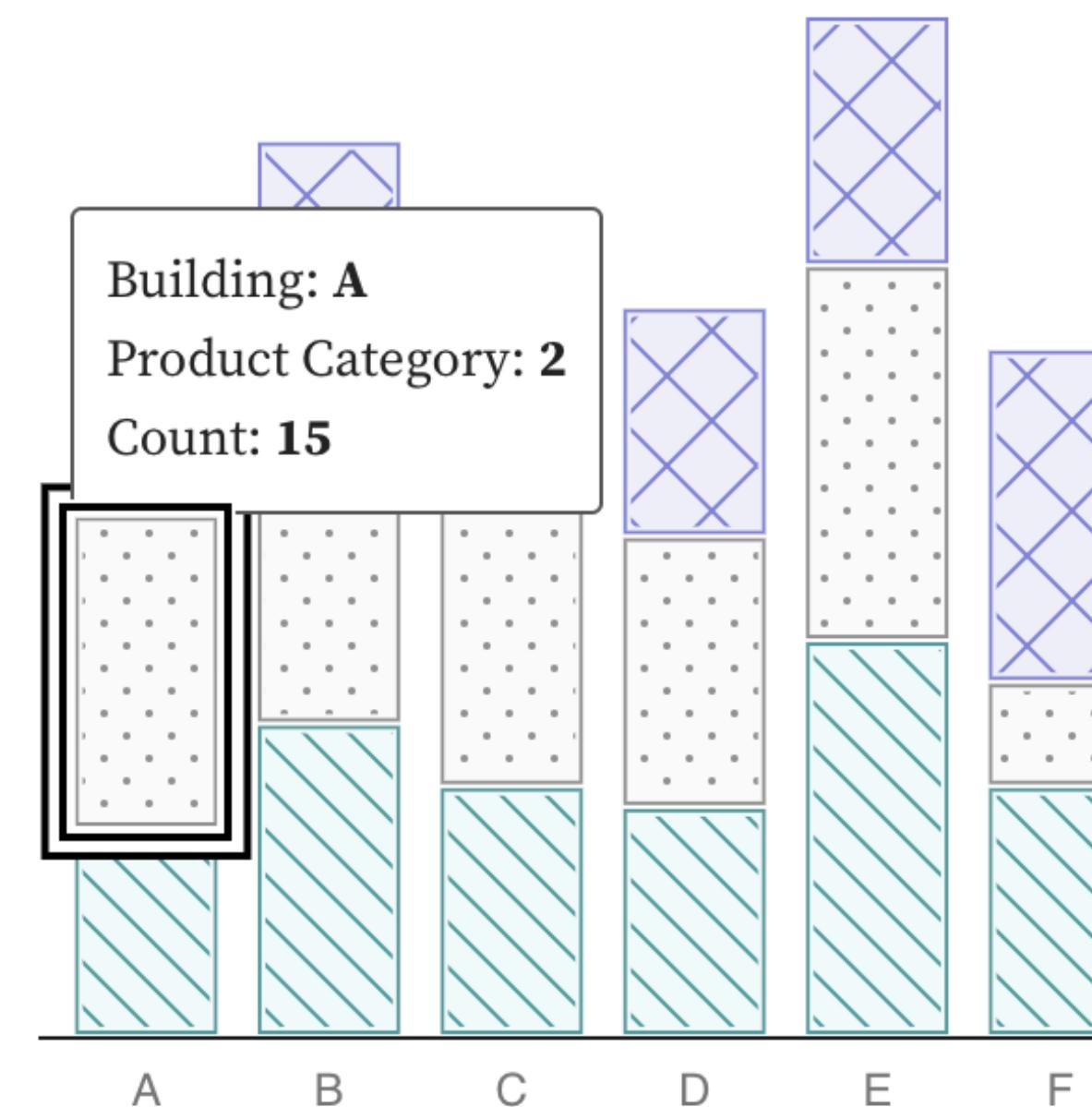
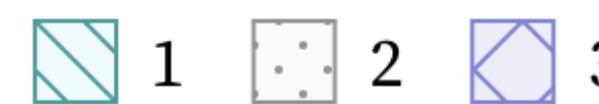
× Building A. Product Category 2.
Count 15. Bar 2 of 3. Image.

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

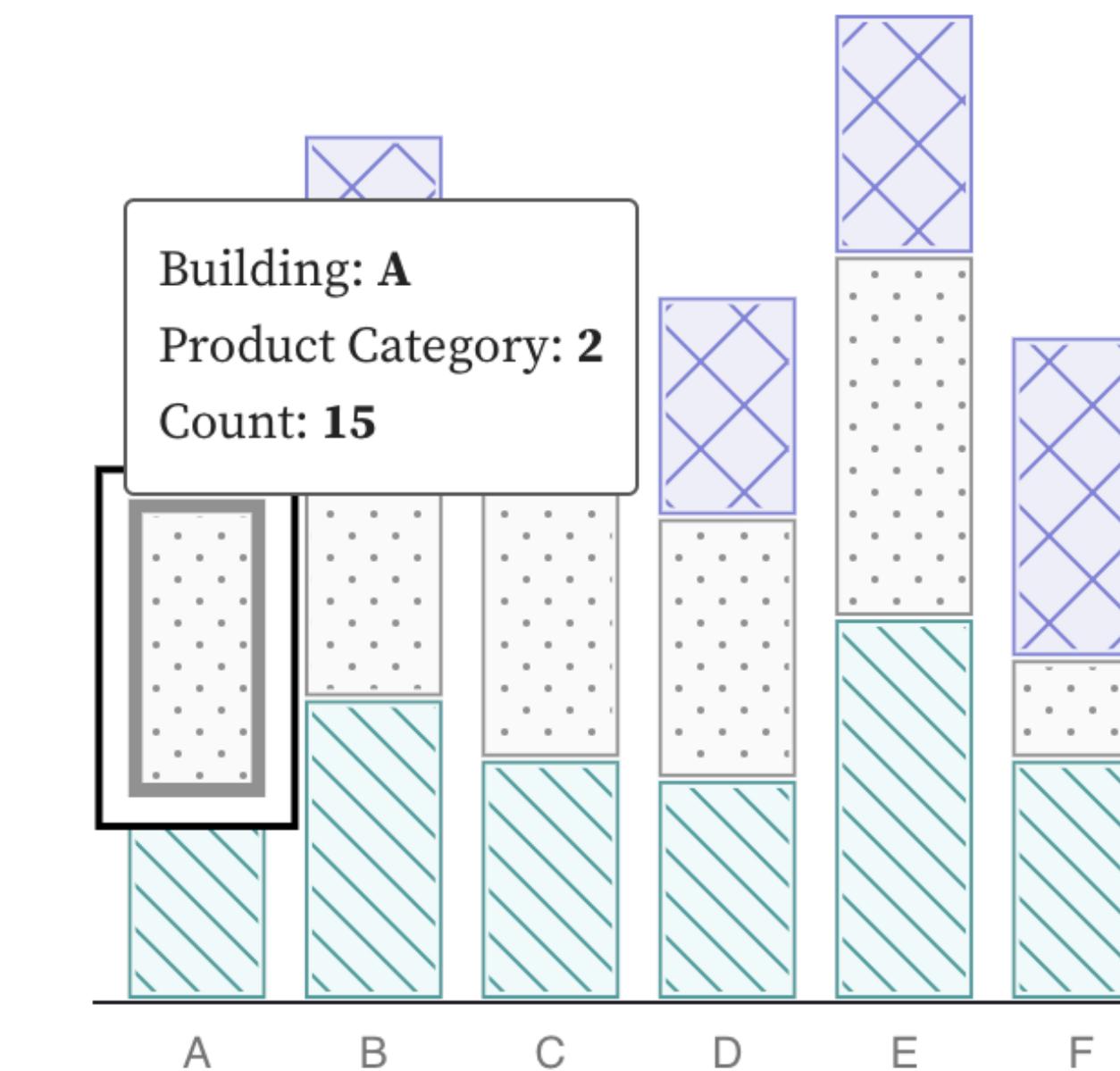
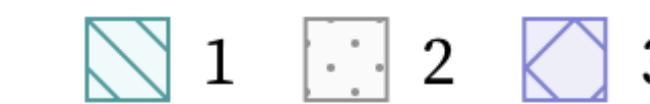
× selected, Building A. Product
Category 2. Count 15. Bar 2 of
3., toggle button

Communicating operability should be visual too

Hovered/focused

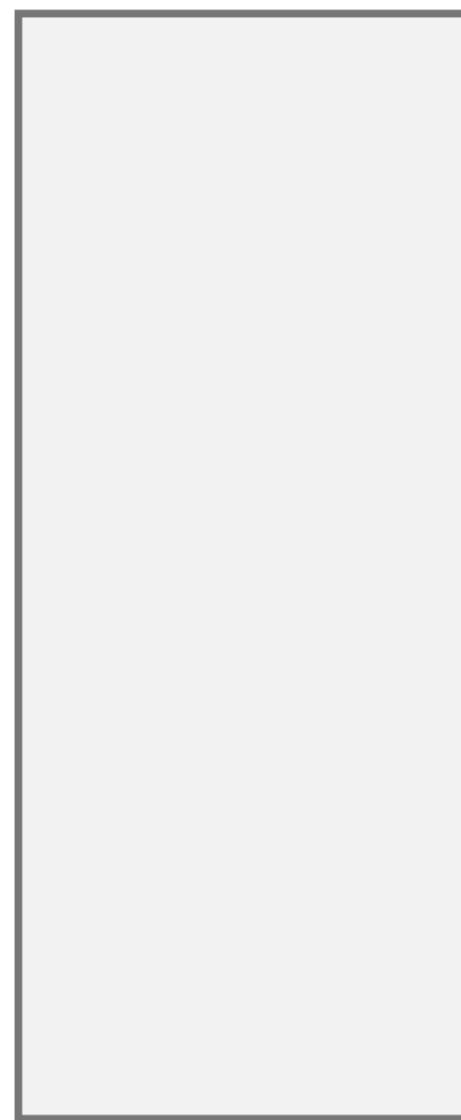


Selected



Design your own interaction styling

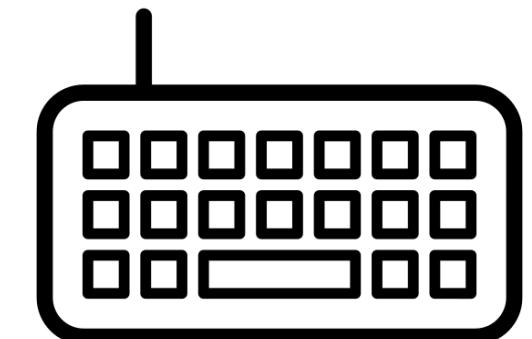
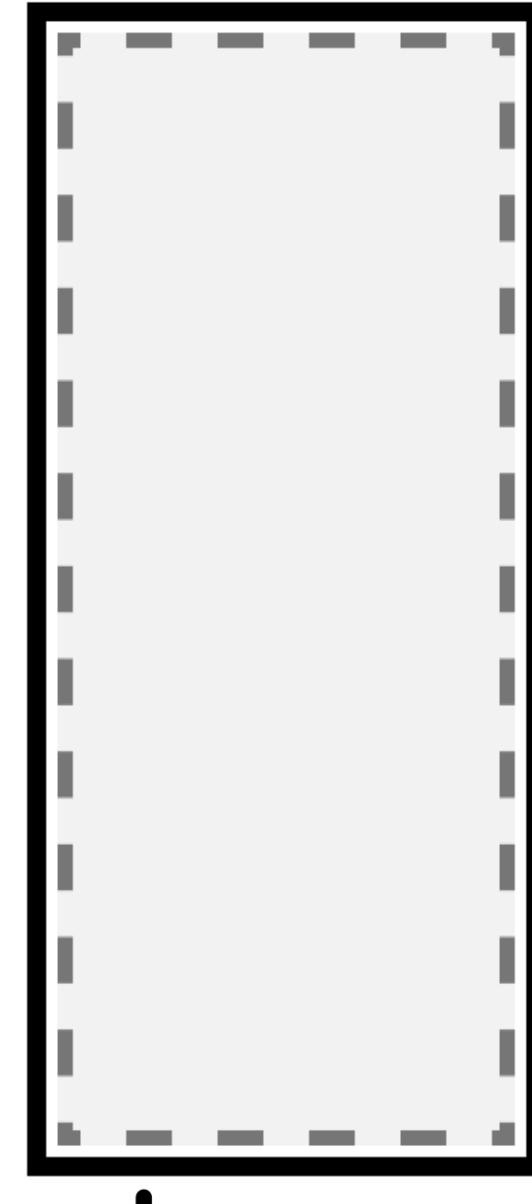
Default



Hovered



Focused



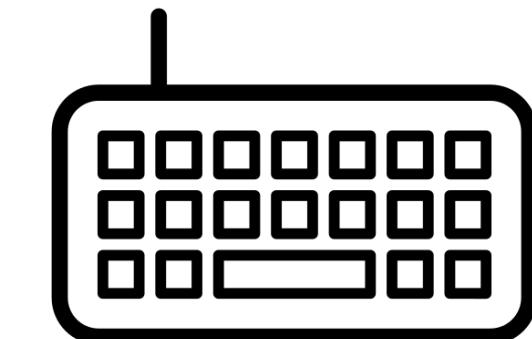
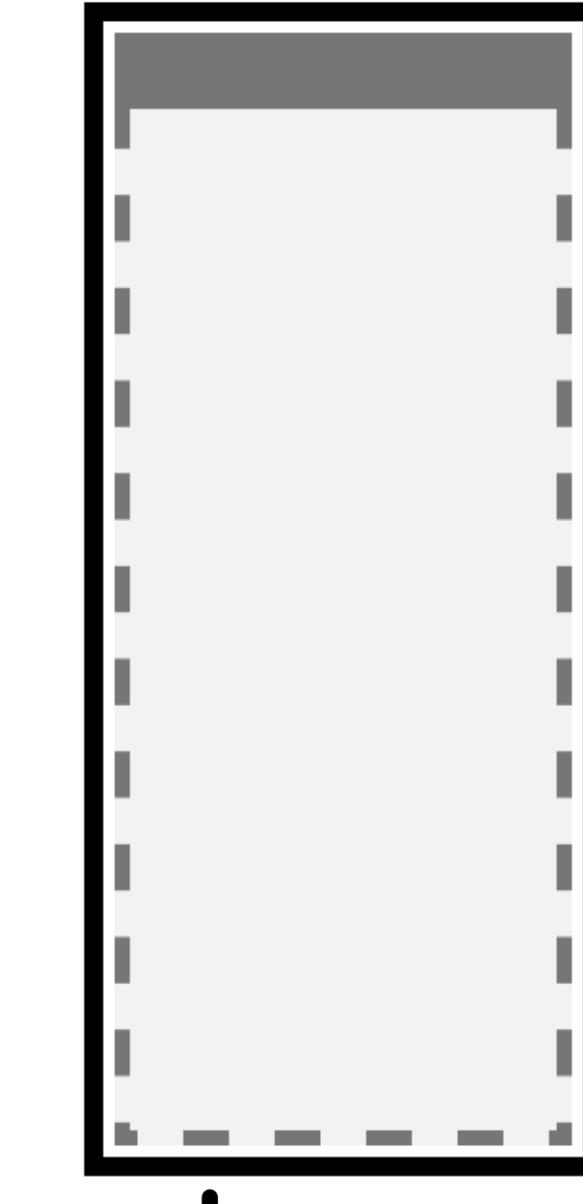
Selected



Hovered + Selected



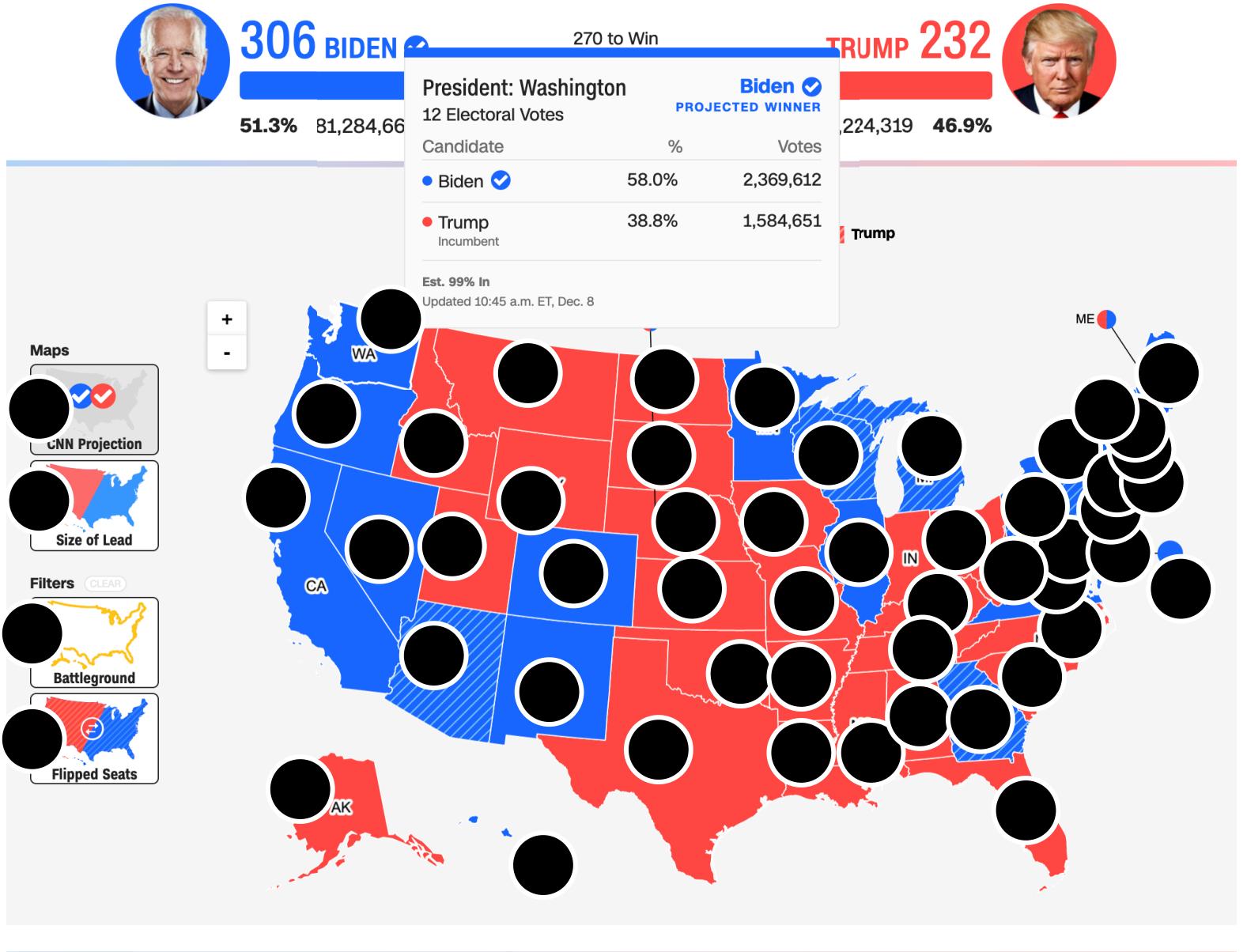
Focused + Selected



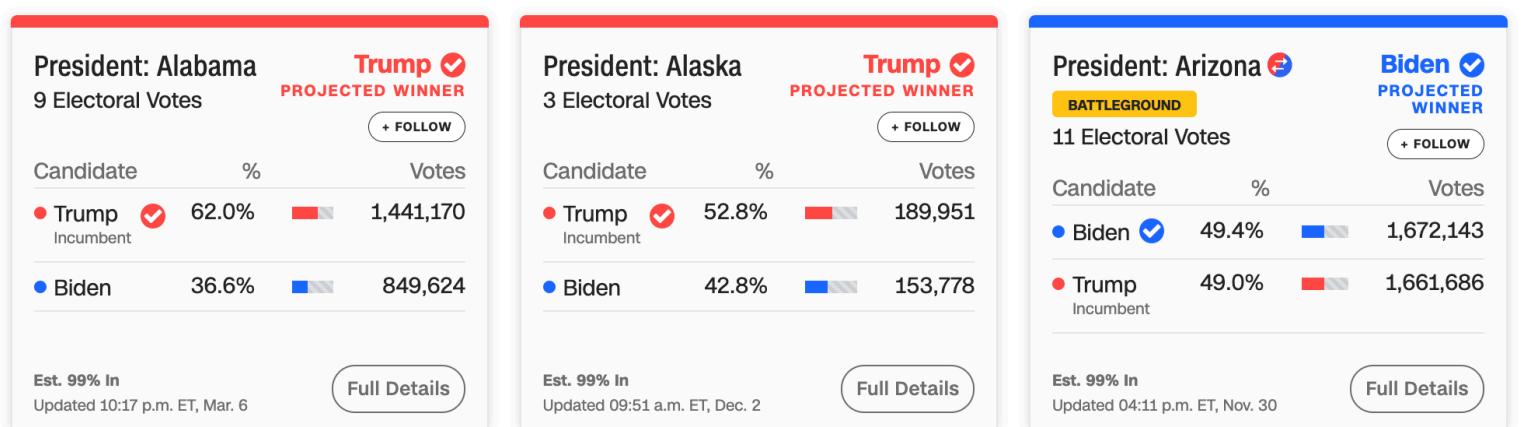
PRESIDENTIAL RESULTS

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.



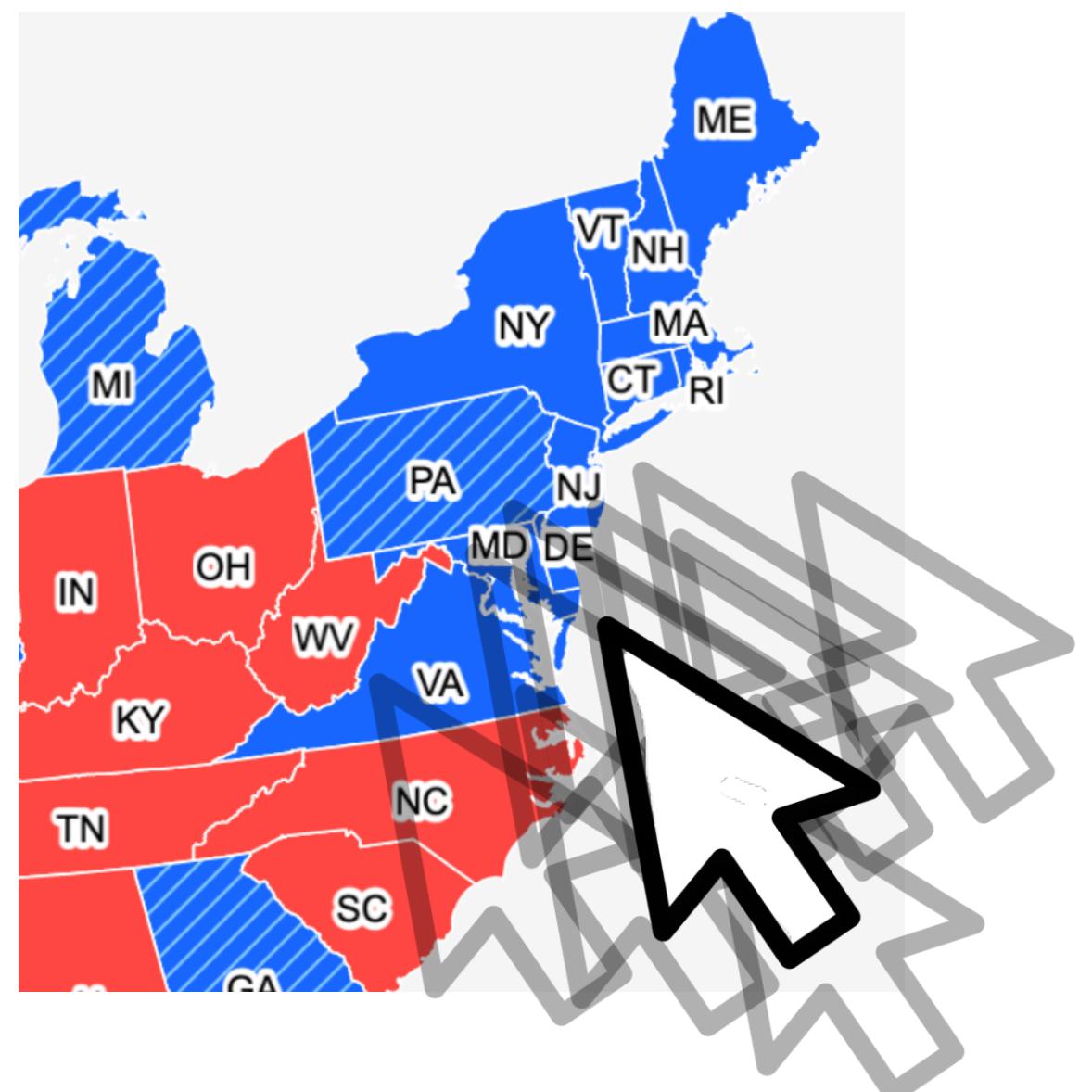
STATE RESULTS



Show More States

54 instances of “only
one input type”

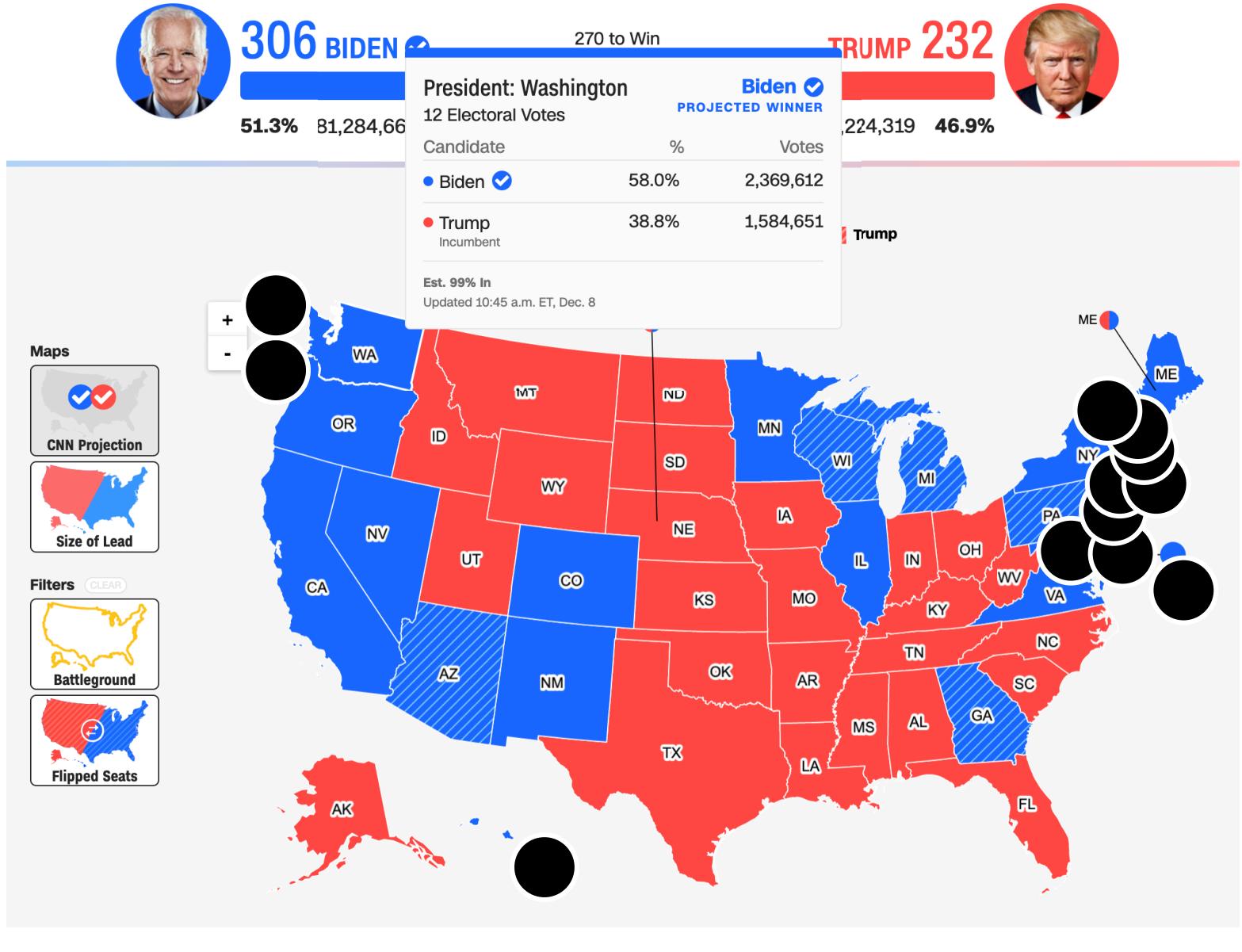
**Expecting users to hover on
something tiny is an accessibility
design failure**



PRESIDENTIAL RESULTS

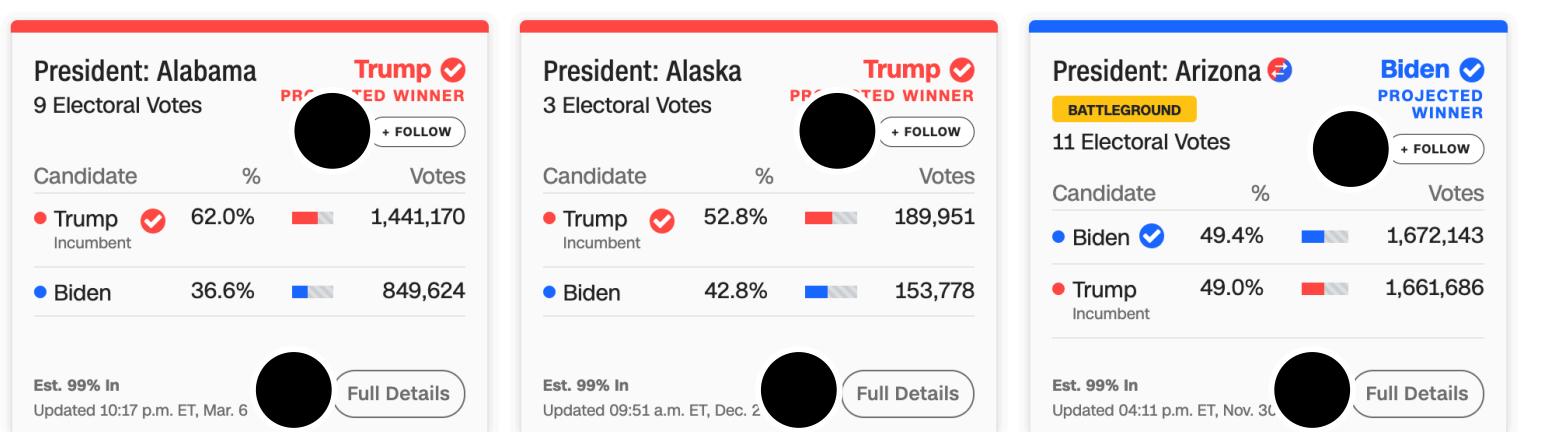
Joe Biden wins election to be the 46th US President

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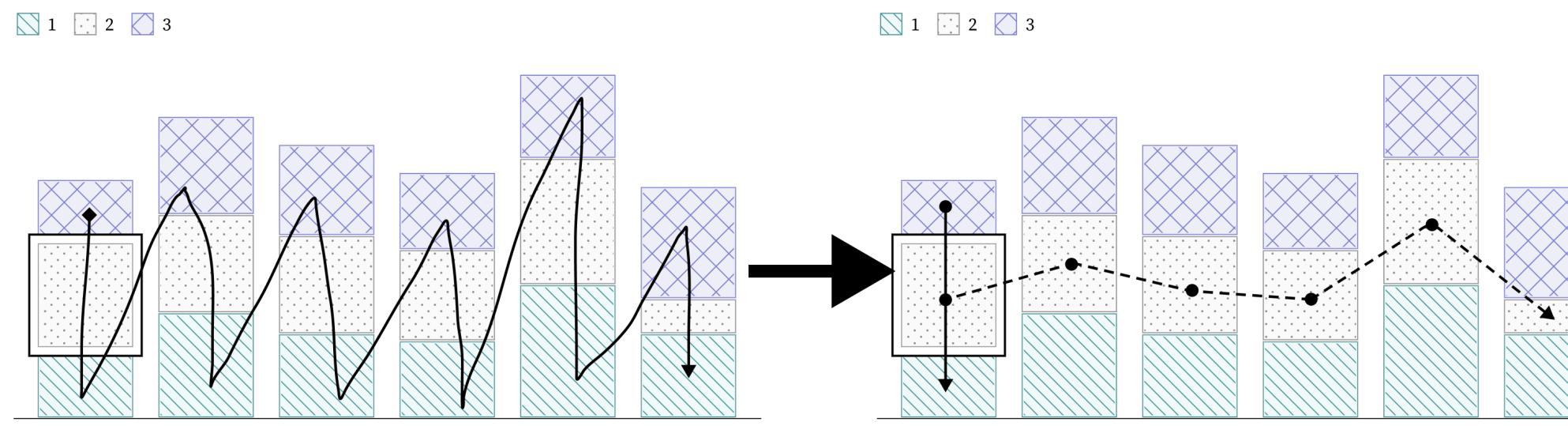
18 instances of
“target pointer size
is too small”

STATE RESULTS

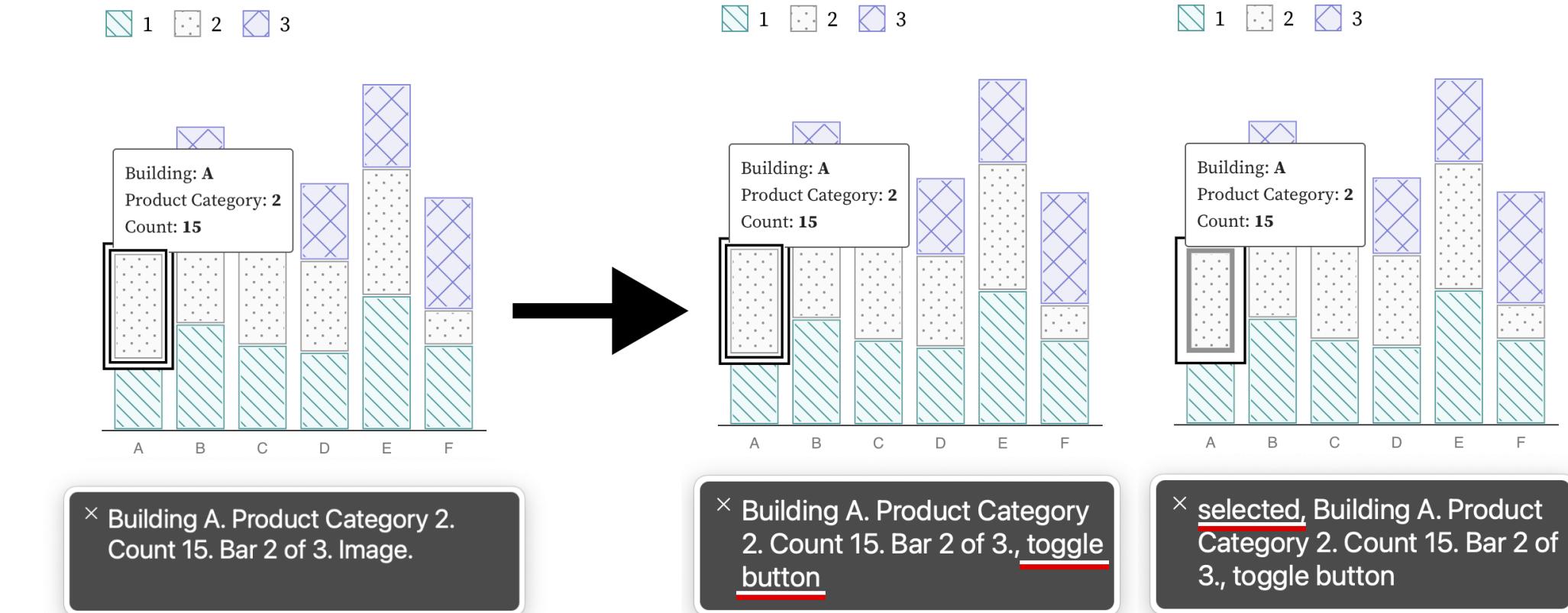


Recap: Operability

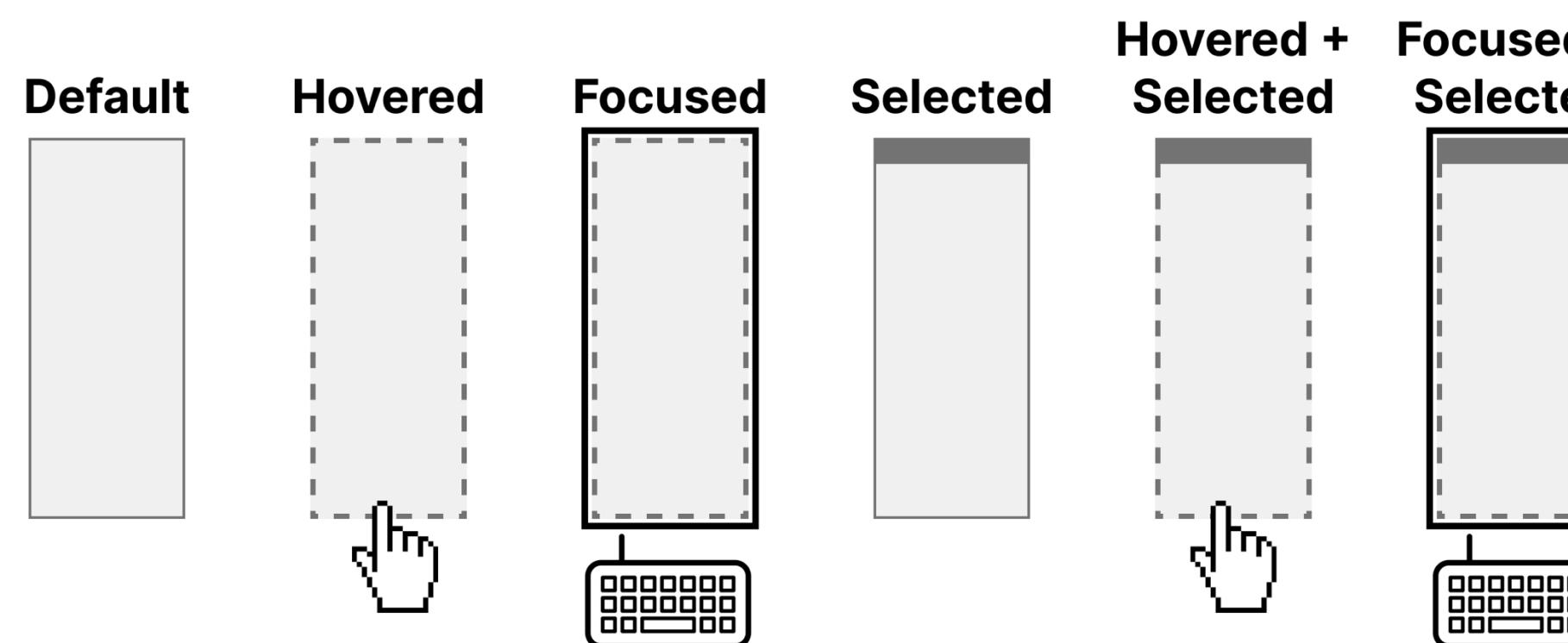
Consider how someone navigates



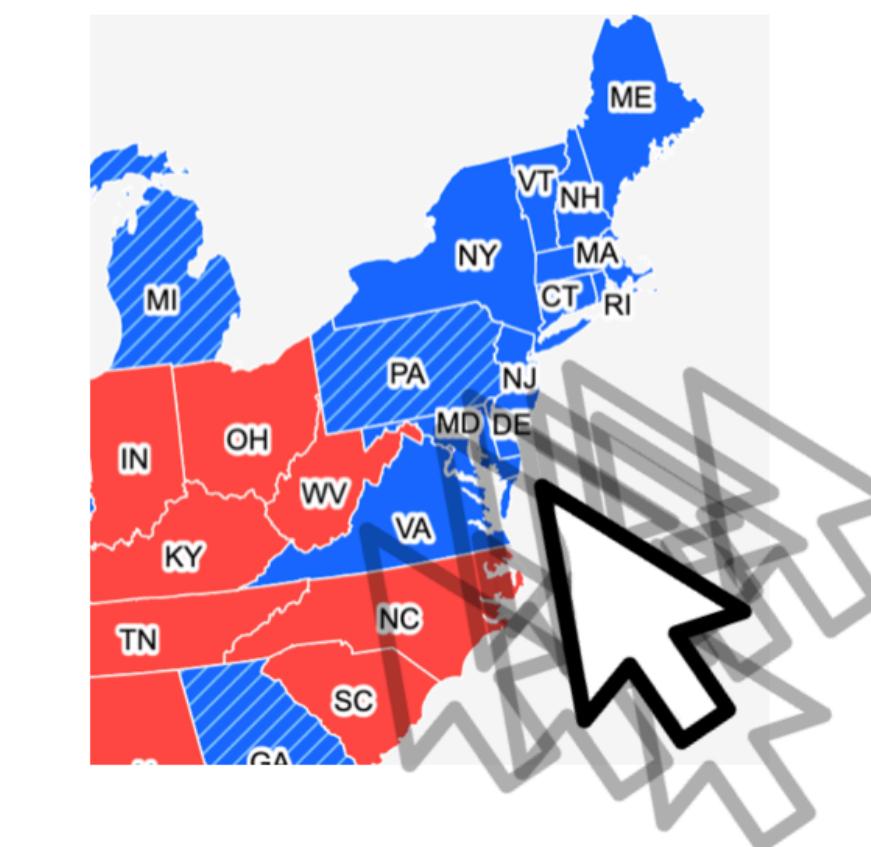
Describe the functionality of elements



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?

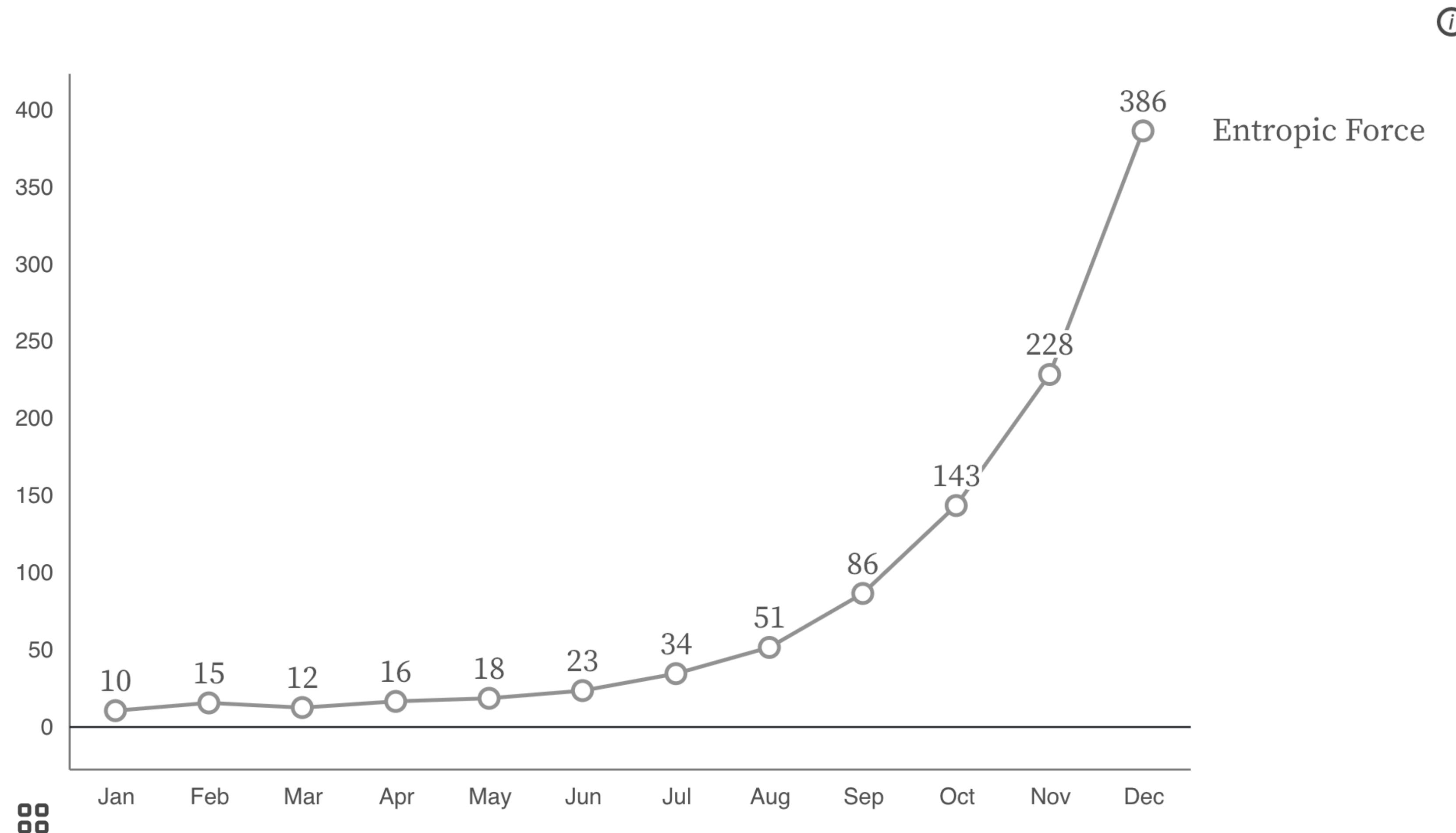
Understandable Checklist:

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

Non-descriptive titles are inaccessible

Entropic Force

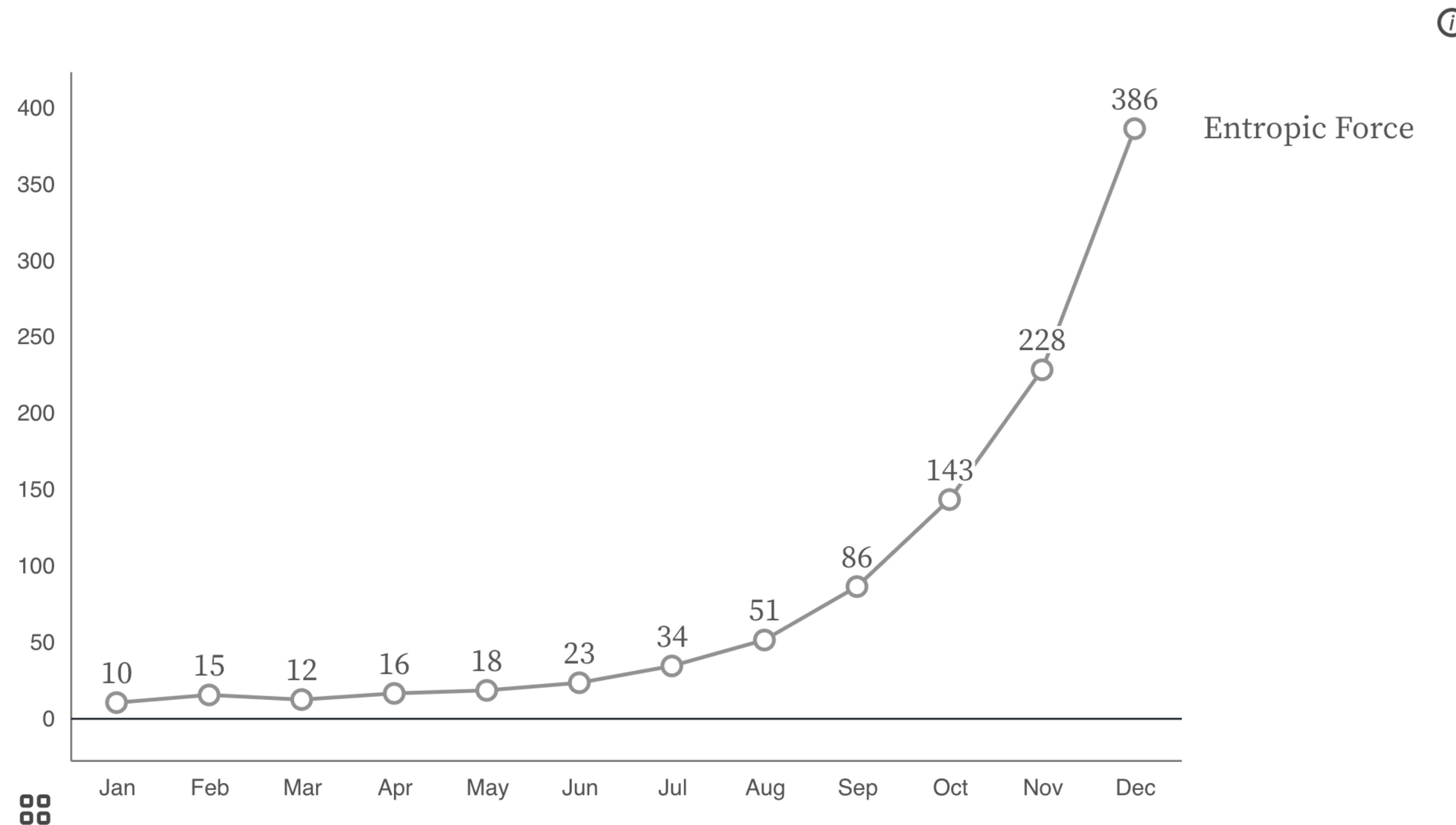
In EF units (non-normalized)



Descriptive titles have summaries/takeaways

Entropic Force has Increased Exponentially

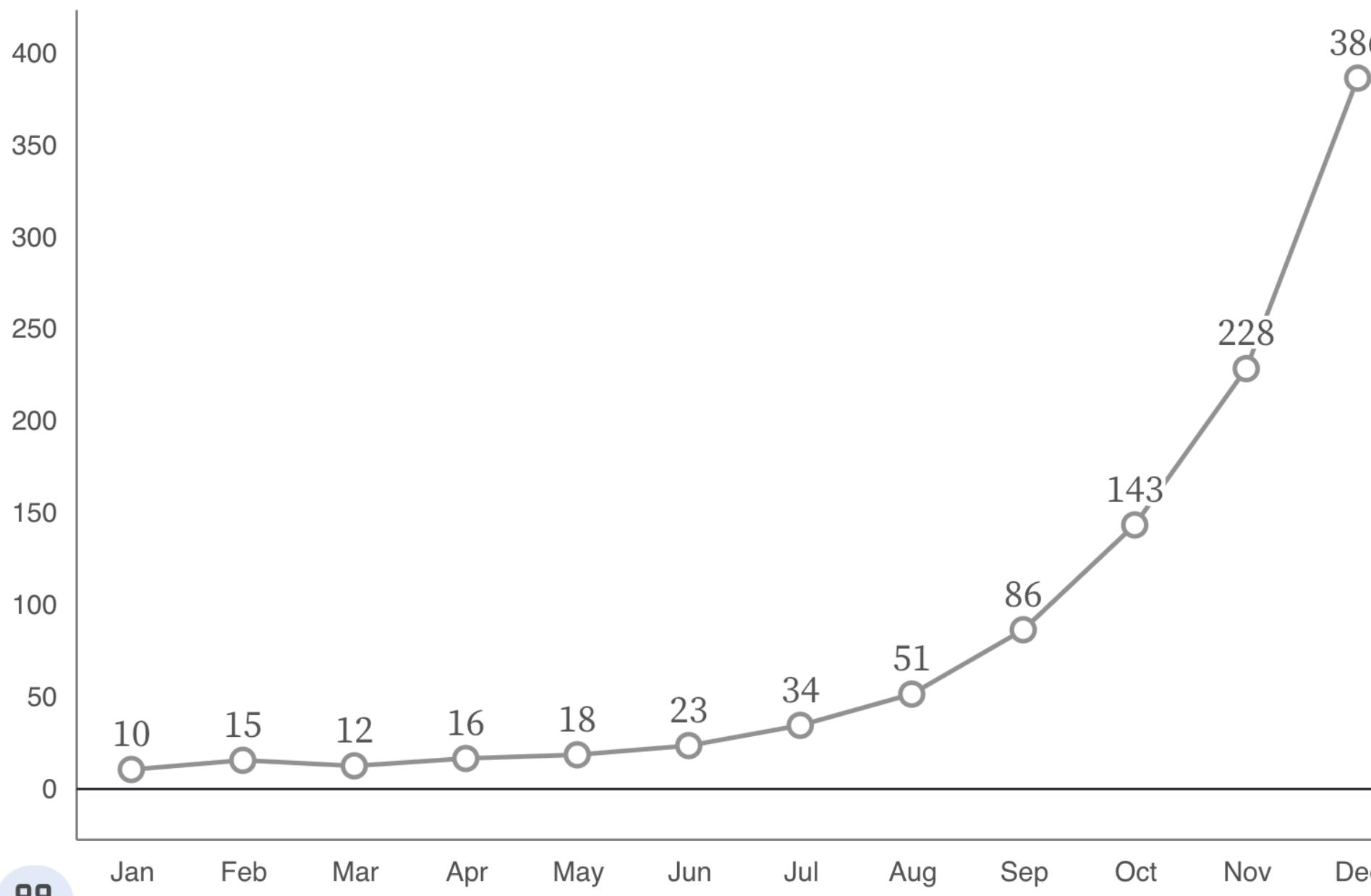
Measured in EF units (non-normalized)



All charts should have data available!

Entropic Force has Increased Exponentially

Measured in EF units (non-normalized)



Line

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 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.

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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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.

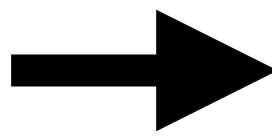
0 of 3 sentences are very hard to read.

Recap: Understandability

Use concise, descriptive titles

Entropic Force

In EF units (non-normalized)



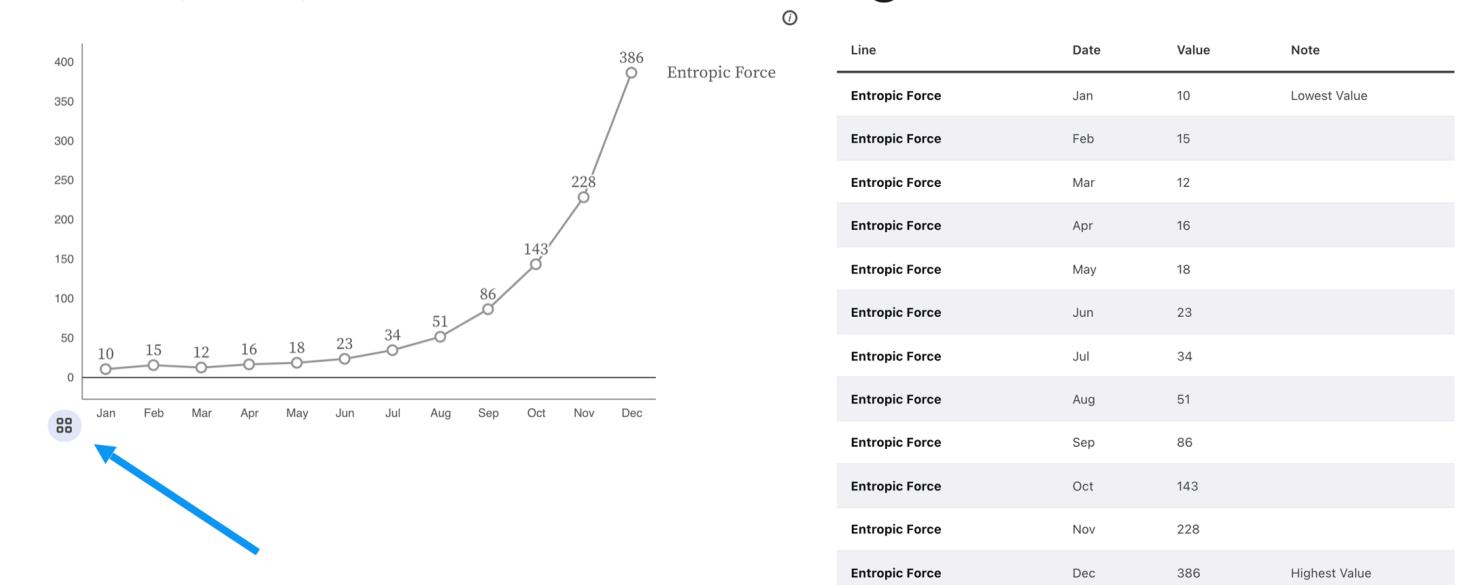
Entropic Force has Increased Exponentially

Measured in EF units (non-normalized)

Add easy-to-access data or tables

Entropic Force has Increased Exponentially

Measured in EF units (non-normalized)



Simplify your language

Hemingway

Readability

Post-graduate

Poor. Aim for 14.

Words: 39

Show More ▾

1 adverb. Aim for 0 or fewer.

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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

Readability

Grade 6

Good

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Show More ▾

0 adverbs. Well done.

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0 of 3 sentences are very hard to read.

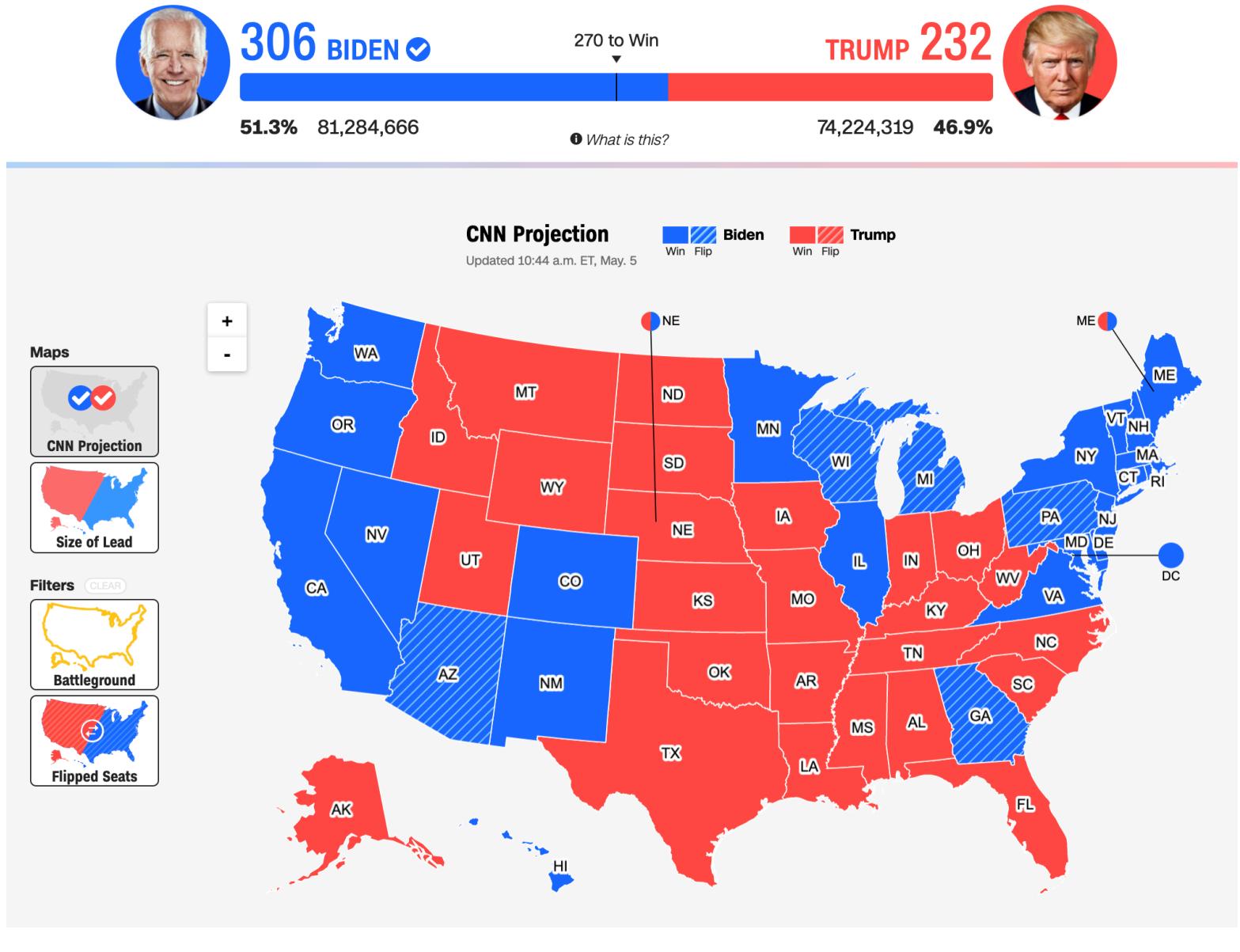
Understandable Evaluation Toolkit:

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?

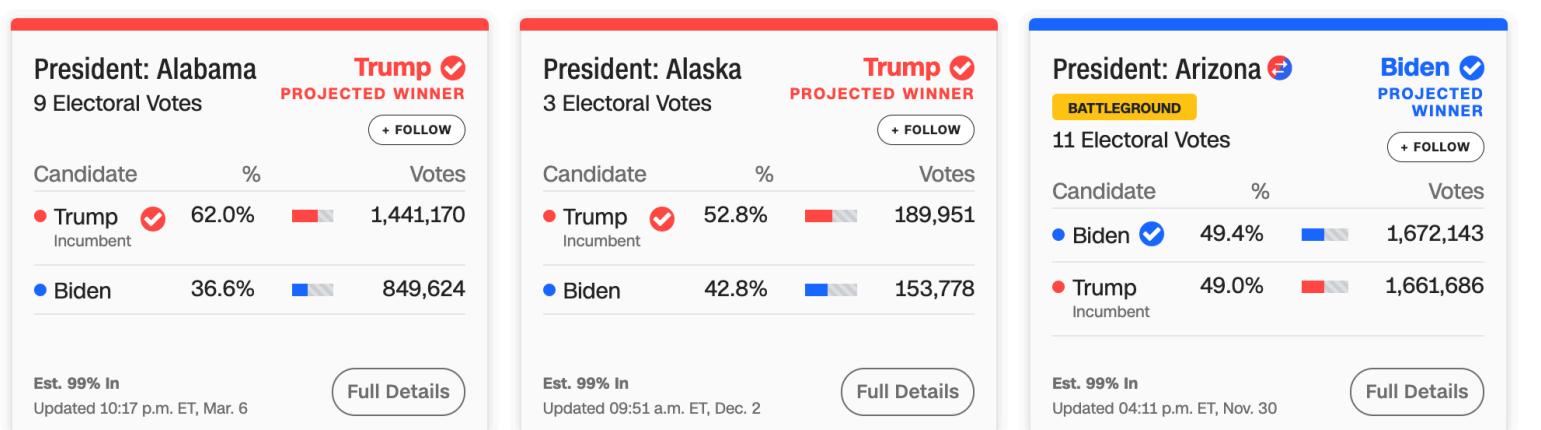
PRESIDENTIAL RESULTS

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STATE RESULTS



Show More States

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

978 access failures found in ~60 minutes.

Perceivable:

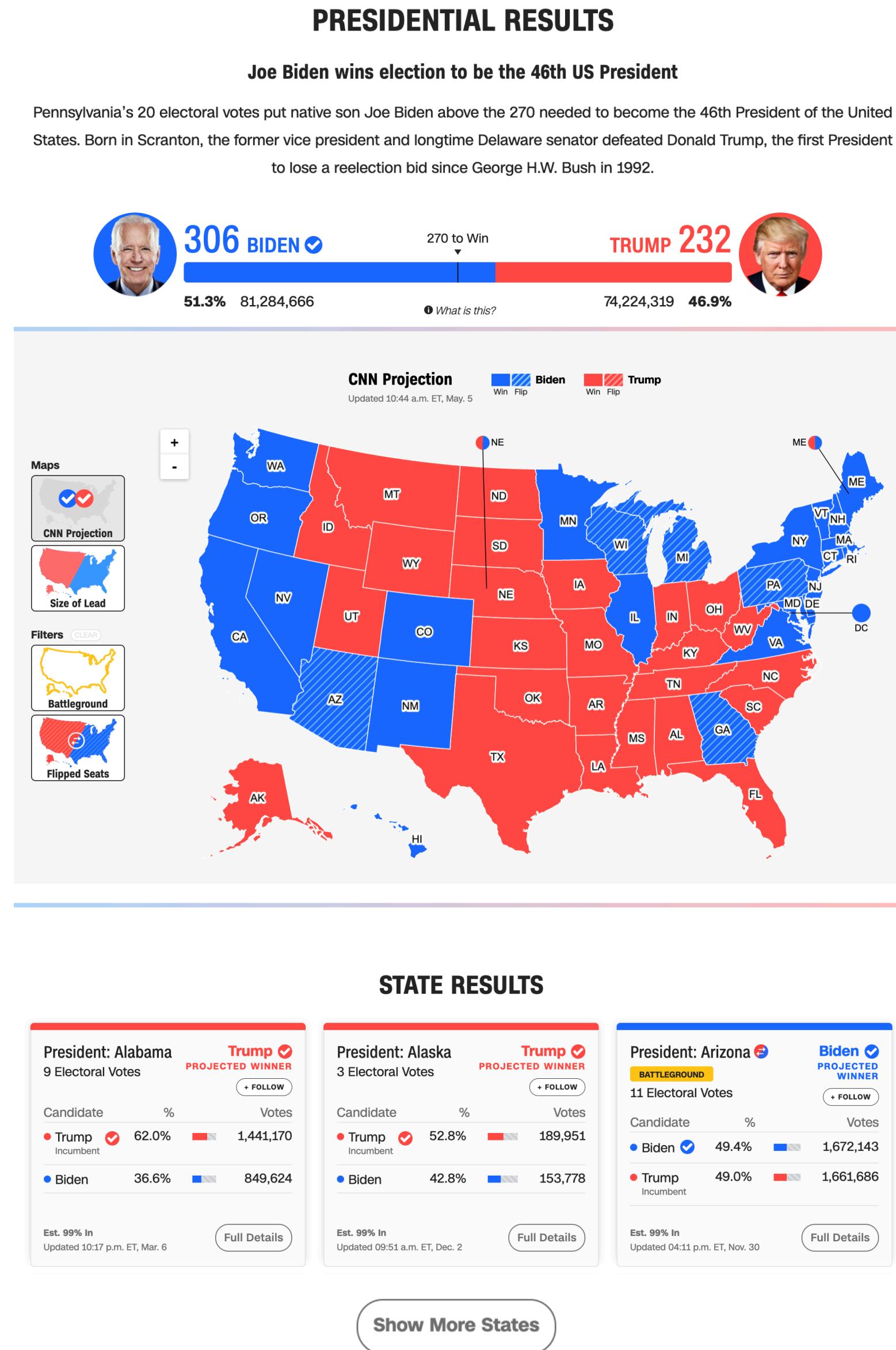
- 6 - Low contrast
- 57 - Content is only visual
- 50 - Color alone is used
- 3 - Meaningful elements can be distinguished

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

Accessibility and Visualization

An introduction.



Frank Elavsky

★Slides here



Human-
Computer
Interaction
Institute



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