



BGGN 213

Data visualization with R

Lecture 5

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UC San Diego

<http://thegrantlab.org/bggn213>

Recap From Last Time:

- What is R and why should we use it?
- Familiarity with R's basic syntax.
- Familiarity with major R data structures namely **vectors** and **data.frames**.
- Understand the basics of using **functions** (arguments, vectorization and re-cycling).
- Appreciate how you can use R scripts to aid with reproducibility.

DataCamp Homework Reminder!!

Today's Learning Goals

- Appreciate the major elements of **exploratory data analysis** and why it is important to visualize data.
- Be conversant with **data visualization best practices** and understand how good visualizations optimize for the human visual system.
- Be able to generate informative graphical displays including **scatterplots**, **histograms**, **bar graphs**, **boxplots**, **dendograms** and **heatmaps** and thereby gain exposure to the extensive graphical capabilities of R.
- Appreciate that you can build even more complex charts with **ggplot** and additional R packages such as **rgl**.

Why visualize at all?

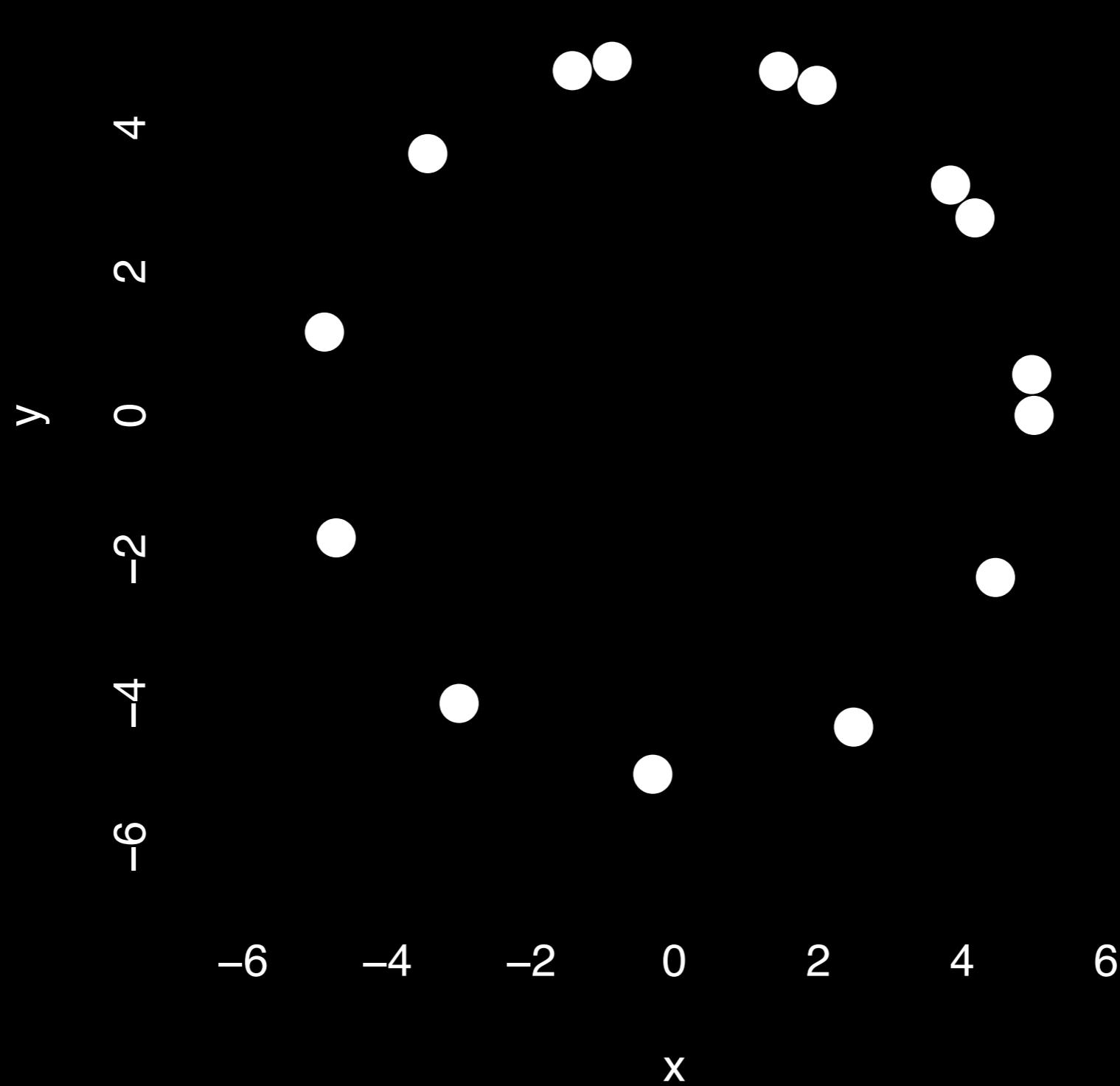
Over-the-Counter

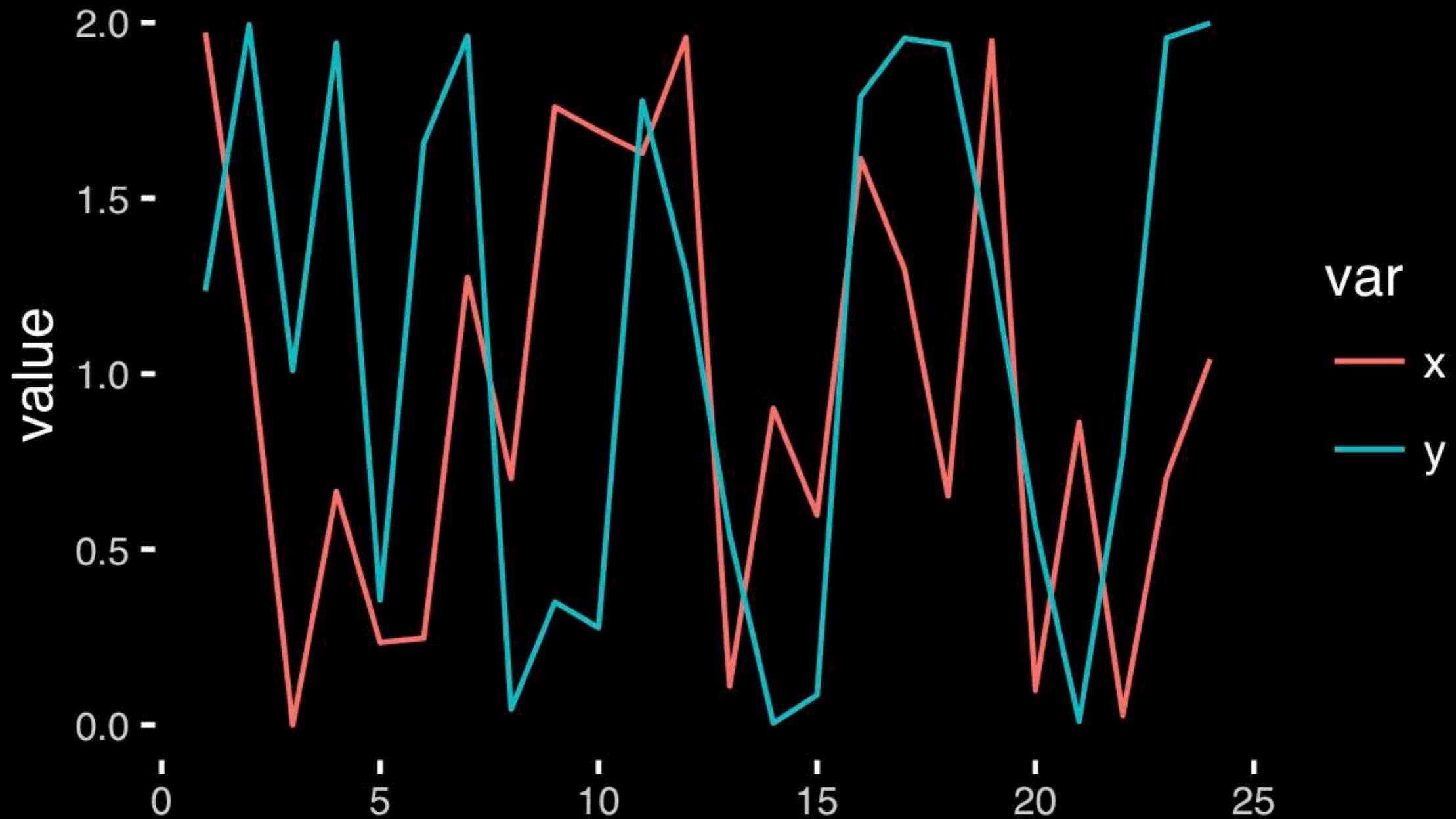
National Market System

The companies listed below reflect the volume in 100's of shares on a daily basis and the closing price and net change are reflected from the previous day based on trades as provided under the ASX200 Retailer Market System.

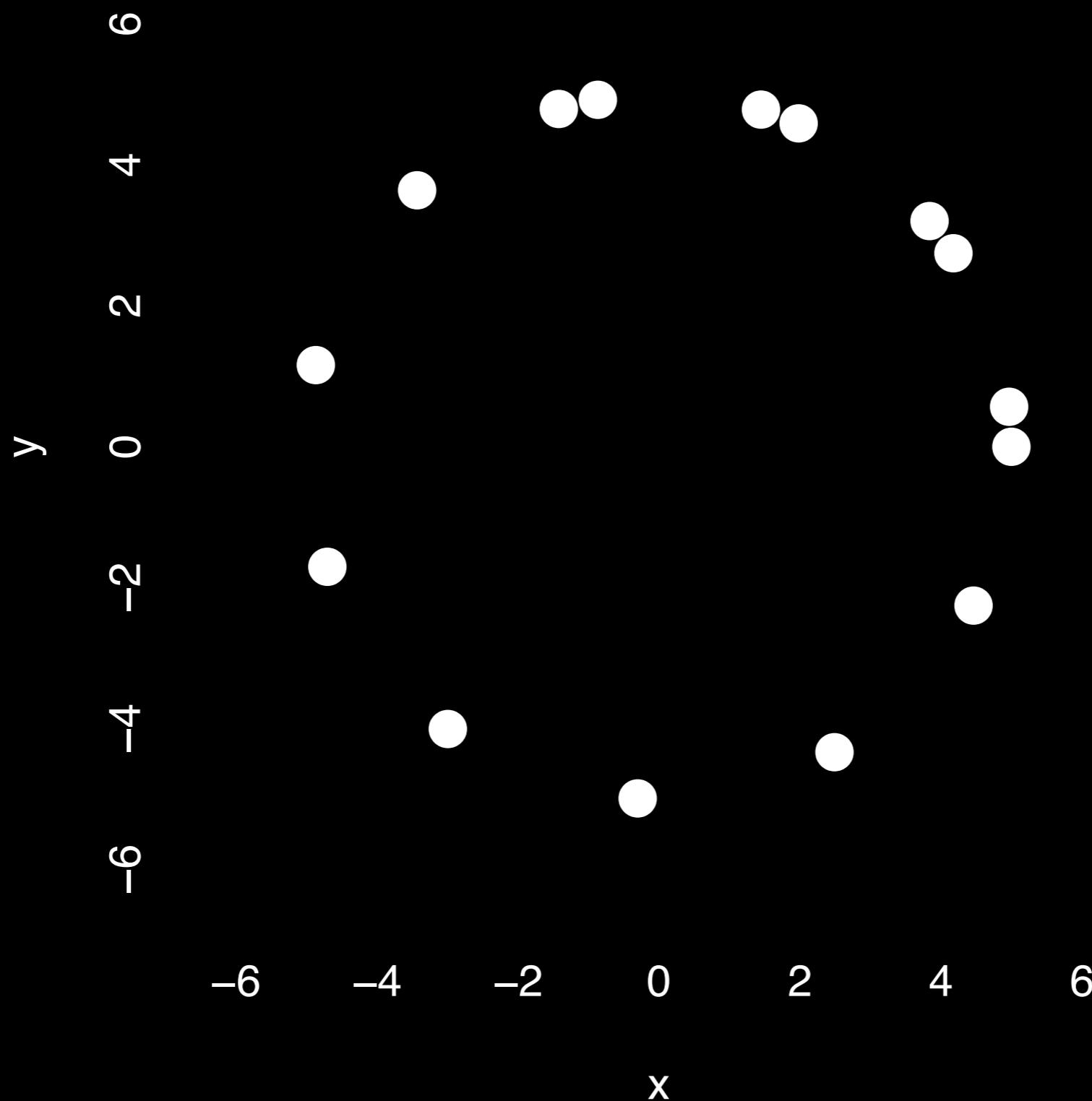
	x	y
1	5.00	0.00
2	4.18	2.75
3	1.98	4.59
4	-0.86	4.92
5	-3.43	3.64
6	-4.86	1.16
7	-4.70	-1.70
8	-2.99	-4.01
9	-0.30	-4.99
10	2.49	-4.34
11	4.46	-2.25
12	4.97	0.57
13	3.84	3.20
14	1.45	4.79
15	-1.42	4.79

	x	y
Min.	-4.86	-4.99
1st Qu.	-2.21	-1.98
Median	1.45	1.16
Mean	0.65	0.87
3rd Qu.	4.01	4.12
Max.	5.00	4.92





https://bioboot.github.io/bggns18/class-material/05_draw_circle_points/

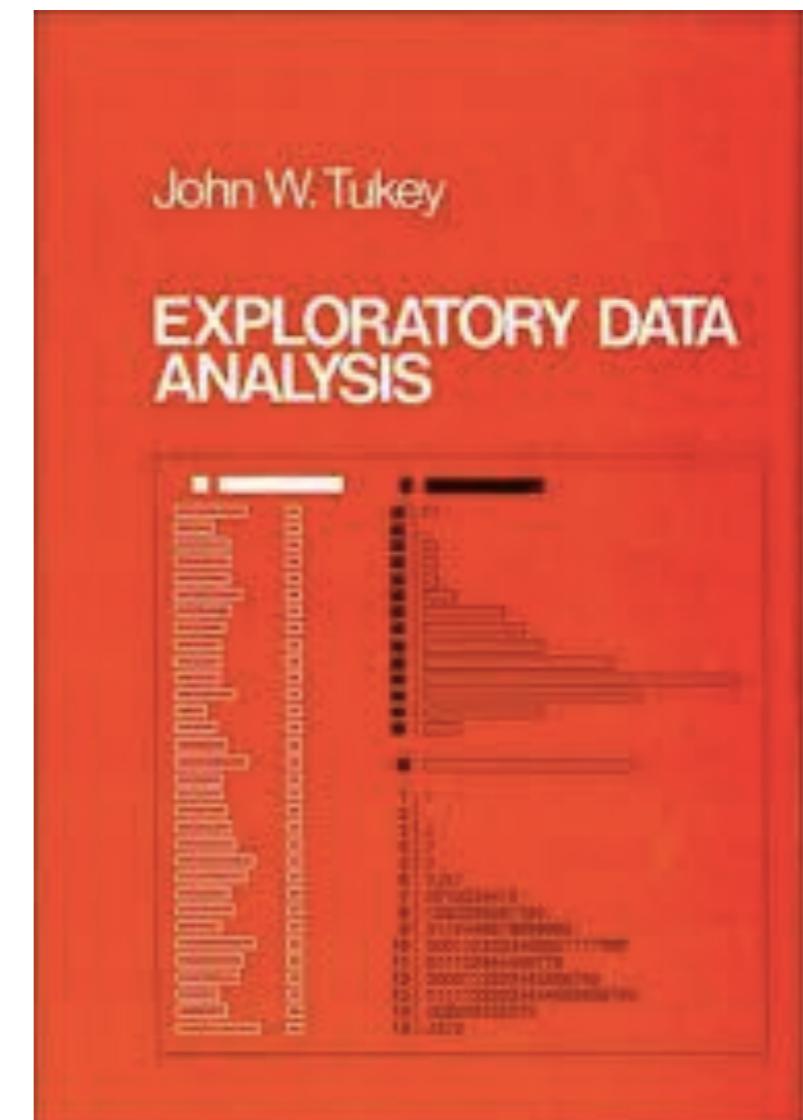


Exploratory Data Analysis

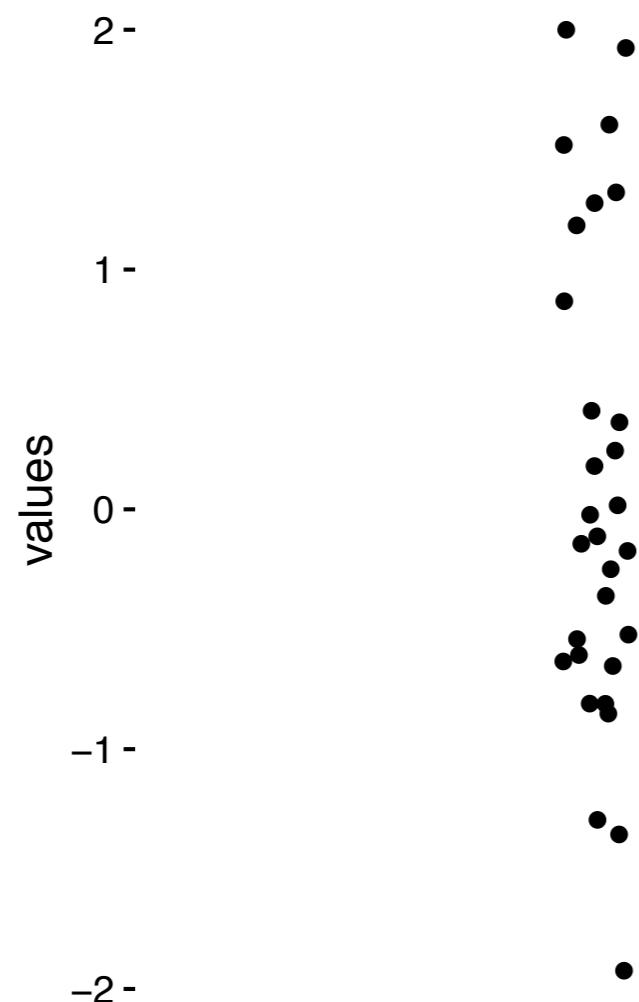
- ALWAYS look at your data!
- If you can't see it, then don't believe it!
- Exploratory Data Analysis (EDA) allows us to:
 1. Visualize distributions and relationships
 2. Detect errors
 3. Assess assumptions for confirmatory analysis
- EDA is the first step of data analysis!

Exploratory Data Analysis 1977

- Based on insights developed at Bell Labs in the 60's
- Techniques for visualizing and summarizing data
- What can the data tell us? (in contrast to "confirmatory" data analysis)
- Introduced many basic techniques:
 - 5-number summary, box plots, stem and leaf diagrams,...
- 5 Number summary:
 - extremes (min and max)
 - median & quartiles
 - More robust to skewed & longtailed distributions



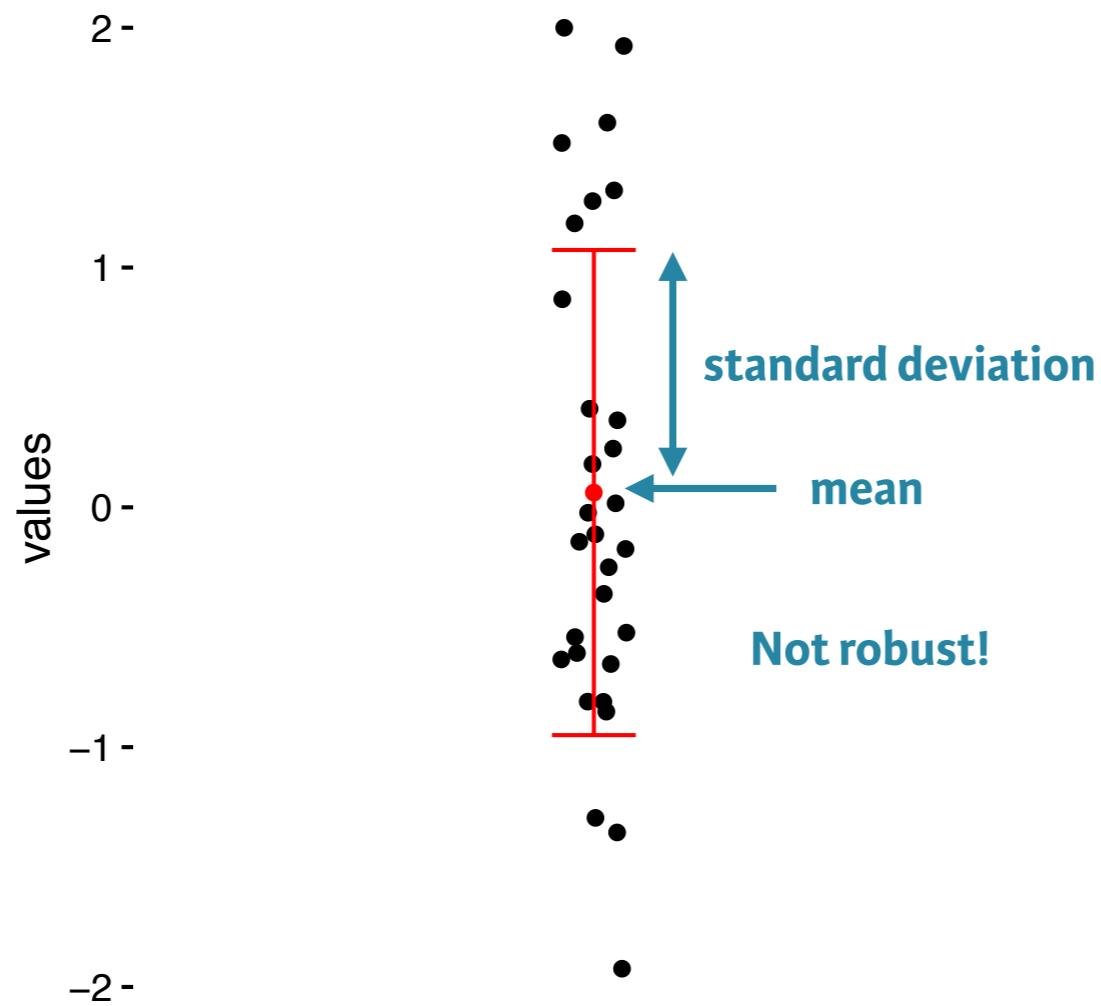
Side-note: How to summarize data?



```
x <- rnorm(1000)
```

Side-note: Mean & standard deviation

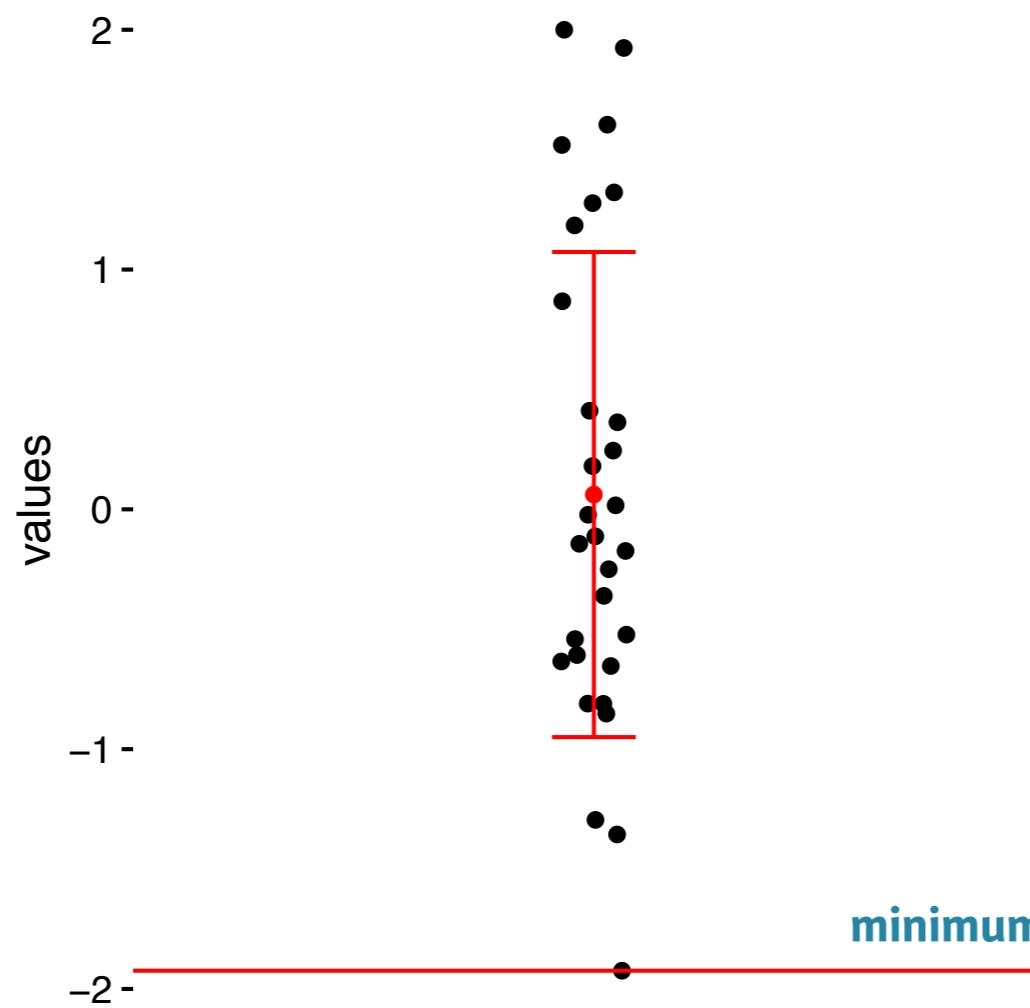
Fine for normally distributed data



```
x <- rnorm(1000)  
mean(x)  
sd(x)
```

Side-note: 5 number summary

Minimum, Q1, Q2, Q3, and maximum



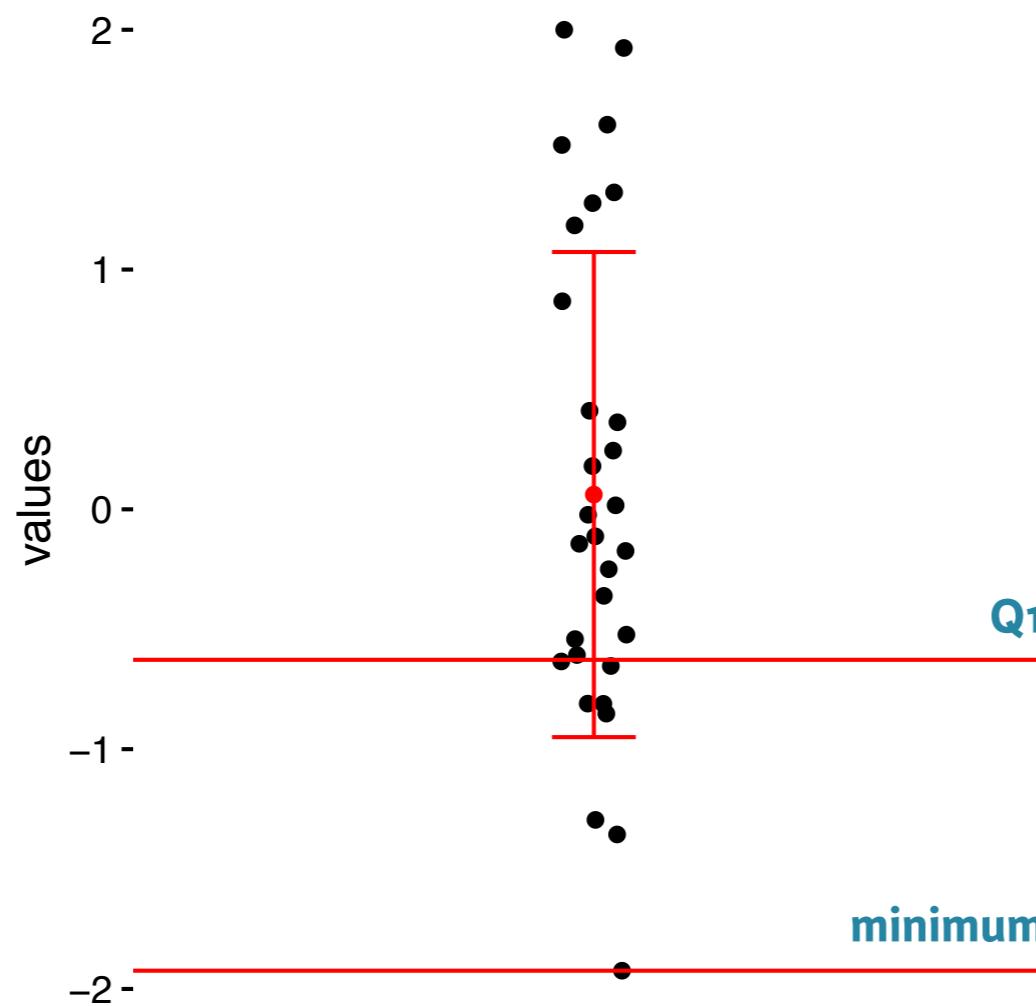
```
x <- rnorm(1000)
```

```
mean(x)  
sd(x)
```

```
summary(x)
```

Side-note: 5 number summary

Minimum, Q1, Q2, Q3, and maximum



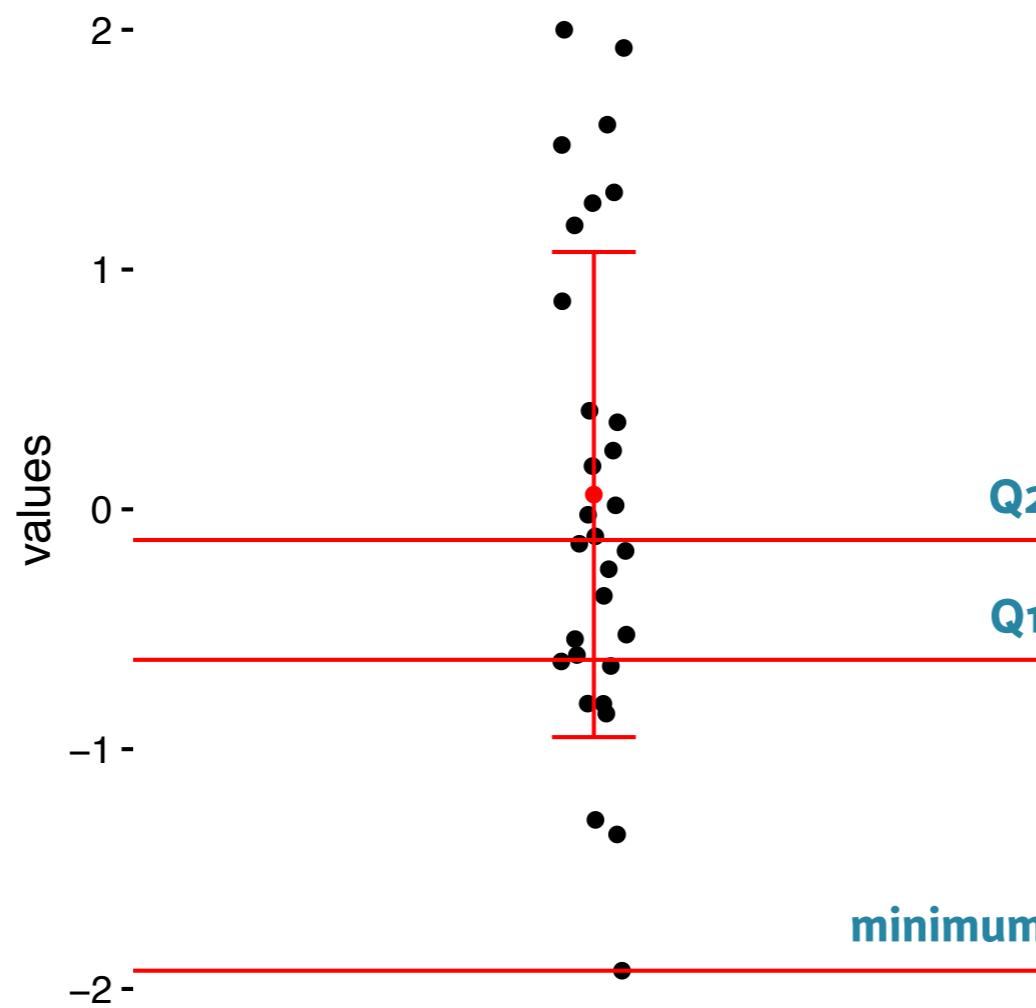
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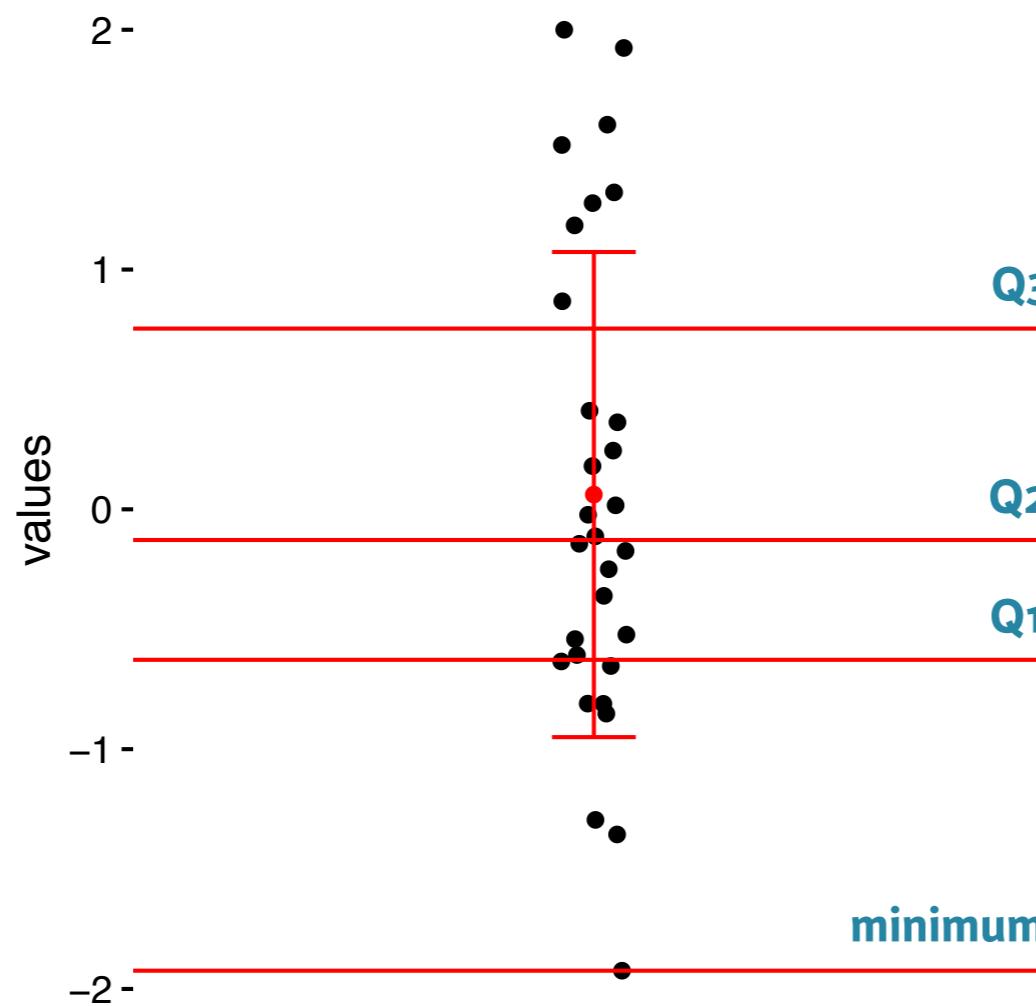
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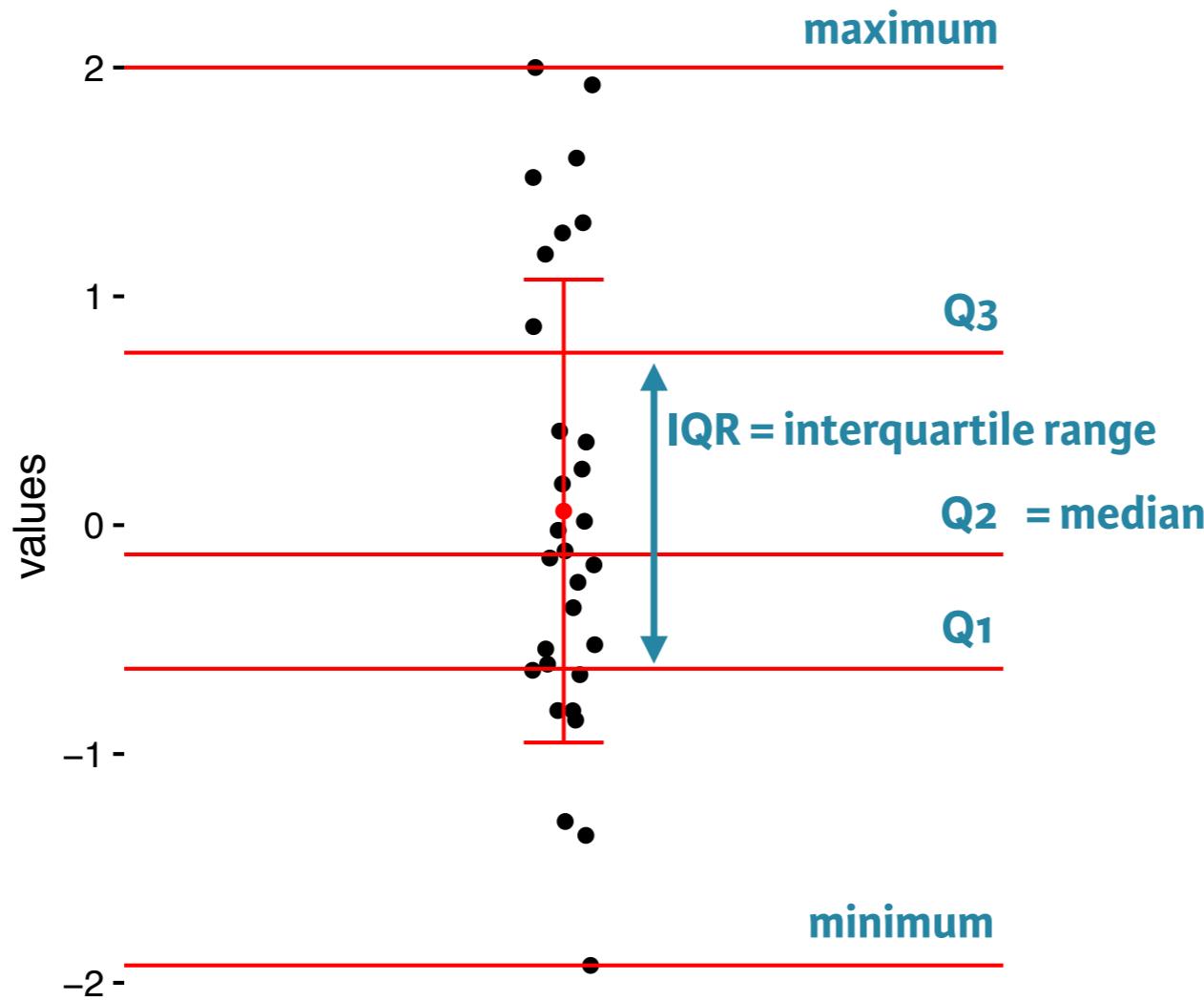
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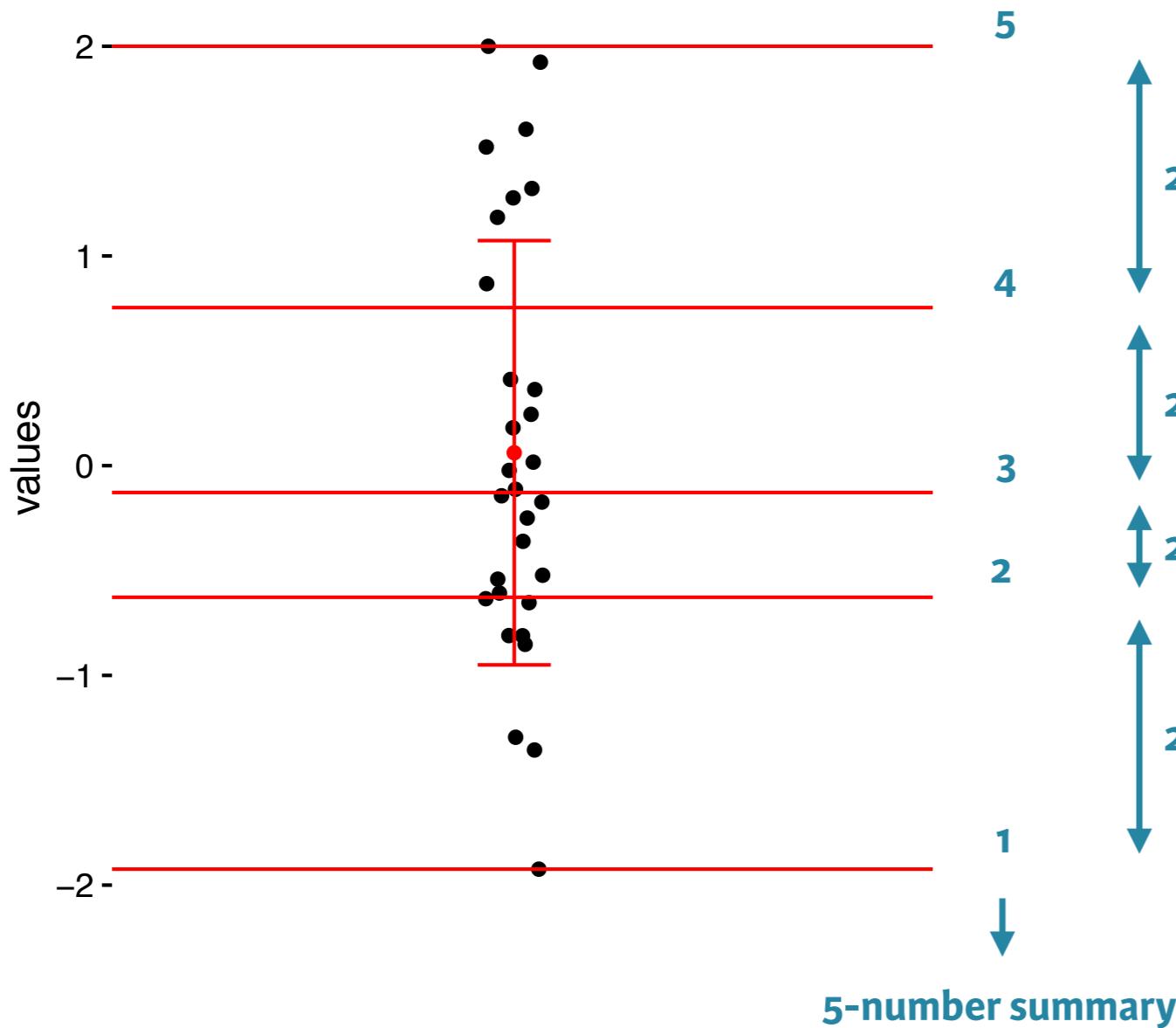
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x <- rnorm(1000)
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```
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sd(x)
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```
summary(x)
```

Side-note: boxplot

Graphical form of the 5 number summary!

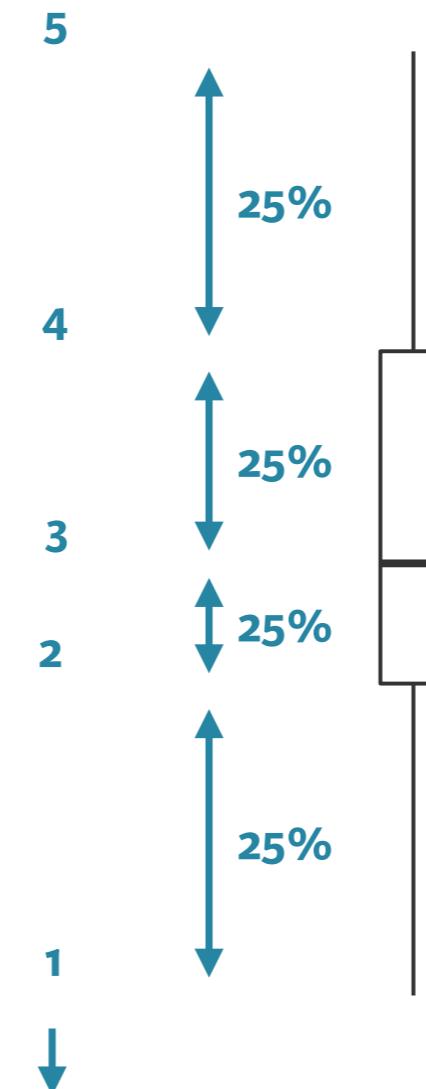
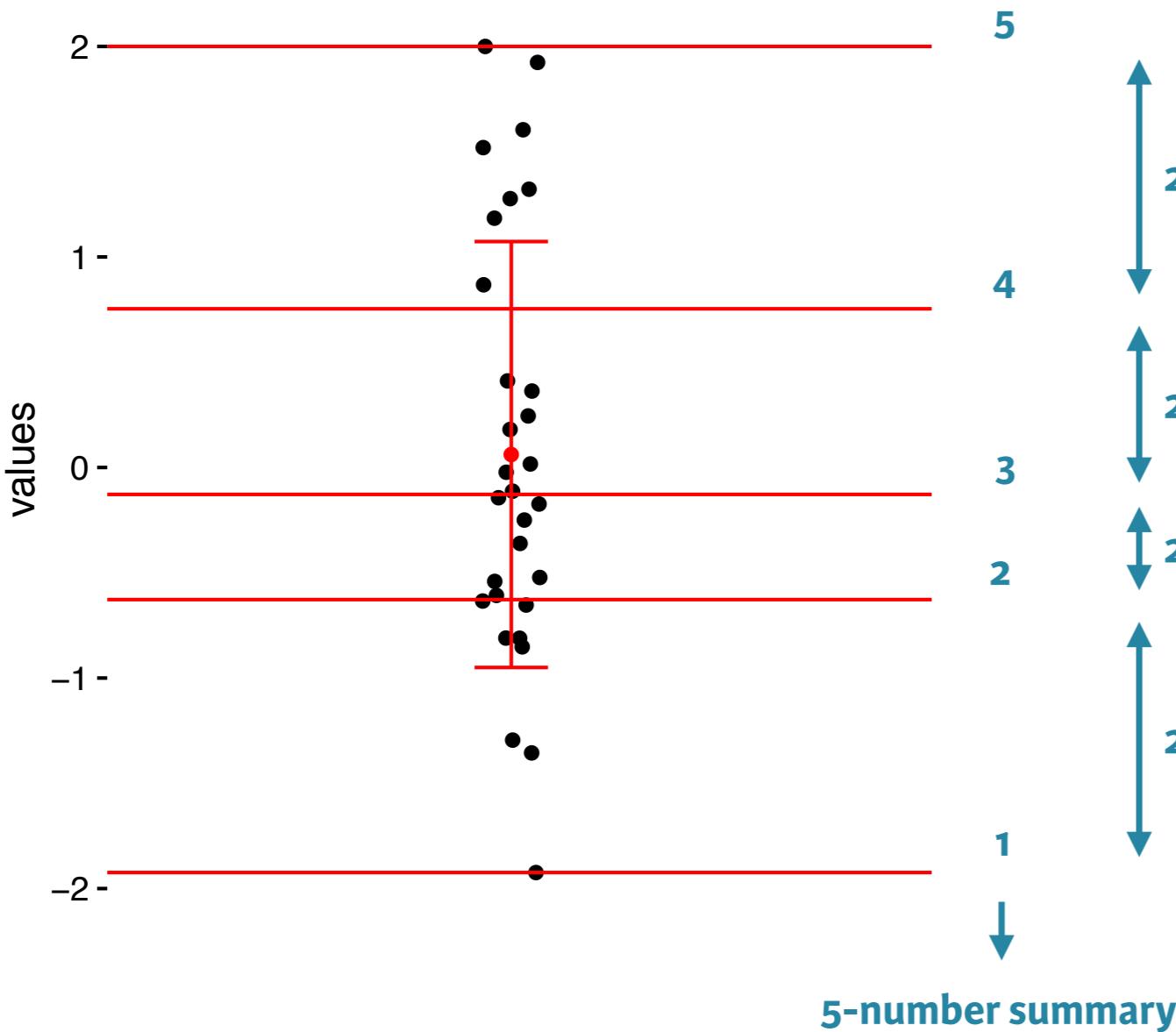


```
x <- rnorm(1000)  
mean(x)  
sd(x)  
summary(x)  
boxplot(x)
```

Also called box-and-whisker plots;
See also violin plots etc.

Side-note: boxplot

Graphical form of the 5 number summary!



`x <- rnorm(1000)`

`mean(x)`
`sd(x)`

`summary(x)`
`boxplot(x)`

`hist(x)`
`rug(x)`

Also called box-and-whisker plots;
See also violin plots etc.

The Trouble with Summary Stats

Set A		Set B		Set C		Set D	
X	Y	X	Y	X	Y	X	Y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.1	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.1	4	5.39	19	12.5
12	10.84	12	9.11	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

Summary Statistics Linear Regression

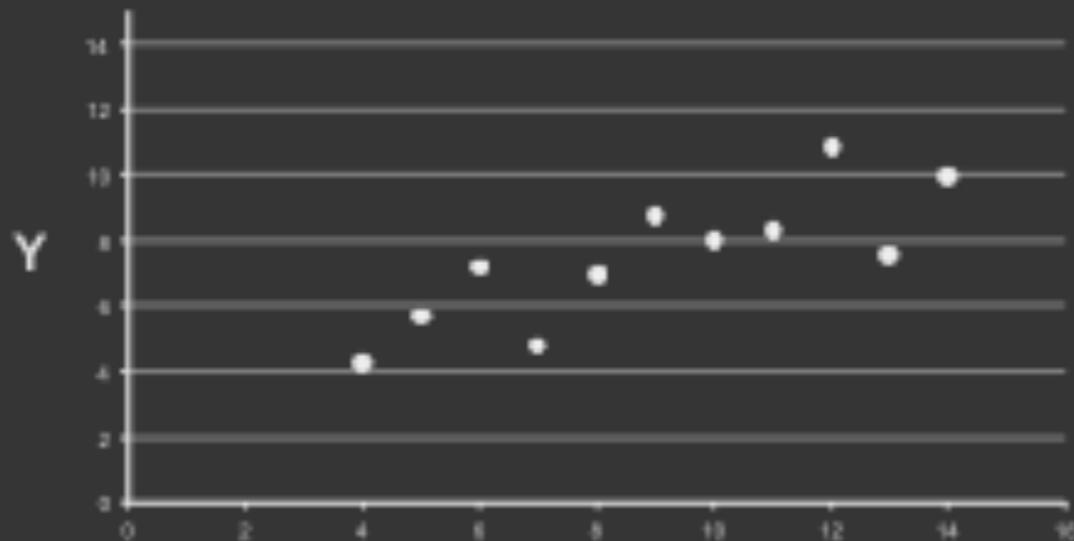
$$\begin{aligned} \mu_X &= 9.0 & \sigma_X &= 3.317 \\ \mu_Y &= 7.5 & \sigma_Y &= 2.03 \end{aligned}$$

$$\begin{aligned} Y &= 3 + 0.5 X \\ R^2 &= 0.67 \end{aligned}$$

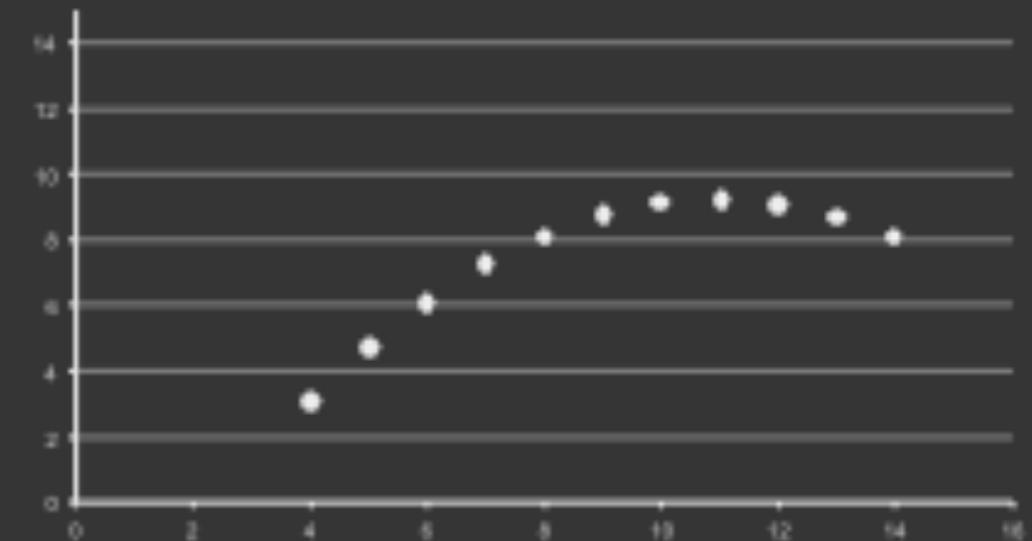
[Anscombe 73]

Looking at Data

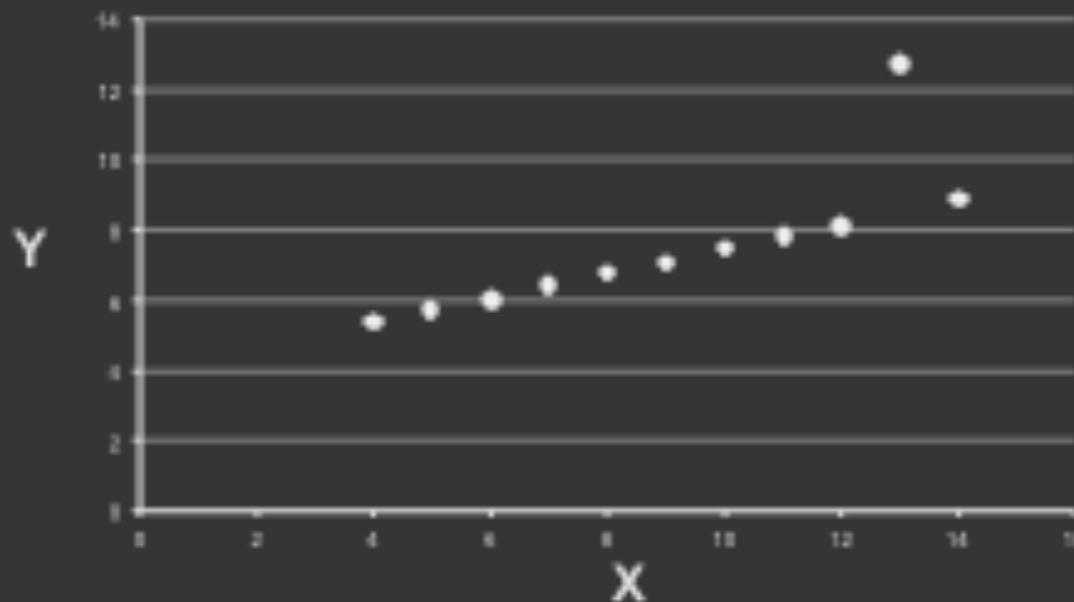
Set A



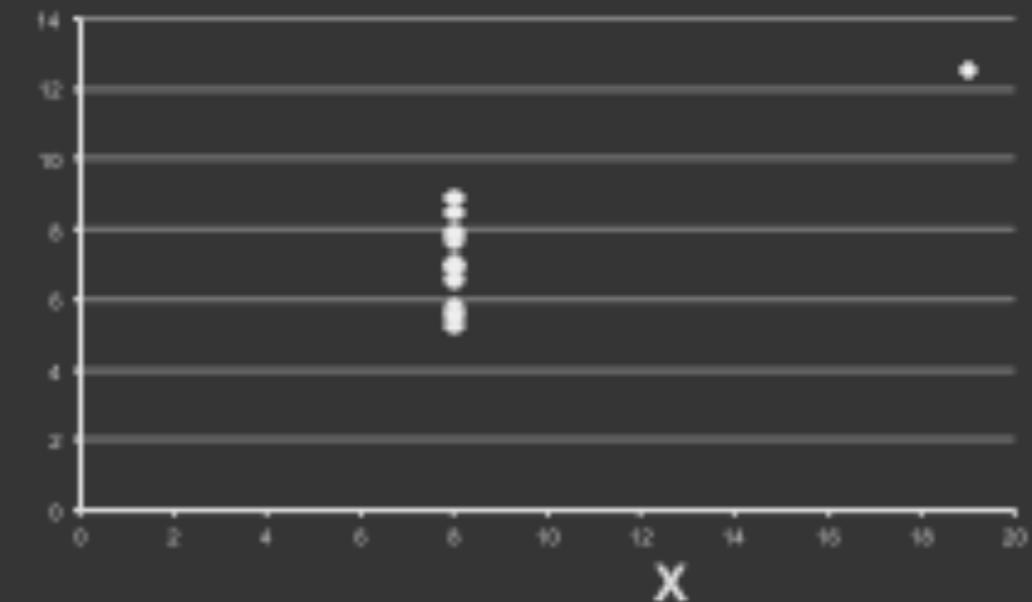
Set B

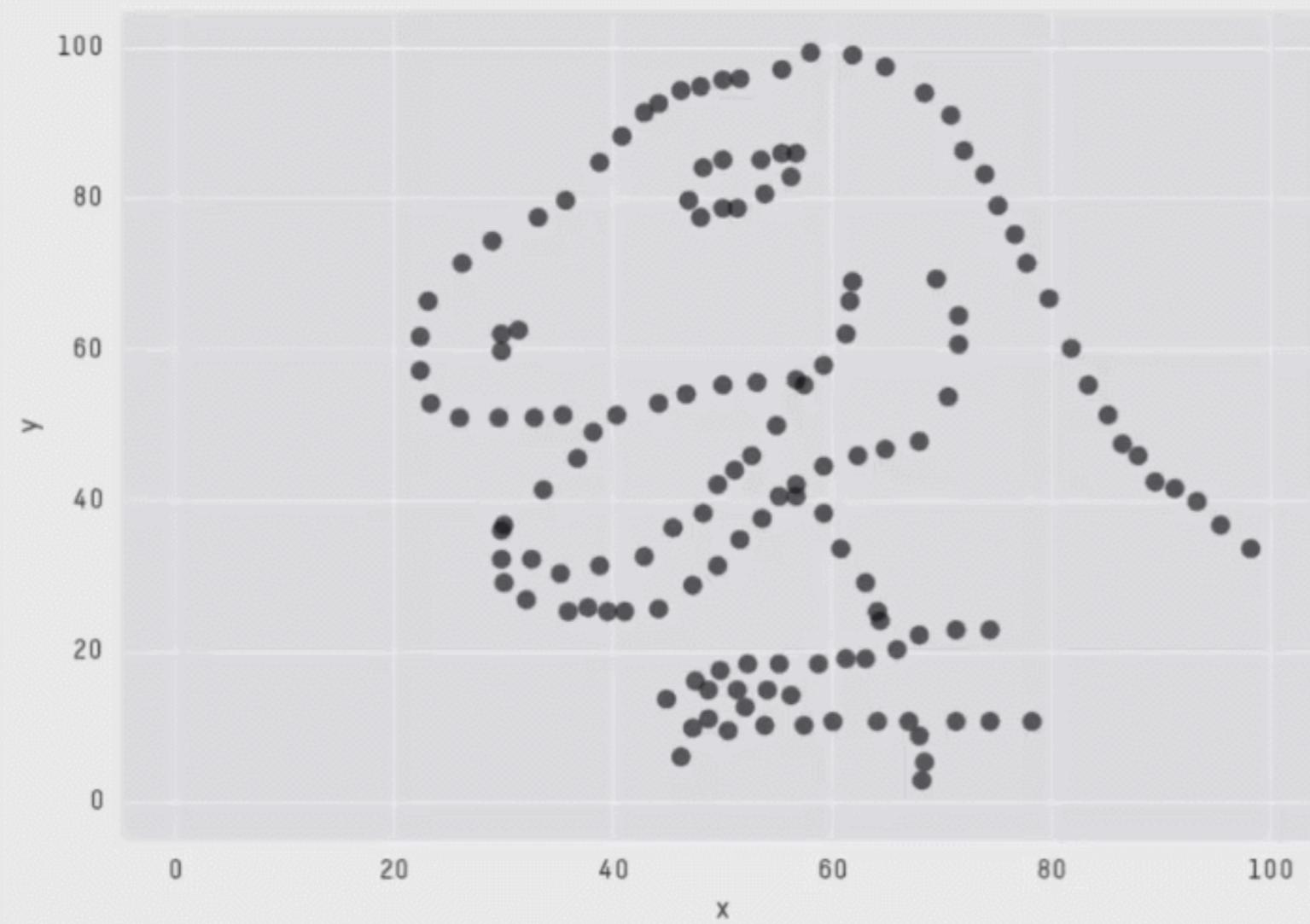


Set C



Set D





X Mean: 54.2659224
Y Mean: 47.8313999
X SD : 16.7649829
Y SD : 26.9342120
Corr. : -0.0642526

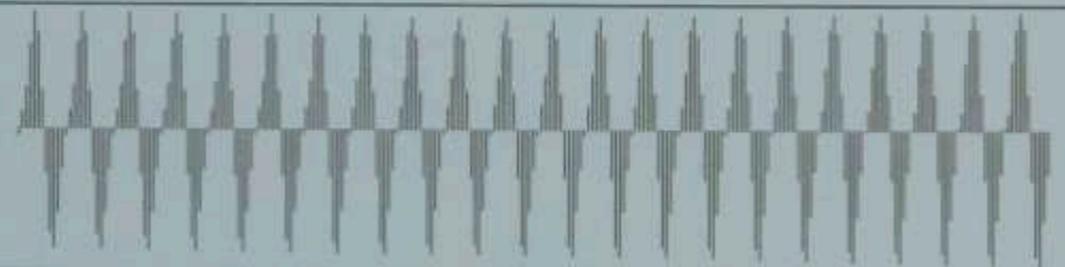
Key point: You need to visualize your data!

<https://github.com/stephlocke/datasauRus>

Today's Learning Goals

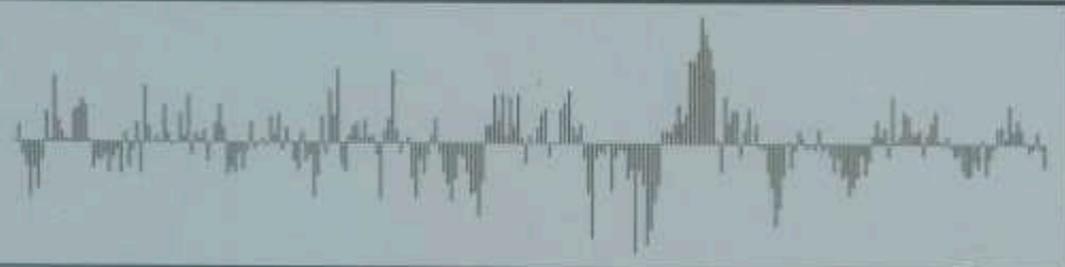
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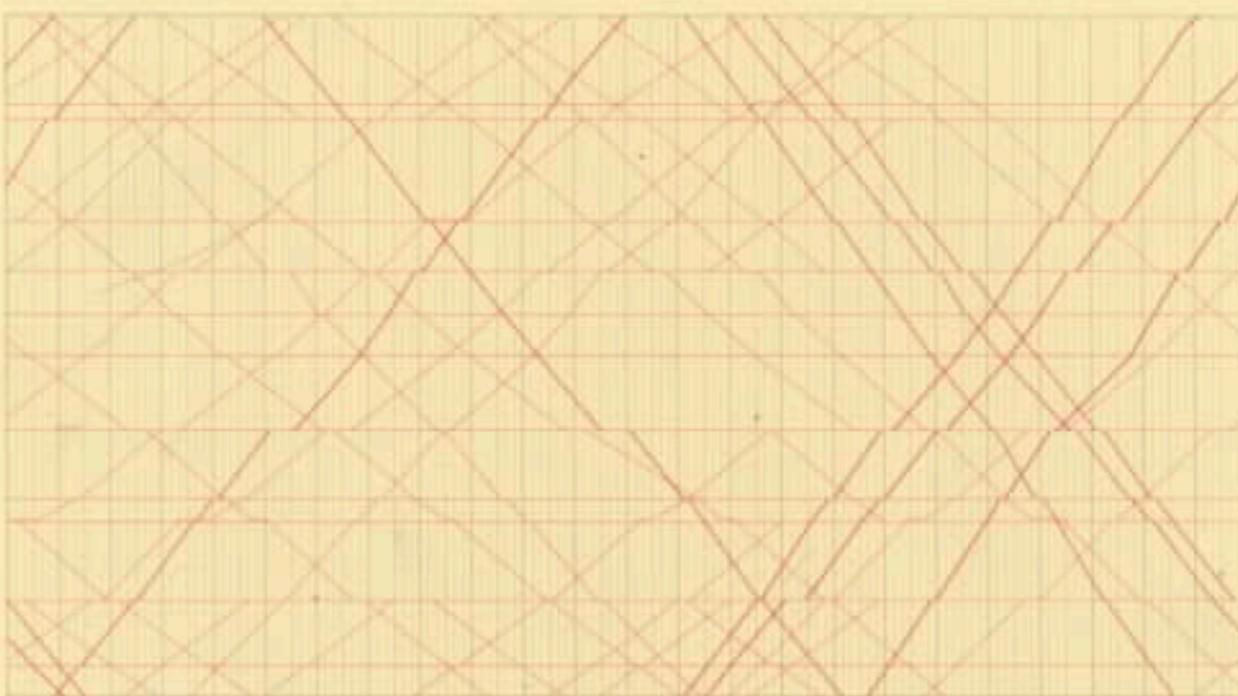


The Elements of Graphing Data

William S. Cleveland



Copyrighted Material



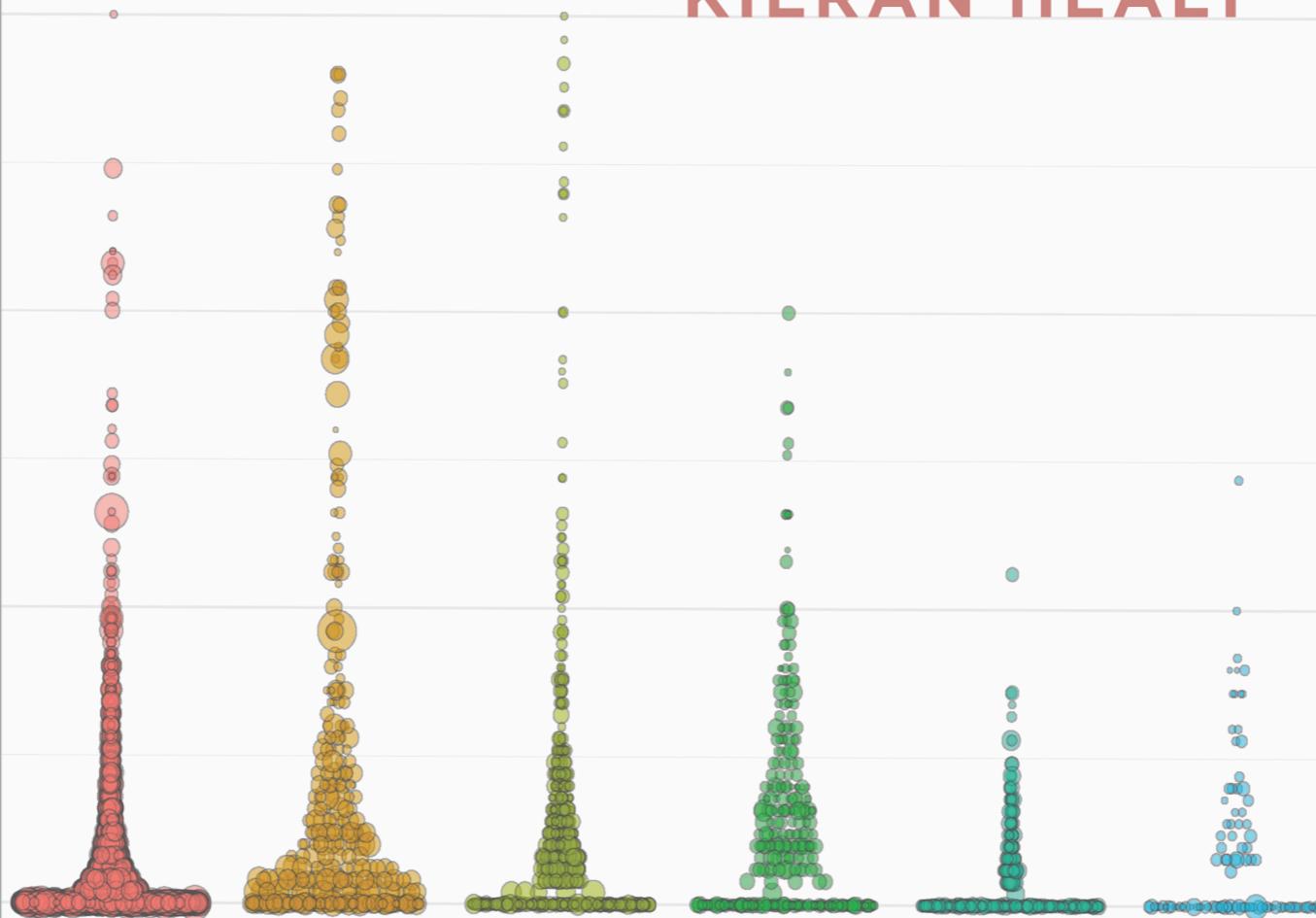
The Visual Display
of Quantitative Information

EDWARD R. TUFTE

DATA VISUALIZATION

A PRACTICAL INTRODUCTION

KIERAN HEALY



<http://socviz.co/>

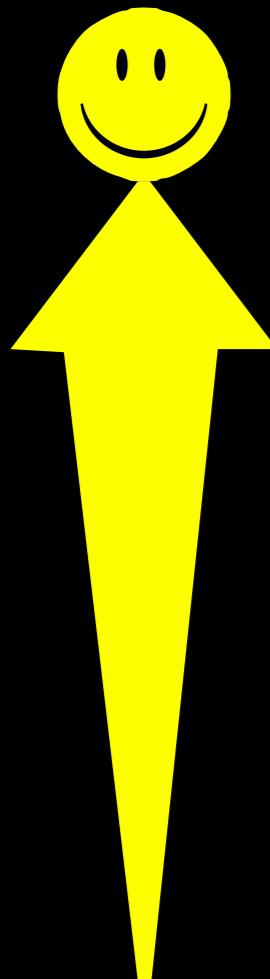
Key Point:

Good visualizations optimize
for the human visual system.

Key Point: The most important measurement should exploit the highest ranked encoding possible

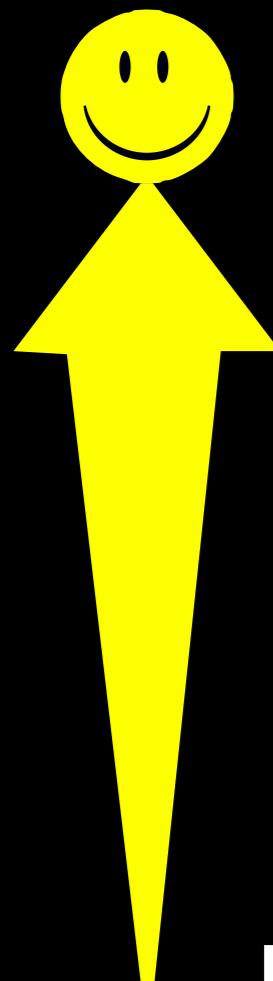
- Position along a common scale
- Position on identical but nonaligned scales
- Length
- Angle or Slope
- Area
- Volume or Density or Color saturation/hue

Key Point: The most important measurement should exploit the highest ranked encoding possible



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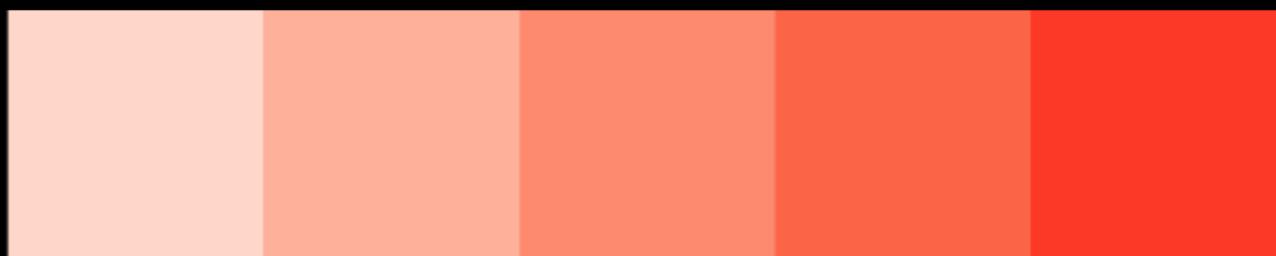


- Position along a common scale
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luminance

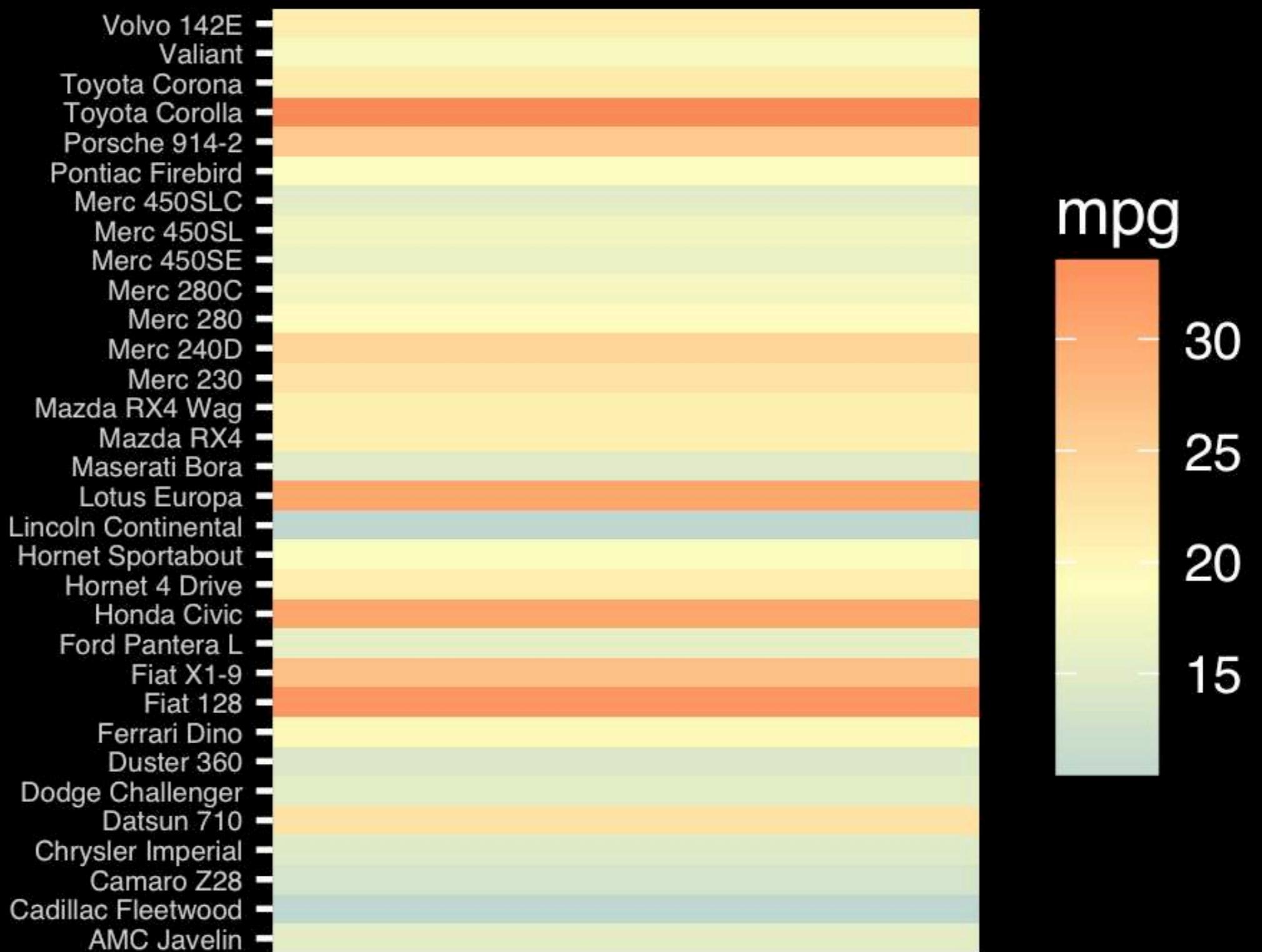


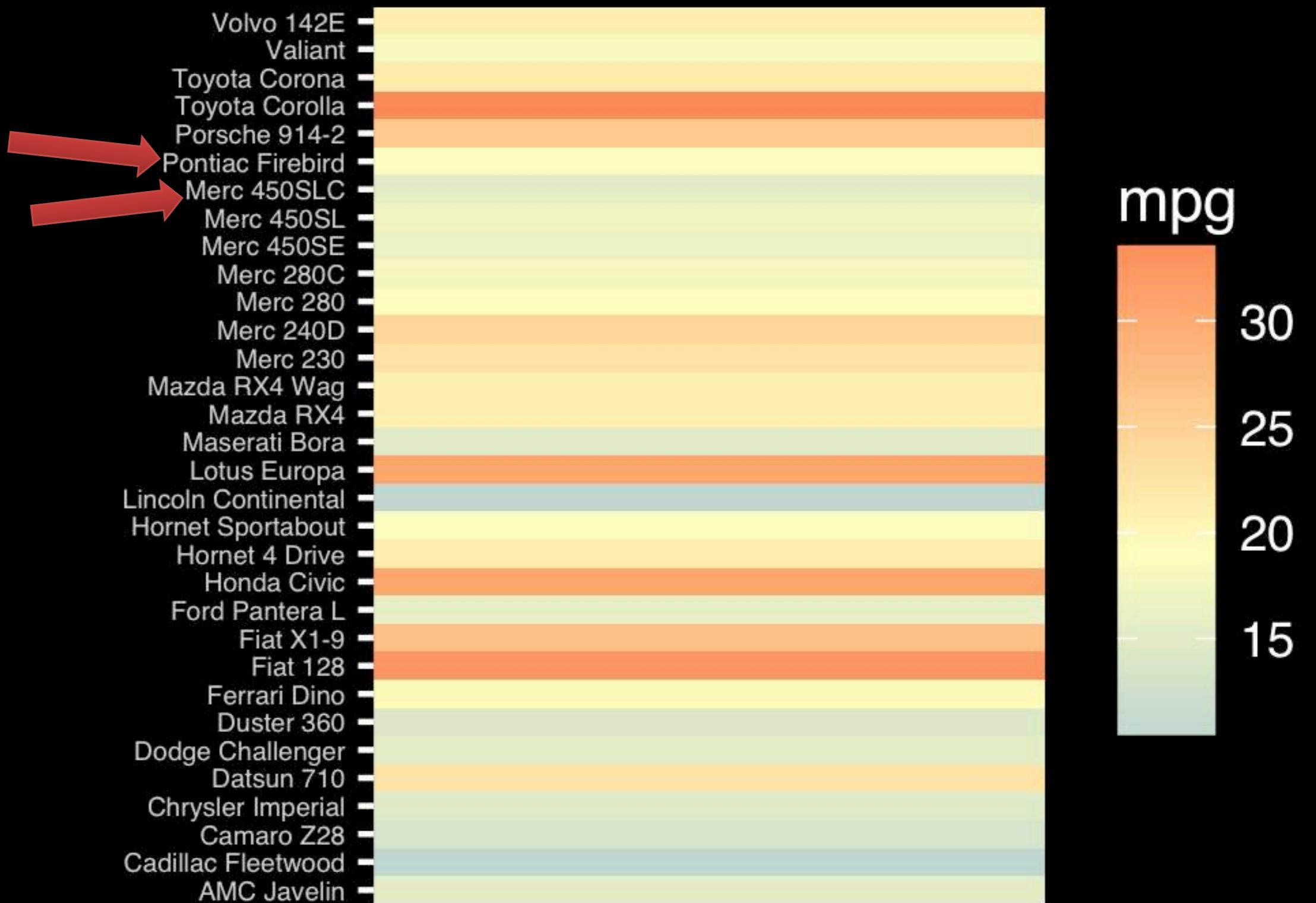
saturation

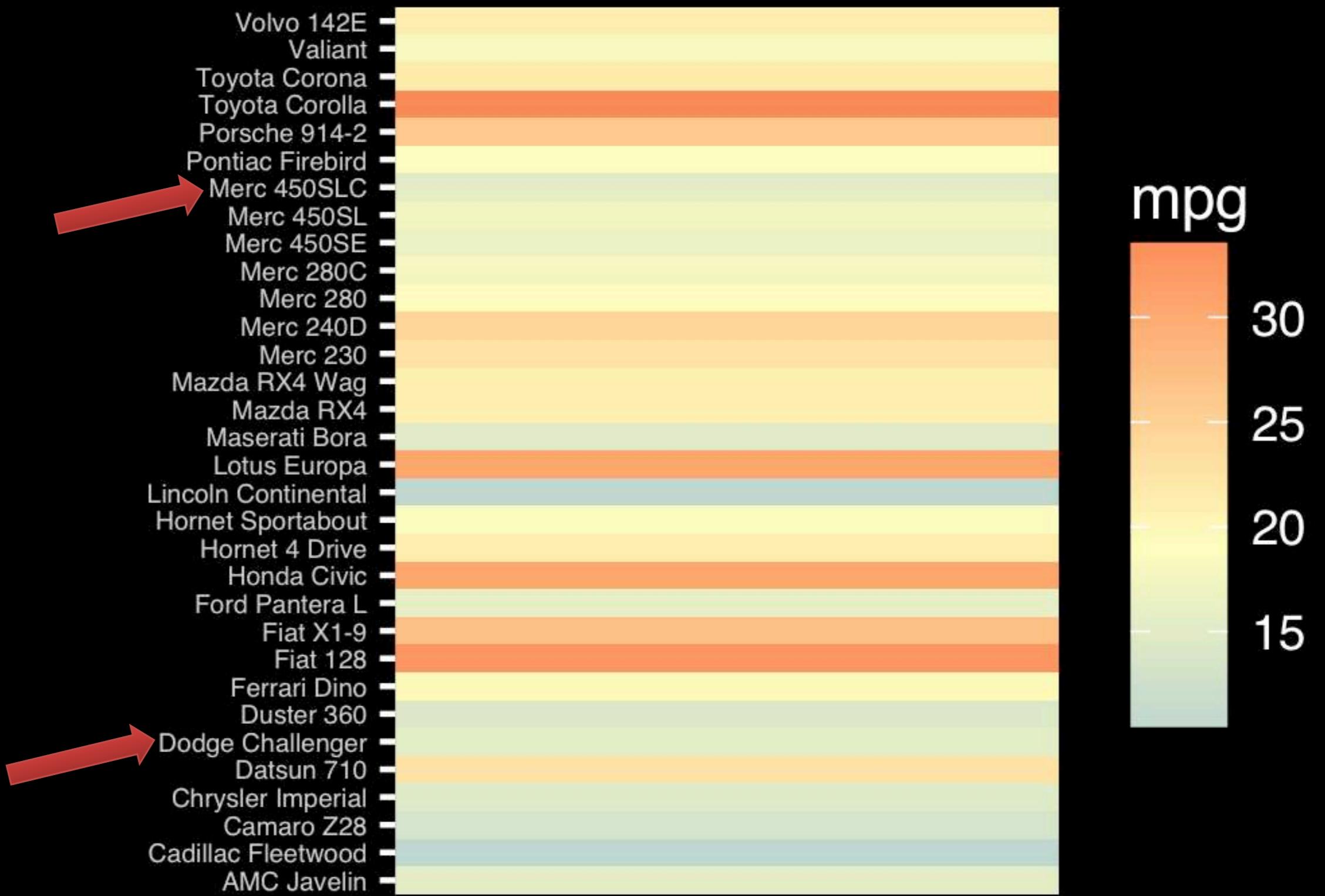


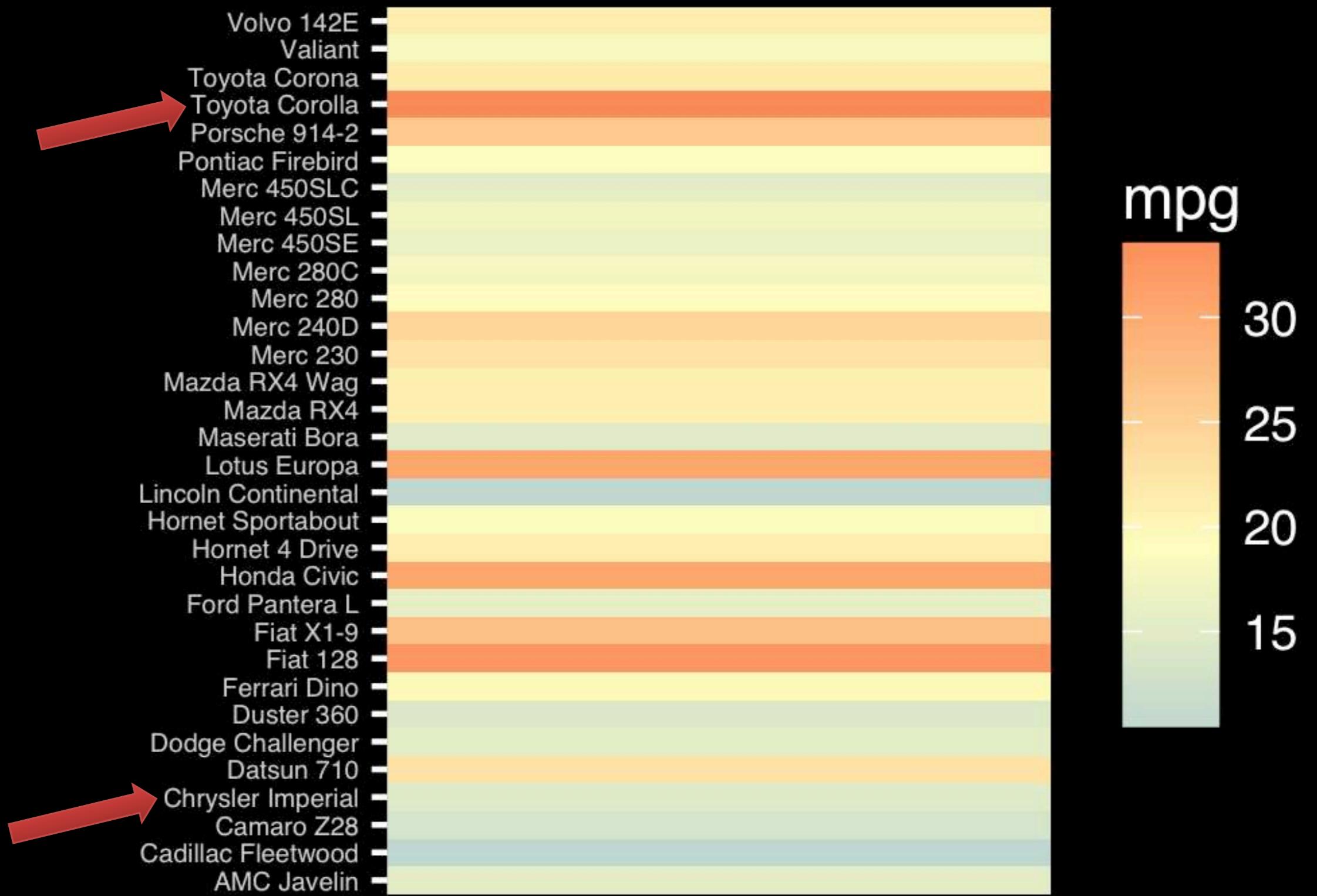
hue



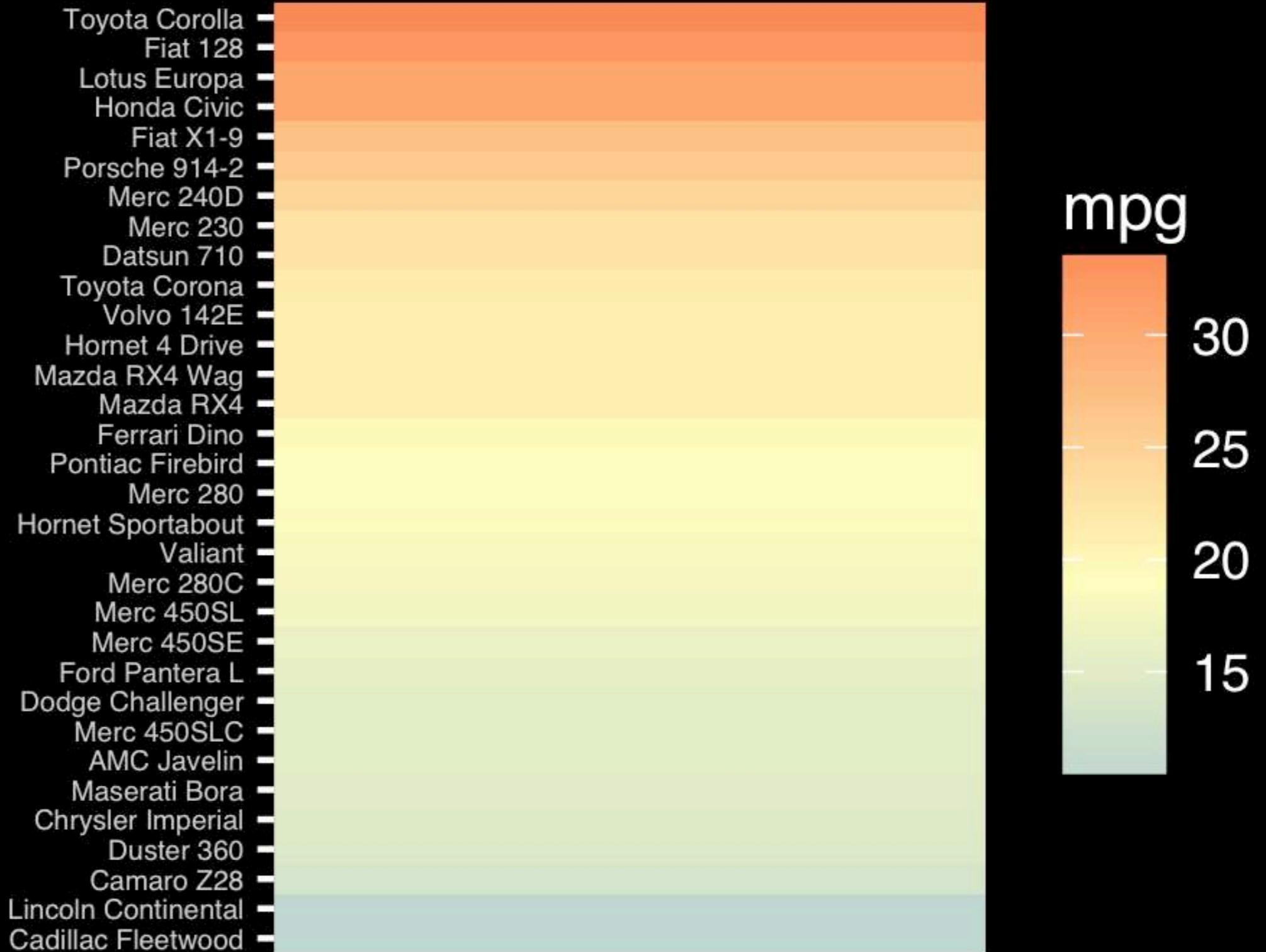


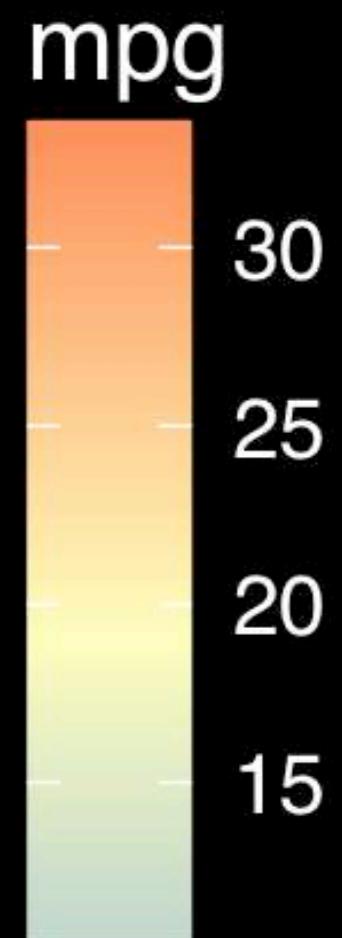
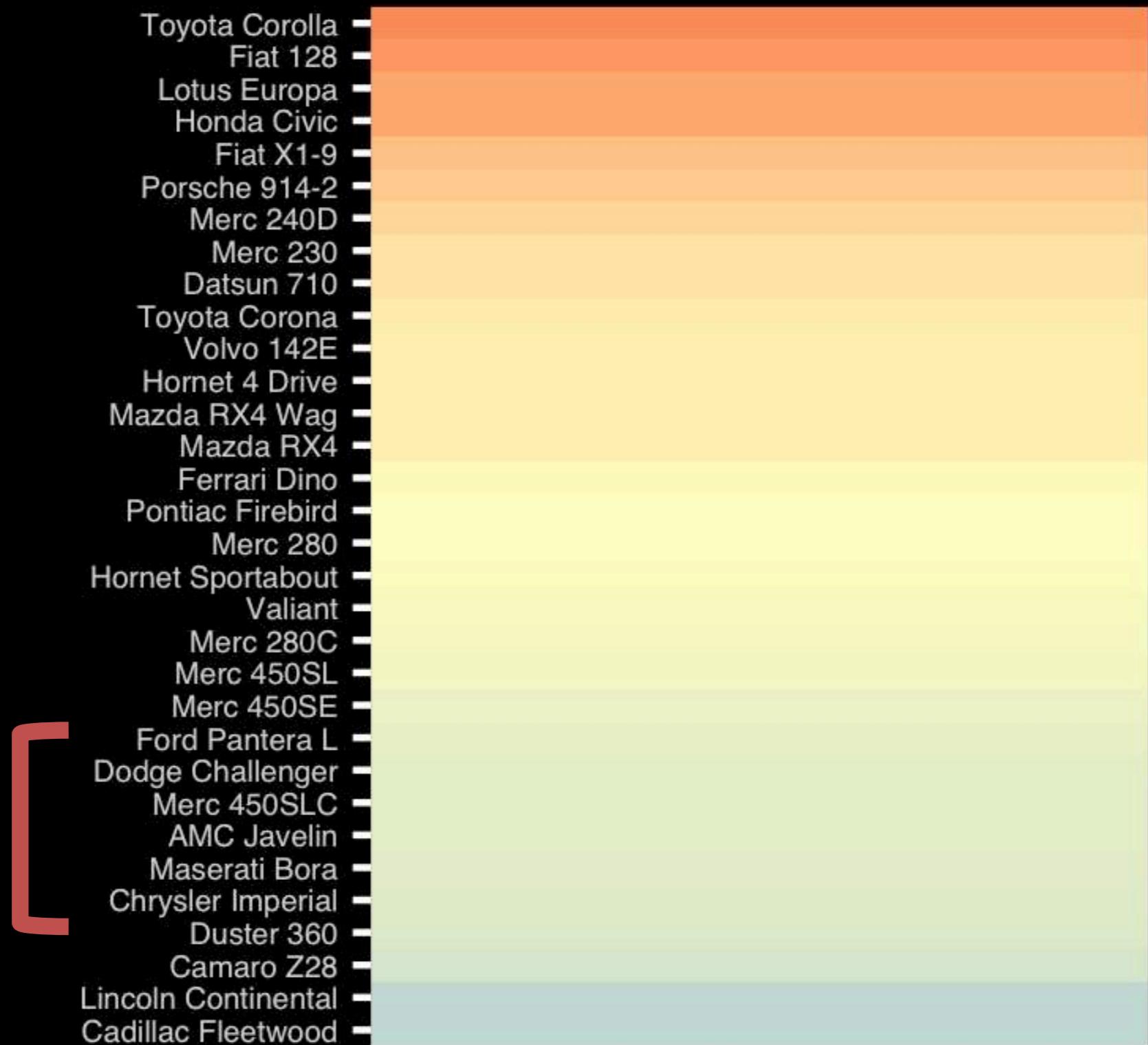


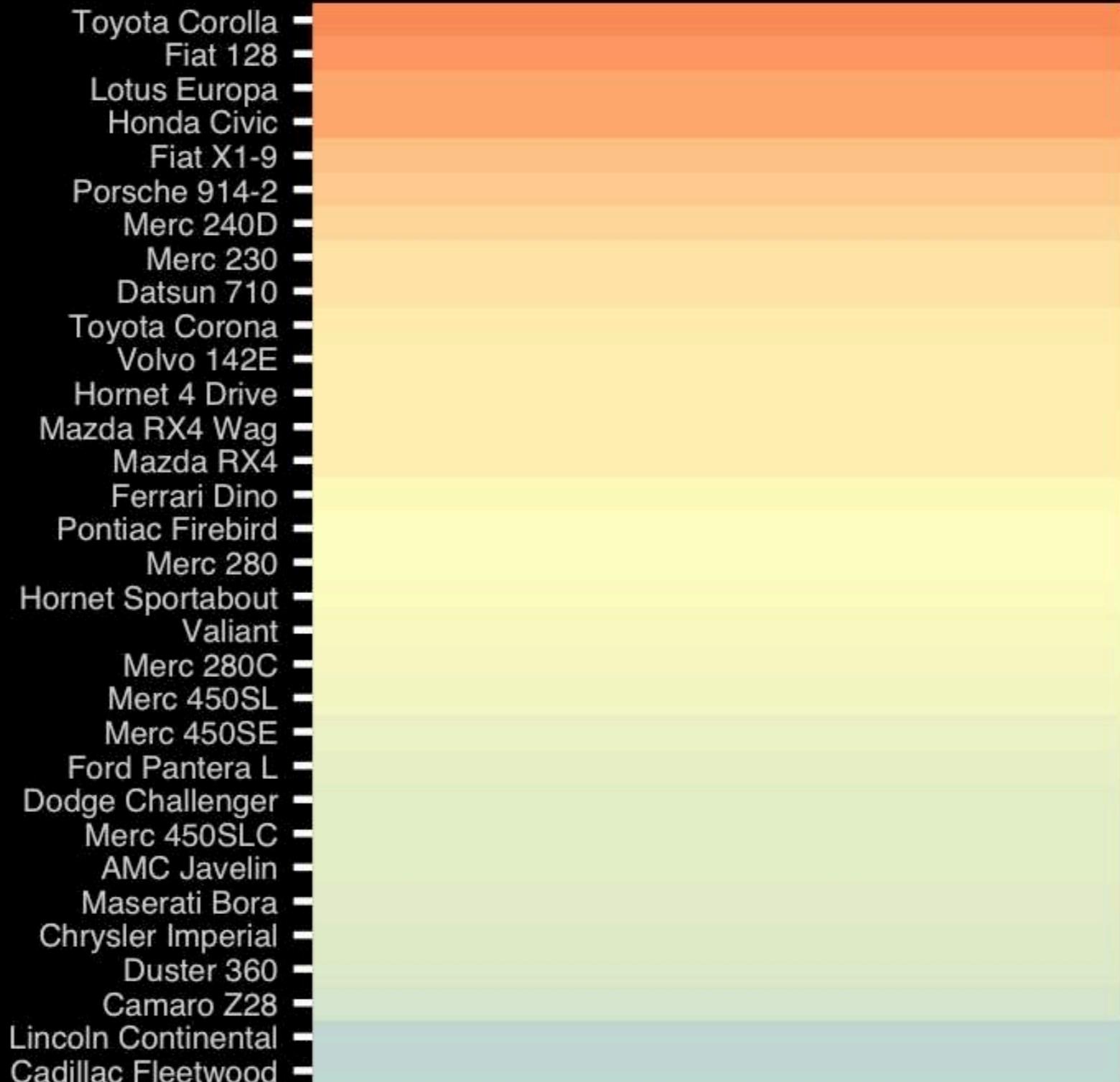




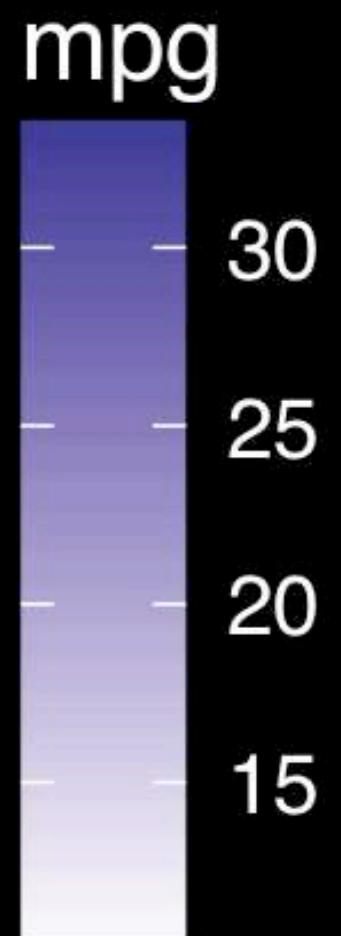
Observation: Alphabetical is almost never the correct ordering of a categorical variable.





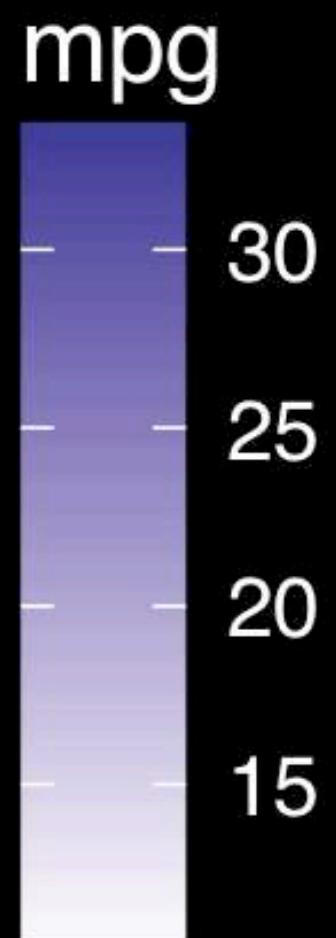
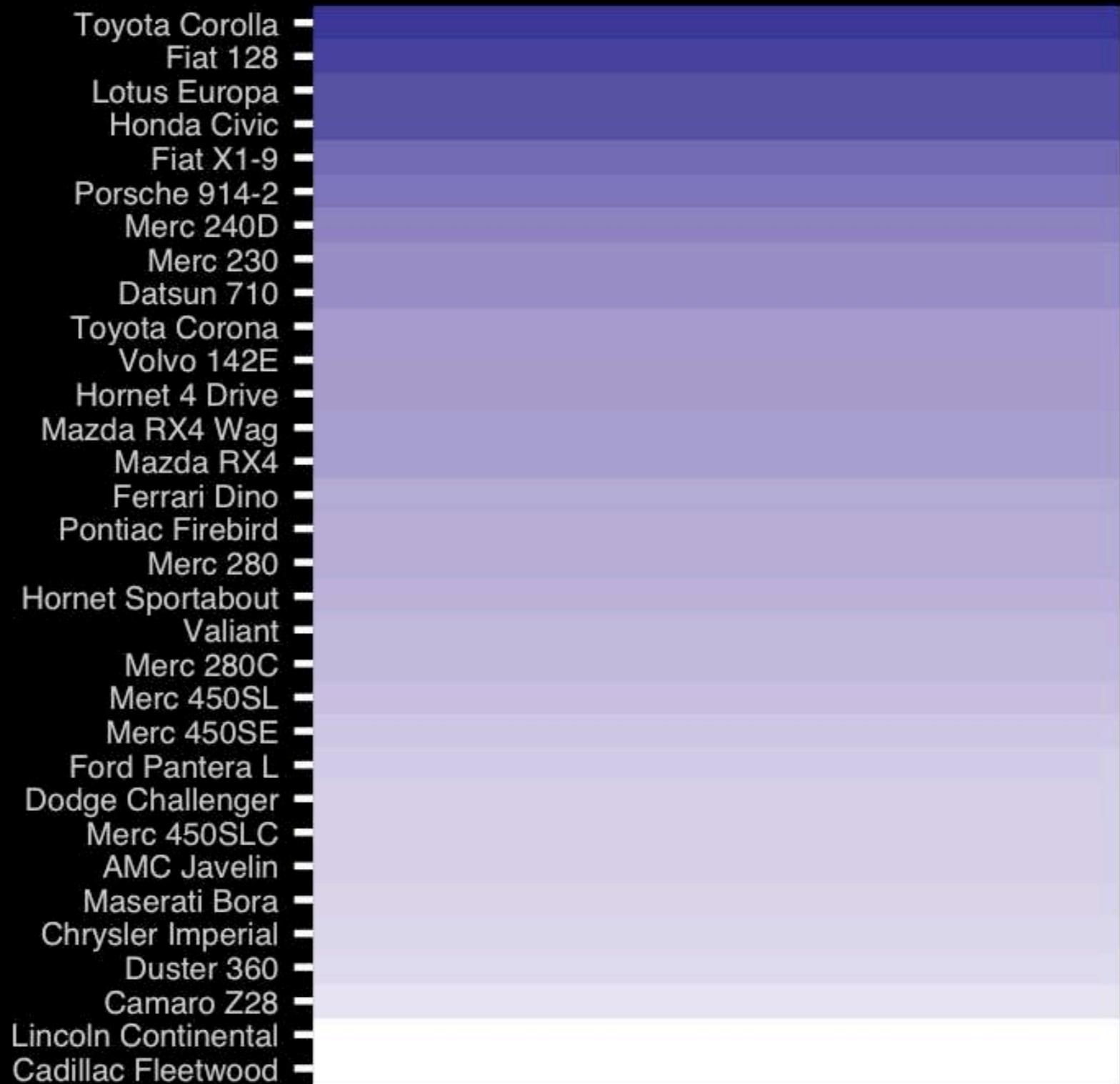


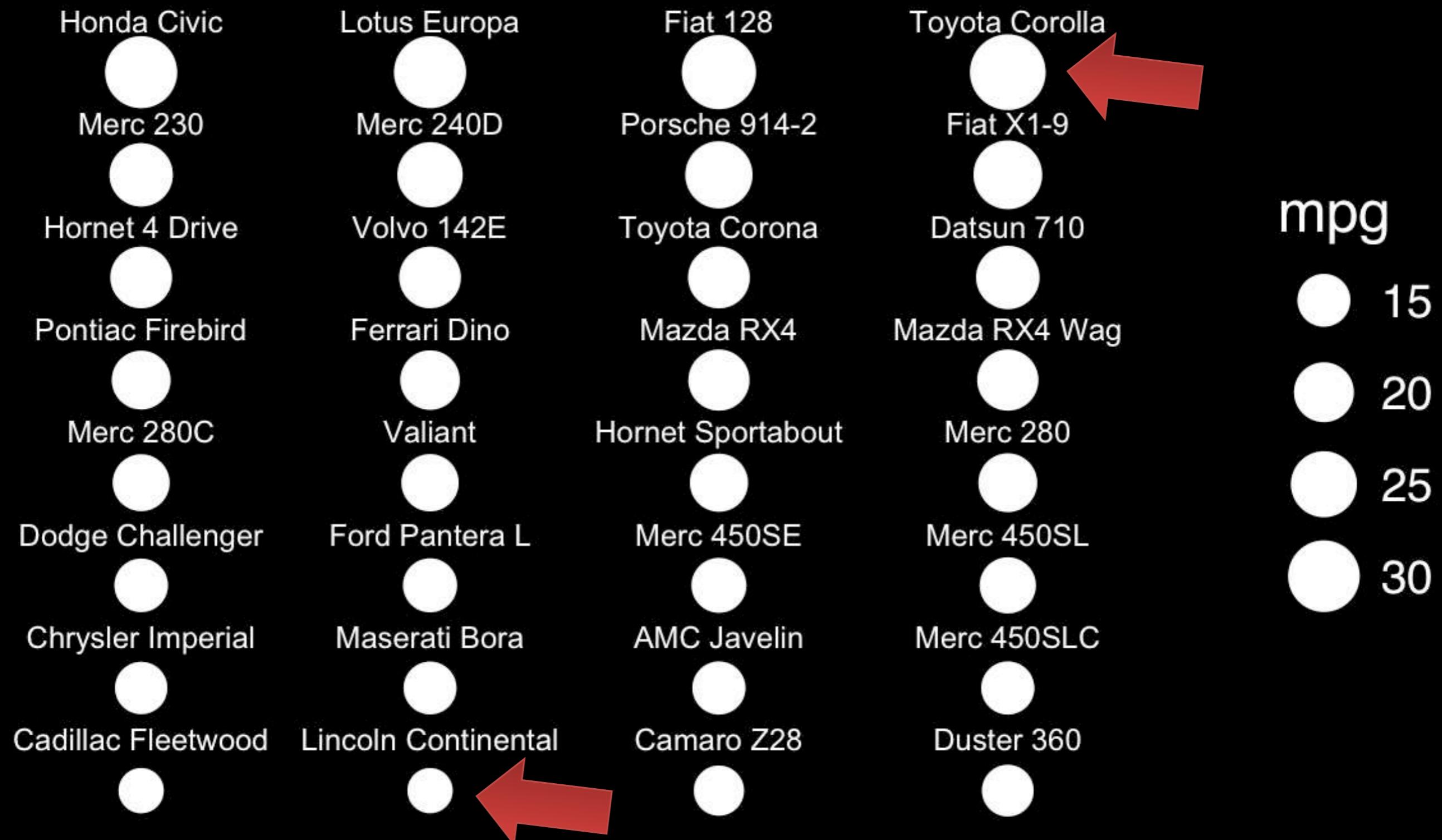
If we did not have the legend would you know which was low or high mpg?

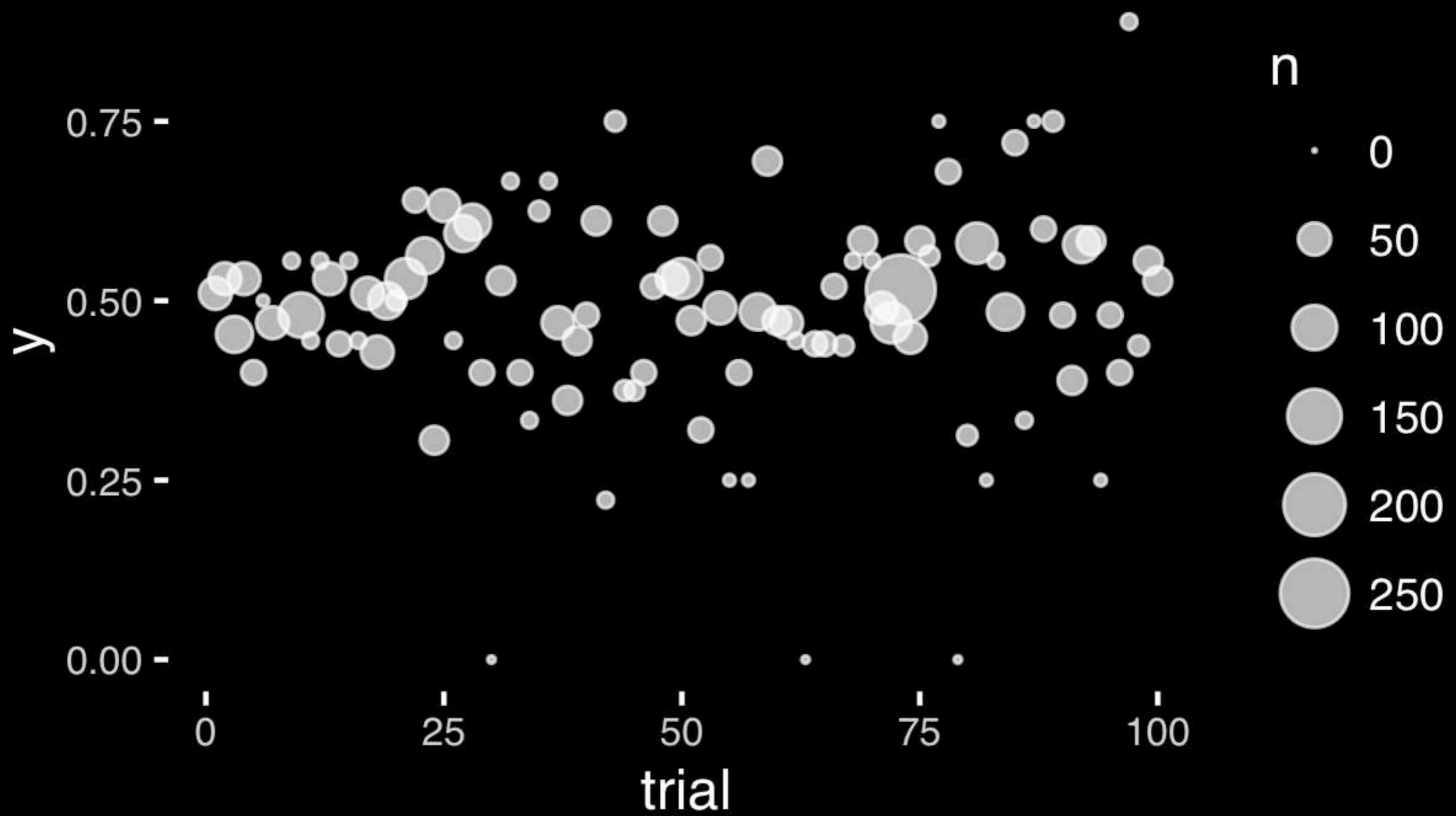


The most important measurement should exploit the highest ranked encoding possible.

- Position along a common scale
- Position on identical but nonaligned scales
- Length
- Angle or Slope
- **Area**
- Volume or Density or Color saturation/hue







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Cadillac Fleetwood Lincoln Continental Camaro Z28 Duster 360 Chrysler Imperial Maserati Borghese AMC Javelin Merc 450SLC

Dodge Challenger Ford Pantera Merc 450SE Merc 450SL Merc 280C Valiant Hornet Sport Merc 280

Pontiac Firebird Ferrari Dino Mazda RX4 Mazda RX4 1 Hornet 4 Dr Volvo 142E Toyota Corolla Datsun 710

Merc 230 Merc 240D Porsche 914 Fiat X1-9 Honda Civic Lotus Europa Fiat 128 Toyota Corolla

Cadillac Fleetwood Lincoln Continental Camaro Z28 Duster 360 Chrysler Imperial Maserati Bora AMC Javelin Merc 450SLC

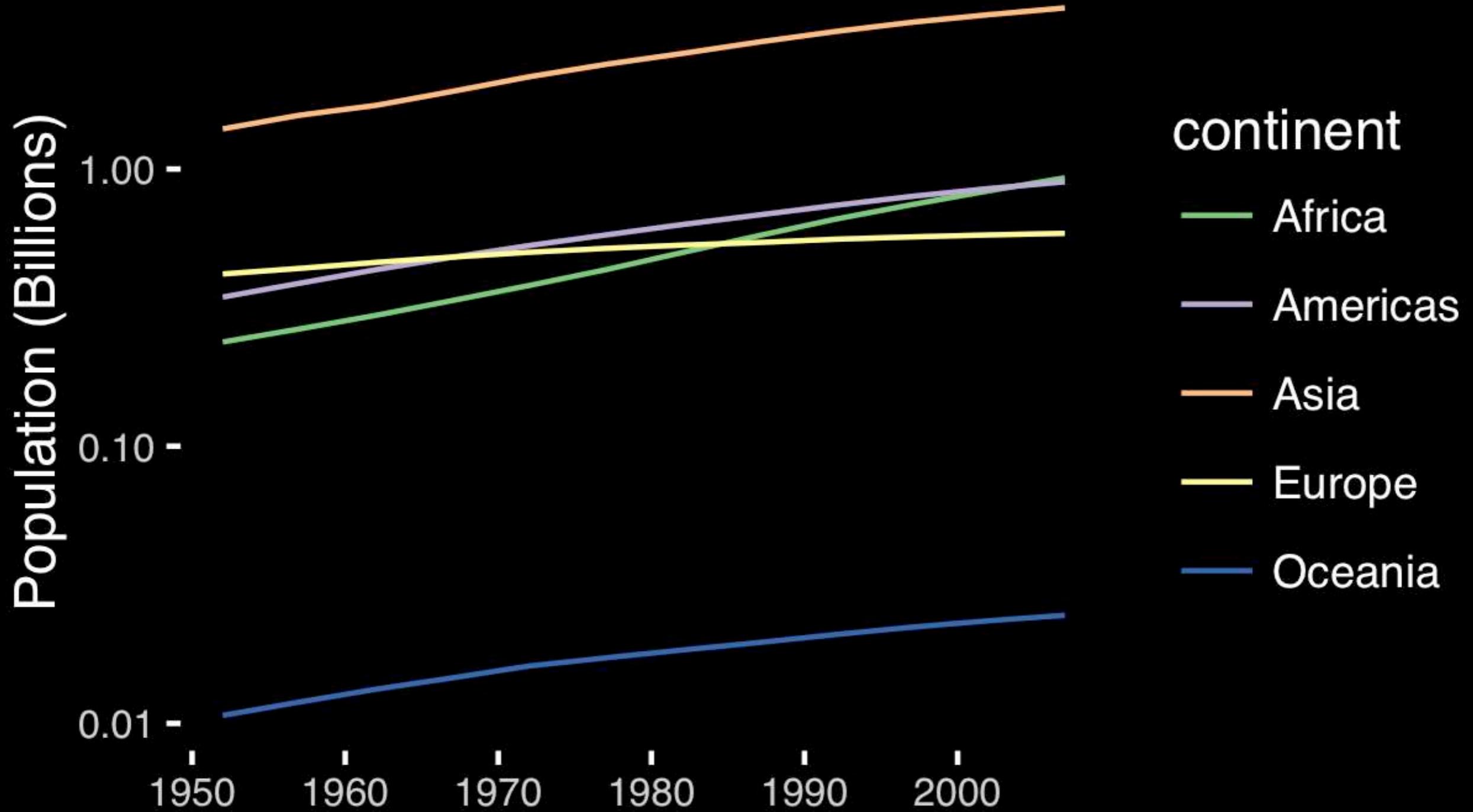


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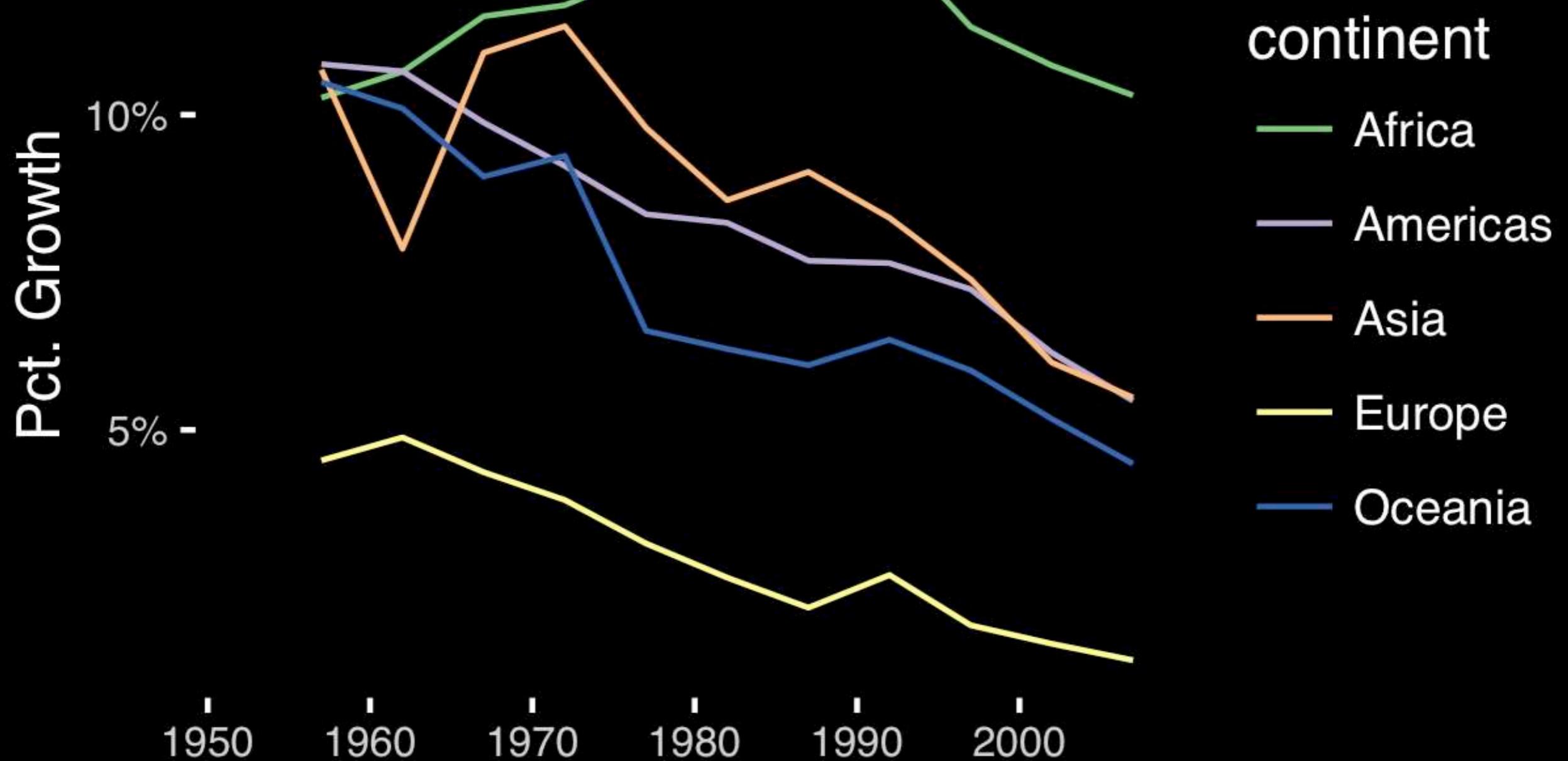
Pontiac Firebird Ferrari Dino Mazda RX4 Mazda RX4 1 Hornet 4 Dr Volvo 142E Toyota Corolla Datsun 710

Merc 230 Merc 240D Porsche 914 Fiat X1-9 Honda Civic Lotus Europa Fiat 128 Toyota Corolla





If growth (slope) is important, plot it directly.



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Observation: Pie charts
are ALWAYS a mistake.

Apart from MPAs :-)

Piecharts are the information visualization equivalent of a roofing hammer to the frontal lobe. They have no place in the world of grownups, and occupy the same semiotic space as short pants, a runny nose, and chocolate smeared on one's face. They are as professional as a pair of assless chaps.

<http://blog.codahale.com/2006/04/29/google-analytics-the-goggles-they-do-nothing/>

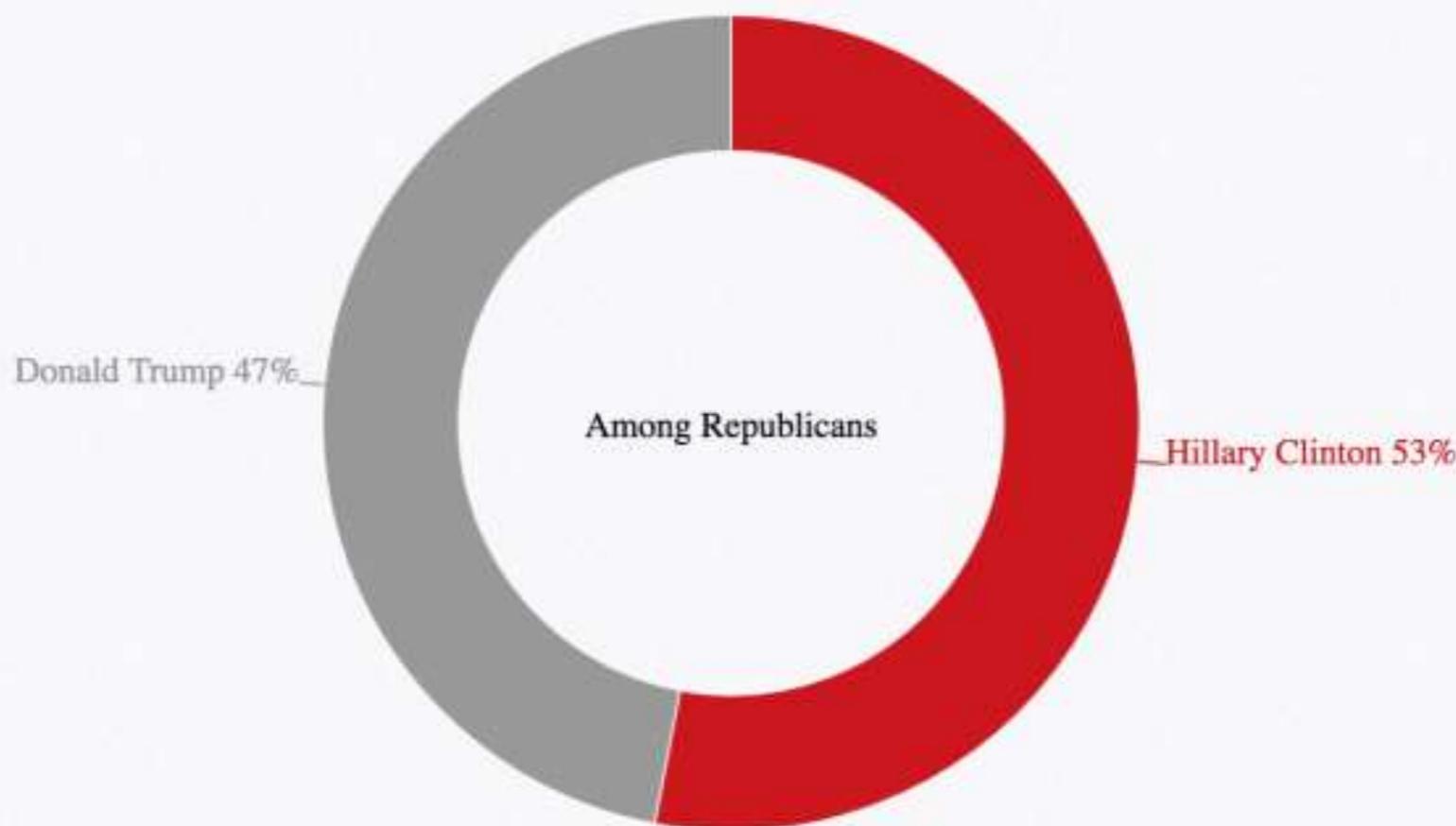
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Who do you think did a better job in tonight's debate?

Among Republicans

Among Democrats



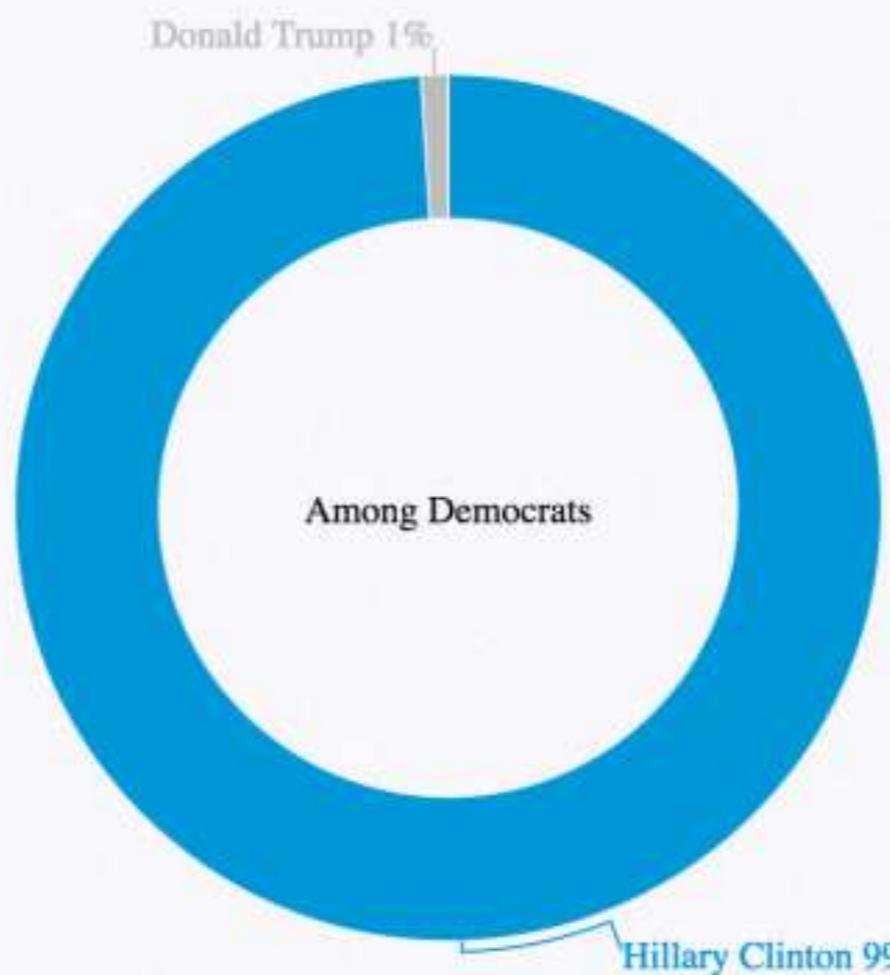
Share

POLITICO

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 Share

POLITICO

Tables are preferable to graphics for many small data sets. A table is nearly always better than a dumb pie chart; the only thing worse than a pie chart is several of them, for then the viewer is asked to compare quantities located in spatial disarray both within and between pies... Given their low data-density and failure to order numbers along a visual dimension, **pie charts should never be used.**

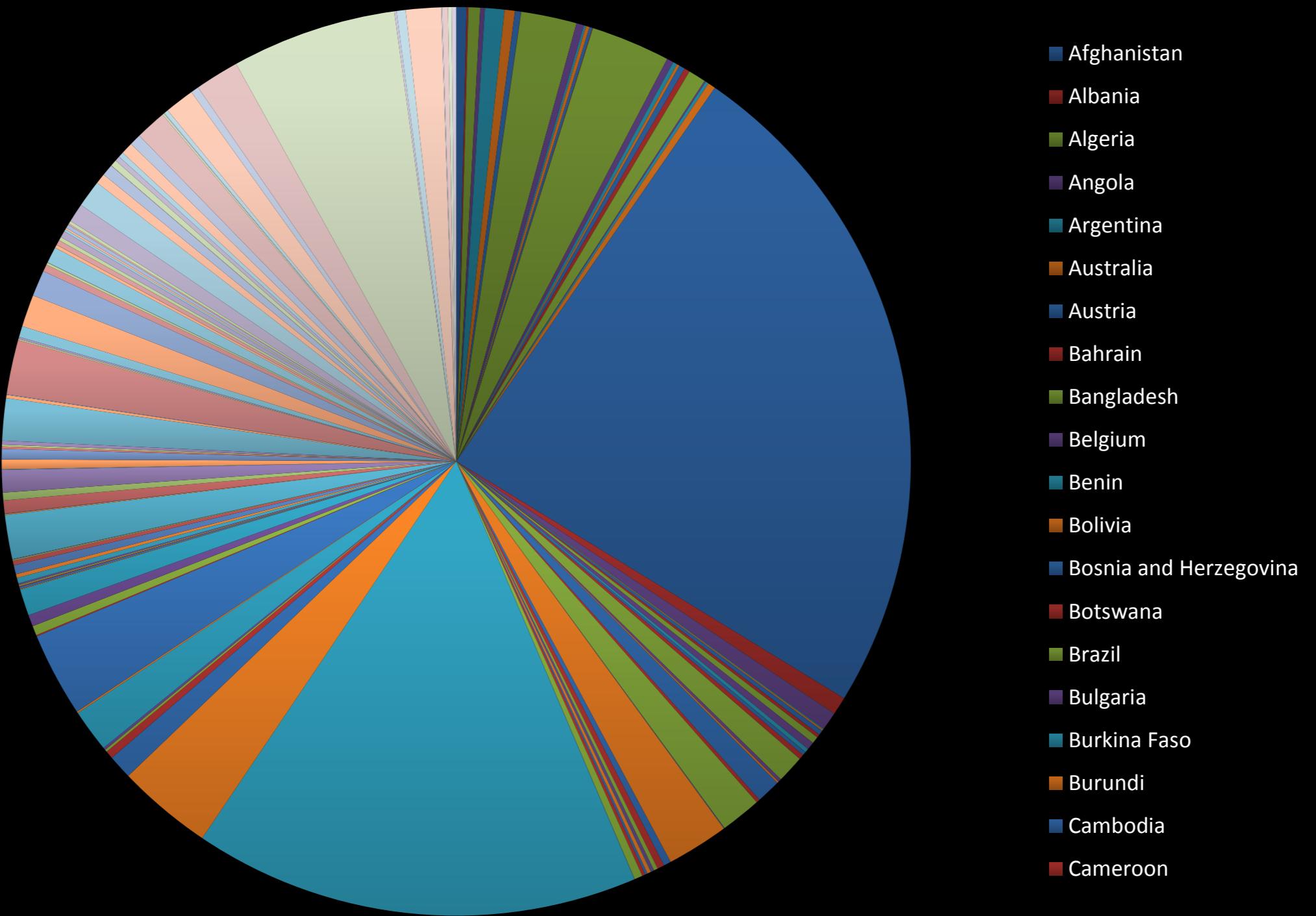
-Edward Tufte, *The Visual Display of Quantitative Information*

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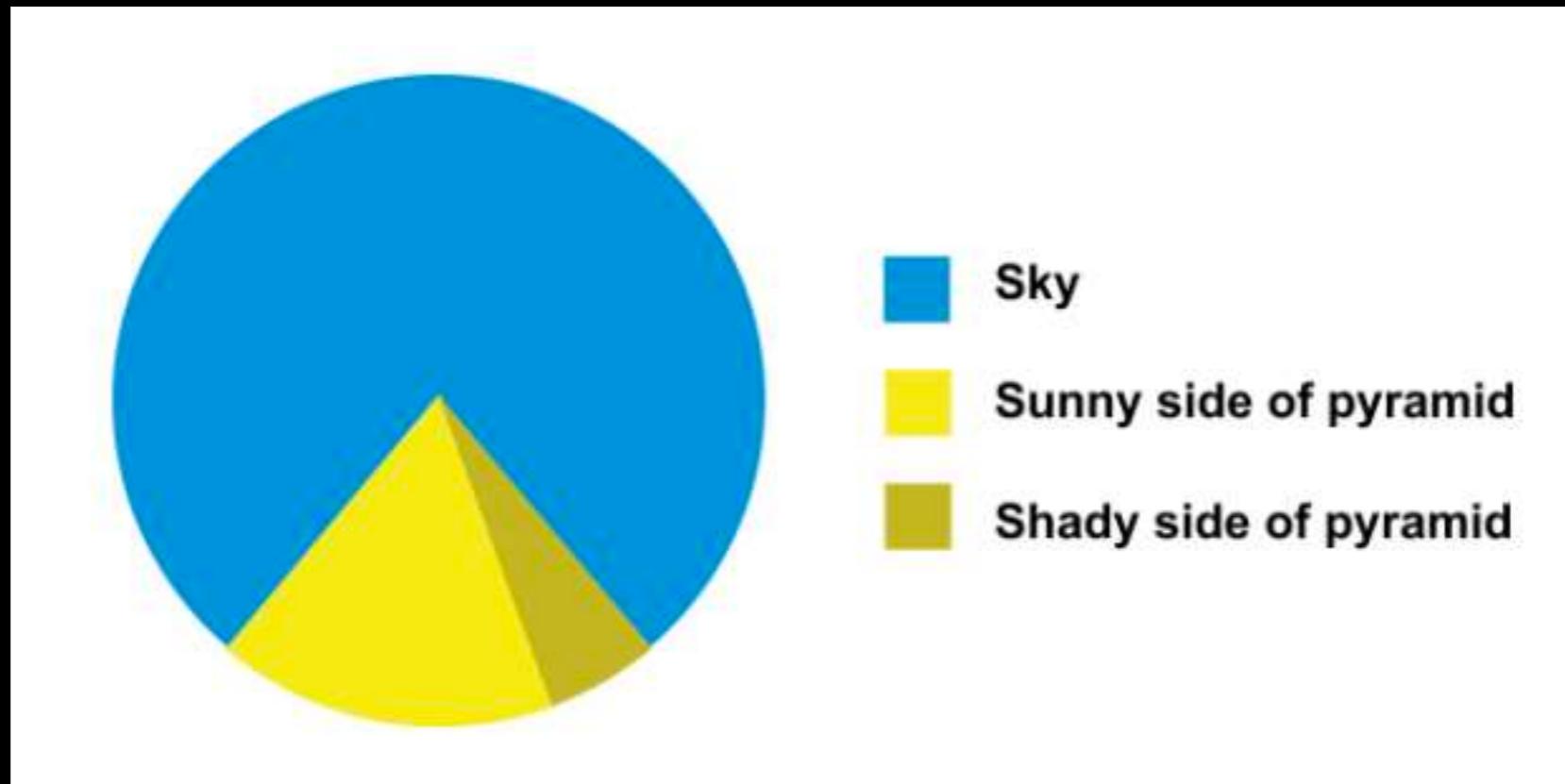
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Who do you think did a better job in tonight's debate?

	Clinton	Trump
Among Democrats	99%	1%
Among Republicans	53%	47%

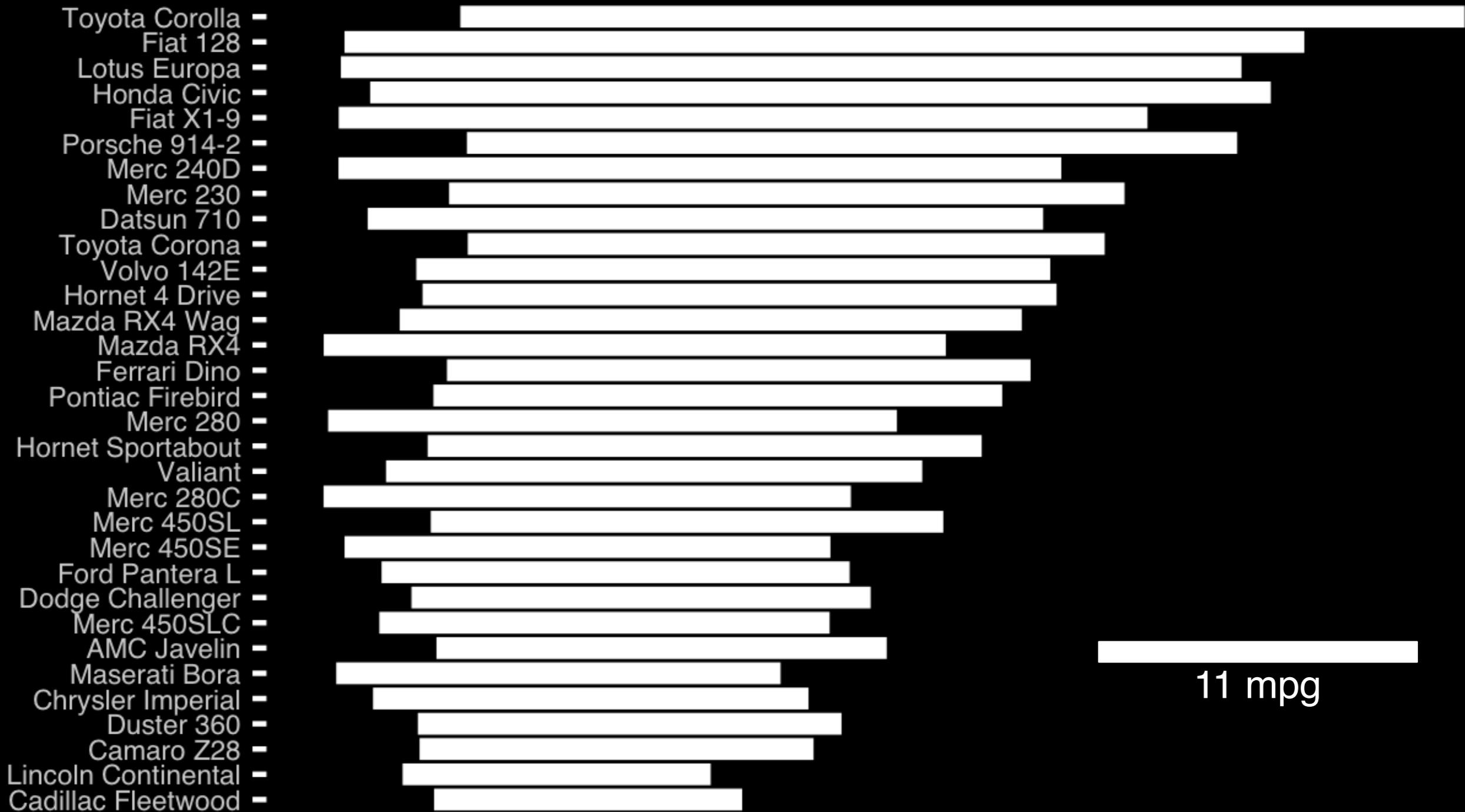


All good pie charts are jokes...

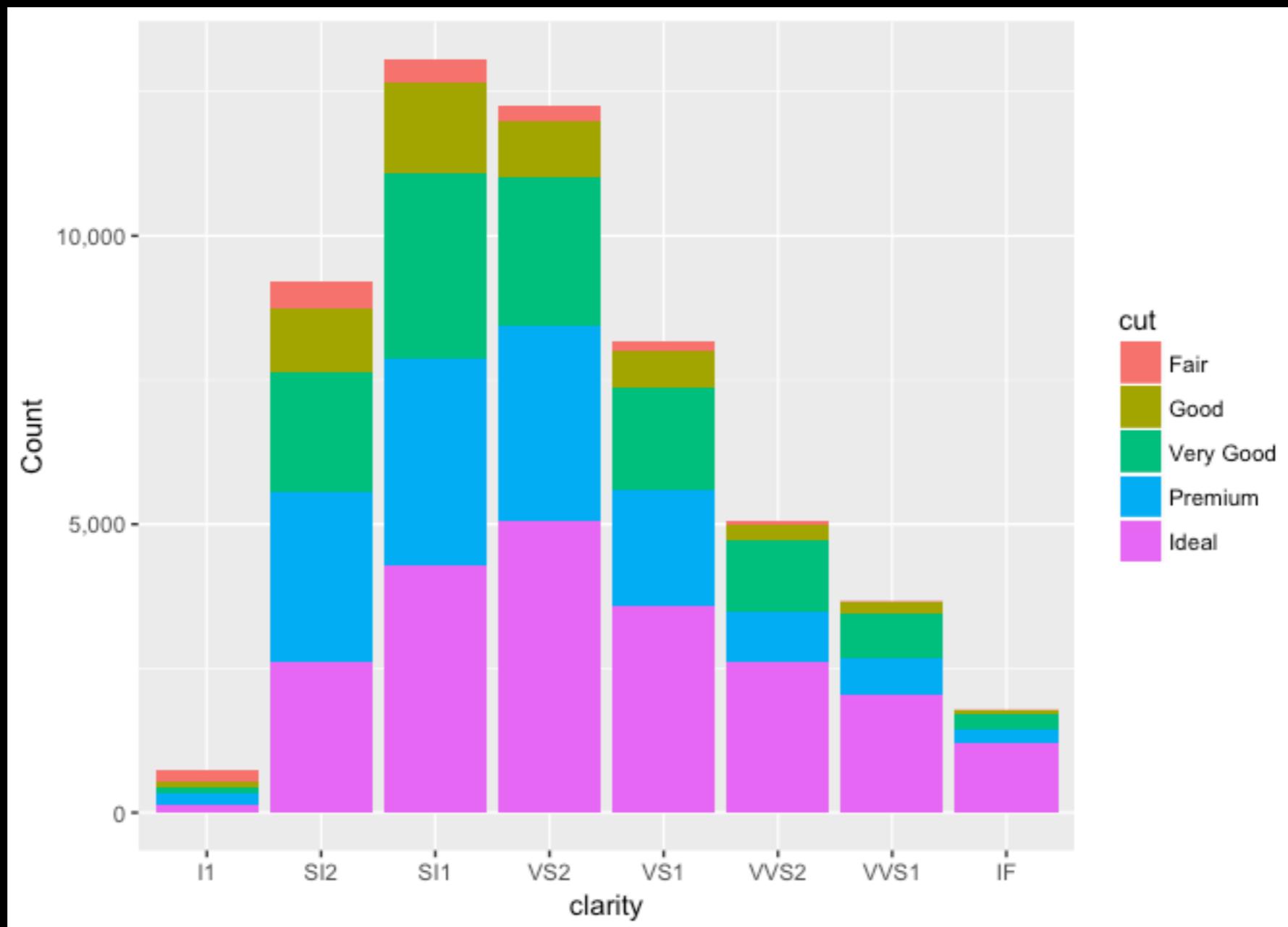


The most important measurement should exploit the highest ranked encoding possible.

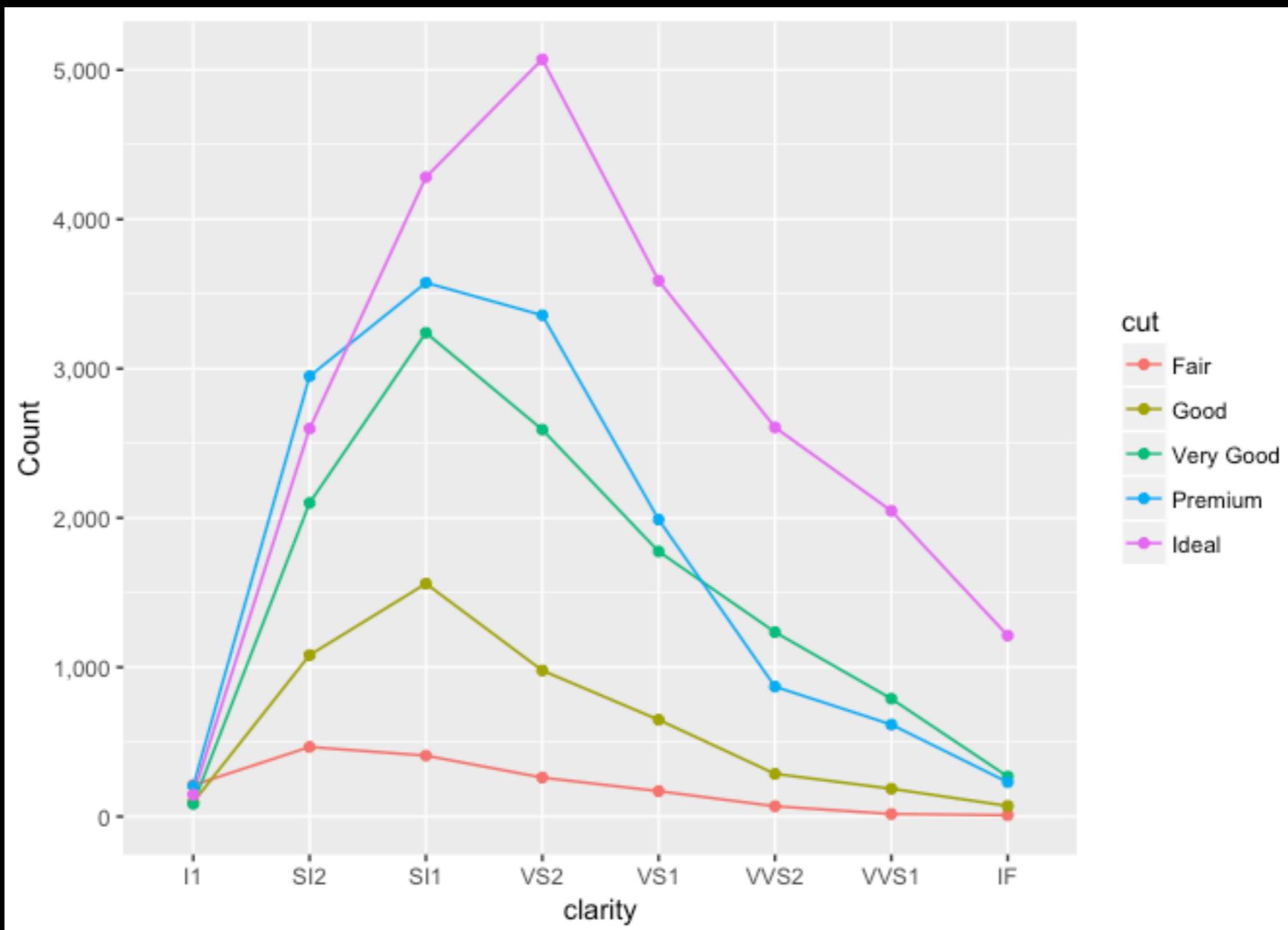
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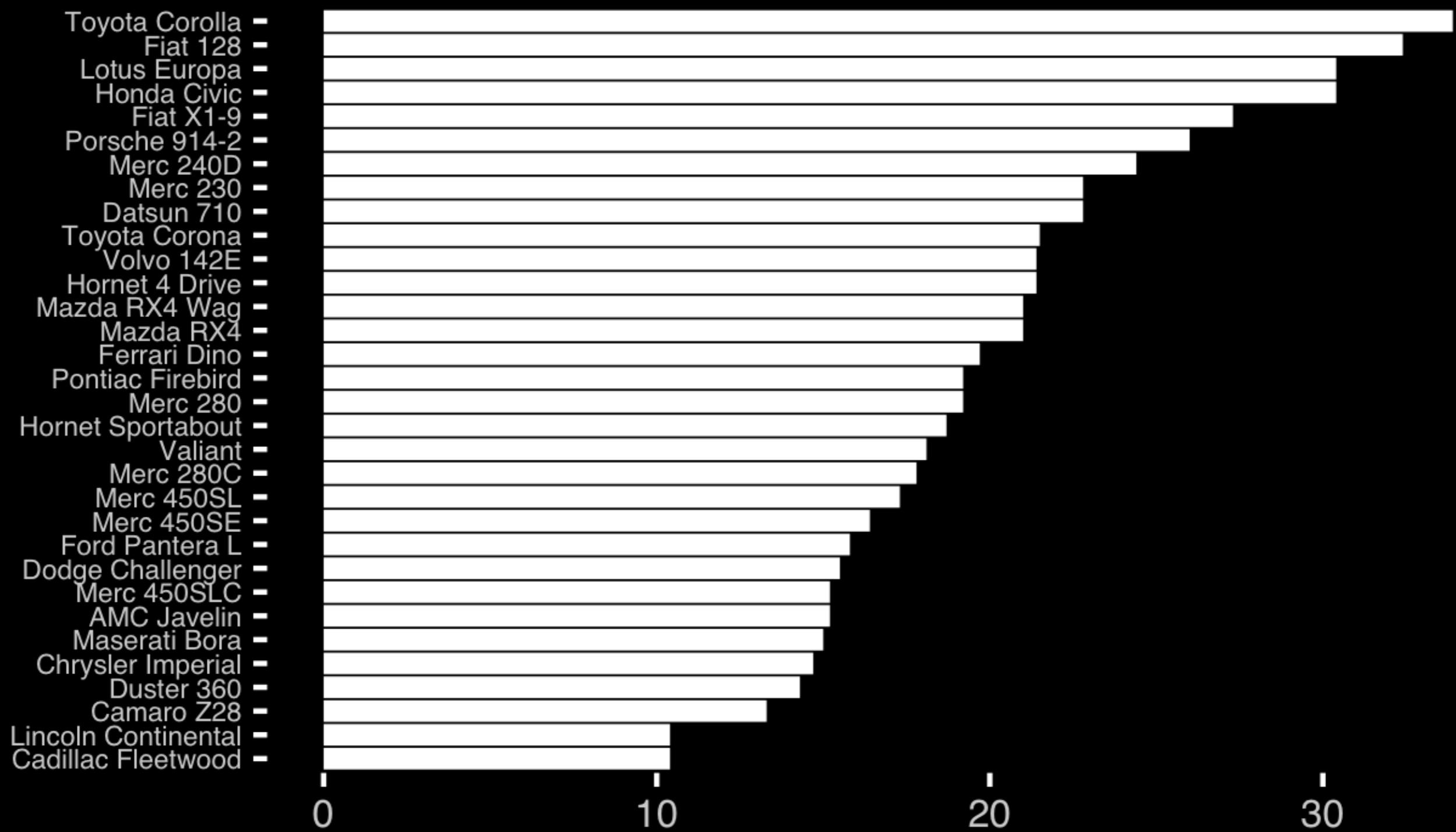


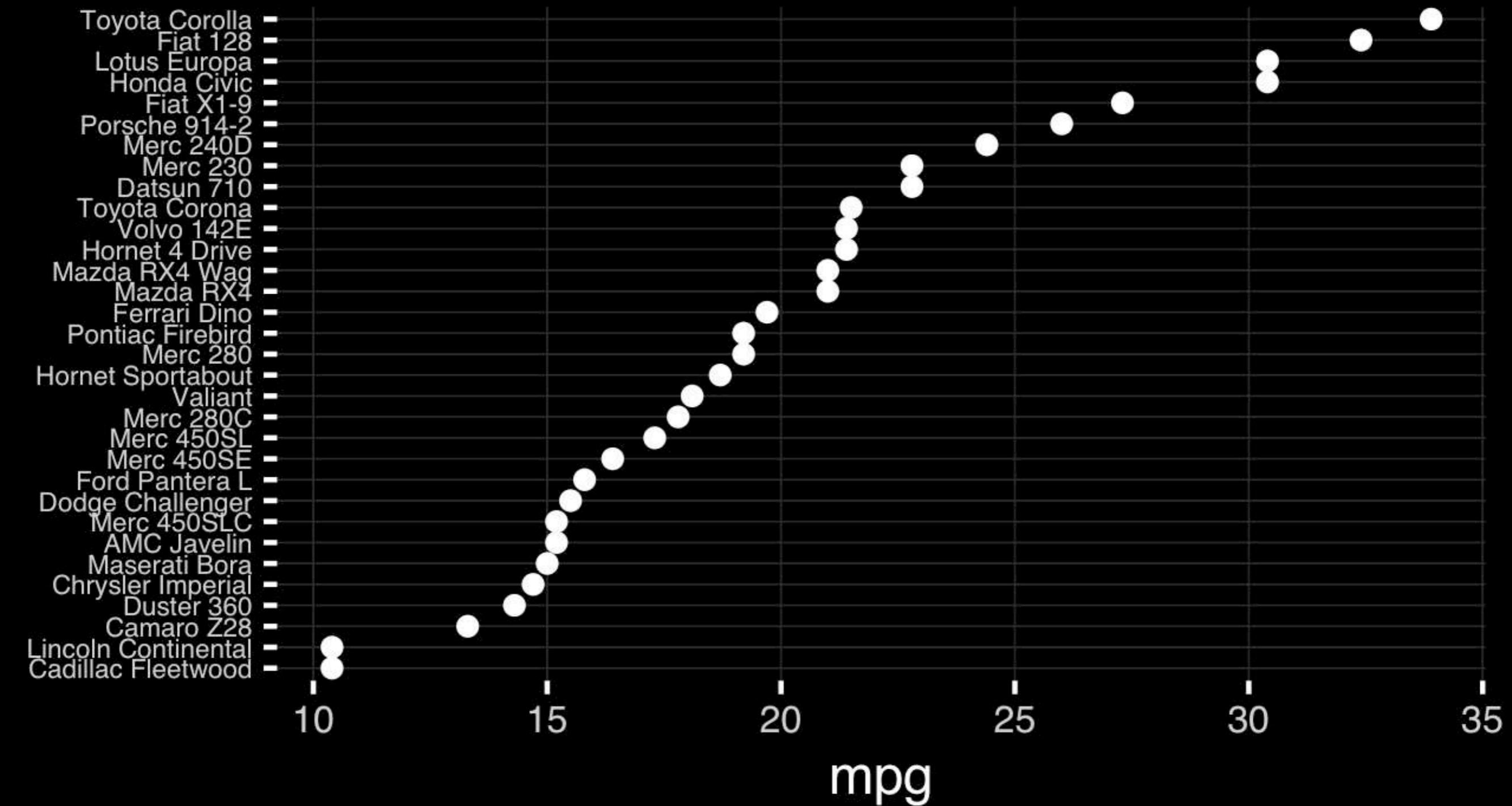
Stacked anything is nearly always a mistake



This is much better...

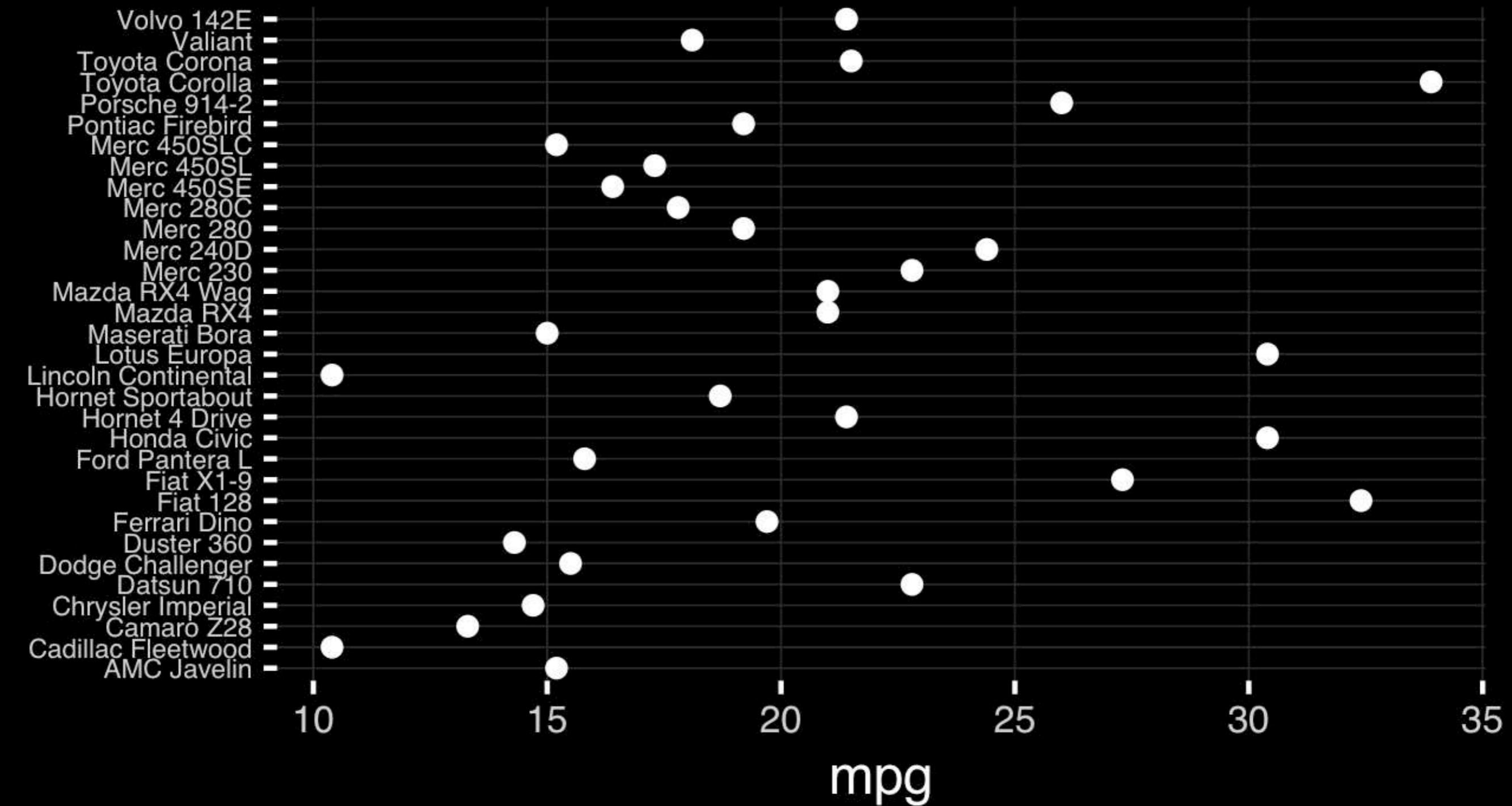


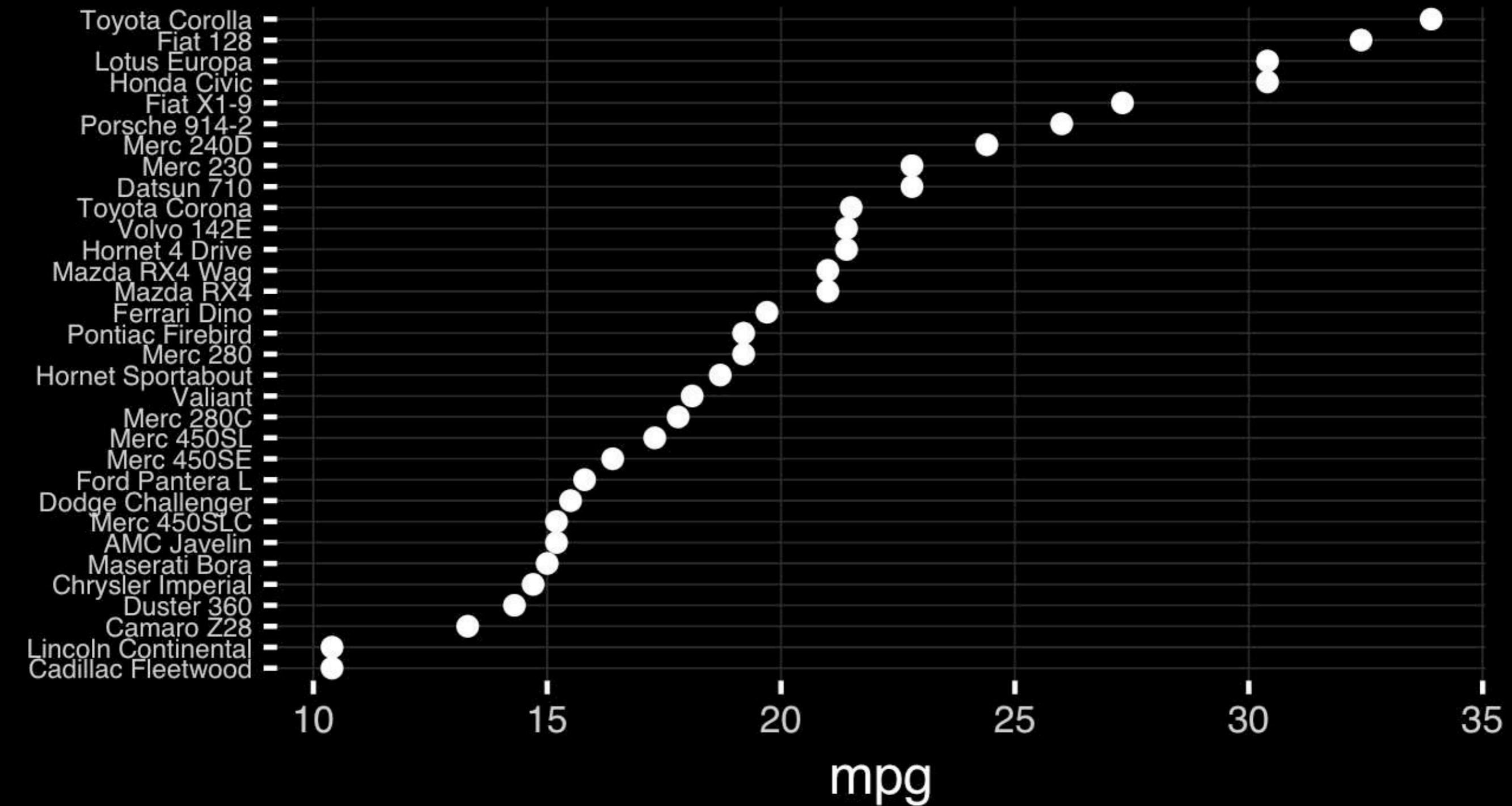


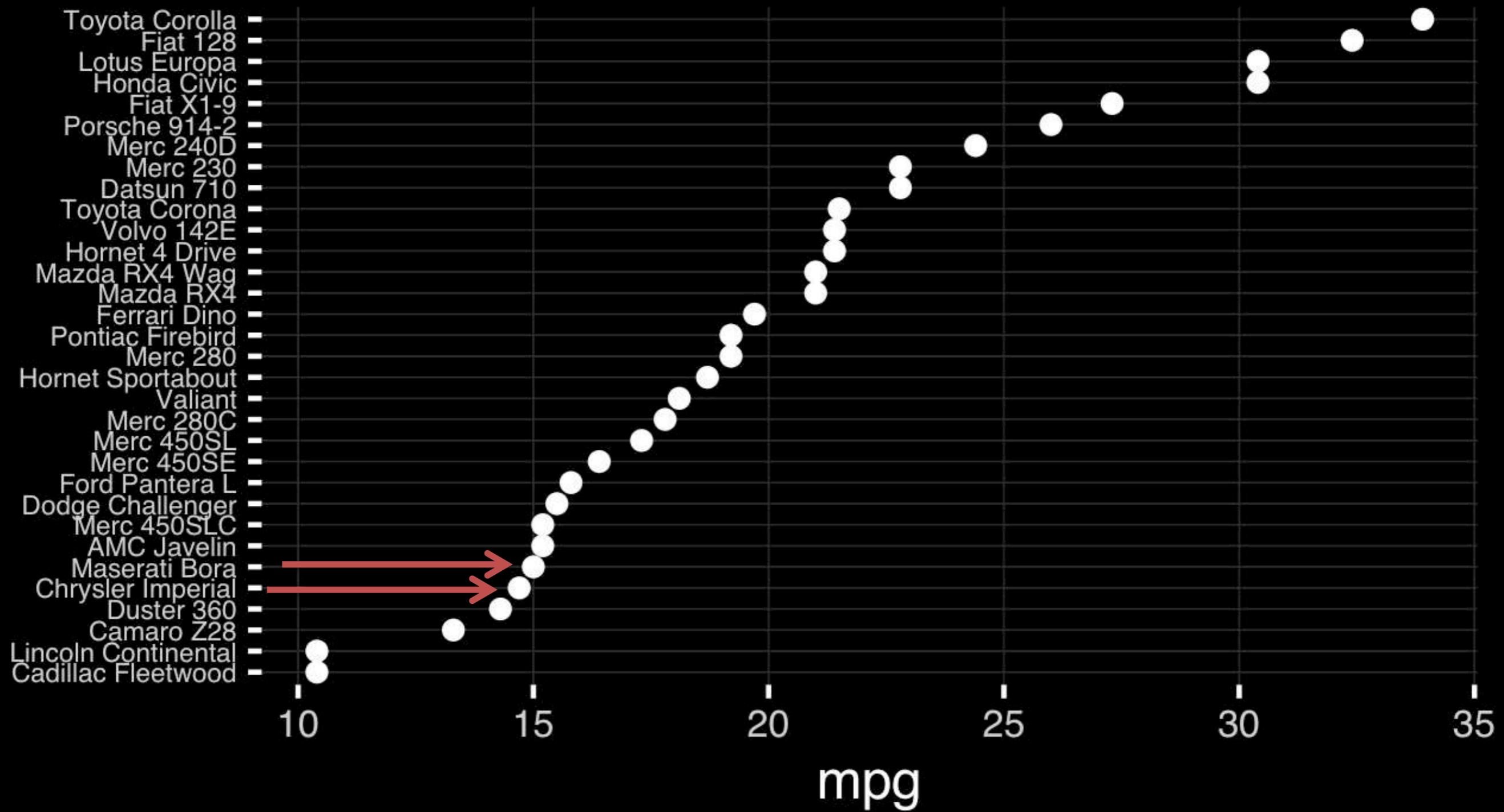


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**Observation: Comparison is
trivial on a common scale.**

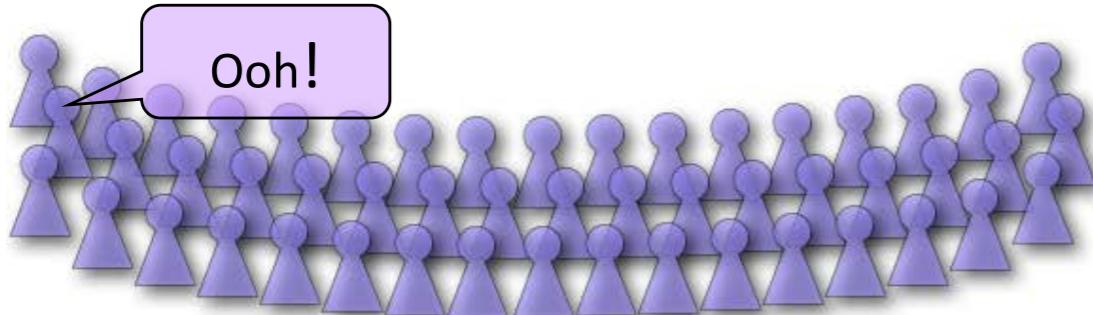
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- Appreciate the major elements of **exploratory data analysis** and why it is important to visualize data.
- Be conversant with **data visualization best practices** and understand how good visualizations optimize for the human visual system.
- Be able to generate informative graphical displays including **scatterplots**, **histograms**, **bar graphs**, **boxplots**, **dendograms** and **heatmaps** and thereby gain exposure to the extensive graphical capabilities of R.
- Appreciate that you can build even more complex charts with **ggplot** and additional R packages such as **rgl**.

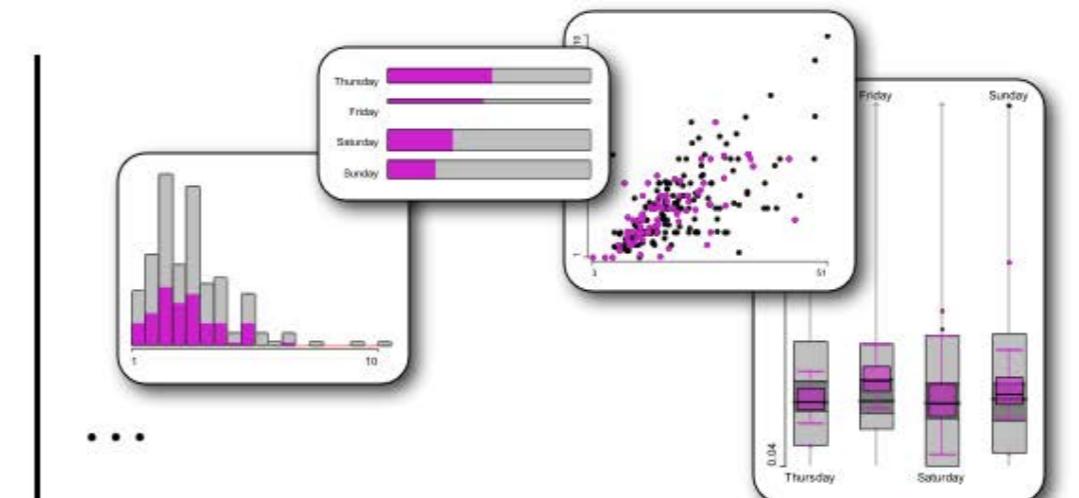
Different graphs for different purposes

Exploratory graphs: many images for a narrow audience (you!)

Presentation graphs: single image for a large audience

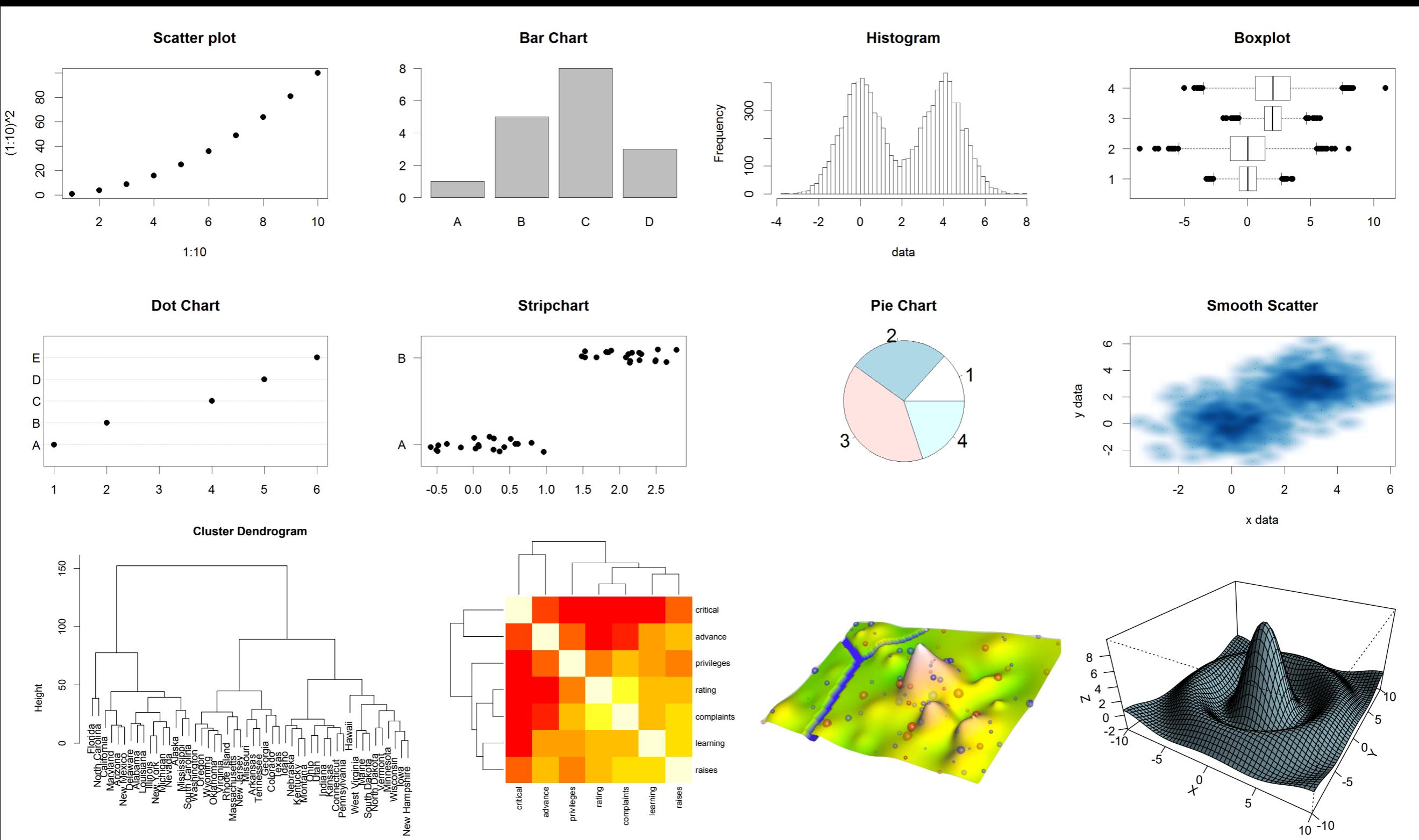


Presentation

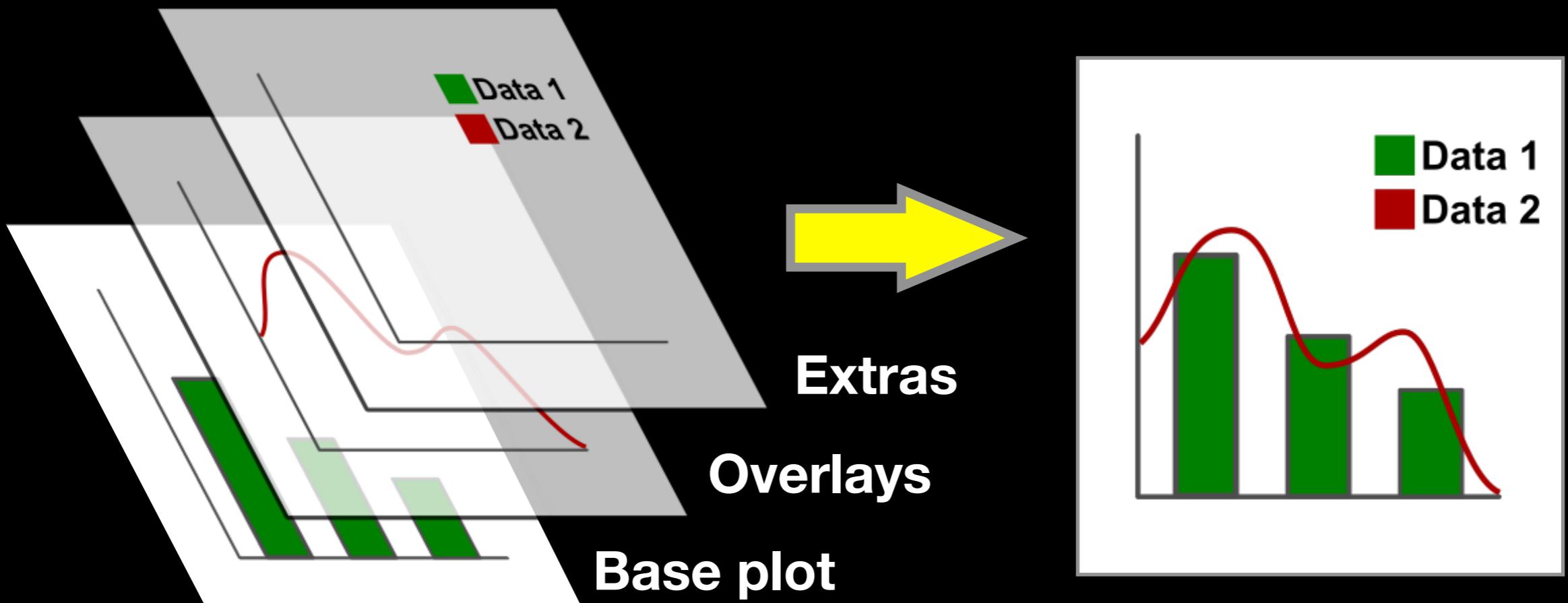


Exploration

Core R Graph Types



The R Painters Model



Side-Note: “Red and green should never be seen”

Hands-on

Section 1 only please

- Create a new **RStudio Project** for this class,
- **Download** the example data files and move them to your project directory,
- Focus on **Sections 1A & 1B** in the **handout**.

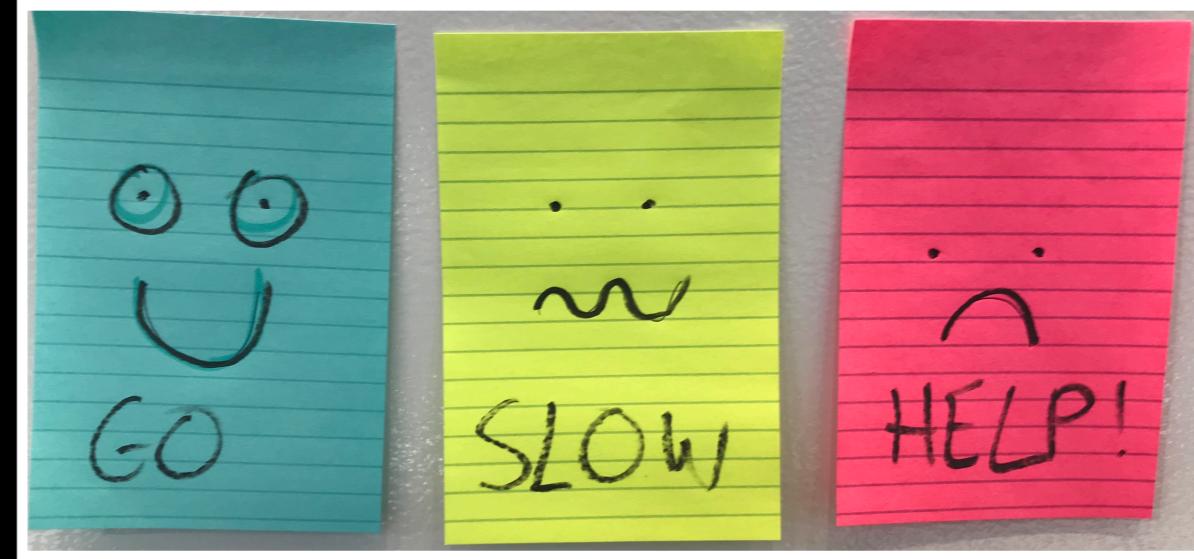
Do it Yourself!



Hands-on

Section 1 only please

- Create a new **RStudio Project** for this class,
- **Download** the example data files and move them to your project directory,
- Focus on **Sections 1A & 1B** in the **handout**.



Hands-on Section 2 Notes

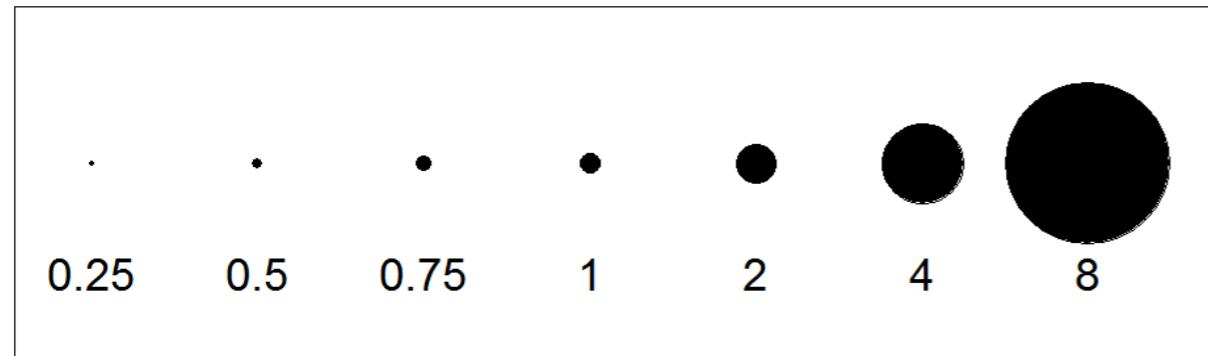
- Focus on Sections 2A & 2B in the lab **handout**.
- Try Section 2C if you have time.
- See notes on the following slides...

Common Options

- Axis scales
 - ▶ `xlim c(min, max)`
 - ▶ `ylim c(min, max)`
 - Axis labels
 - ▶ `xlab(text)`
 - ▶ `ylab(text)`
 - Plot titles
 - ▶ `main(text)`
 - ▶ `sub(text)`
 - Plot characters
 - ▶ `pch(number)`
 - ▶ `cex(number)`
- Local options to change a specific plot
 - Global options to affect all graphs

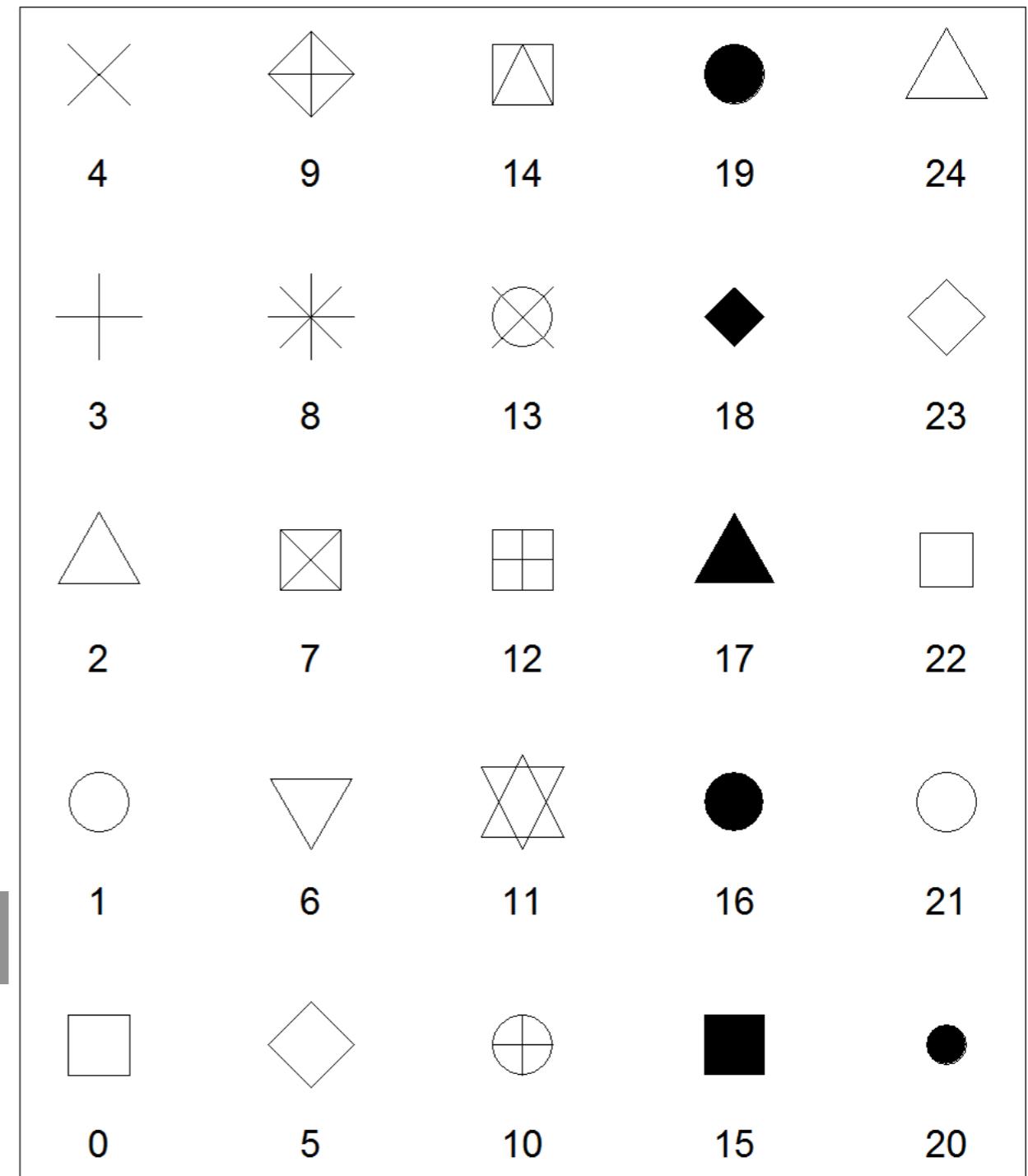
Plot Characters

cex sizes



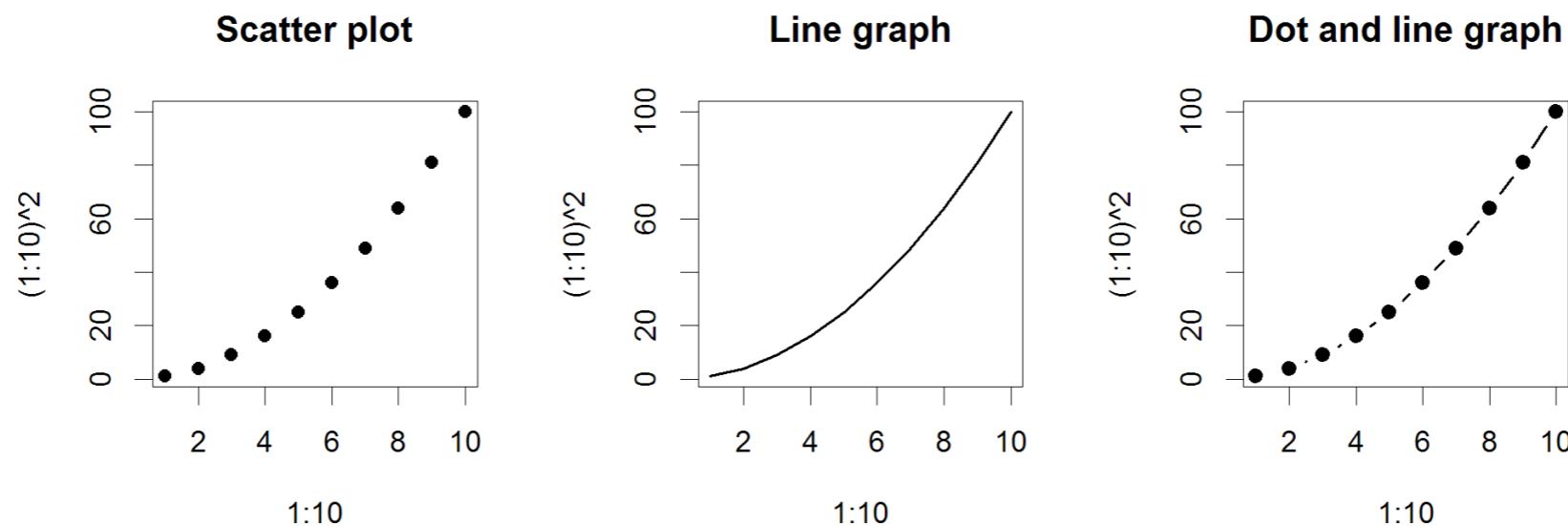
```
plot( 1:5, pch=1:5, cex=1:5 )
```

Plot Characters



Plot Type Specific Options

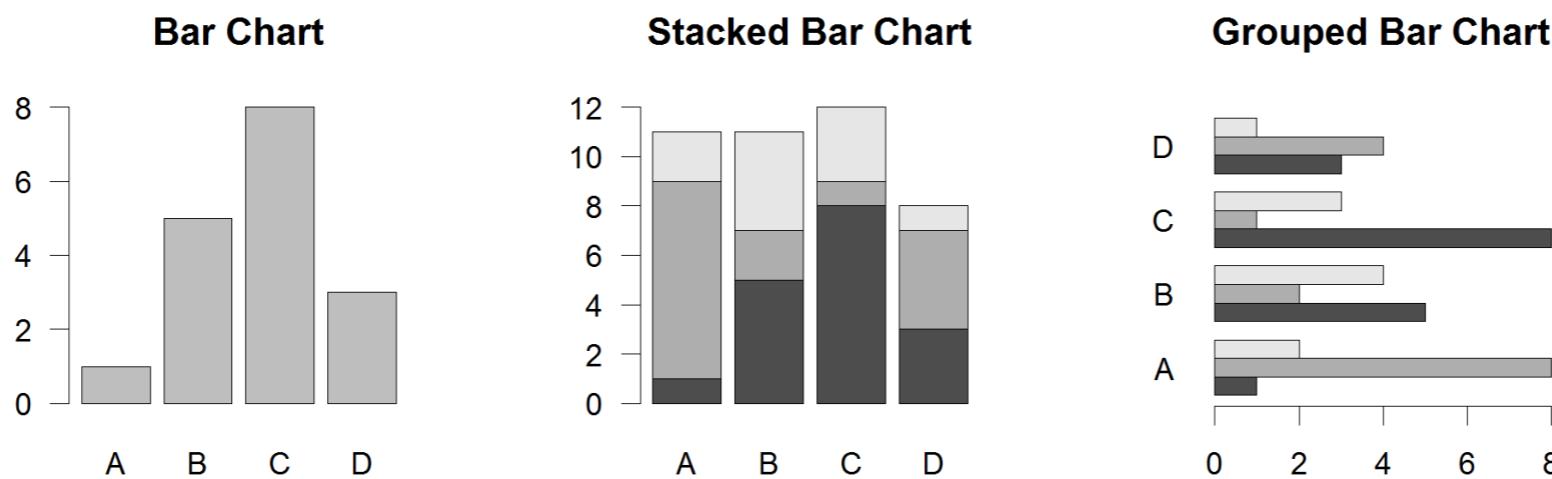
Plot (scatterplots and line graphs)



- Input: Almost anything. 2 x Vectors
- Output: Nothing
- Options:
 - ▶ type `l=line`, `p=point`, `b=line+point`
 - ▶ `lwd` line width (thickness)
 - ▶ `lty` line type (1=solid, 2=dashed, 3=dotted etc.)

```
plot( c(1:10)^2, typ="b", lwd=4, lty=3 )
```

Section 2B: Barplot (a.k.a. bar graphs)



- Input: Vector (single) or Matrix (stack or group)
- Output: Bar centre positions
- Options:
 - ▶ `names.arg` Bar labels (if not from data)
 - ▶ `horiz=TRUE` Plot horizontally
 - ▶ `beside=TRUE` Plot multiple series as a group not stacked

```
barplot(VADeaths, beside = TRUE)
```

Controlling plot area options with par

Par

- The `par()` function controls global parameters affecting all plots in the current plot area
- Changes affect all subsequent plots
- Many `par` options can also be passed to individual plots

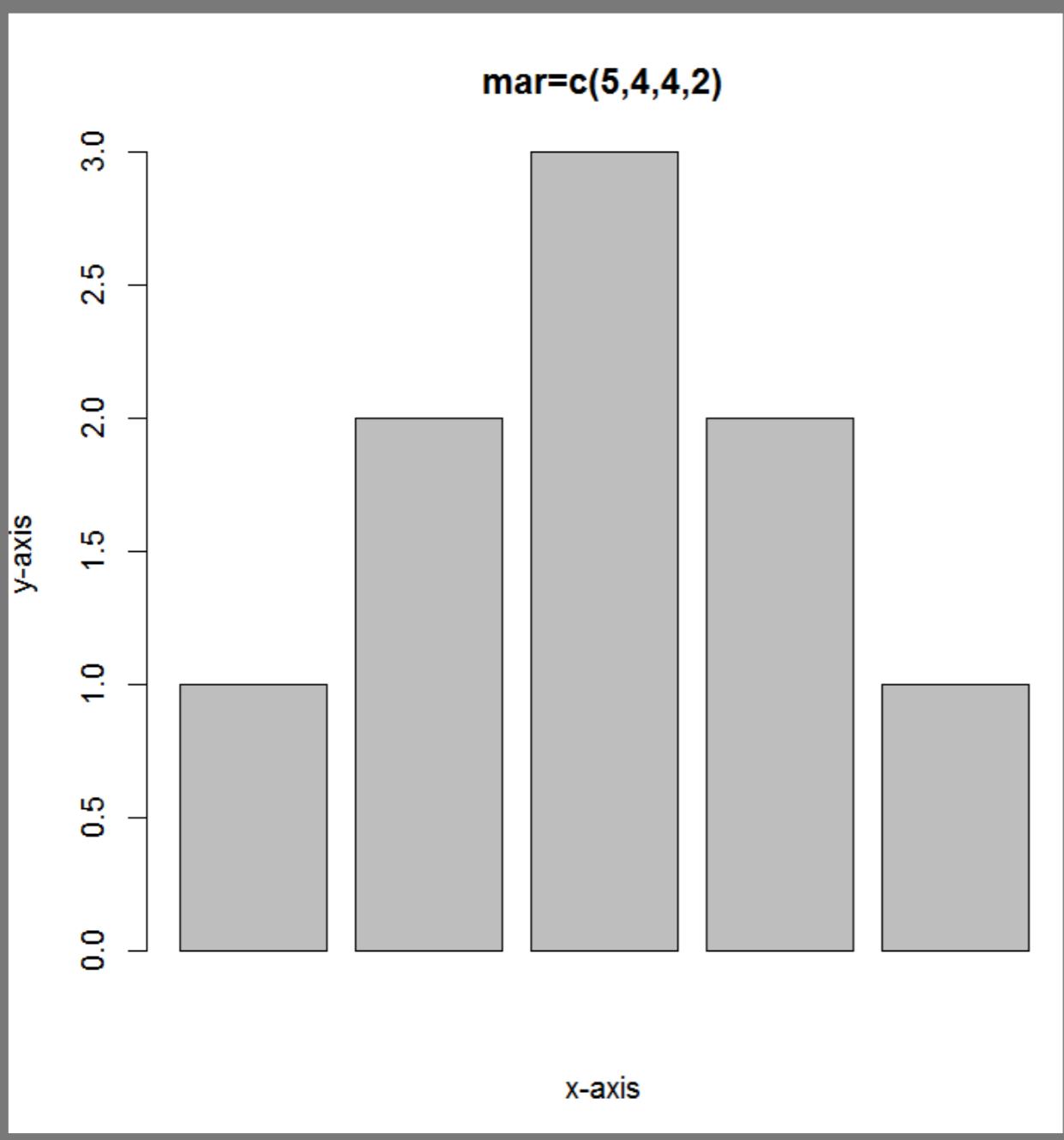
?par

Par examples

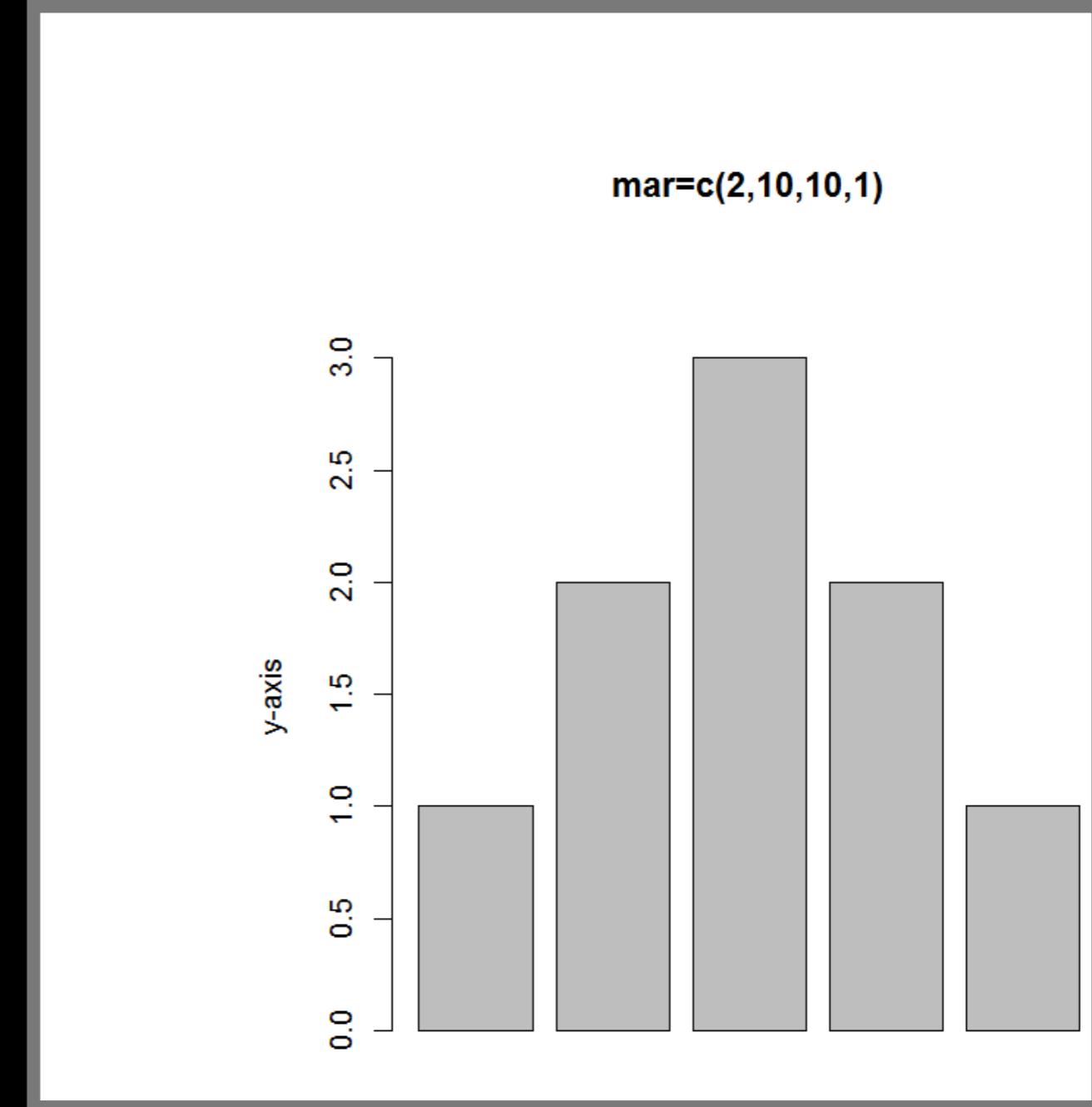
- Reading current value
 - ▶ `old.par <- par()$mar`
- Setting a new value
 - ▶ `par(mar=c(4, 11, 2, 1)) # Do plot`
- Restoring old value after you are done
 - ▶ `par(mar=old.par)`

Margin values are set with a 4 element vector (bottom, left, top, right)

mar=c(5,4,4,2)



mar=c(2,10,10,1)

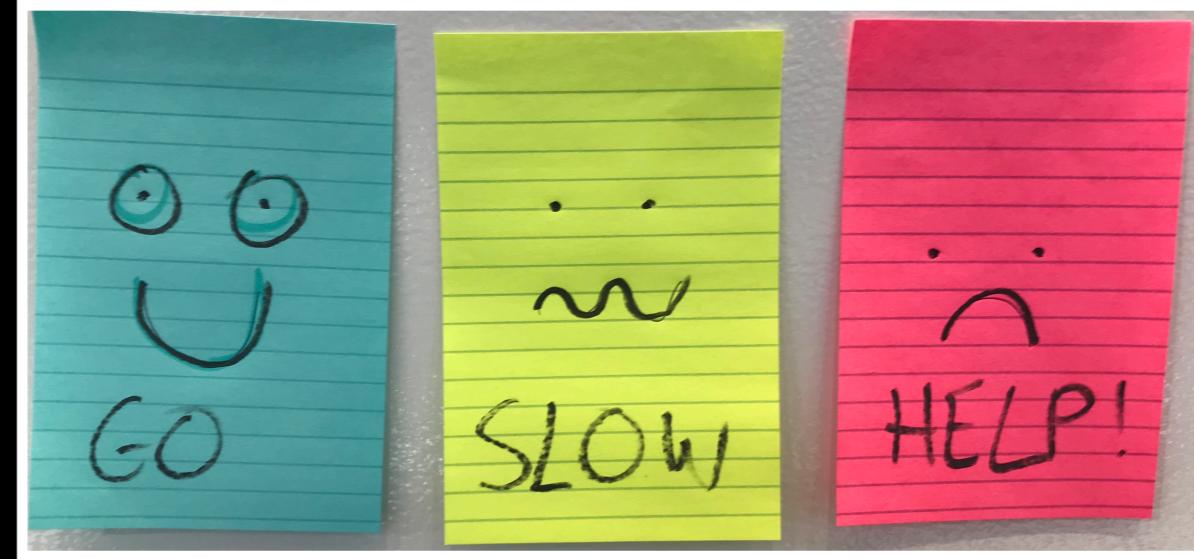


**par(mar=c(2, 10, 10, 1))
barplot(x)**

Par options

- Margins
 - mai (set margins in inches)
 - mar (set margins in number of lines)
 - mex (set lines per inch)
 - 4 element vector (bottom, left, top, right)
- Warning
 - Error in plot.new() : figure margins too large

```
par( mar=c(2, 10, 1, 1) )
```



Hands-on

Section 3 only please

- Focus on Sections 3A & 3B in the lab **handout**.
- Try Section 3C if you have time.
- See notes on the following slides...

Specifying colors

- **Controlled names**
 - ▶ `col=c("red", "green")` etc.
 - ▶ `see colors()`
- **Color by number**
 - ▶ `col=c(1, 2, 3)`
 - ▶ Will give black, red, green etc.
- **Hexadecimal strings string**
 - ▶ Of the form "#RRGGBB" where each of the pairs RR, GG, BB consists of two hexadecimal digits giving a value in the range 00 to FF:
 - ▶ `#FF0000` (red)
 - ▶ `#0000FF` (blue)

Built in color schemes

- Functions to generate colors
- Pass in the number of colors you want,
e.g. to get 7 different colors:
 - ▶ `rainbow(7)`
 - ▶ `heat.colors(7)`
 - ▶ `cm.colors(7)`
 - ▶ `terrain.colors(7)`
 - ▶ `topo.colors(7)`
 - ▶ Etc.

```
rainbow( 7 )
```

Rainbow Colours



Heat Colours



CM Colours



Terrain Colours



Topo Colours



rainbow(7)

Color Packages

- Color Brewer
 - Set of pre-defined, optimized palettes
 - library(RColorBrewer)
 - brewer.pal(n_colours, palette)
- ColorRamps
 - Create smooth palettes for ramped color
 - Generates a function to make actual color vectors
 - colorRampPalette(c("red", "white", "blue"))
 - colorRampPalette(c("red", "white", "blue"))(5)

Applying Color to Plots

- Vector of numbers or specified colors passed to the `col` parameter of a plot function
- Vector of **factors** used to divide the data
 - Colors will be taken from the set color palette
 - Can read or set using `pallette()` function
 - `pallette()`
 - `pallette(brewer.pal(9, "Set1"))`

```
plot( 1:5, col=1:5, pch=15, cex=2)
```

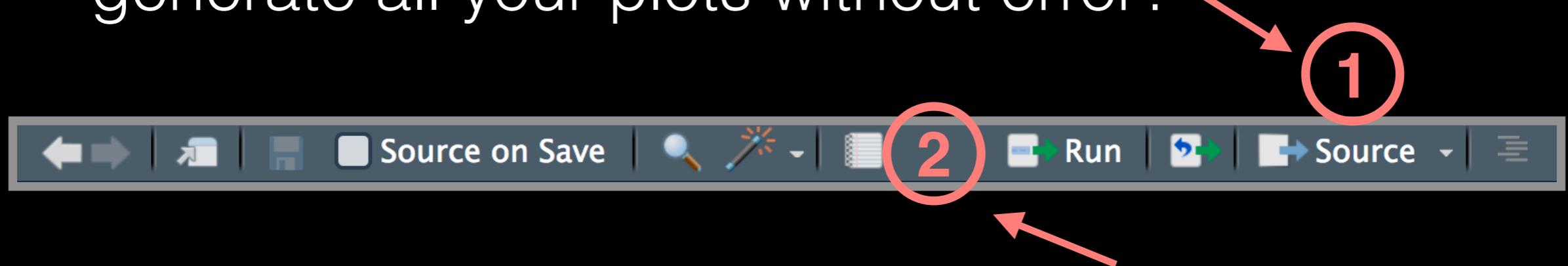
Dynamic use of color

- Coloring by density
 - Pass data and palette to `densCols()`
 - Vector of colors returned
- See Lab Supplement (online):
 - Plotting with color in R

<https://www.rdocumentation.org/packages/grDevices/versions/3.4.3/topics/densCols>

Make a lab report!

- Open your previous **class05** RStudio **project** (and your saved **R script**)
- Can you **source** your **class05.R** file to re-generate all your plots without error?



- If so you can now generate a nice **HTML report** of your work to date...

[Take 2-3 minutes]

Homework!

New DataCamp Assignment

- Intermediate R (due next week)
 - Conditionals and Control Flow
 - Functions
 - Loops
- Intermediate R: Practice (Optional)

Muddy Point Assessment Form Link

Useful new website: <https://www.data-to-viz.com/>