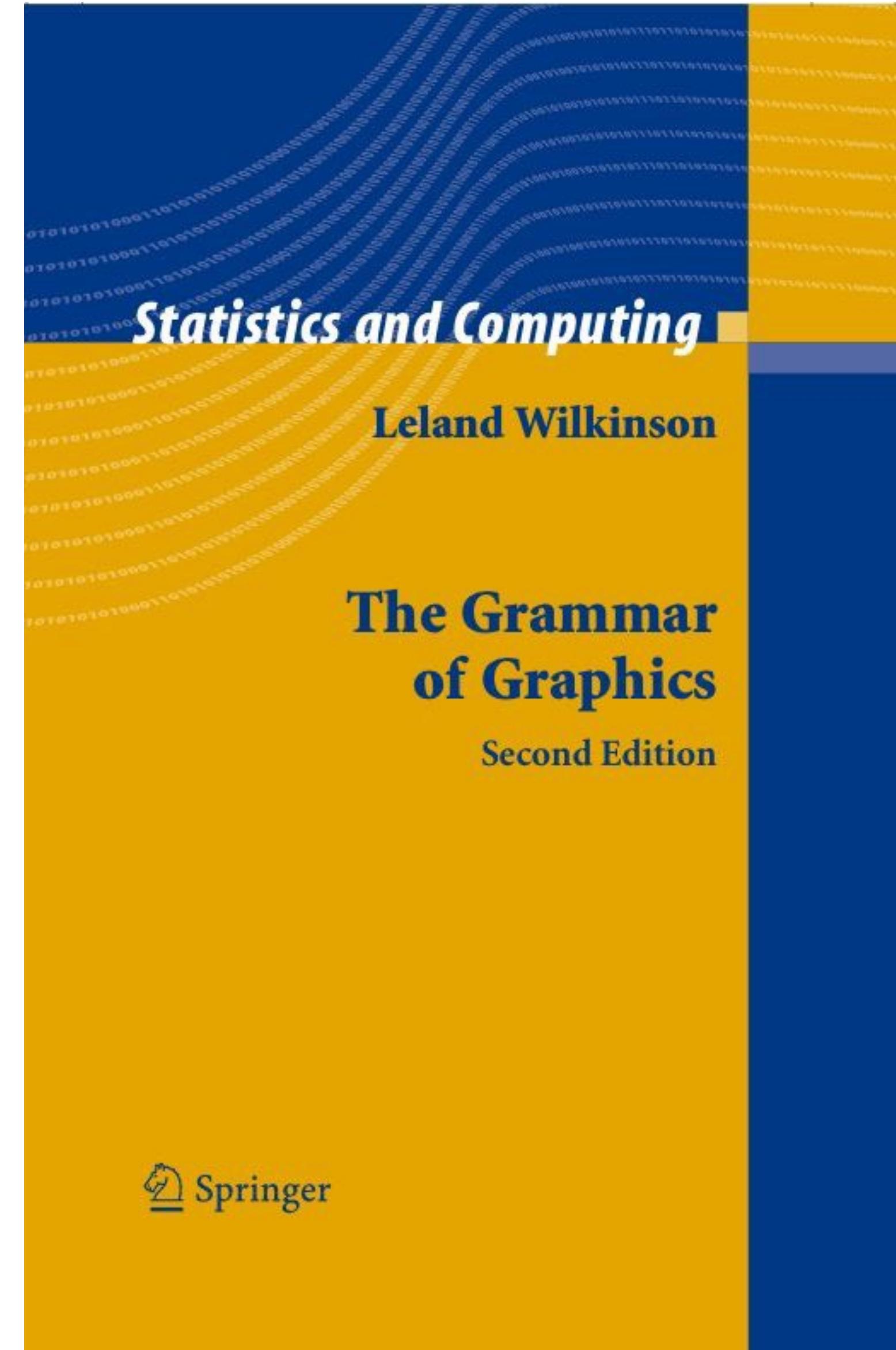


Grammar of graphics



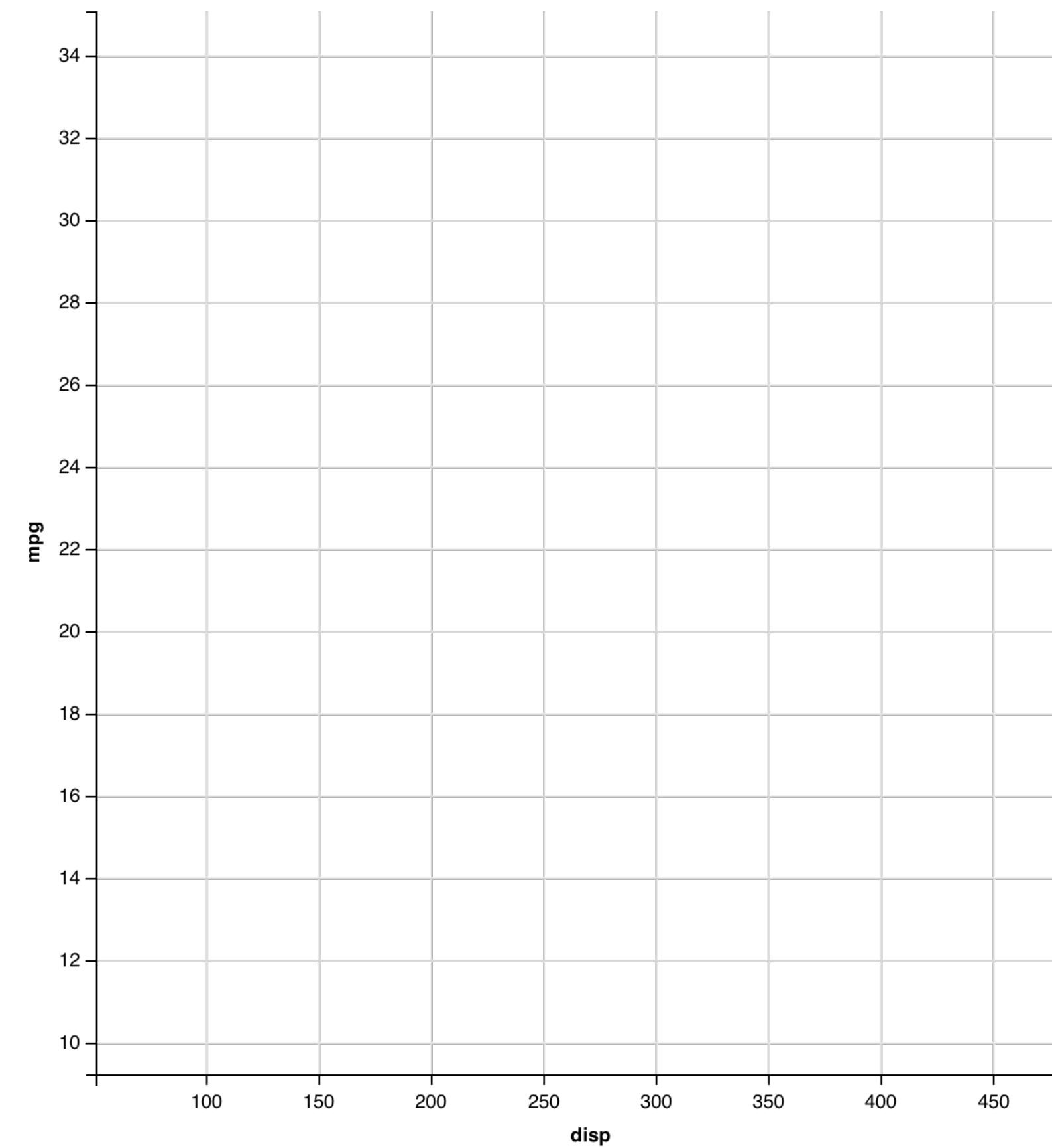
The Grammar of Graphics

*Coordinates
Statistics
Facets
Geometries
Aesthetics
Data*



mpg	cyl	disp	hp
21.0	6	160.0	2
21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1

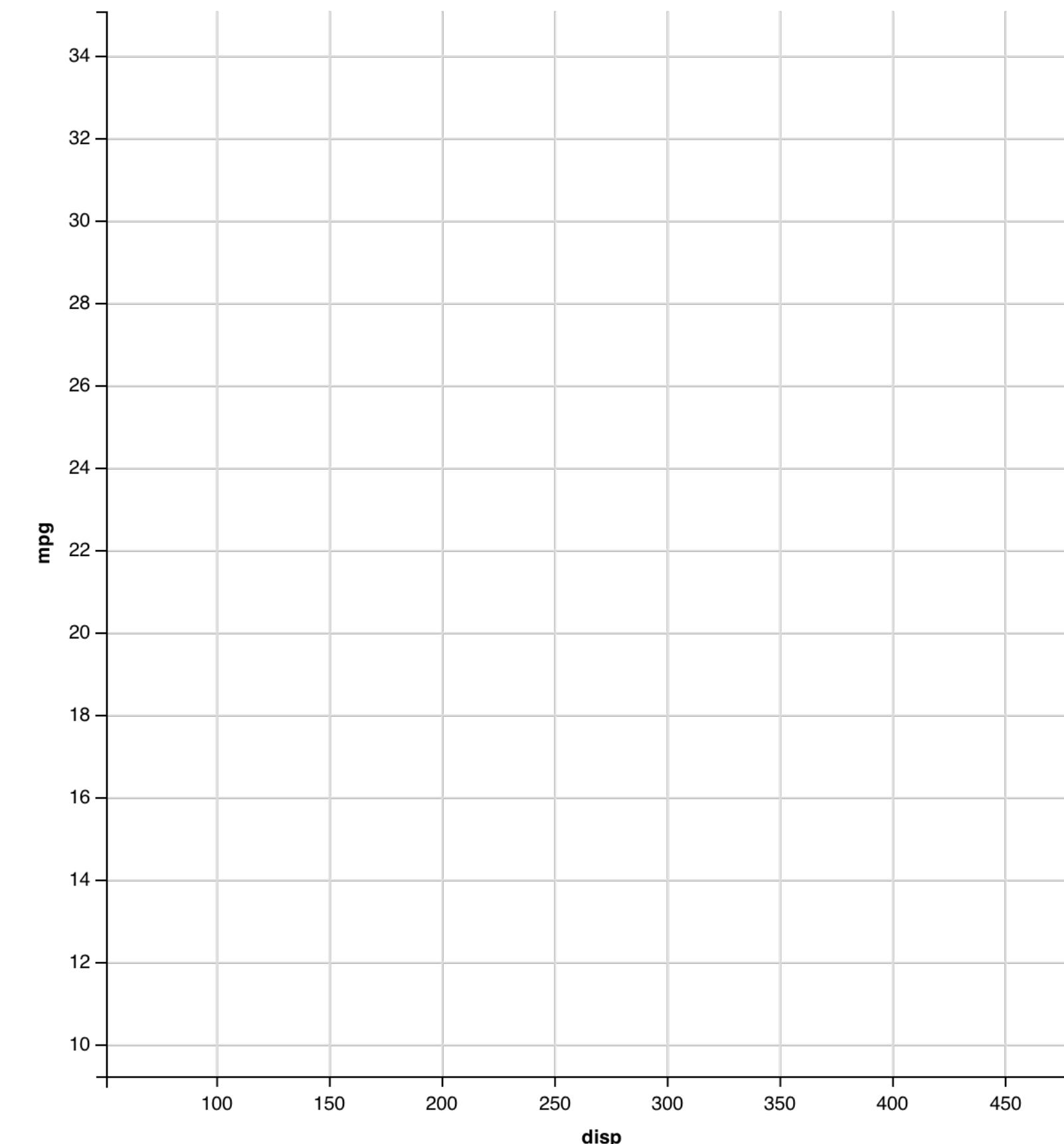
data



mpg	cyl	disp	hp
21.0	6	160.0	2
21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1

data

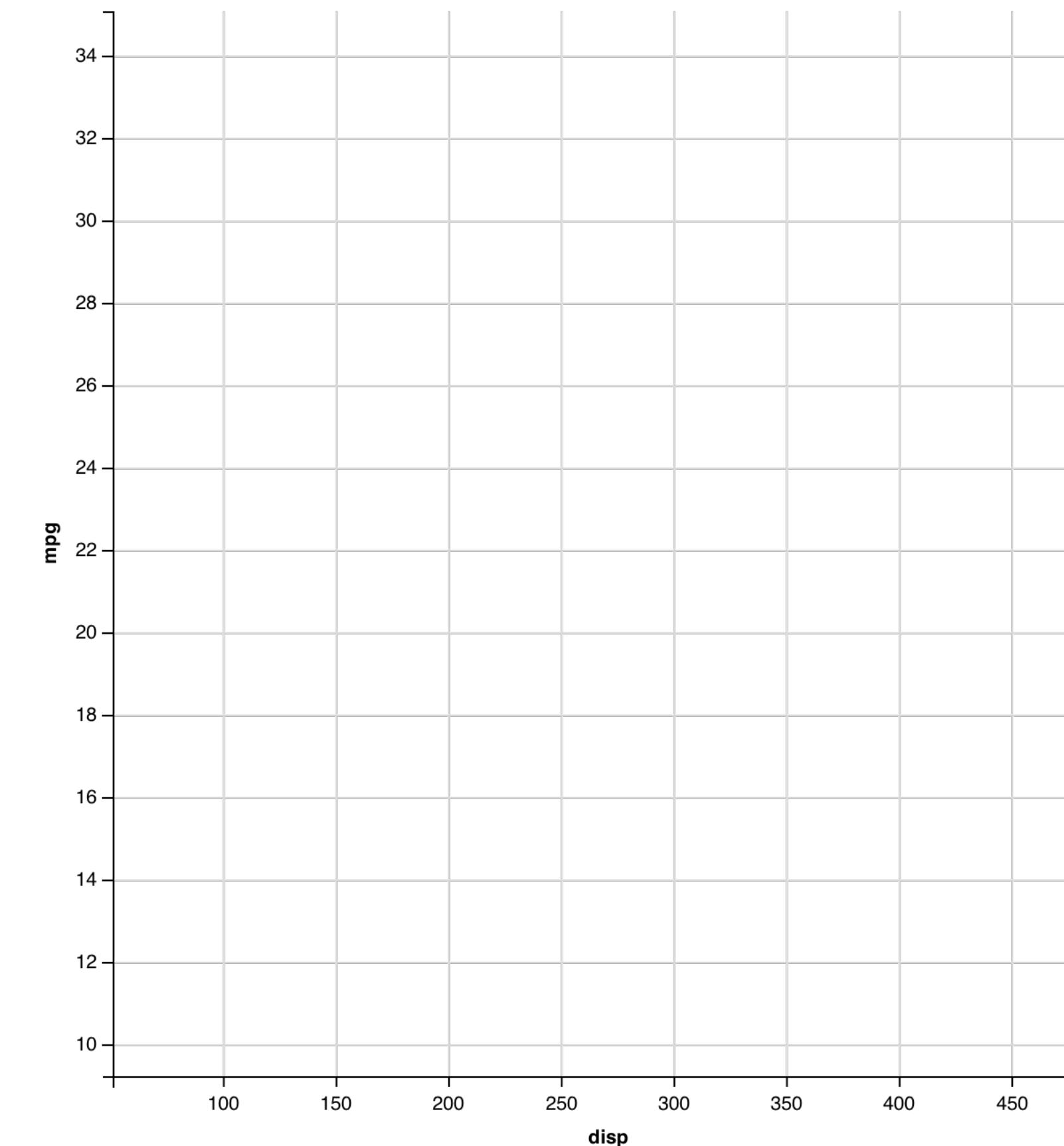
geom



mpg	cyl	disp	hp
21.0	6	160.0	2
21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1

data

geom



mappings

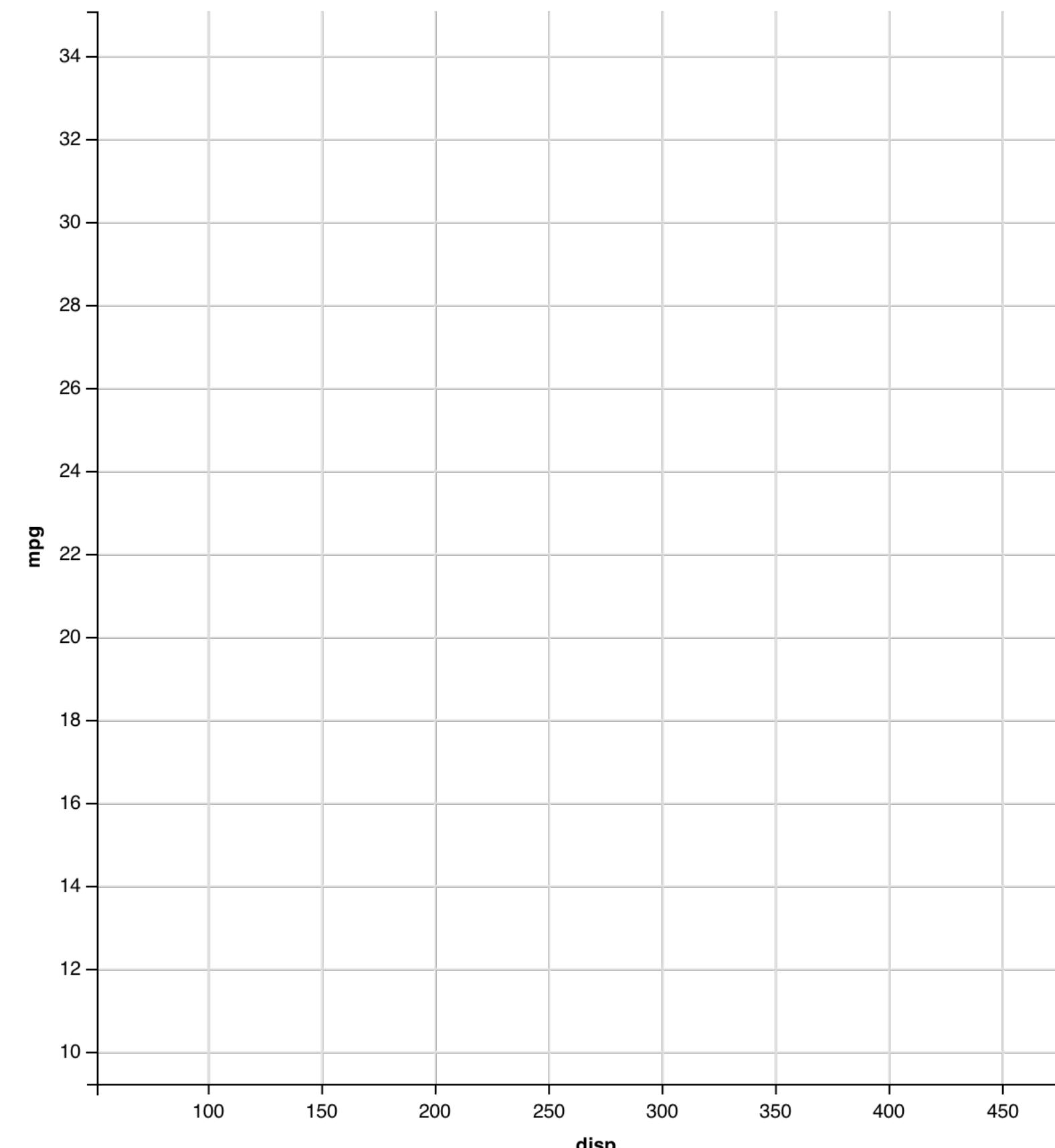
mpg	cyl	disp	hp
21.0	6	160.0	2
21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1

fill



data

geom



mappings

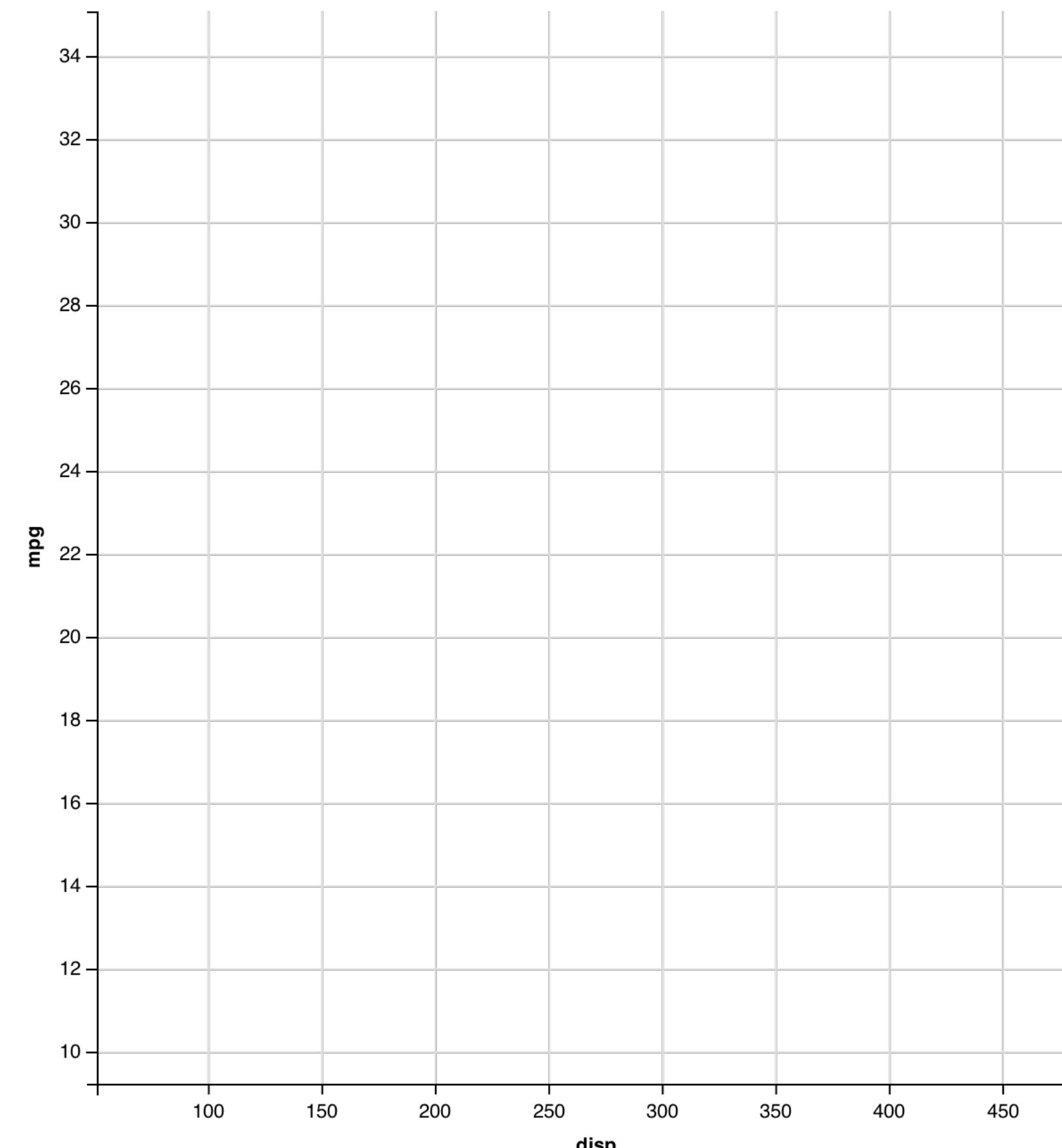
mpg	cyl	disp	hp
21.0	6	160.0	2
21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1

fill
↑↓



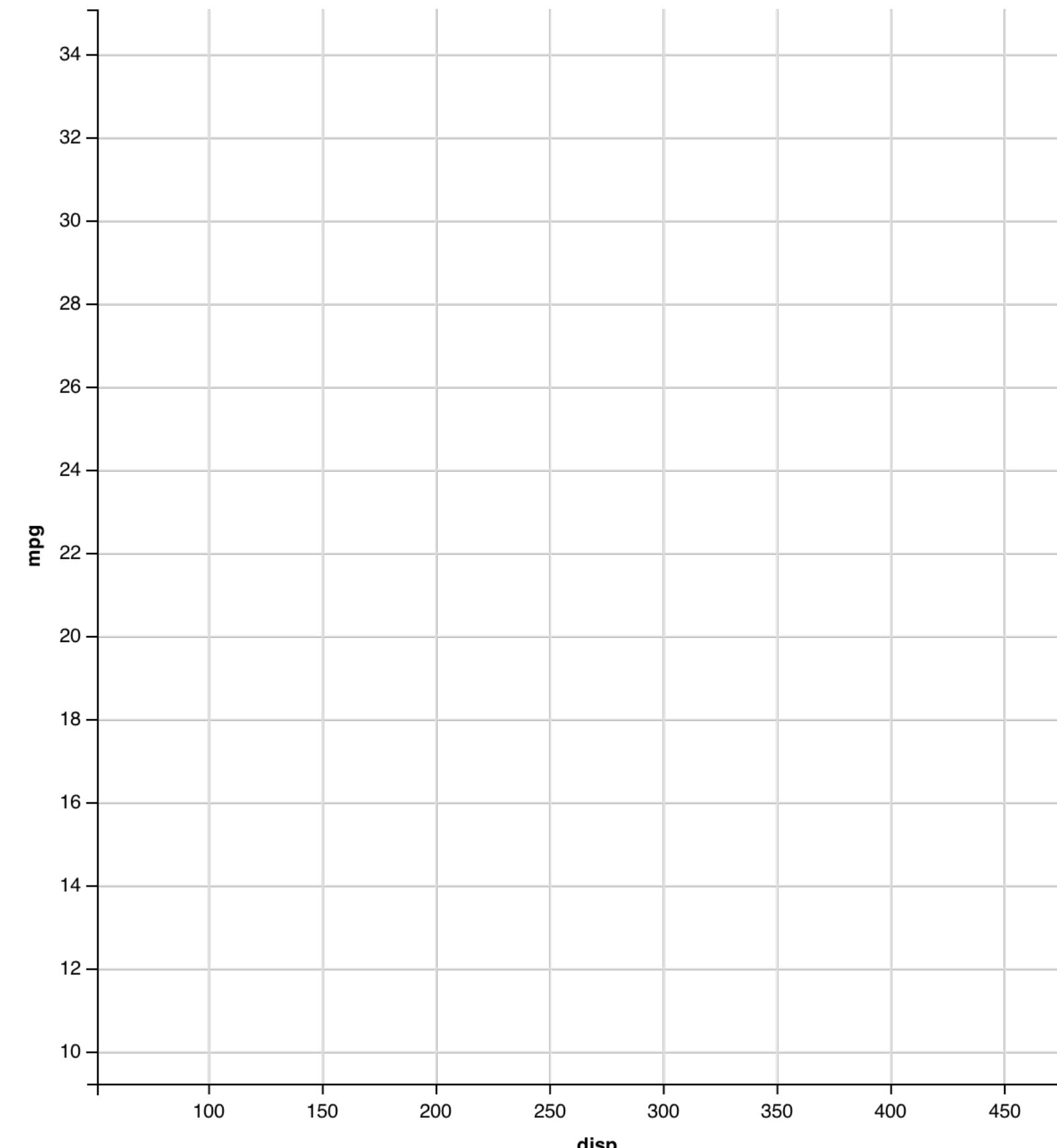
data

geom



mappings

shape		fill	
mpg	cyl	disp	hp
21.0	6 +	160.0	2
21.0	6 +	160.0	2
22.8	4 ●	108.0	1
21.4	6 +	258.0	2
18.7	8 ♦	360.0	3
18.1	6 +	225.0	2
14.3	8 ♦	360.0	5
24.4	4 ●	146.7	1
22.8	4 ●	140.8	1
19.2	6 +	167.6	2
17.8	6 +	167.6	2
16.4	8 ♦	275.8	3
17.3	8 ♦	275.8	3
15.2	8 ♦	275.8	3
10.4	8 ♦	472.0	4
10.4	8 ♦	460.0	4
14.7	8 ♦	440.0	4
32.4	4 ●	78.7	1
30.4	4 ●	75.7	1
33.9	4 ●	71.1	1

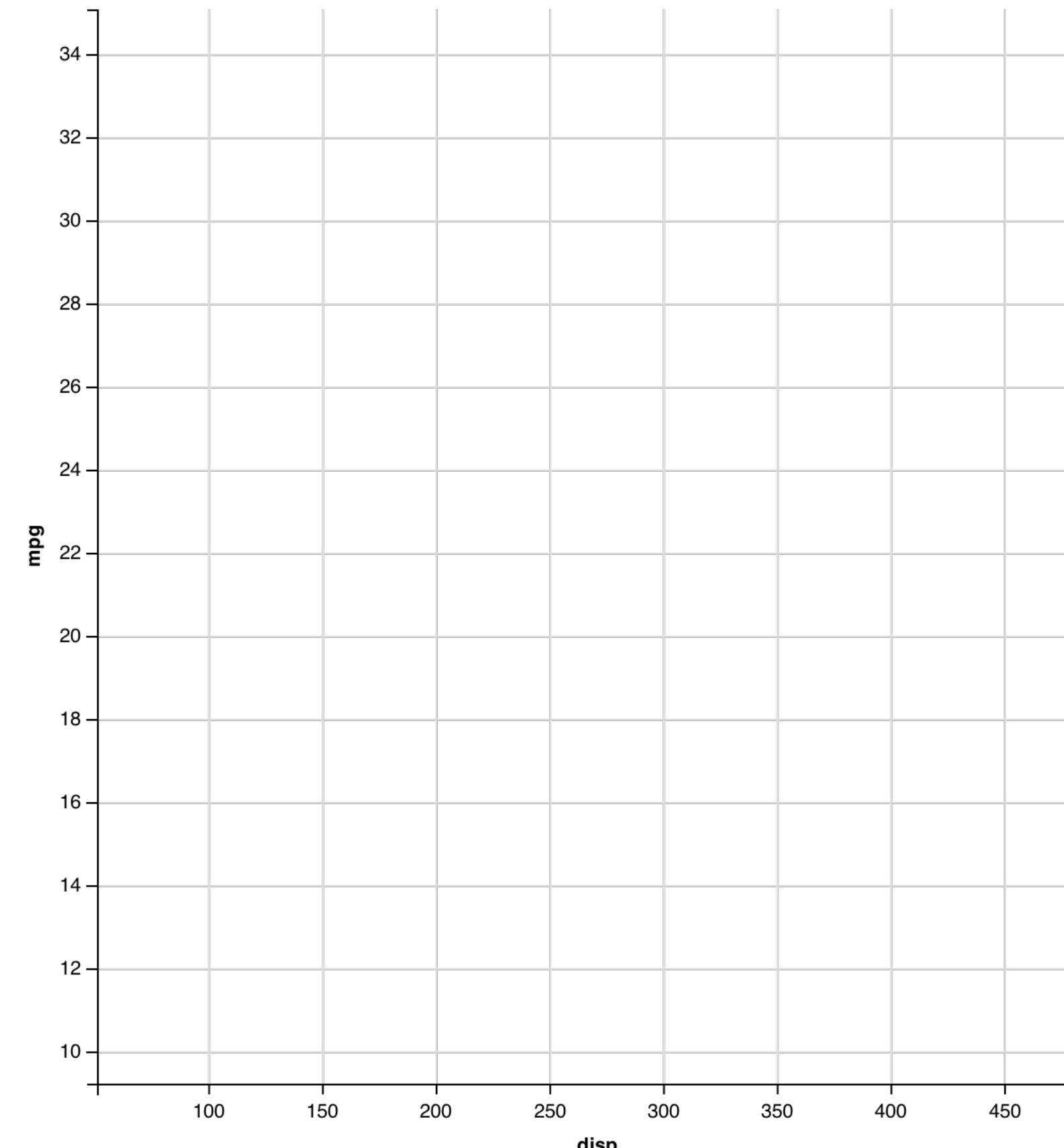


data

geom

mappings

	shape		fill
mpg	cyl	disp	hp
21.0	6	160.0	2
21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1



data

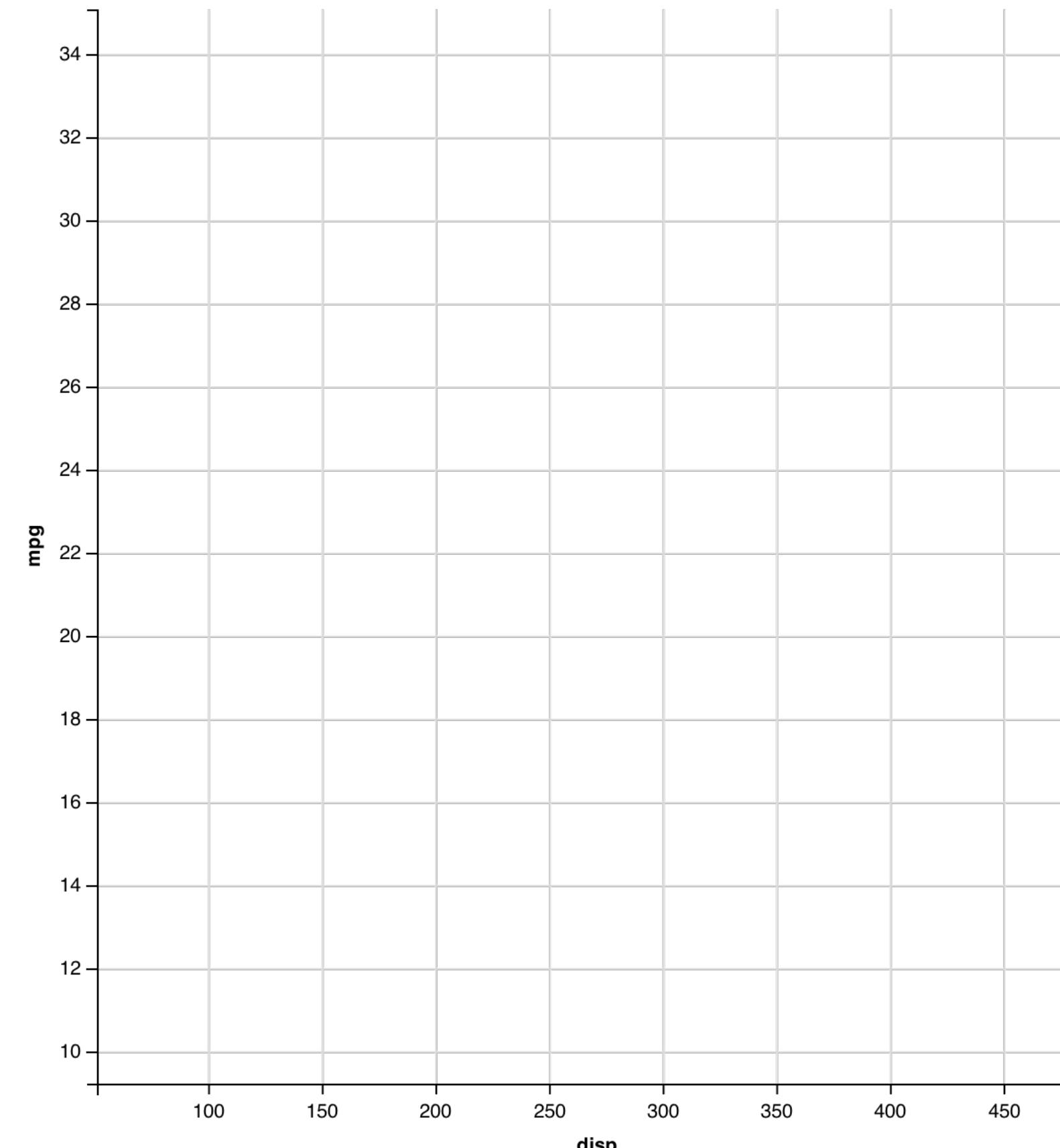
geom

mappings

mpg	cyl	disp	hp
21.0	6	160.0	2
21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1

data

geom

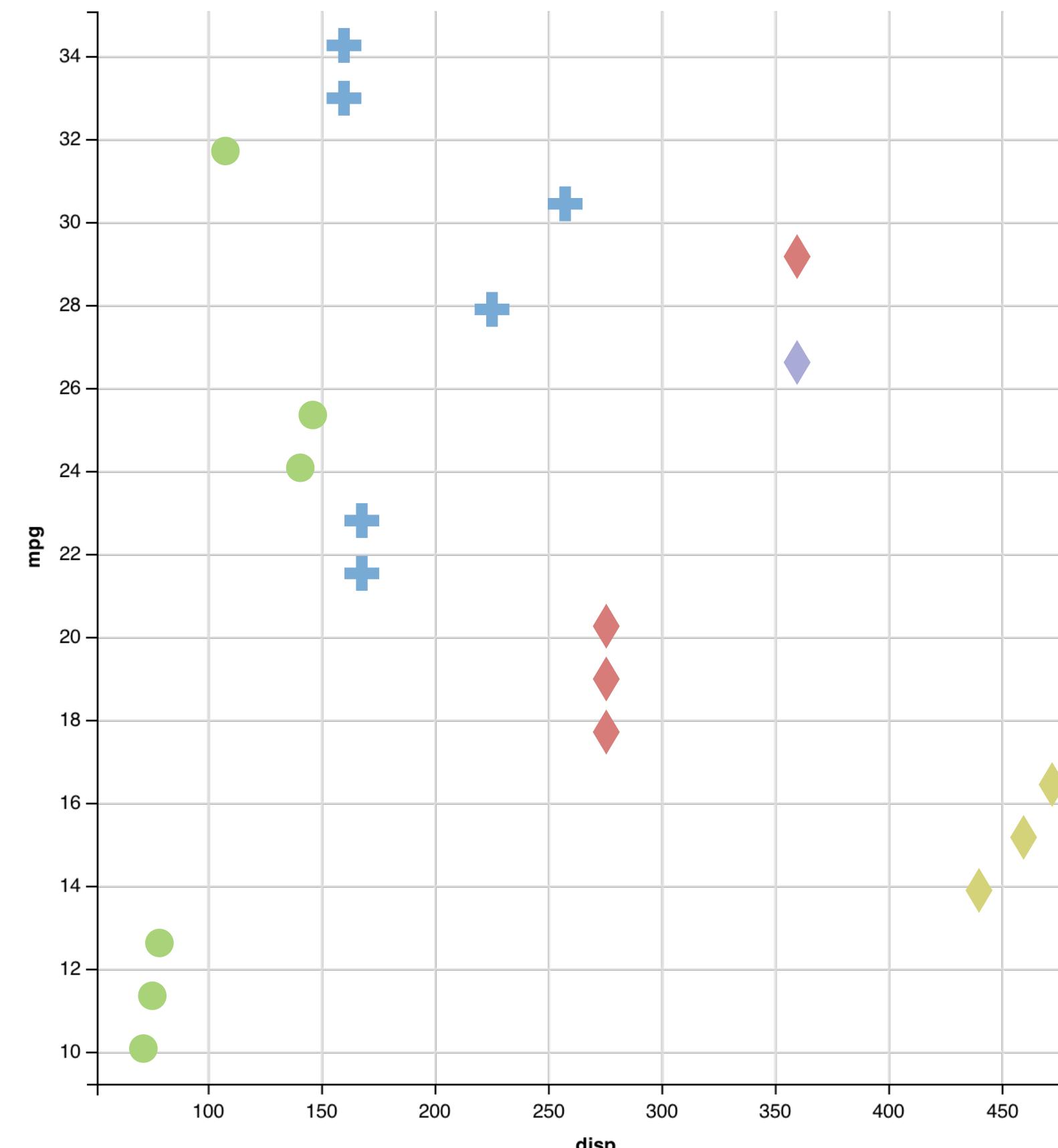


mappings

shape	x	fill	
	↑	↑	
mpg	cyl	disp	hp
21.0	6	160.0	2
21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1

data

geom

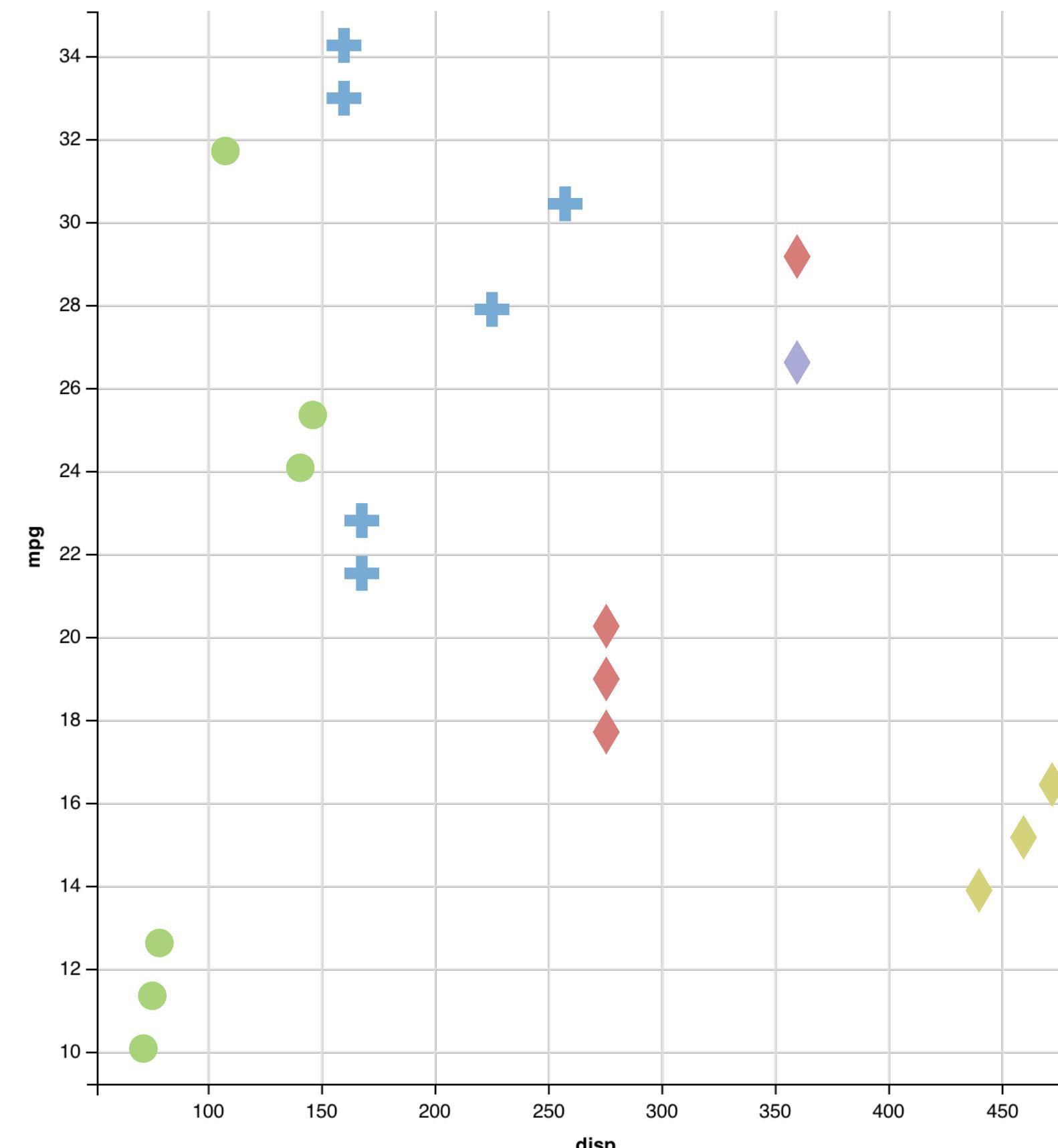


mappings

shape	x	fill	
mpg	cyl	disp	hp
21.0	6	160.0	2
21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1

data

geom

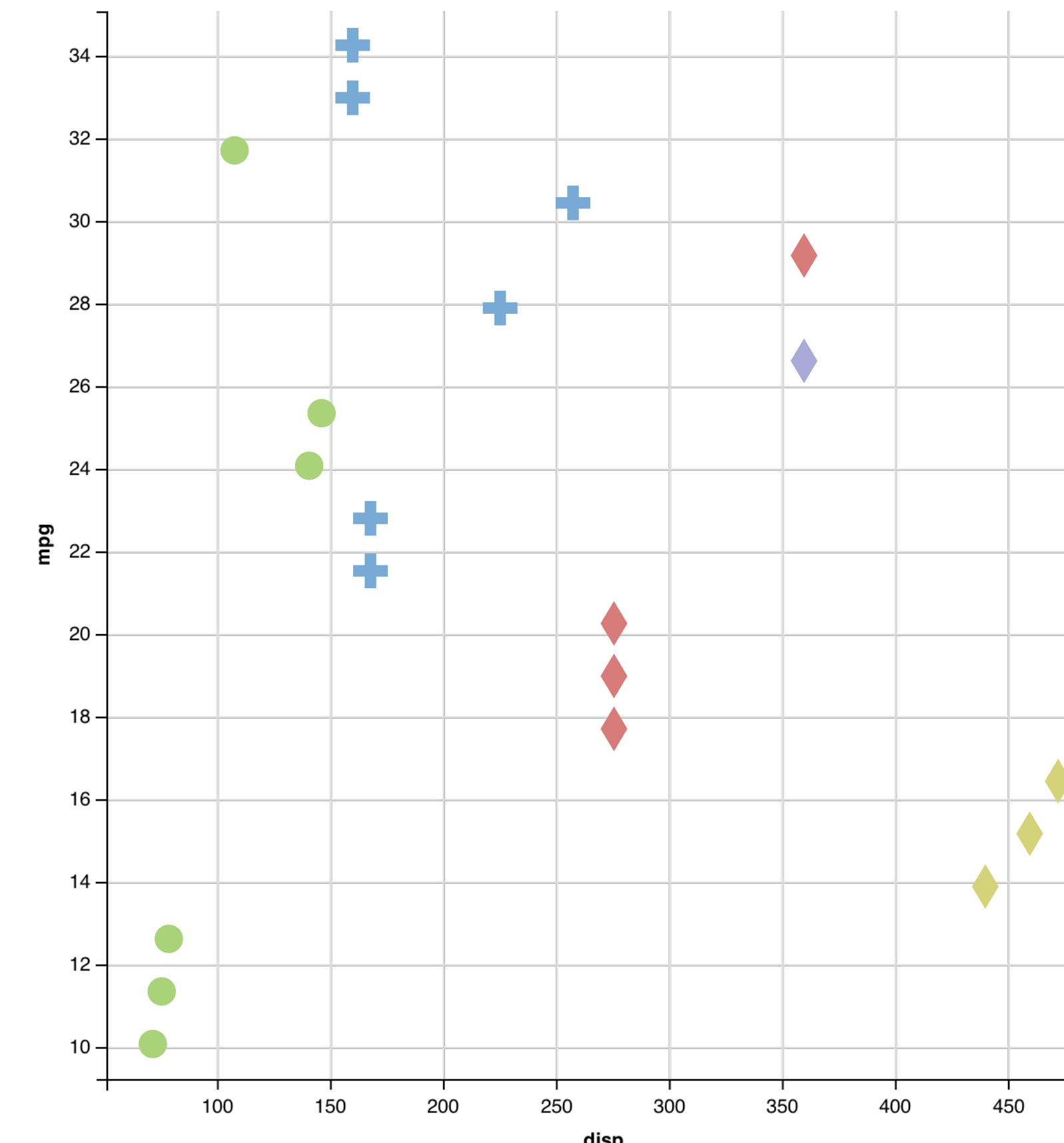


mappings

	y	shape	x	fill
	mpg	cyl	disp	hp
21.0	6	160.0	2	
21.0	6	160.0	2	
22.8	4	108.0	1	
21.4	6	258.0	2	
18.7	8	360.0	3	
18.1	6	225.0	2	
14.3	8	360.0	5	
24.4	4	146.7	1	
22.8	4	140.8	1	
19.2	6	167.6	2	
17.8	6	167.6	2	
16.4	8	275.8	3	
17.3	8	275.8	3	
15.2	8	275.8	3	
10.4	8	472.0	4	
10.4	8	460.0	4	
14.7	8	440.0	4	
32.4	4	78.7	1	
30.4	4	75.7	1	
33.9	4	71.1	1	

data

geom



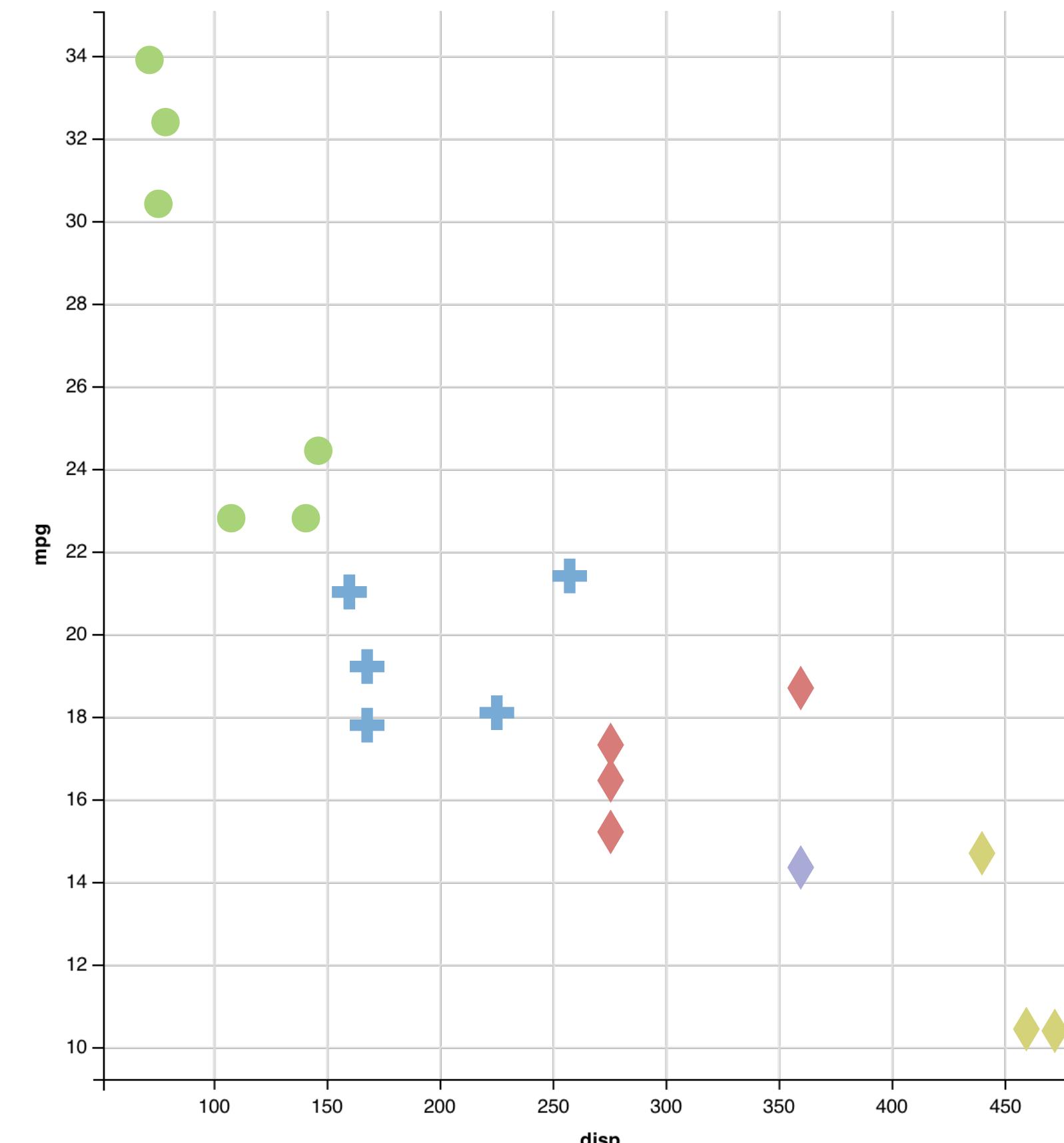
mappings

	y	shape	x	fill
	mpg	cyl	disp	hp
21.0	6	160.0	2	
21.0	6	160.0	2	
22.8	4	108.0	1	
21.4	6	258.0	2	
18.7	8	360.0	3	
18.1	6	225.0	2	
14.3	8	360.0	5	
24.4	4	146.7	1	
22.8	4	140.8	1	
19.2	6	167.6	2	
17.8	6	167.6	2	
16.4	8	275.8	3	
17.3	8	275.8	3	
15.2	8	275.8	3	
10.4	8	472.0	4	
10.4	8	460.0	4	
14.7	8	440.0	4	
32.4	4	78.7	1	
30.4	4	75.7	1	
33.9	4	71.1	1	



data

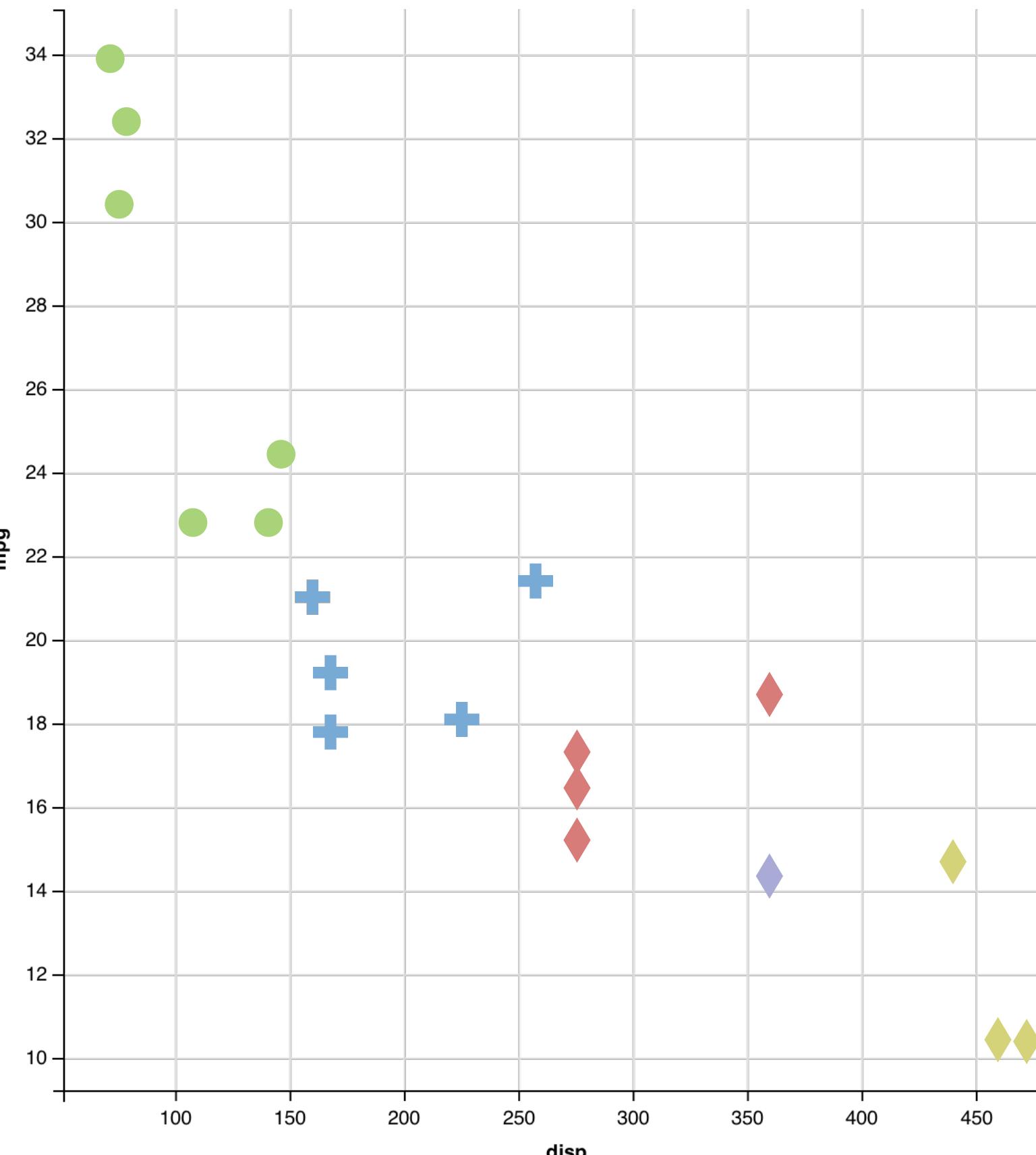
geom



mappings

	y	shape	x	fill
	mpg	cyl	disp	hp
21.0	6	160.0	2	
21.0	6	160.0	2	
22.8	4	108.0	1	
21.4	6	258.0	2	
18.7	8	360.0	3	
18.1	6	225.0	2	
14.3	8	360.0	5	
24.4	4	146.7	1	
22.8	4	140.8	1	
19.2	6	167.6	2	
17.8	6	167.6	2	
16.4	8	275.8	3	
17.3	8	275.8	3	
15.2	8	275.8	3	
10.4	8	472.0	4	
10.4	8	460.0	4	
14.7	8	440.0	4	
32.4	4	78.7	1	
30.4	4	75.7	1	
33.9	4	71.1	1	

geom



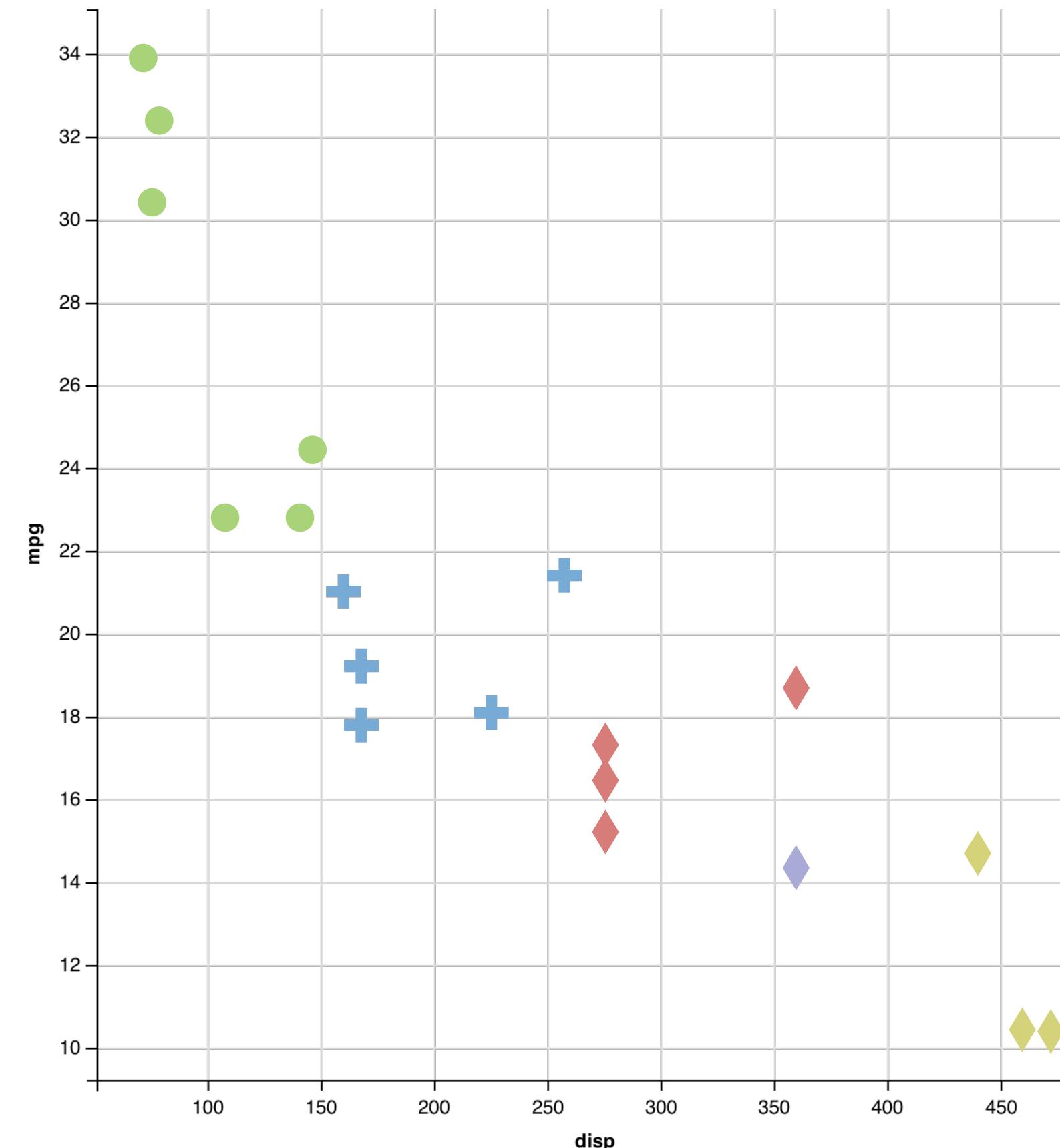
data

mappings

Y
↑
mpg cyl disp hp

X
↓
mpg cyl disp hp

mpg	cyl	disp	hp	
21.0	6	160.0	2	—
21.0	6	160.0	2	—
22.8	4	108.0	1	—
21.4	6	258.0	2	—
18.7	8	360.0	3	◆
18.1	6	225.0	2	—
14.3	8	360.0	5	◊
24.4	4	146.7	1	—
22.8	4	140.8	1	—
19.2	6	167.6	2	—
17.8	6	167.6	2	—
16.4	8	275.8	3	◆
17.3	8	275.8	3	◊
15.2	8	275.8	3	—
10.4	8	472.0	4	—
10.4	8	460.0	4	—
14.7	8	440.0	4	—
32.4	4	78.7	1	—
30.4	4	75.7	1	—
33.9	4	71.1	1	—

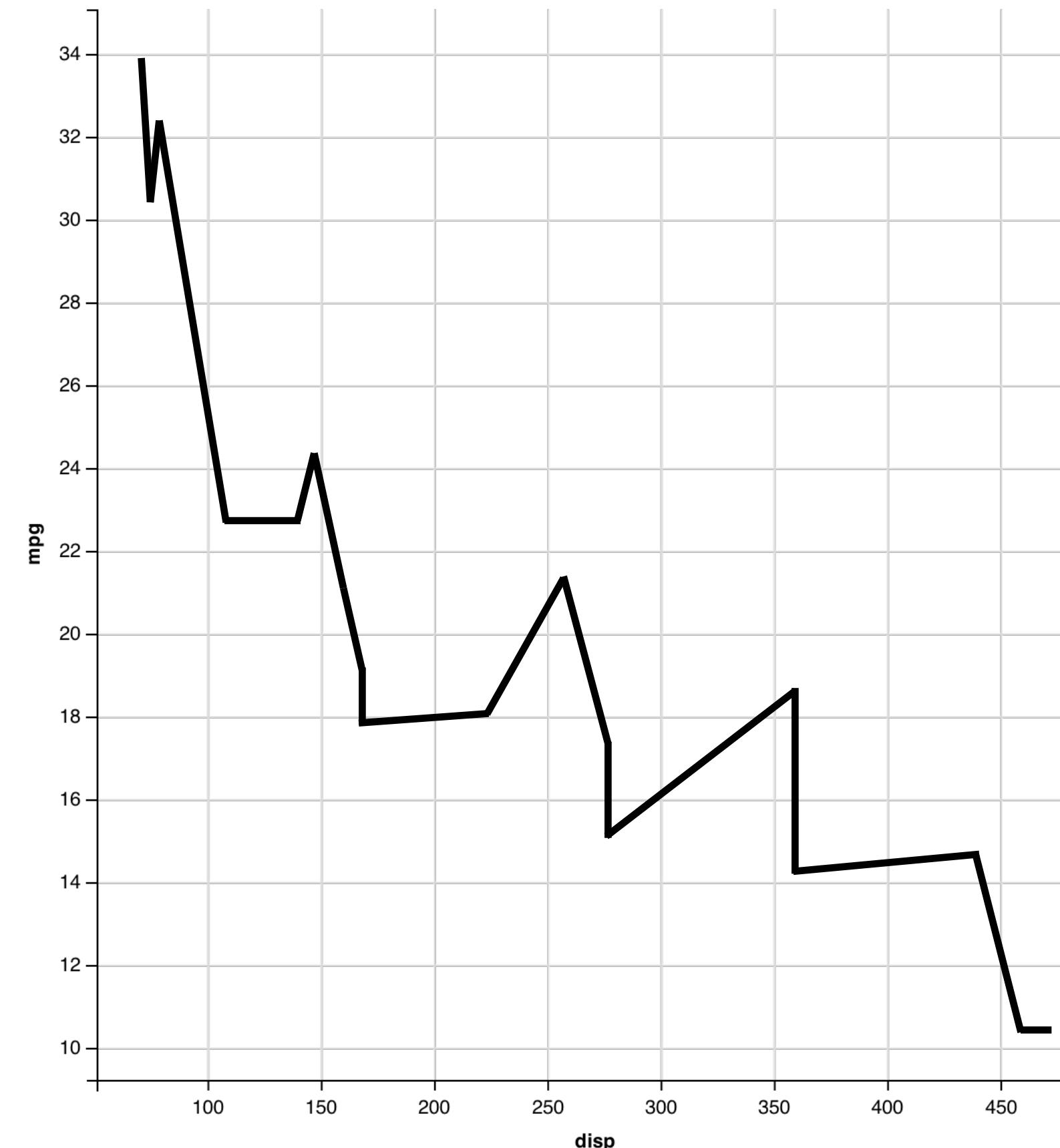


data

geom
points
lines

mappings

mpg	cyl	disp	hp	
21.0	6	160.0	2	—
21.0	6	160.0	2	—
22.8	4	108.0	1	—
21.4	6	258.0	2	—
18.7	8	360.0	3	◆
18.1	6	225.0	2	—
14.3	8	360.0	5	◆
24.4	4	146.7	1	—
22.8	4	140.8	1	—
19.2	6	167.6	2	—
17.8	6	167.6	2	—
16.4	8	275.8	3	◆
17.3	8	275.8	3	—
15.2	8	275.8	3	◆
10.4	8	472.0	4	—
10.4	8	460.0	4	—
14.7	8	440.0	4	—
32.4	4	78.7	1	—
30.4	4	75.7	1	—
33.9	4	71.1	1	—

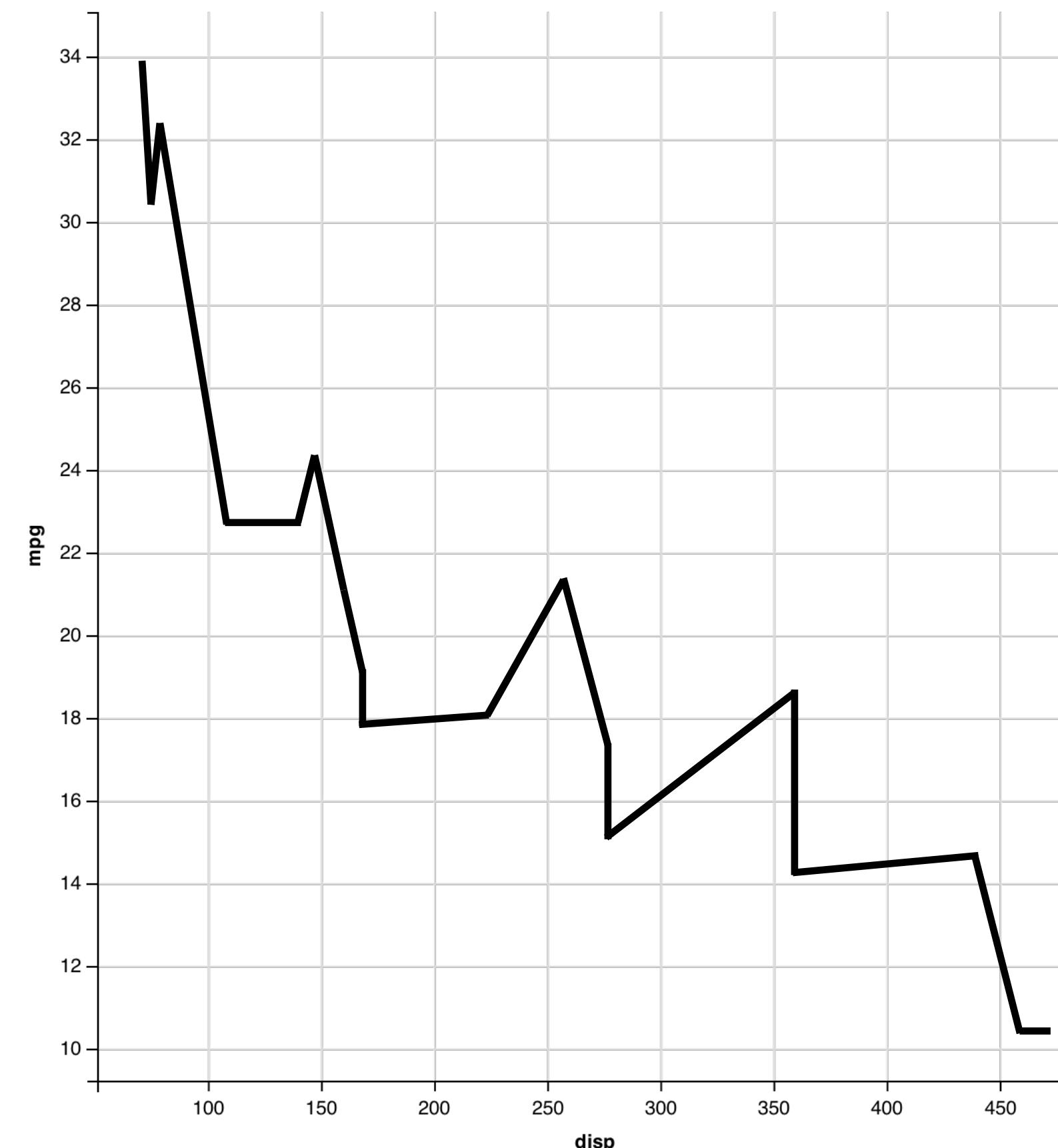


data

geom
points
lines

mappings

mpg	cyl	disp	hp	
21.0	6	160.0	2	—
21.0	6	160.0	2	—
22.8	4	108.0	1	—
21.4	6	258.0	2	—
18.7	8	360.0	3	—
18.1	6	225.0	2	—
14.3	8	360.0	5	—
24.4	4	146.7	1	—
22.8	4	140.8	1	—
19.2	6	167.6	2	—
17.8	6	167.6	2	—
16.4	8	275.8	3	—
17.3	8	275.8	3	—
15.2	8	275.8	3	—
10.4	8	472.0	4	—
10.4	8	460.0	4	—
14.7	8	440.0	4	—
32.4	4	78.7	1	—
30.4	4	75.7	1	—
33.9	4	71.1	1	—



data

geom
points
lines

mappings

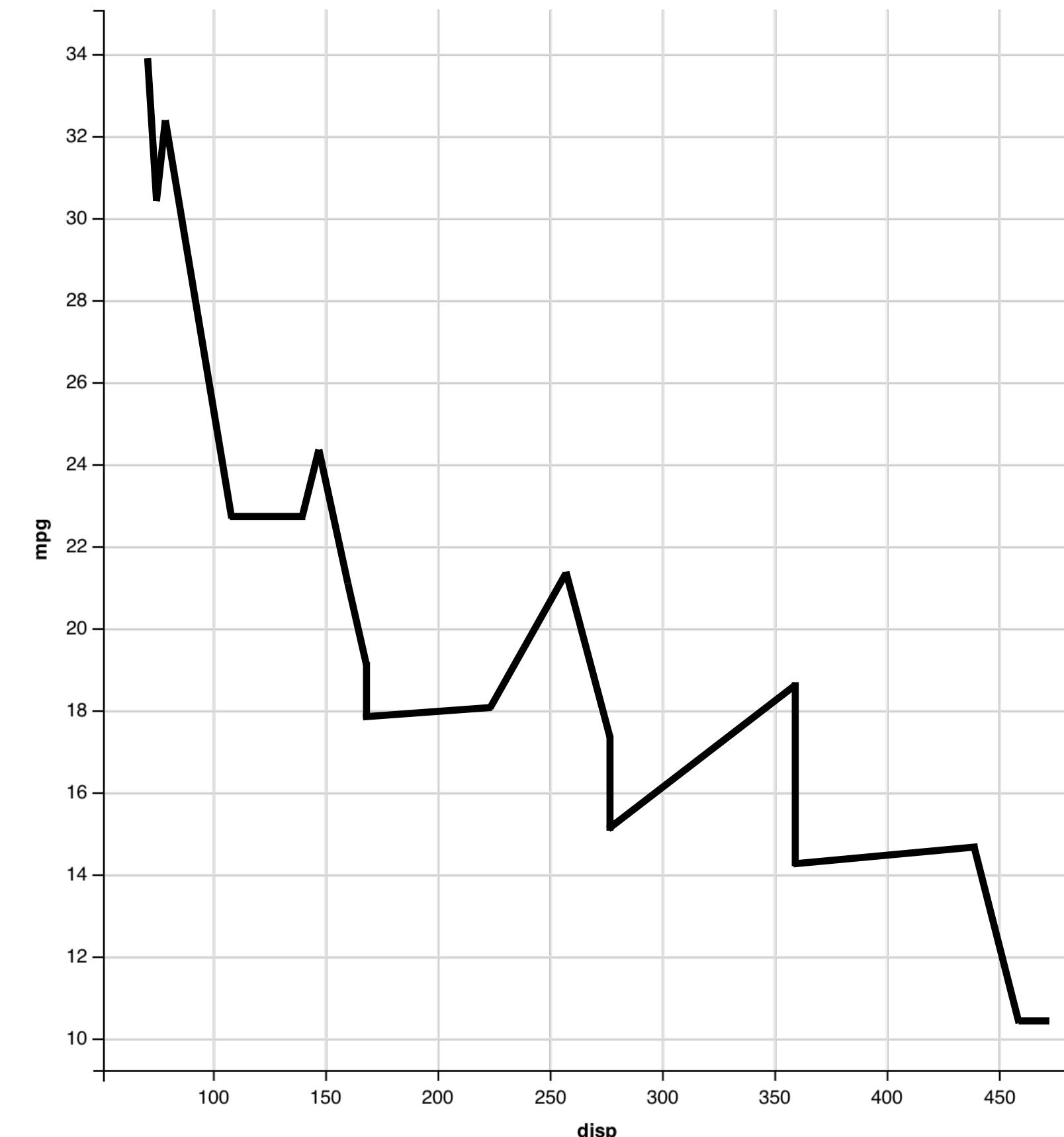
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21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1



data

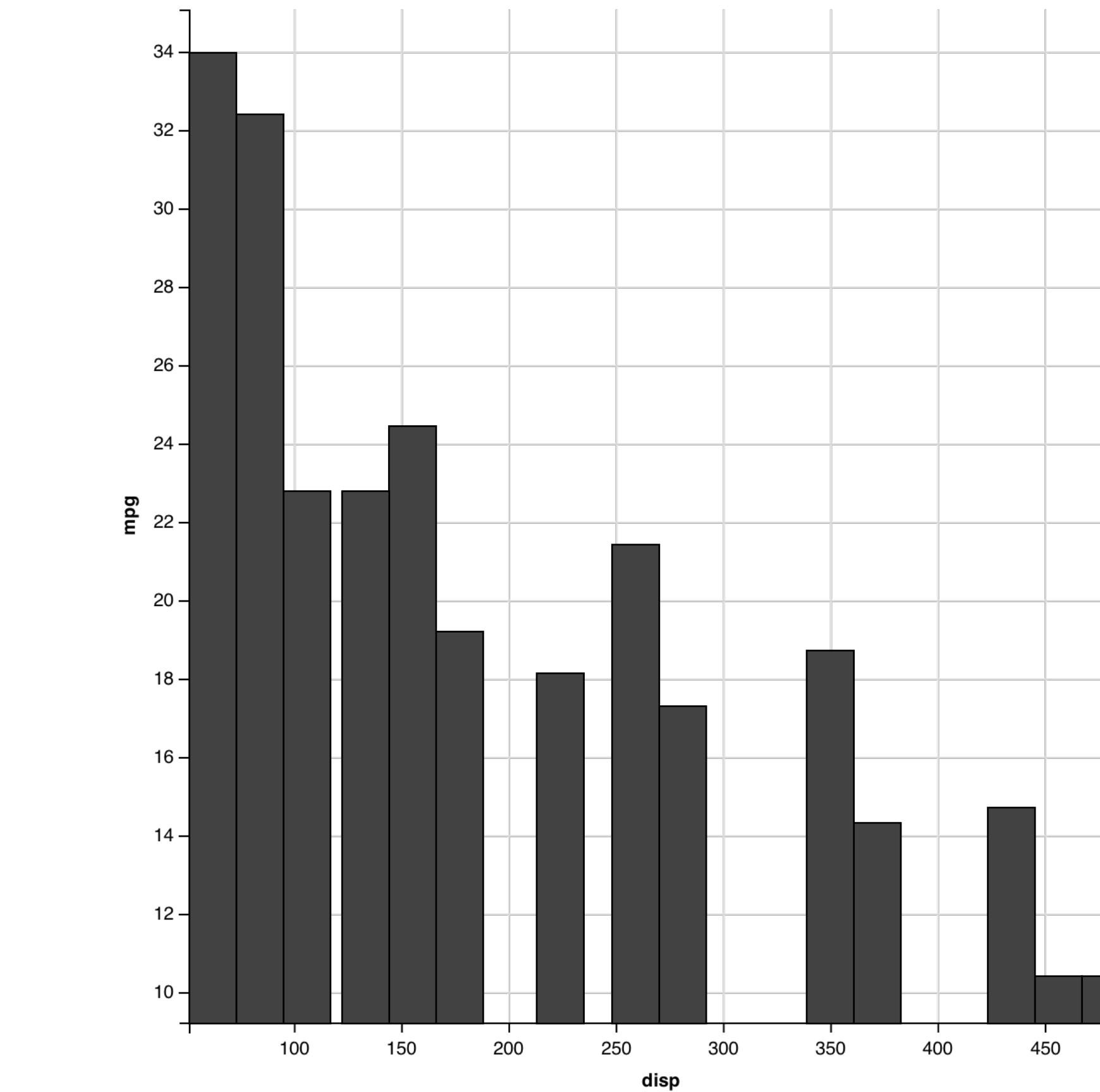
geom

points
lines
bars



mappings

mpg	cyl	disp	hp
21.0	6	160.0	2
21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1



data

geom
points
lines
bars

mappings

mpg	cyl	disp	hp
21.0	6	160.0	2
21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1



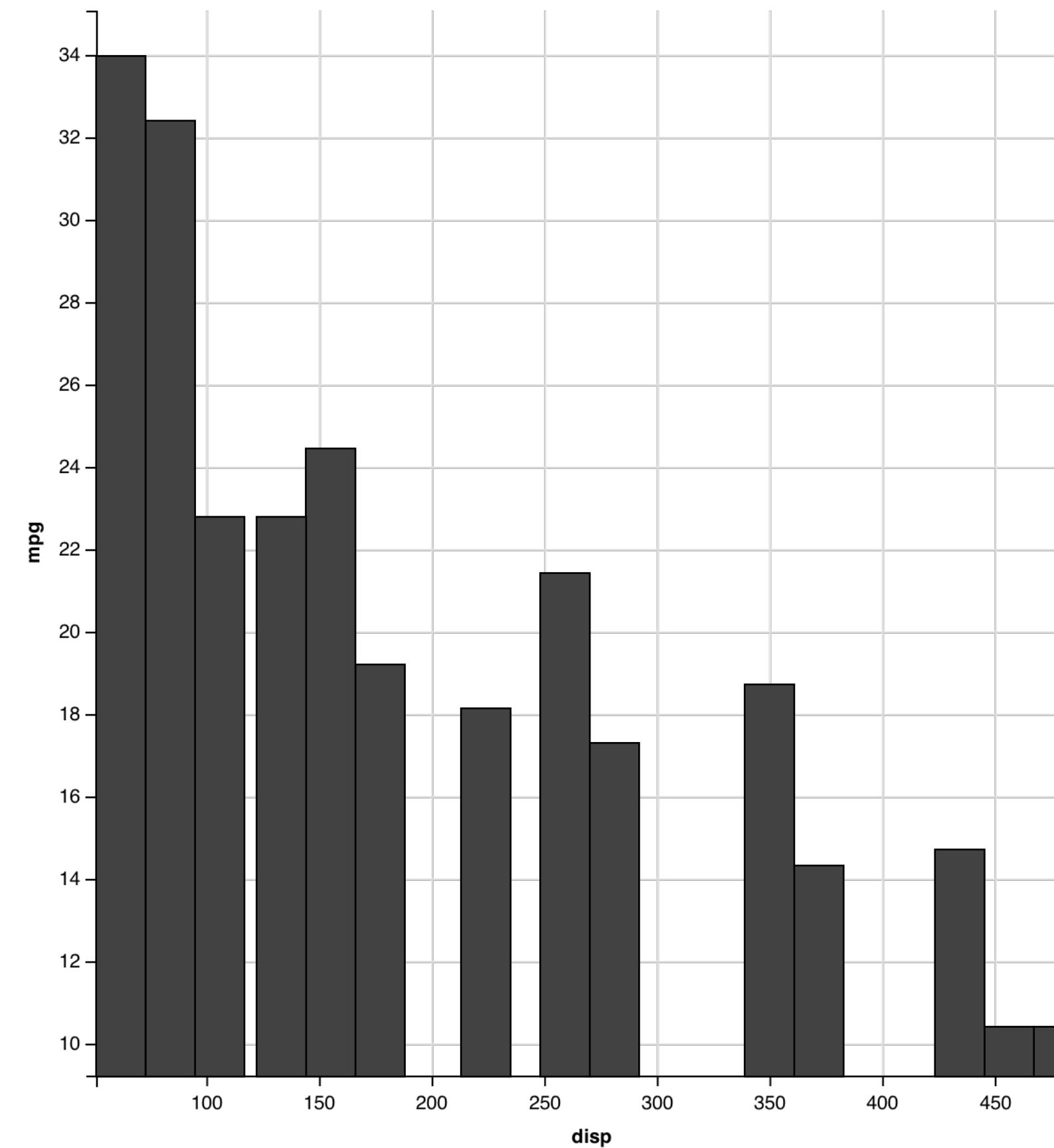
data

geom

points

lines

bars



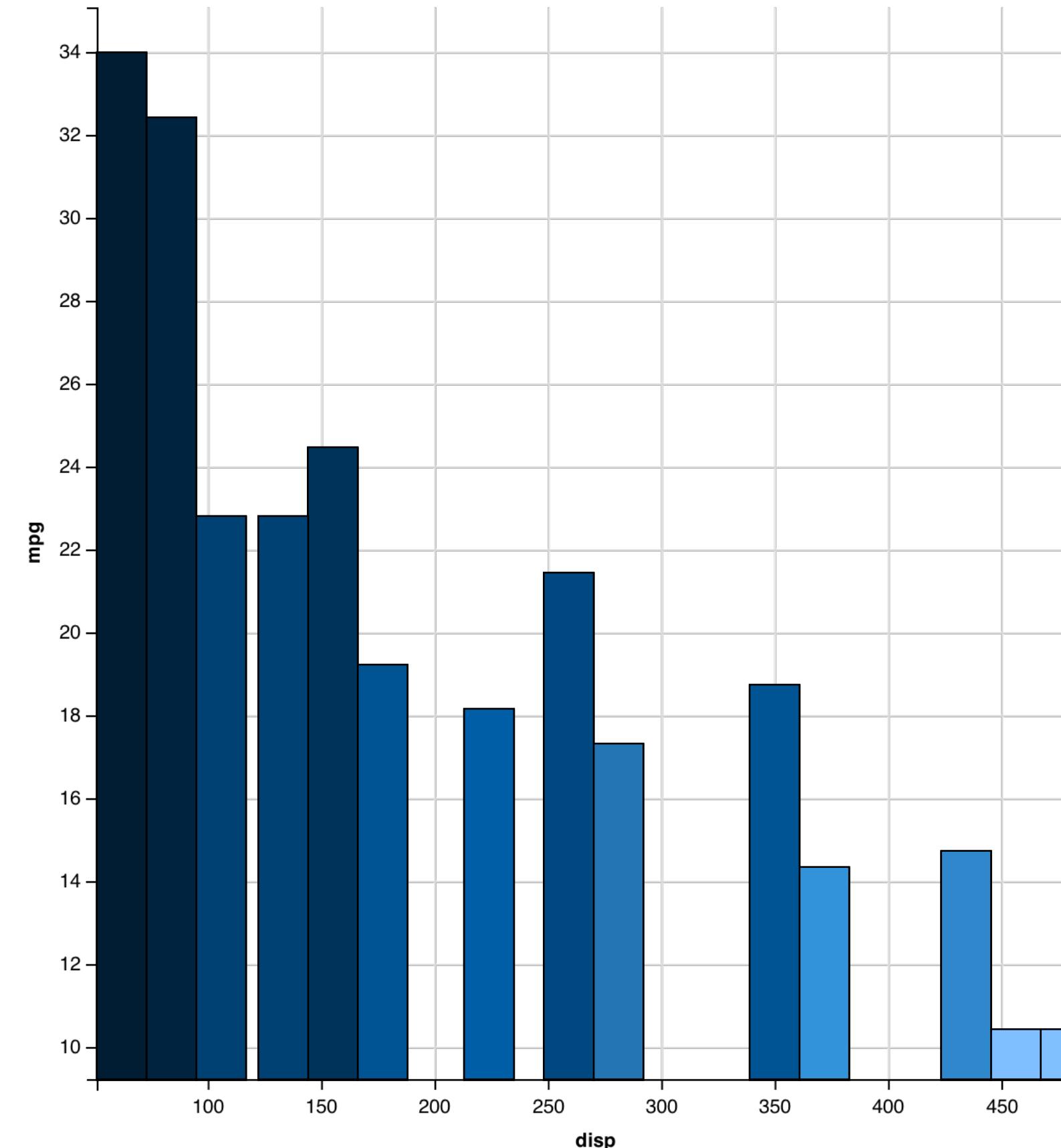
mappings

mpg	cyl	x fill disp	hp
21.0	6	160.0	2
21.0	6	160.0	2
22.8	4	108.0	1
21.4	6	258.0	2
18.7	8	360.0	3
18.1	6	225.0	2
14.3	8	360.0	5
24.4	4	146.7	1
22.8	4	140.8	1
19.2	6	167.6	2
17.8	6	167.6	2
16.4	8	275.8	3
17.3	8	275.8	3
15.2	8	275.8	3
10.4	8	472.0	4
10.4	8	460.0	4
14.7	8	440.0	4
32.4	4	78.7	1
30.4	4	75.7	1
33.9	4	71.1	1

data

geom

points
lines
bars

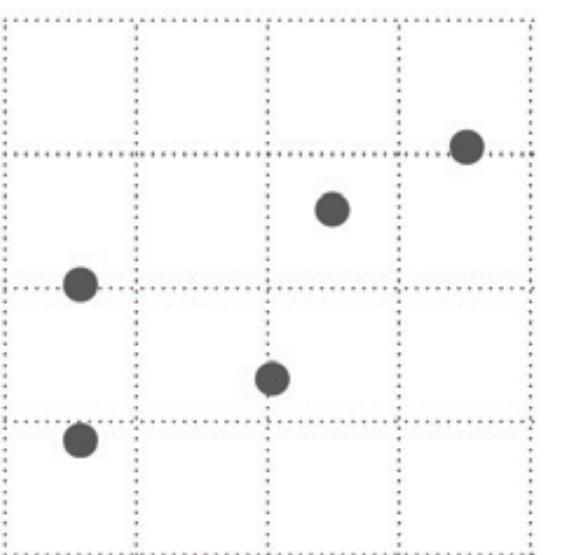


Visual cues

When you visualize data, you encode values to shapes, sizes, and colors.

Position

Where in space the data is



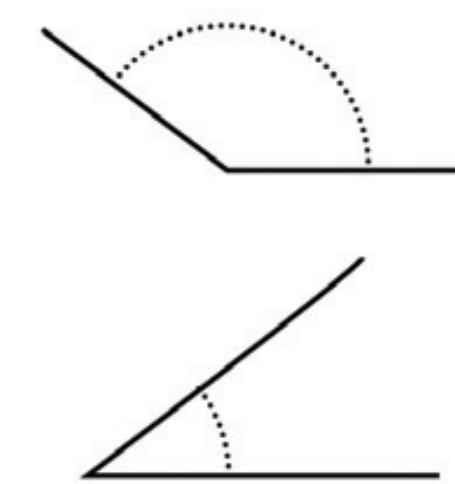
Length

How long the shapes are



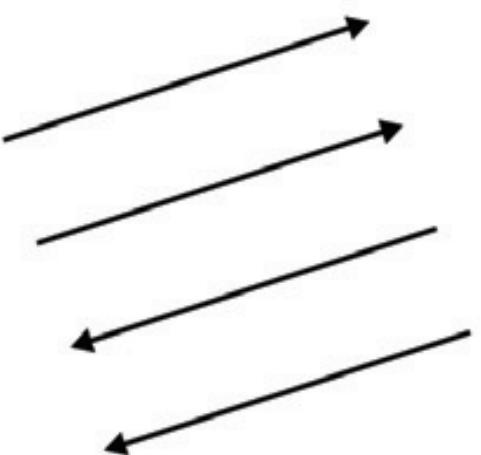
Angle

Rotation between vectors



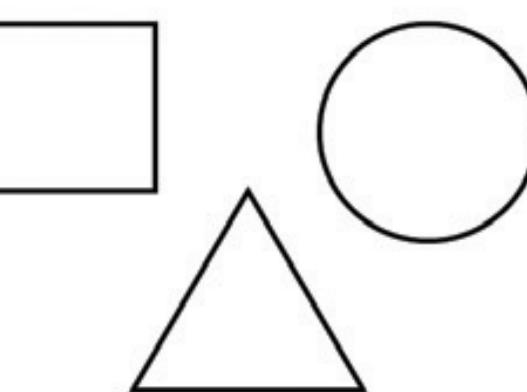
Direction

Slope of a vector in space



Shapes

Symbols as categories



Area

How much 2-D space



Volume

How much 3-D space



Color saturation

Intensity of a color hue



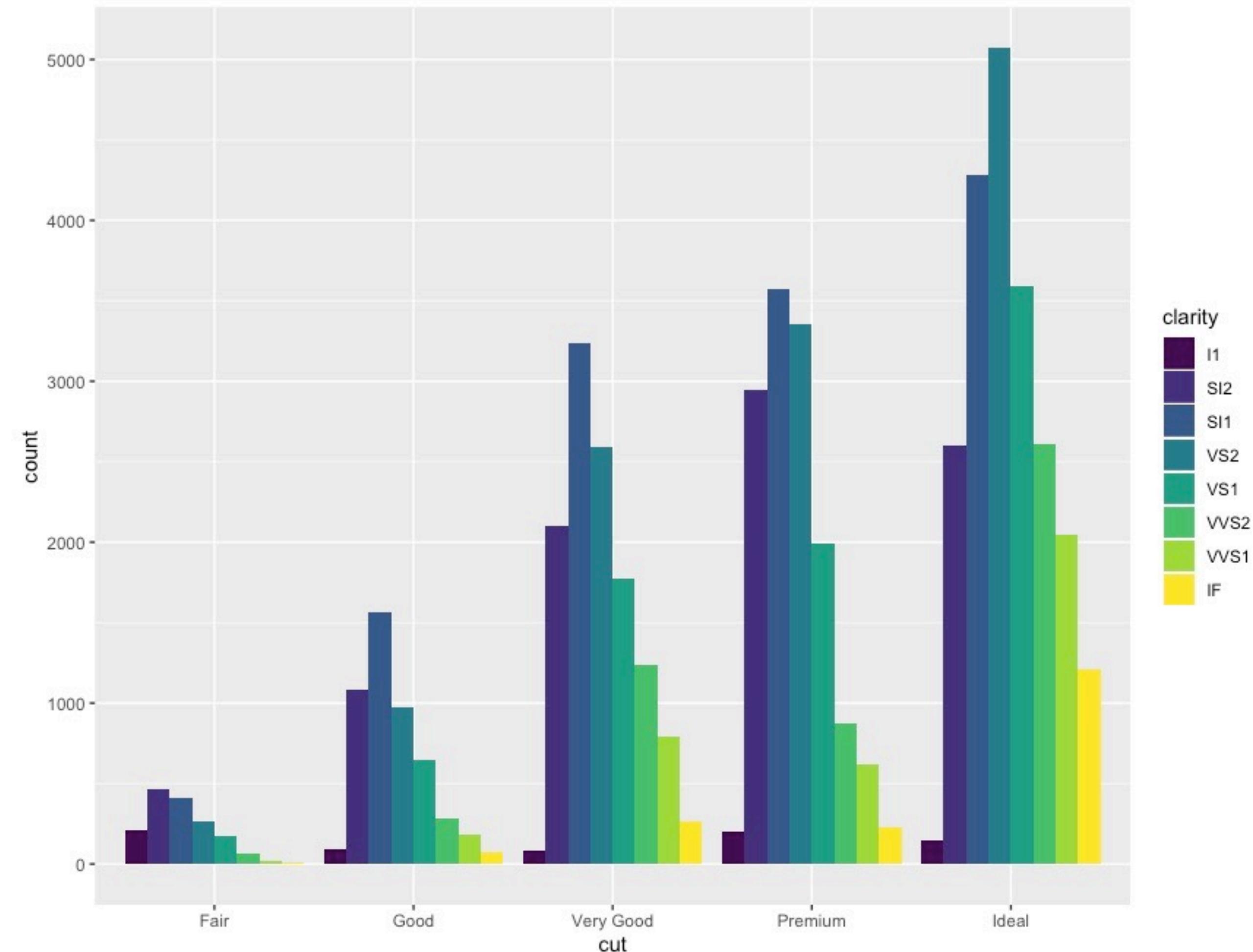
Color hue

Usually referred to as color



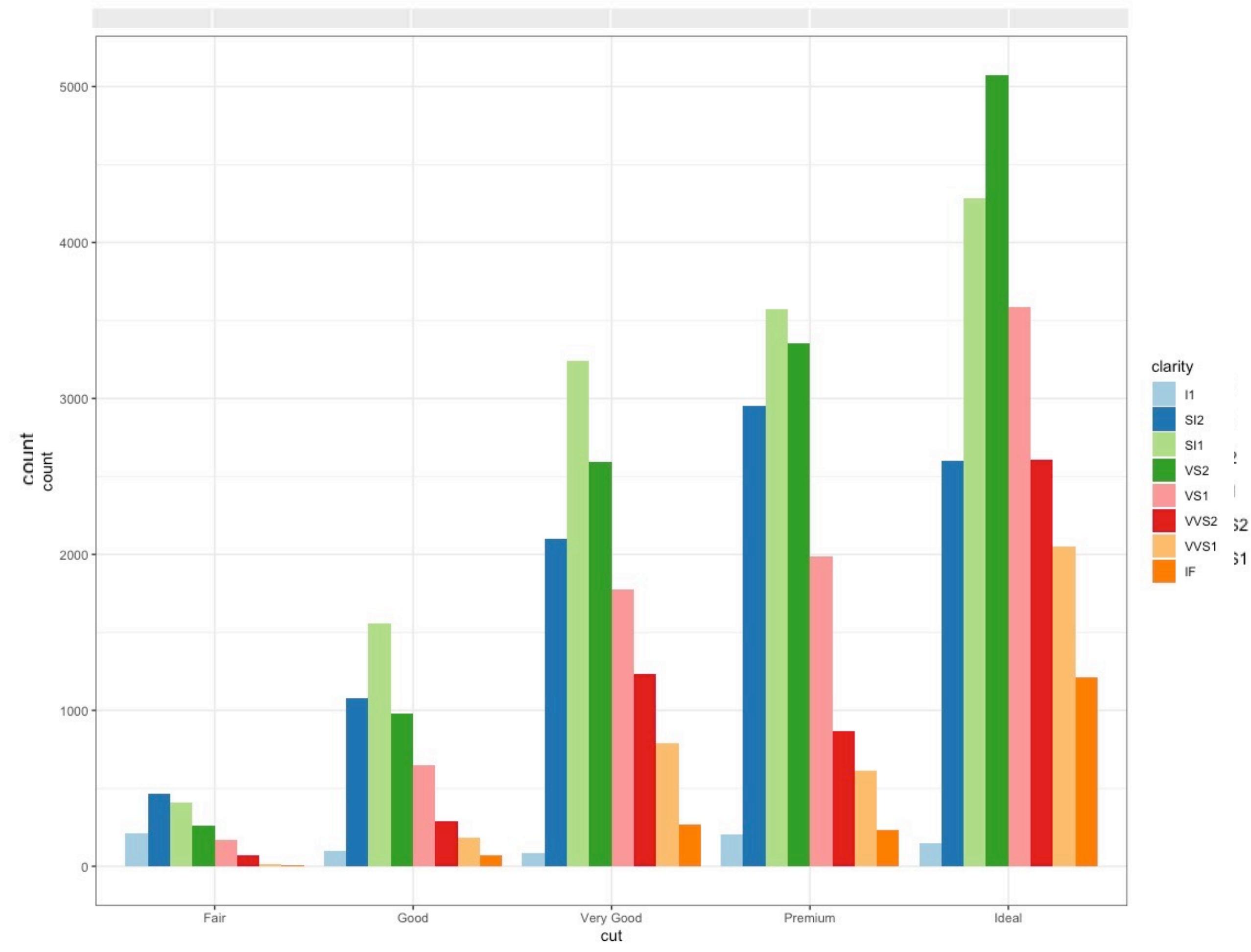
Position Adjustments

How overlapping objects are arranged



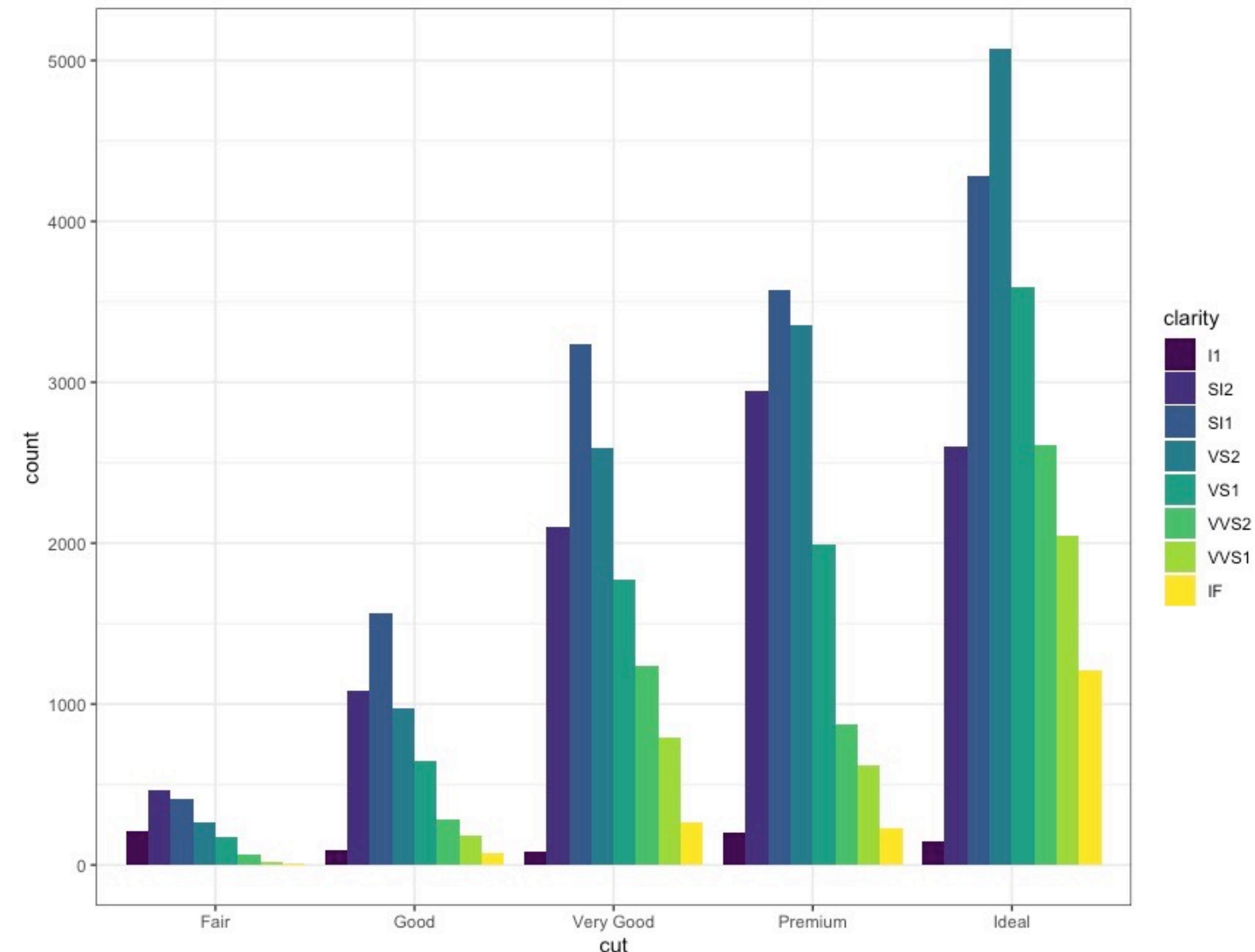
Scales

Customize color scales, other mappings

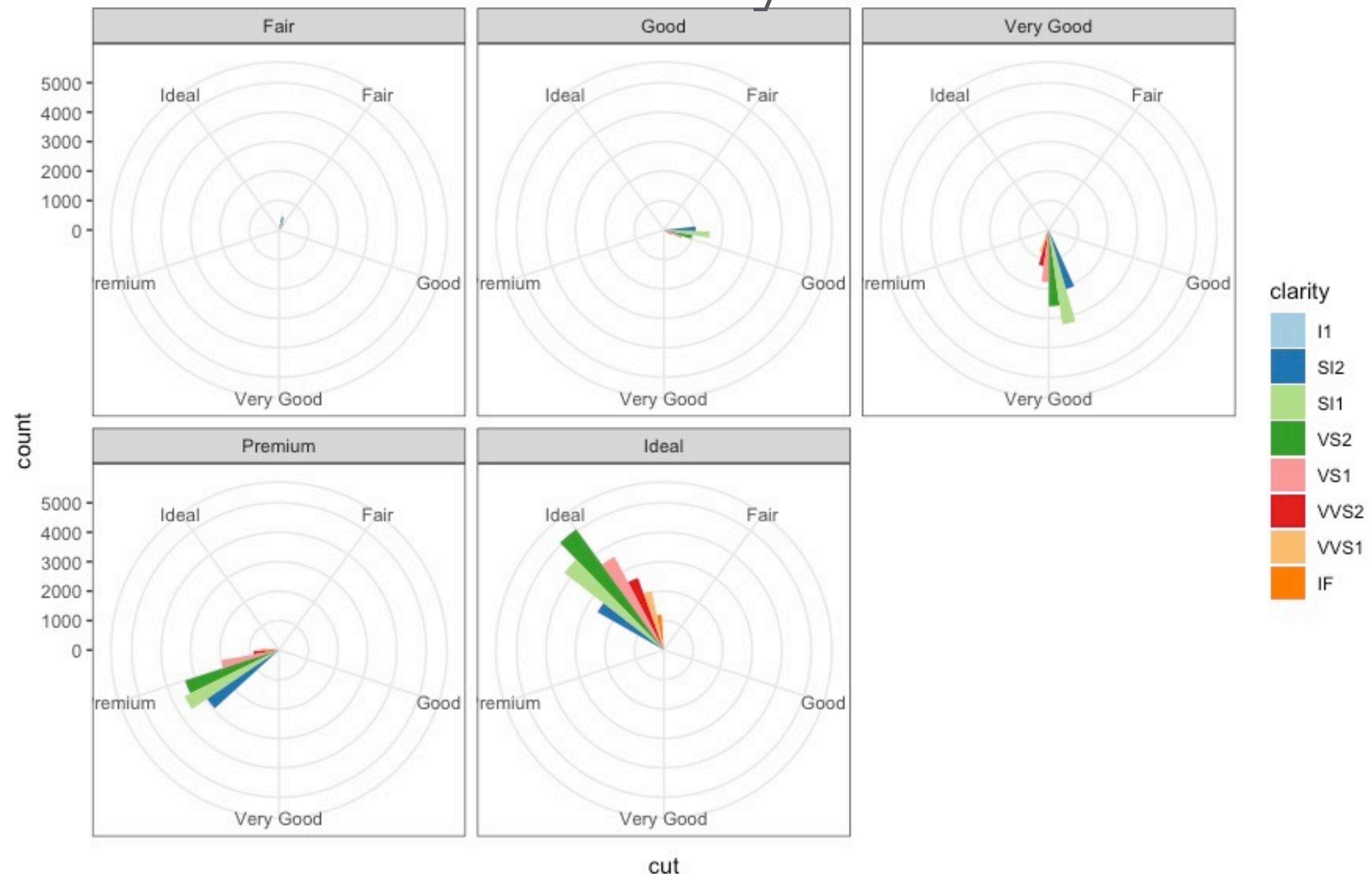


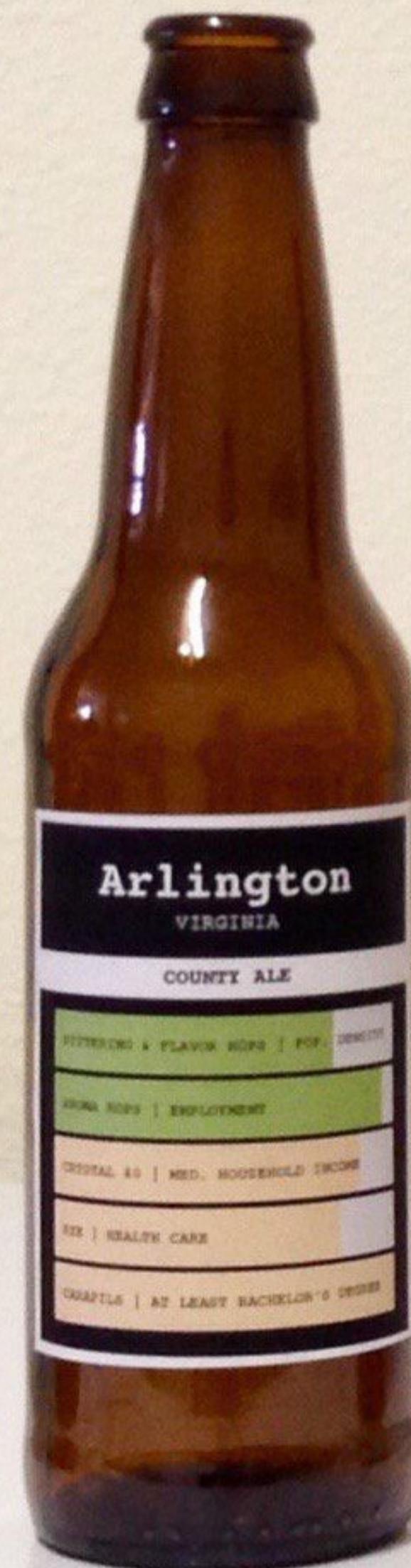
Themes

Visual appearance of non-data elements



Coordinate systems





Many implementations of the grammar of graphics

- ggplot2 (R package)
- d3.js (JavaScript package)
- Vega-lite (easier to use d3)
- Tableau (data visualization enterprise software)
- Plotly (Python library with ports to other languages)

SAT scores

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1400

1200

1000

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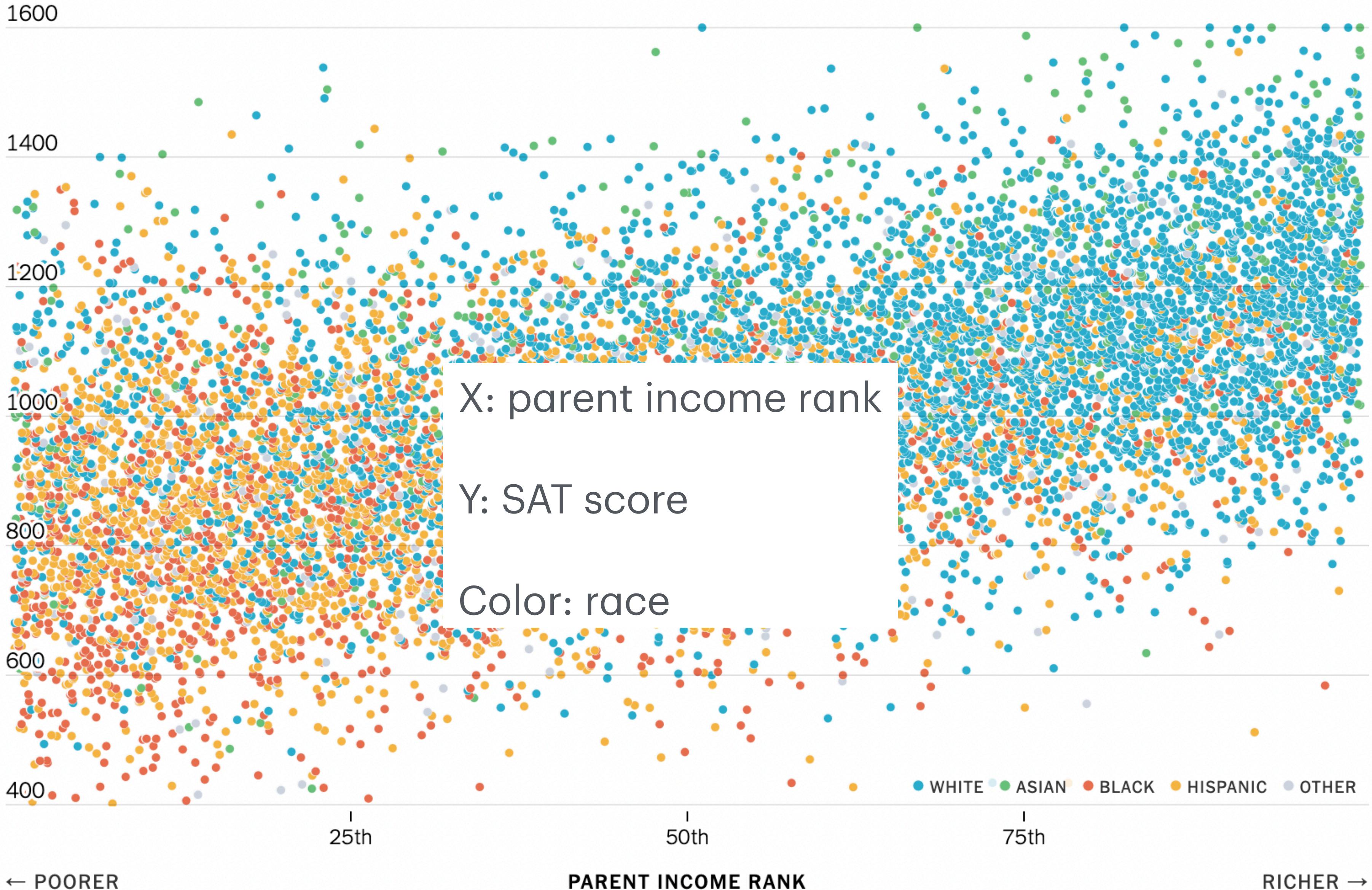
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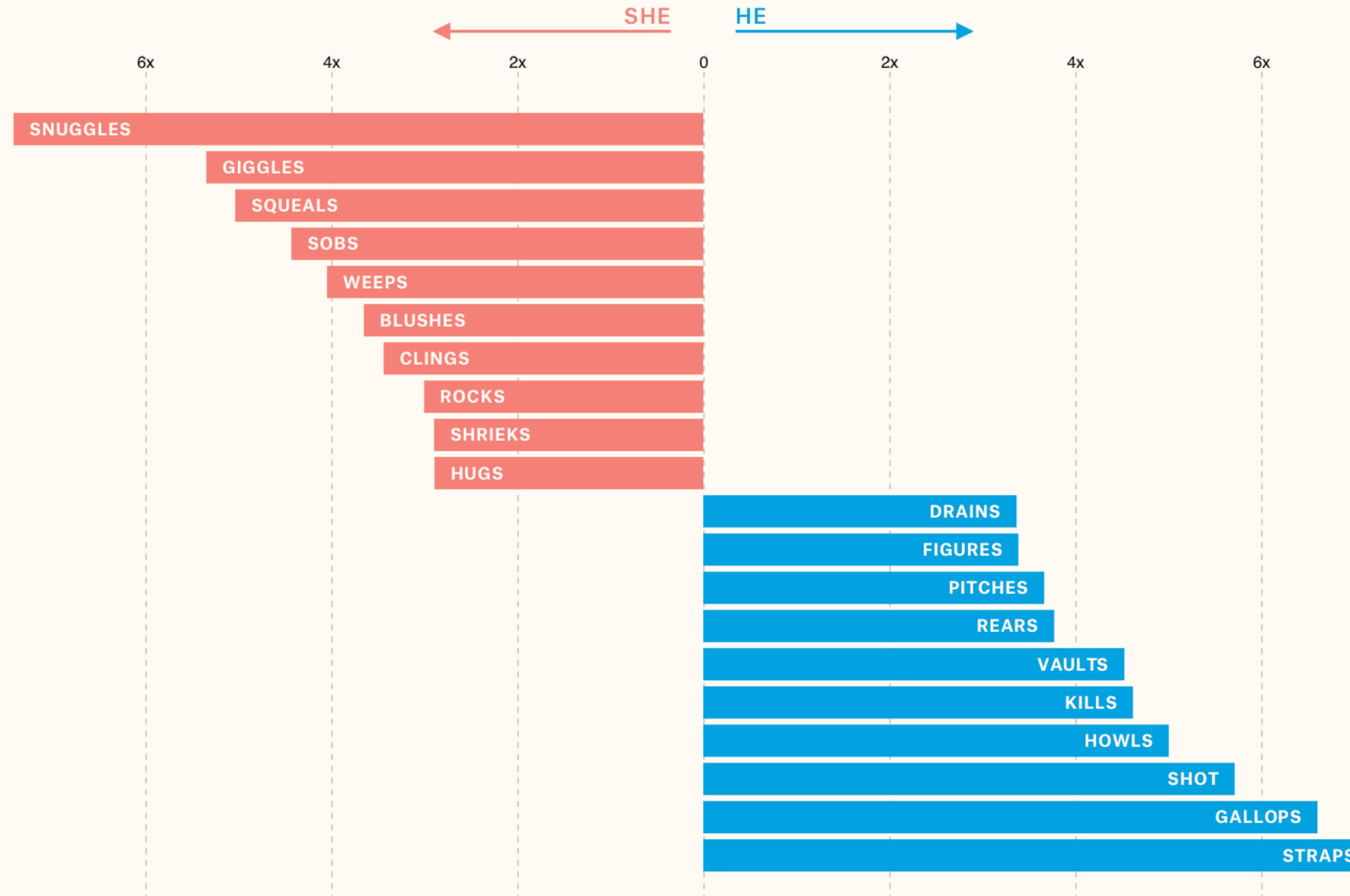
SAT scores



Can You Create a Diverse College Class Without Affirmative Action? Aatish Bhatia and Emily Badger
<https://www.nytimes.com/interactive/2024/03/09/upshot/affirmative-action-alternatives.html>

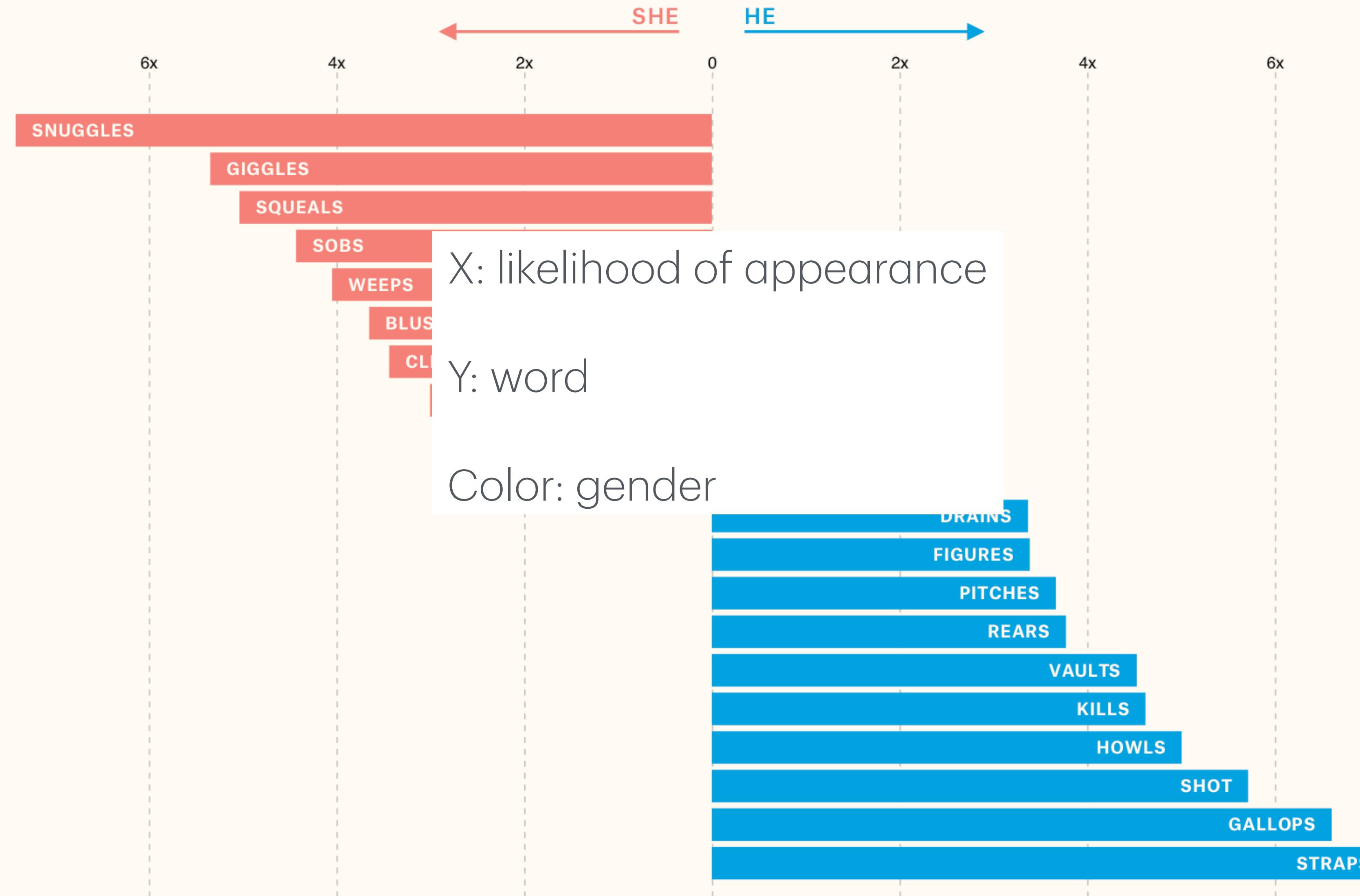
The most used words for women vs. men

Likelihood that certain words appear after “he” vs. “she” in screen direction.

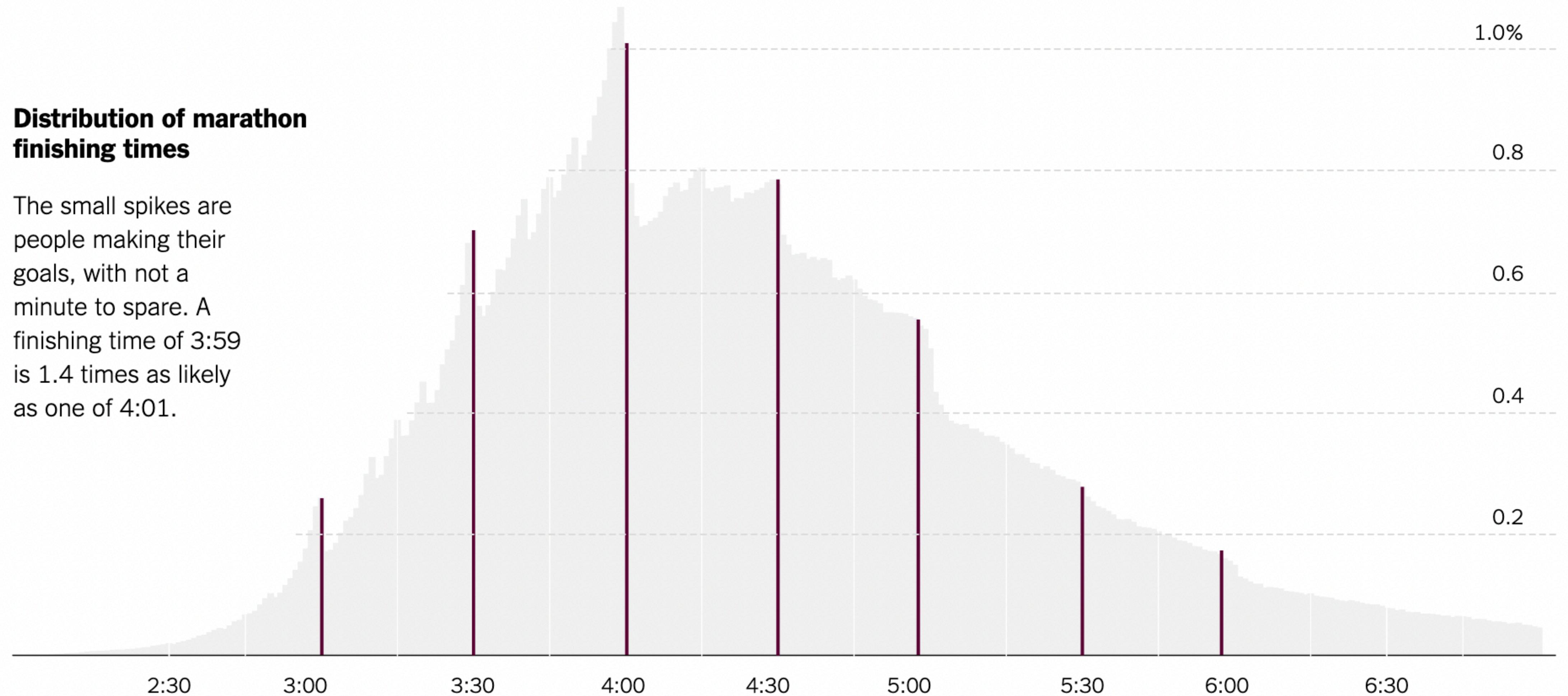


The most used words for women vs. men

Likelihood that certain words appear after “he” vs. “she” in screen direction.



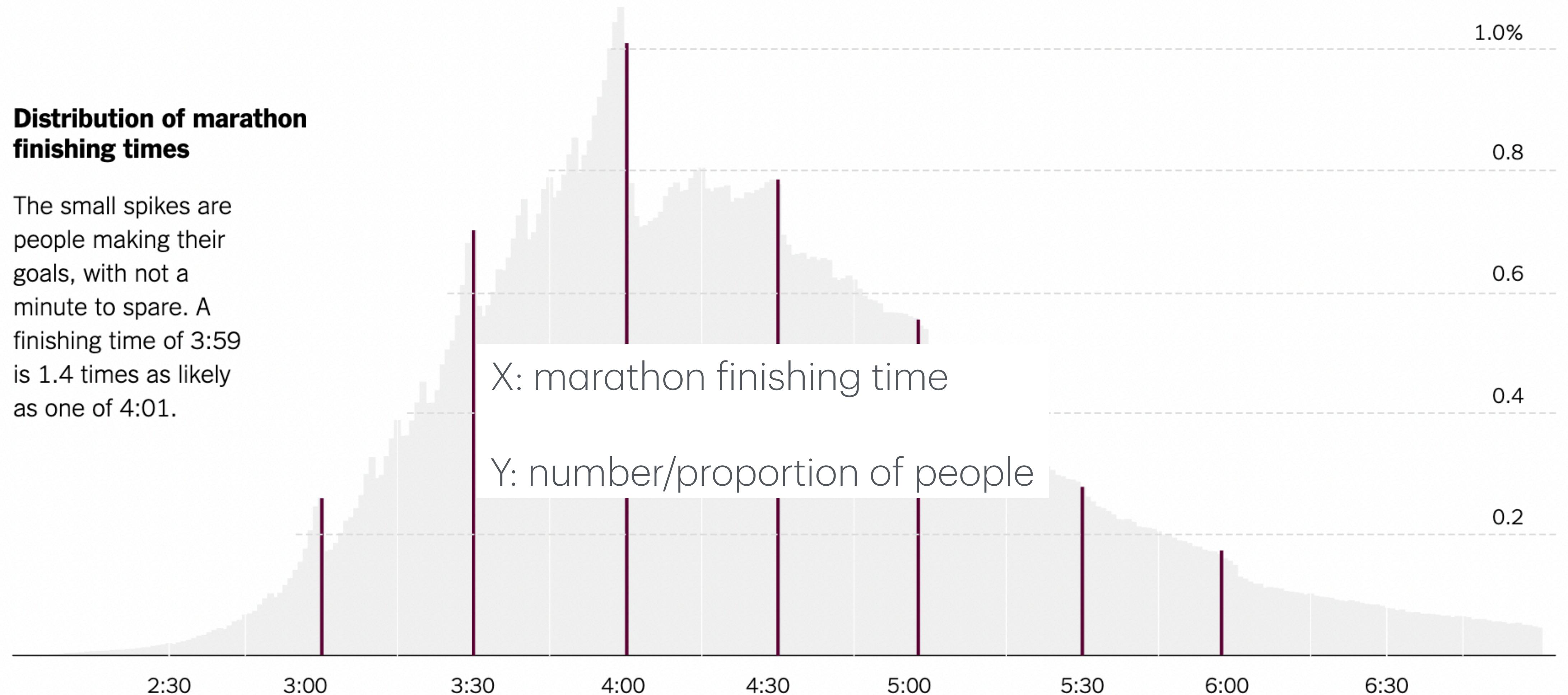
Arbitrary goals, like round numbers, can be motivating – just ask 9 million marathoners.



Based on data from Eric Allen, USC, Patricia Dechow, U.C. Berkeley, Devin Pope and George Wu, University of Chicago.

What Good Marathons and Bad Investments Have in Common. Justin Wolfers
<https://www.nytimes.com/2014/04/23/upshot/what-good-marathons-and-bad-investments-have-in-common.html>

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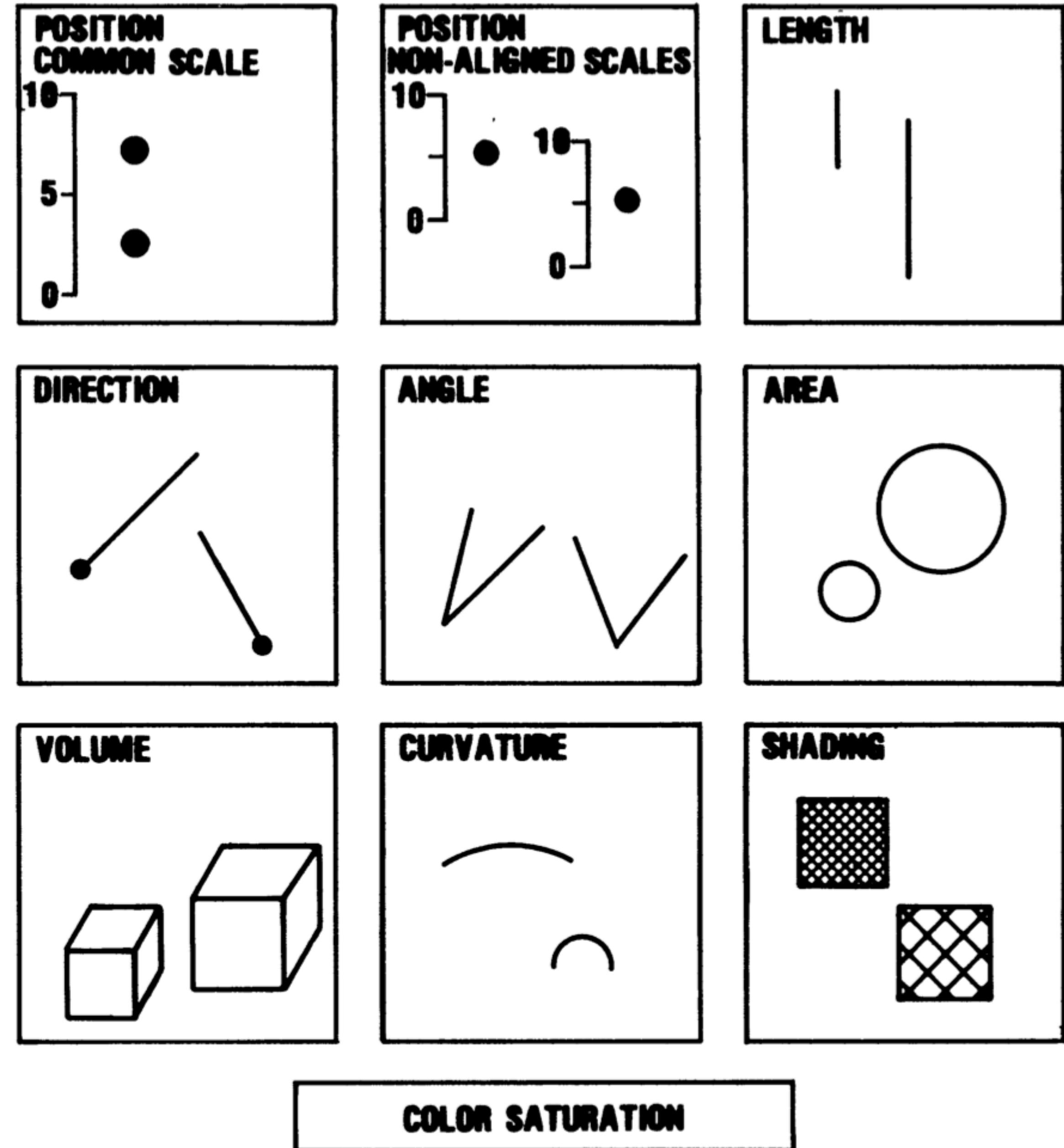
<https://www.nytimes.com/2014/04/23/upshot/what-good-marathons-and-bad-investments-have-in-common.html>

Graphical perception

Cleveland and McGill, 1984

The following are the 10 elementary tasks in Figure 1, ordered from most to least accurate:

1. Position along a common scale
2. Positions along nonaligned scales
3. Length, direction, angle
4. Area
5. Volume, curvature
6. Shading, color saturation



William Cleveland and Robert McGill. "Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods." Journal of the American Statistical Association, 79(387). 1984.
<http://info.slis.indiana.edu/~katy/S637-S11/cleveland84.pdf>

Figure 1. Elementary perceptual tasks.

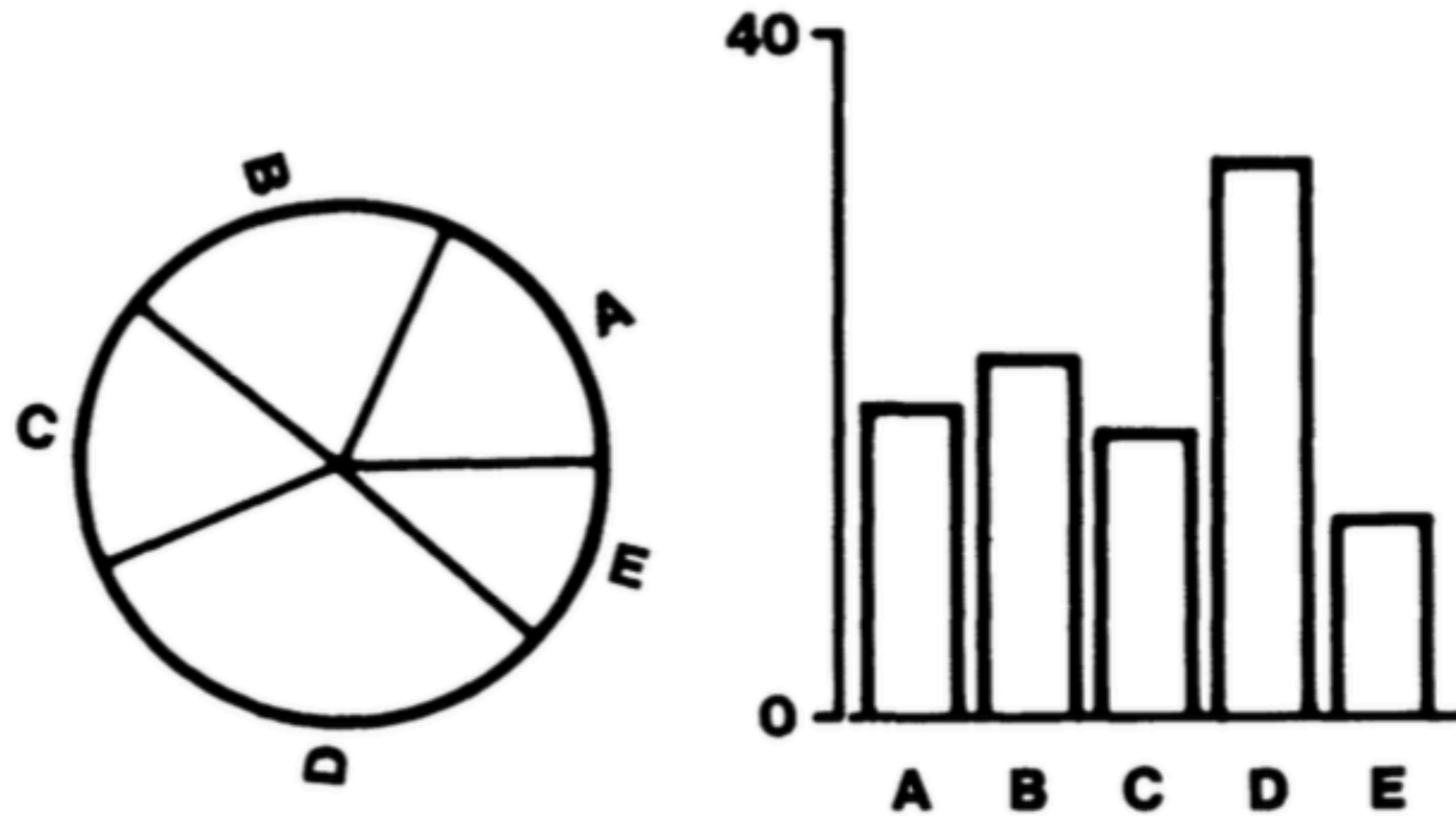


Figure 3. Graphs from position-angle experiment.

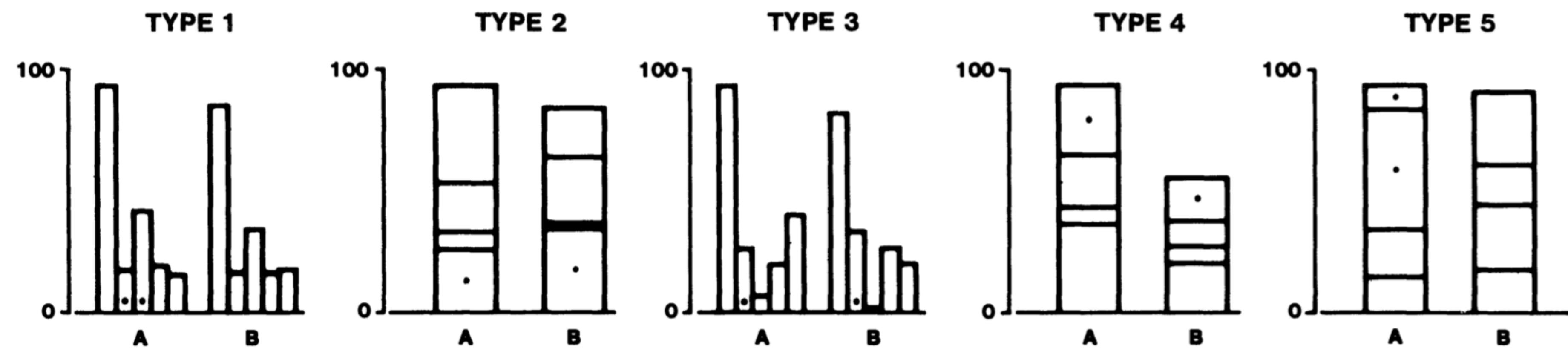
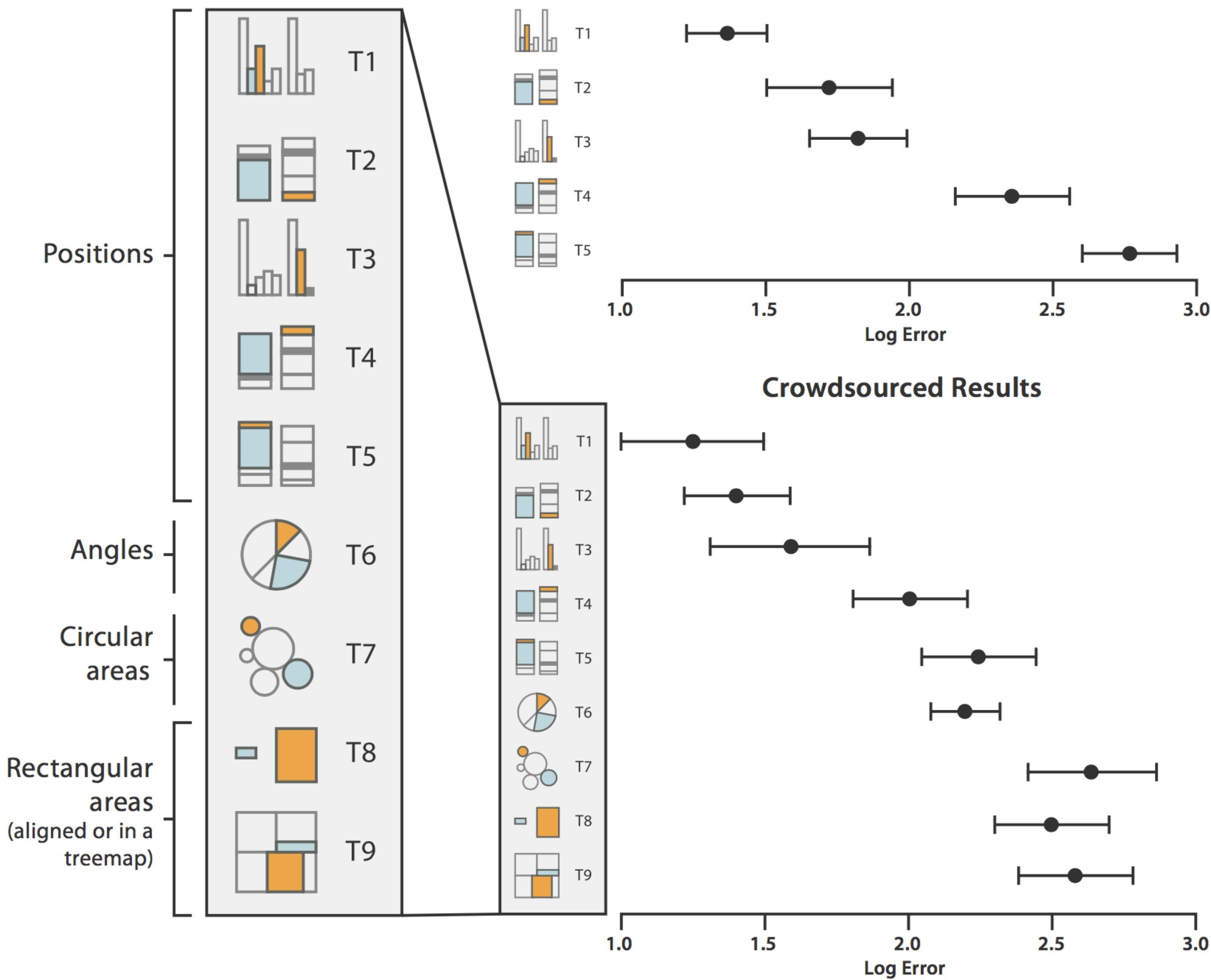


Figure 4. Graphs from position-length experiment.

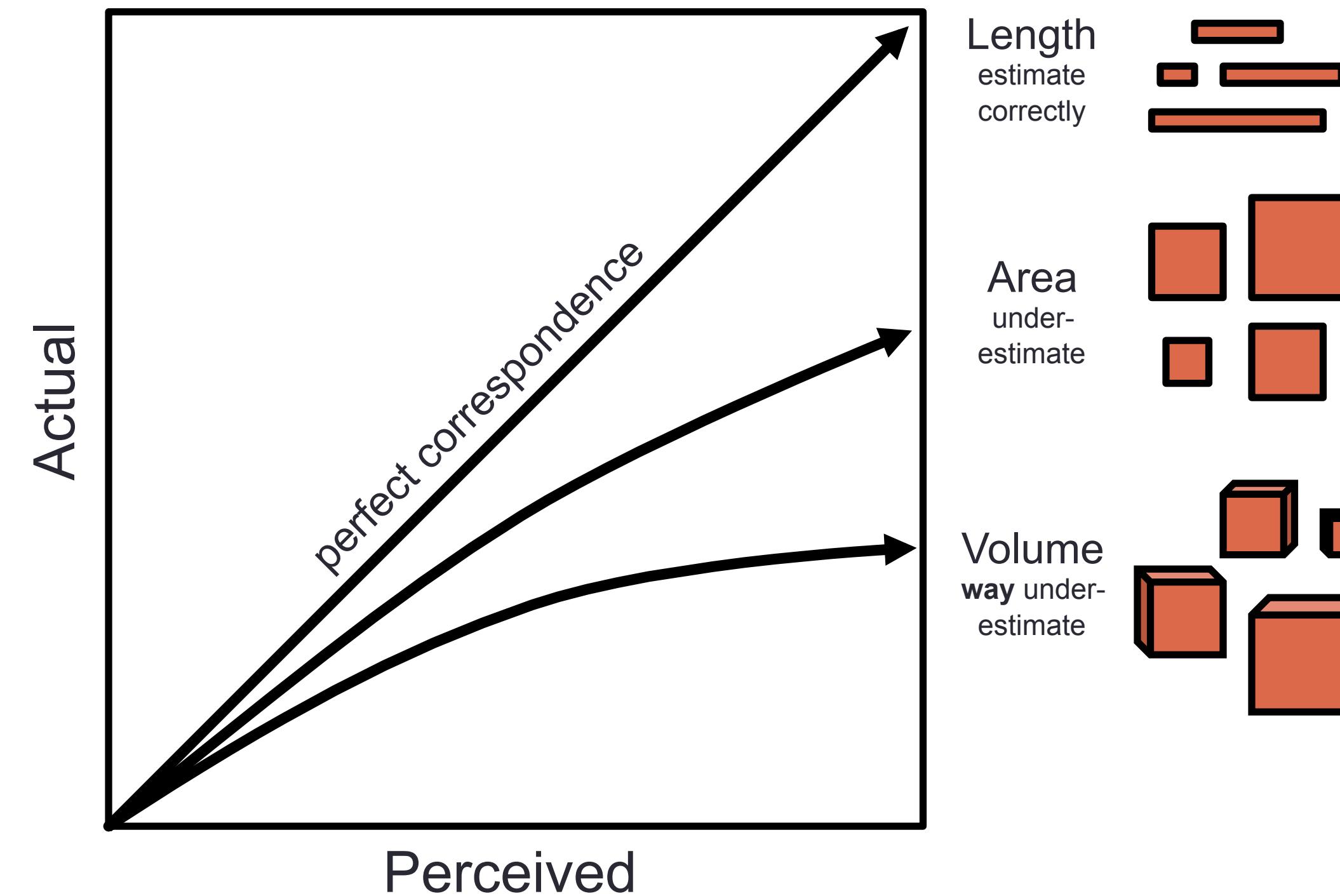
Cleveland & McGill's Results

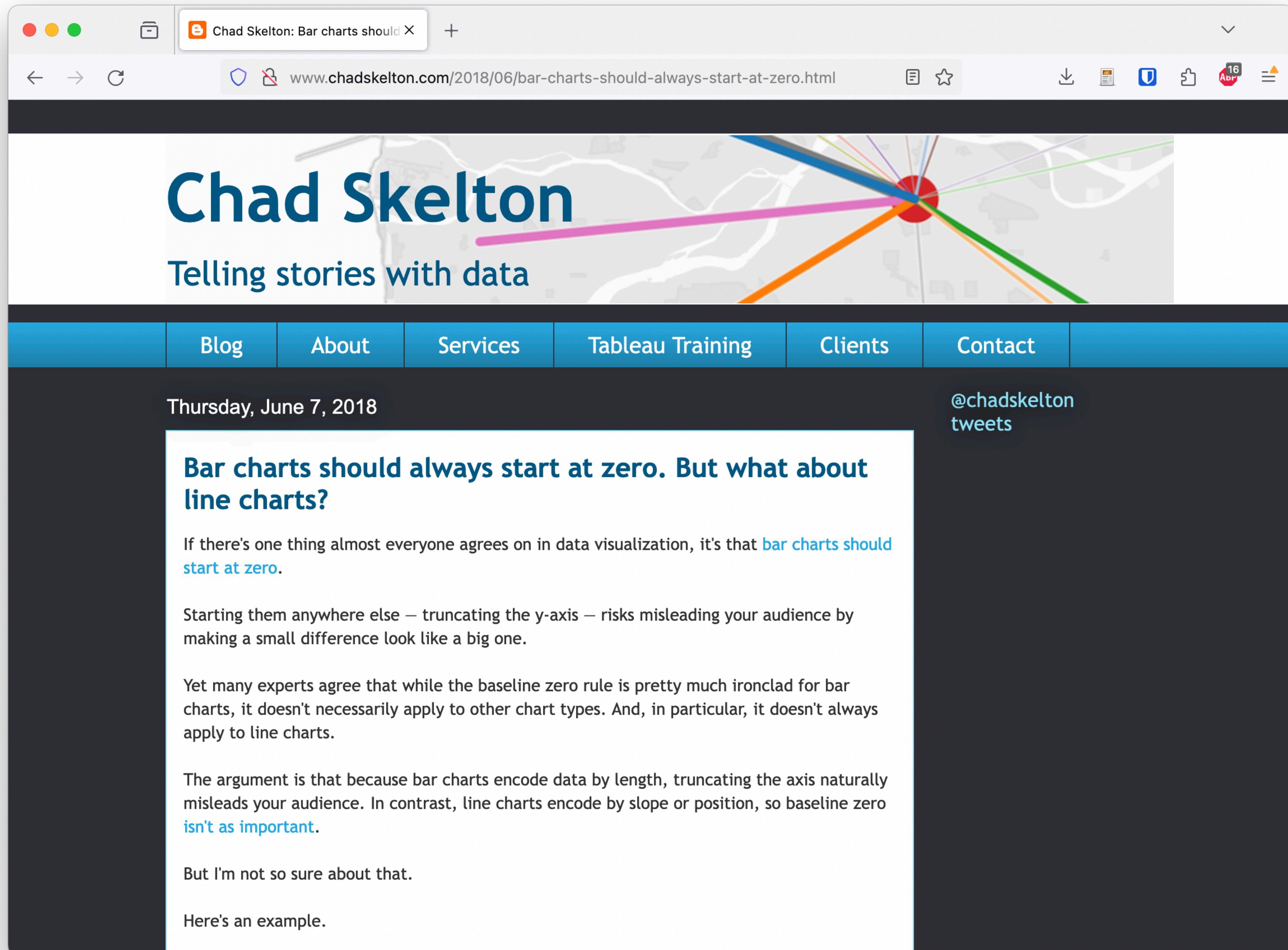


Crowdsourced Results

Jeff Heer and Mike Bostock. "Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design" <http://vis.stanford.edu/files/2010-MTurk-CHI.pdf>

“Apparent” magnitude





A screenshot of a web browser displaying the homepage of www.chadskelton.com. The page features a large banner with the text "Chad Skelton" and "Telling stories with data". Below the banner is a navigation menu with links to "Blog", "About", "Services", "Tableau Training", "Clients", and "Contact". A date "Thursday, June 7, 2018" is displayed near the top left. On the right side, there is a link "@chadskelton tweets". The main content area contains an article titled "Bar charts should always start at zero. But what about line charts?". The article discusses the conventions of data visualization, specifically regarding bar charts starting at zero and how this rule applies differently to line charts.

Chad Skelton

Telling stories with data

Blog About Services Tableau Training Clients Contact

Thursday, June 7, 2018

@chadskelton tweets

Bar charts should always start at zero. But what about line charts?

If there's one thing almost everyone agrees on in data visualization, it's that [bar charts should start at zero](#).

Starting them anywhere else – truncating the y-axis – risks misleading your audience by making a small difference look like a big one.

Yet many experts agree that while the baseline zero rule is pretty much ironclad for bar charts, it doesn't necessarily apply to other chart types. And, in particular, it doesn't always apply to line charts.

The argument is that because bar charts encode data by length, truncating the axis naturally misleads your audience. In contrast, line charts encode by slope or position, so baseline zero [isn't as important](#).

But I'm not so sure about that.

Here's an example.

Bar charts should always start at zero. But what about line charts? Chad Skelton
<http://www.chadskelton.com/2018/06/bar-charts-should-always-start-at-zero.html>

The screenshot shows a web browser window displaying a blog post titled "New Video: The Science of Pie Charts" from the website eagereyes.org. The browser interface includes a top bar with tabs, a search bar, and various icons. The main content area features a large heading, a detailed text explanation, and a video thumbnail.

Eagereyes

Blog

- Blog 2024 >
- Blog 2023 >
- Blog 2022 >
- Blog 2021 >
- New Video: The Science of Pie Charts
- Paper: From Jam Session to Recital: Synchronous Communication and Collaboration Around Data in Organizations
- EagerEyes Turns 15
- Can A Timeline Pie Chart Work?
- New video: Chart Appreciation, Iraq's Bloody Toll by Simon Scarr
- When the Wrong Chart Is the Right Choice
- New Video: Linear vs. Quadratic Change
- New video: Florence Nightingale's Famous Rose Chart (aka "Coxcomb")

New Video: The Science of Pie Charts

The common explanation for how pie charts work is that we read them by angle. That of course would mean that donut charts would be bad, because you can't see the angle when you take away the center of the pie. Changing the radius of a slice wouldn't matter though, because that doesn't change the angle. But there is no evidence that angle is how we read pie charts, quite the opposite actually. In this new video, I walk through five reasons why angle is not how we read pies, and what that means for other things we like to assume about them.

If you've been following this blog, you've seen me talk about [my pie chart papers](#). This video summarizes them in a way that I hope is interesting, informative, and entertaining. You can watch it below or [over on YouTube](#) (the latter is preferred so you can leave a comment, subscribe, etc.).



The Science of Pie Charts, Robert Kosara

<https://eagereyes.org/blog/2021/new-video-the-science-of-pie-charts>