BIMM 143

Data visualization with R

Lecture 5

Barry Grant

UC San Diego

http://thegrantlab.org/bimm143

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, vectorizion and re-cycling).
- Appreciate how you can use R scripts to aid with reproducibility.

DataCamp Homework Reminder!! [MPA Link]

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**, **dendrograms** 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

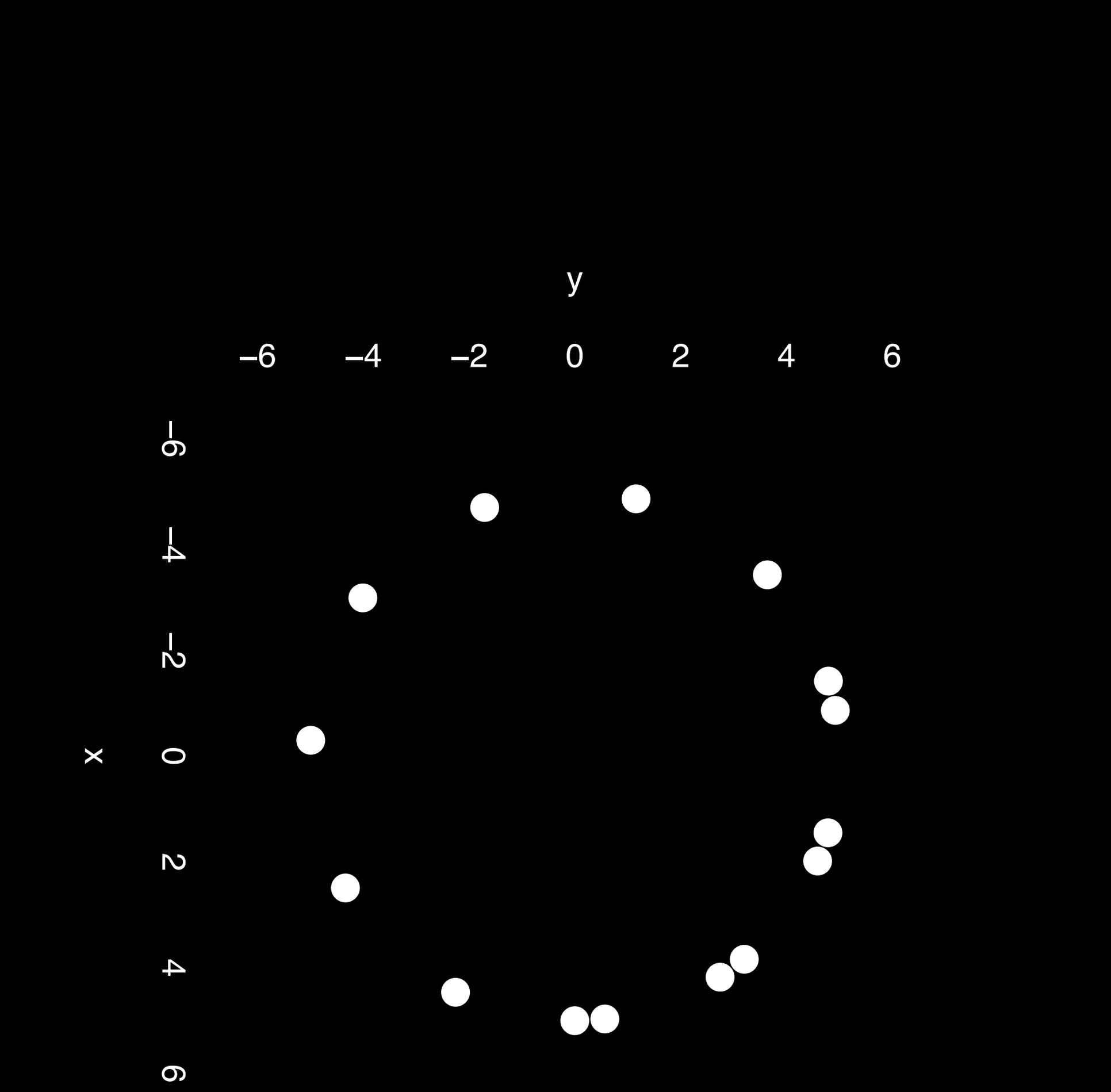
National Market System

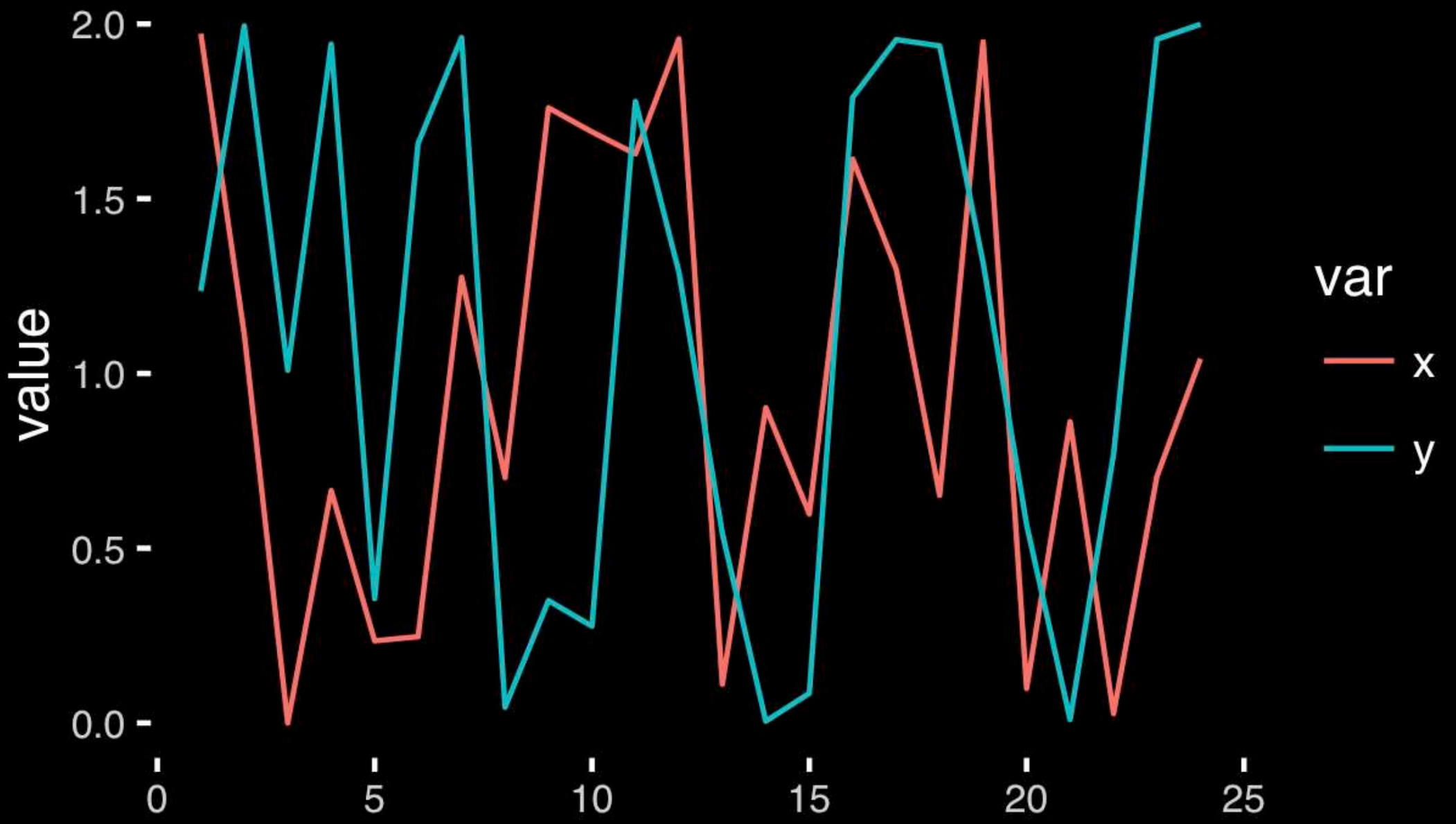
The companies listed below reflect the volume in 100's of shares on a daily basis and the closing price and net change are reflected from the previous day based on trades as provided under the NASD National Market System.

Stock	Sales	Close	Chg.
— A —			
[illegible]	[illegible]	[illegible]	[illegible]
— B —			
[illegible]	[illegible]	[illegible]	[illegible]
— D —			
[illegible]	[illegible]	[illegible]	[illegible]
— F —			
[illegible]	[illegible]	[illegible]	[illegible]
— H —			
[illegible]	[illegible]	[illegible]	[illegible]
— J-K —			
[illegible]	[illegible]	[illegible]	[illegible]
— O-P —			
[illegible]	[illegible]	[illegible]	[illegible]

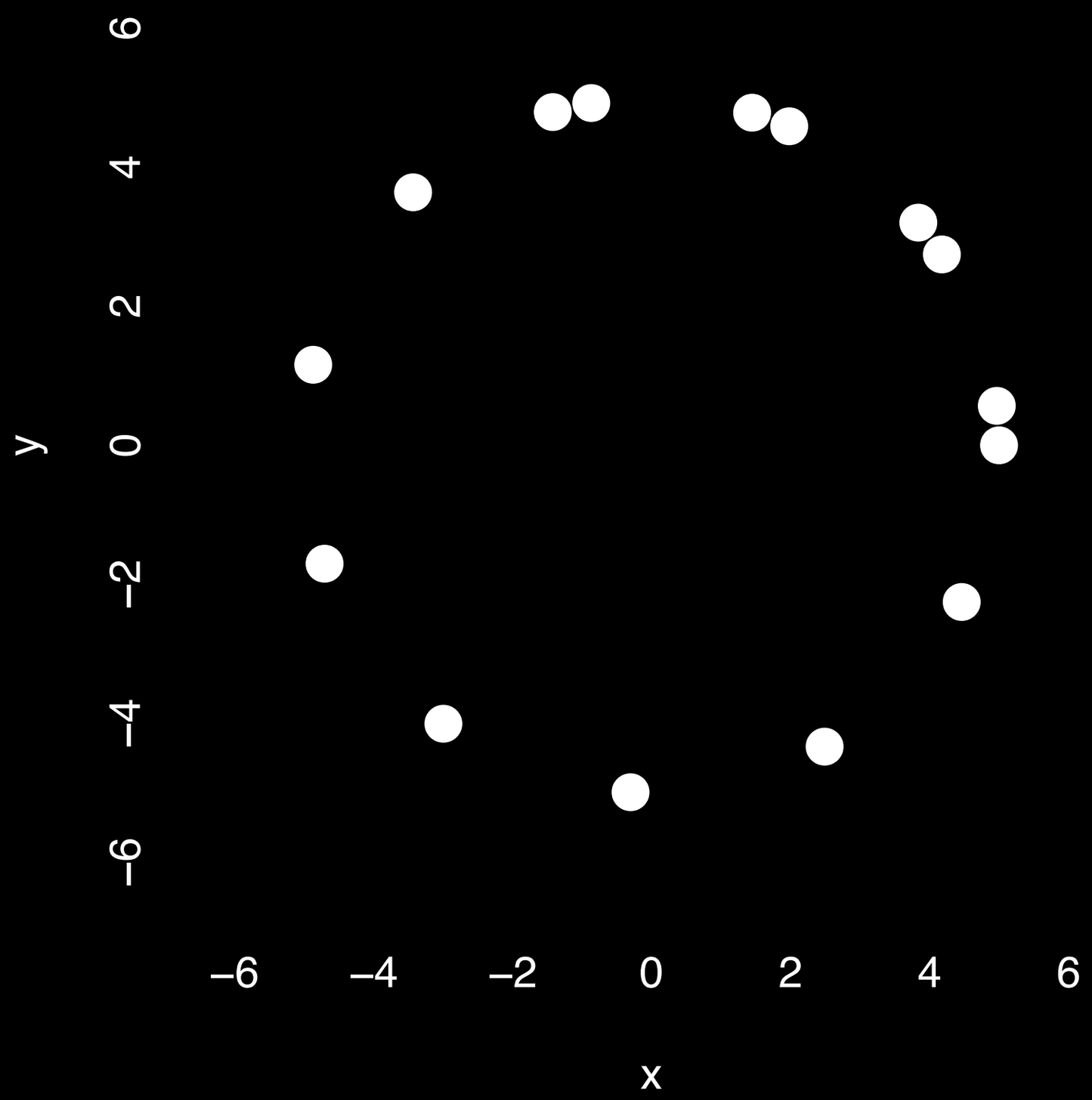
	x	y
1	5.00	0.00
2	4.18	2.75
3	1.98	4.59
4	-0.86	4.92
5	-3.43	3.64
6	-4.86	1.16
7	-4.70	-1.70
8	-2.99	-4.01
9	-0.30	-4.99
10	2.49	-4.34
11	4.46	-2.25
12	4.97	0.57
13	3.84	3.20
14	1.45	4.79
15	-1.42	4.79

	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


y
−6
−4
−2
0
2
4
6
x
−6
−4
−2
0
2
4
6


2.0
1.5
1.0
0.5
0.0
value
0
5
10
15
20
25
var
x
y

https://bioboot.github.io/bimm143_F18/class-material/05_draw_circle_points/

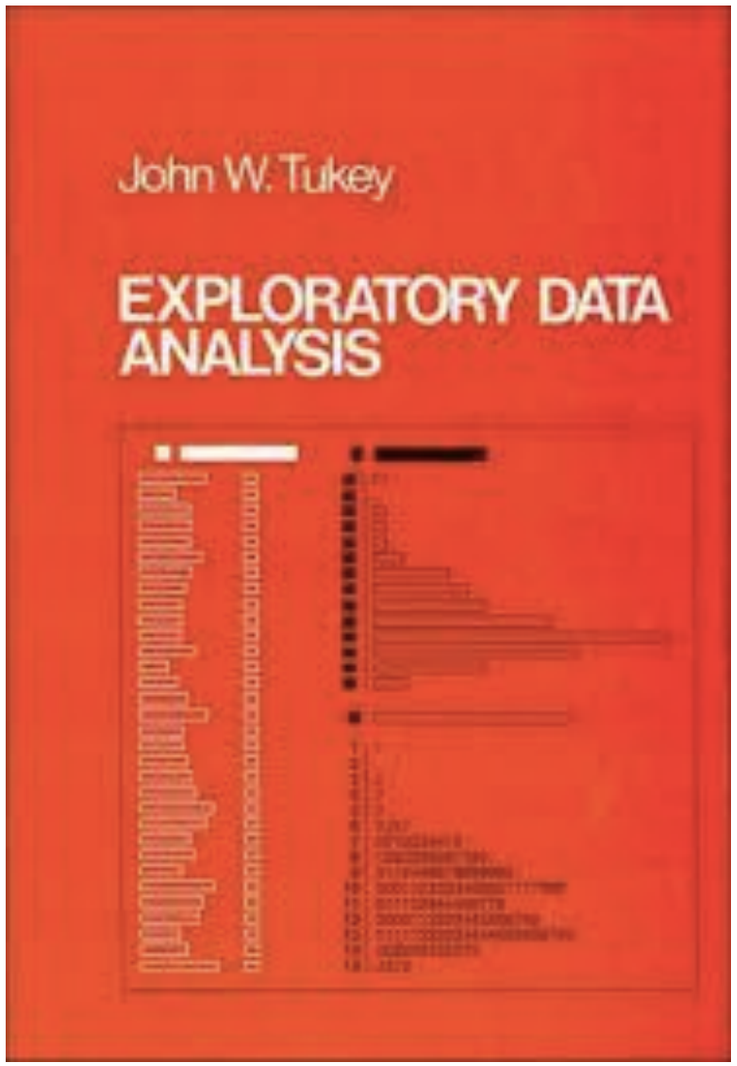


Exploratory Data Analysis

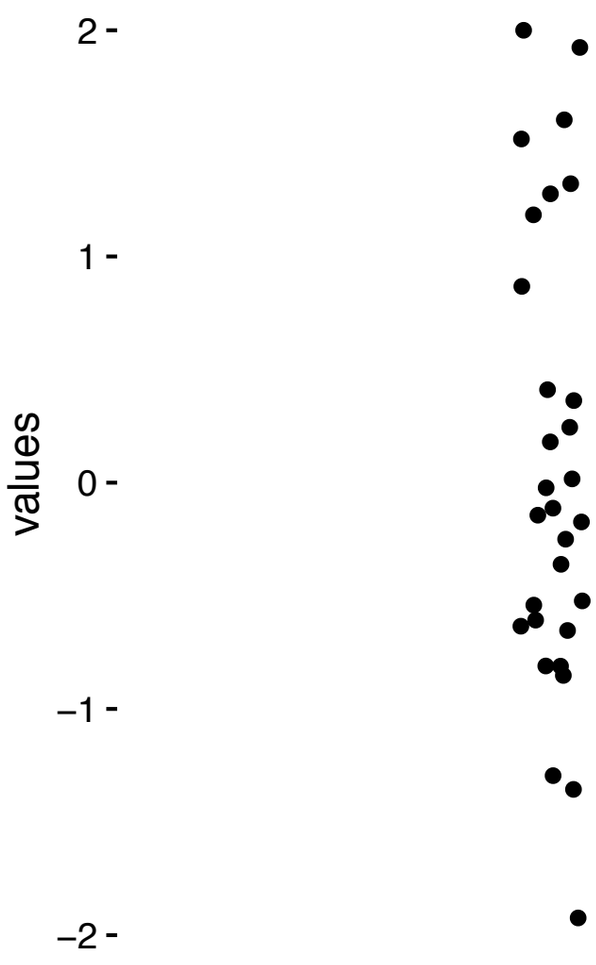
- ALWAYS look at your data!
- If you can’t see it, then don’t believe it!
- Exploratory Data Analysis (EDA) allows us to:
    1. Visualize distributions and relationships
    2. Detect errors
    3. Assess assumptions for confirmatory analysis
- EDA is the first step of data analysis!

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



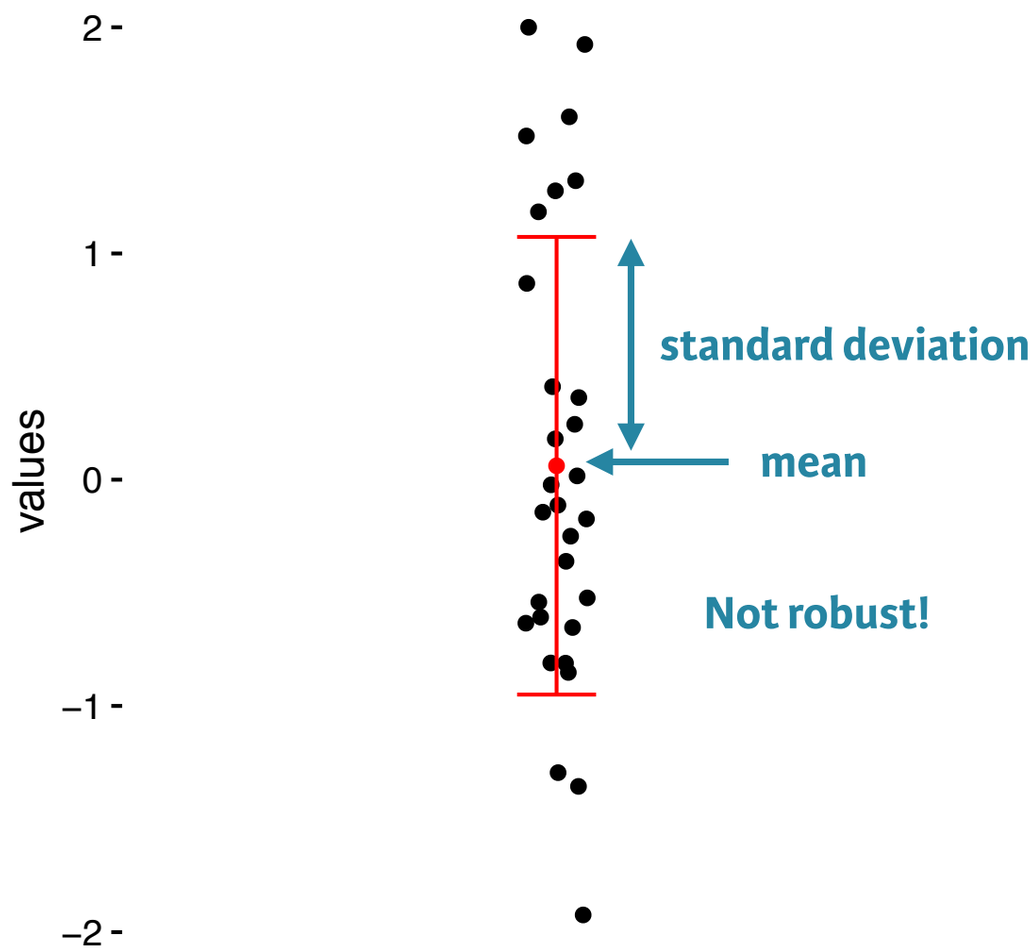
Side-note: How to summarize data?




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

Side-note: Mean & standard deviation

Fine for normally distributed data

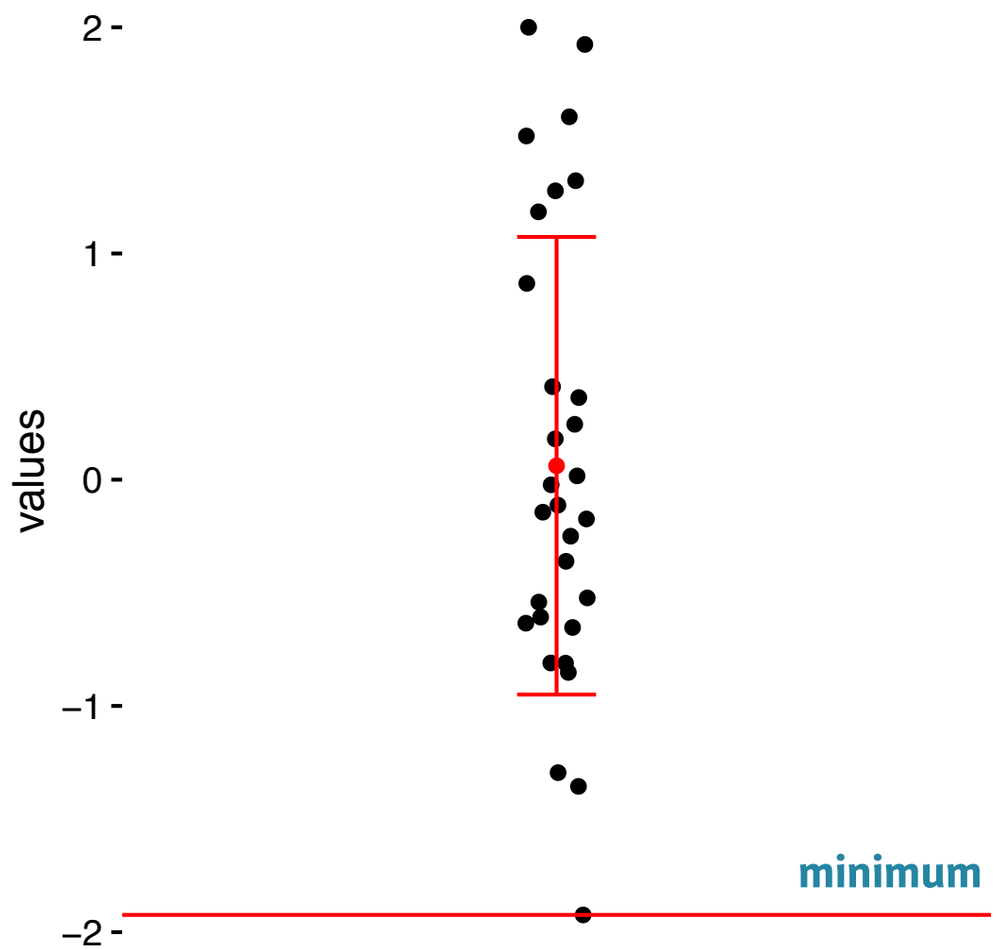



```
x <- rnorm(1000)

mean(x)
sd(x)
```

Side-note: 5 number summary

Minimum, Q1, Q2, Q3, and maximum



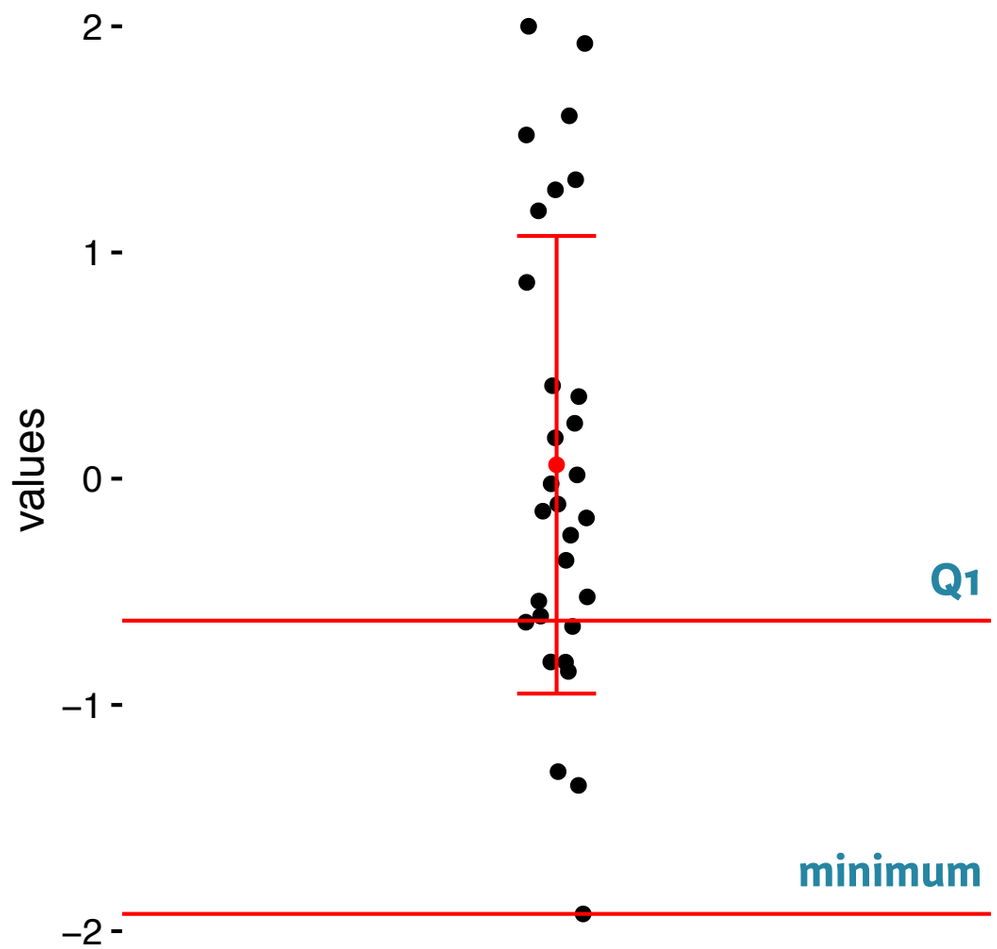

```
x <- rnorm(1000)

mean(x)
sd(x)

summary(x)
```

Side-note: 5 number summary

Minimum, Q1, Q2, Q3, and maximum

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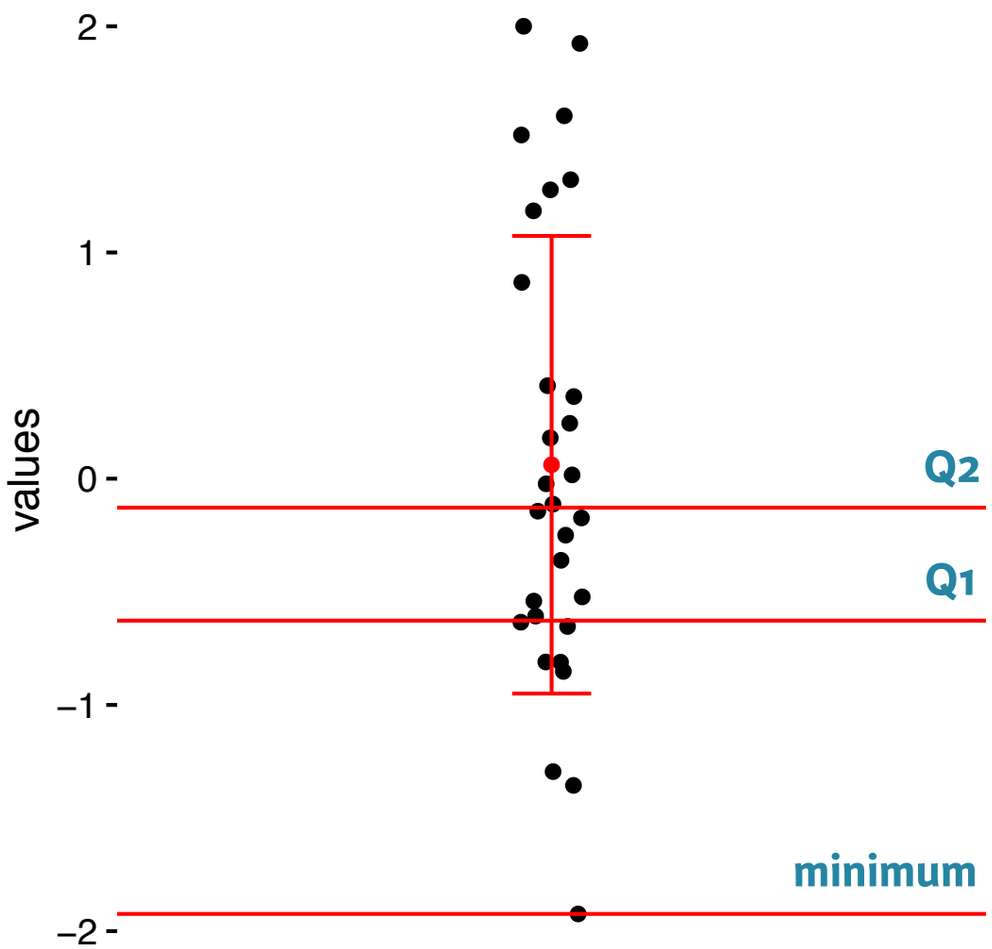


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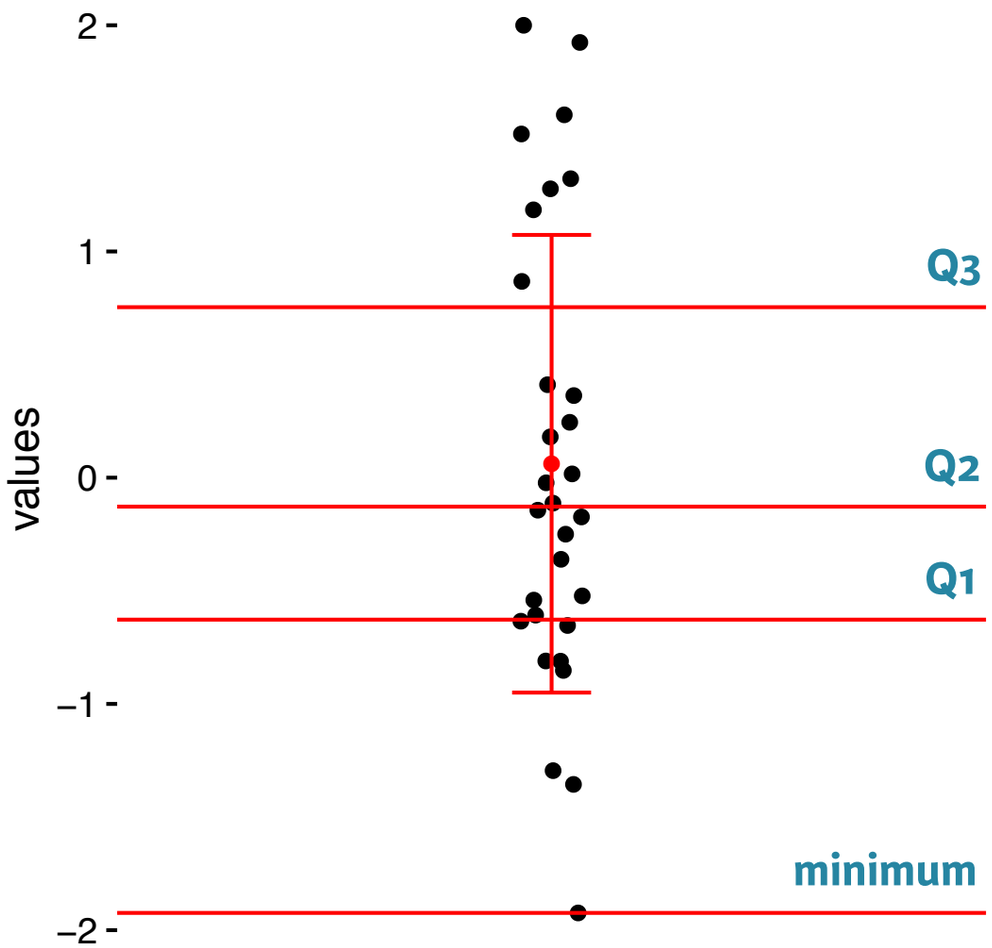


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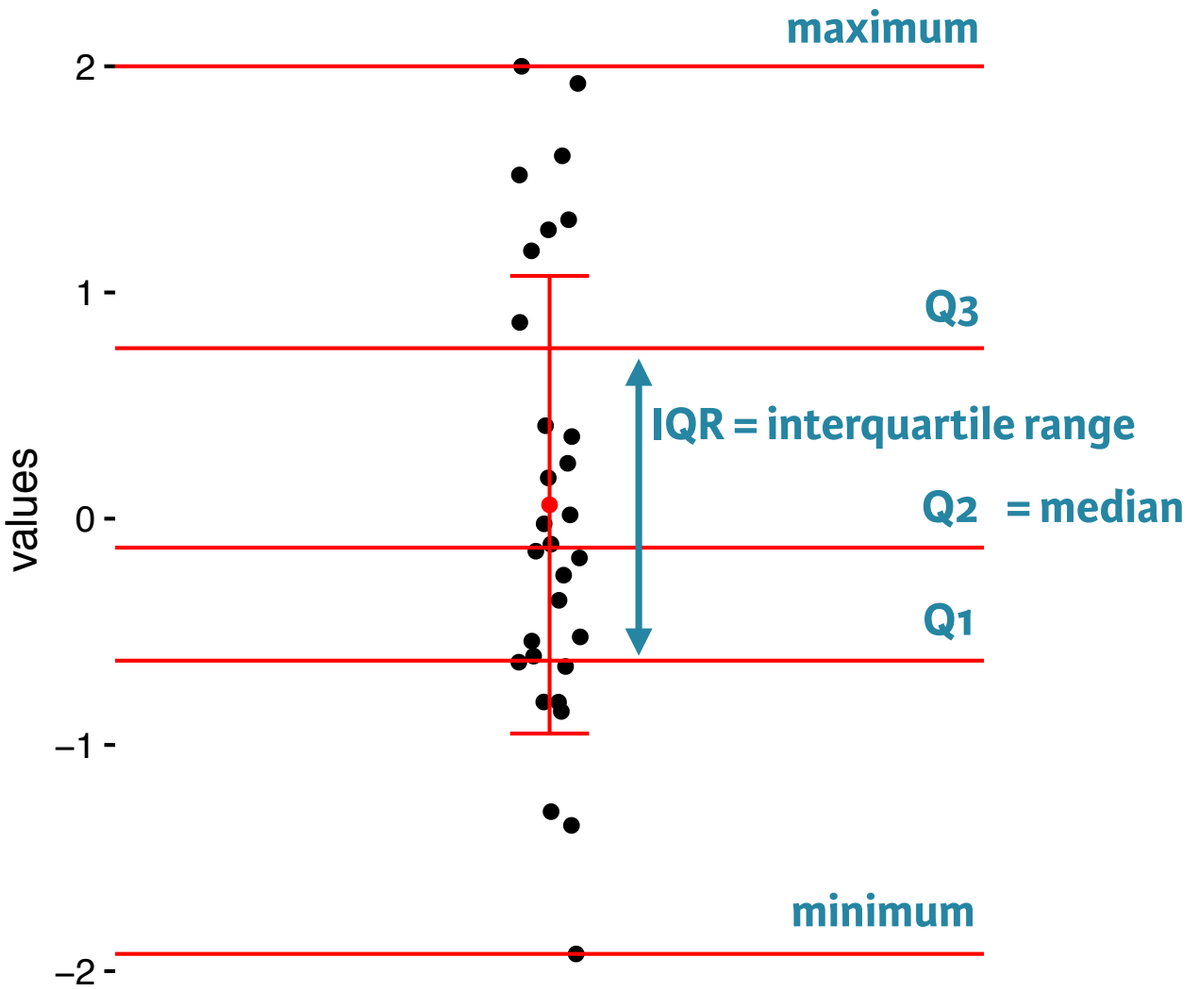


```
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mean(x)
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summary(x)
```
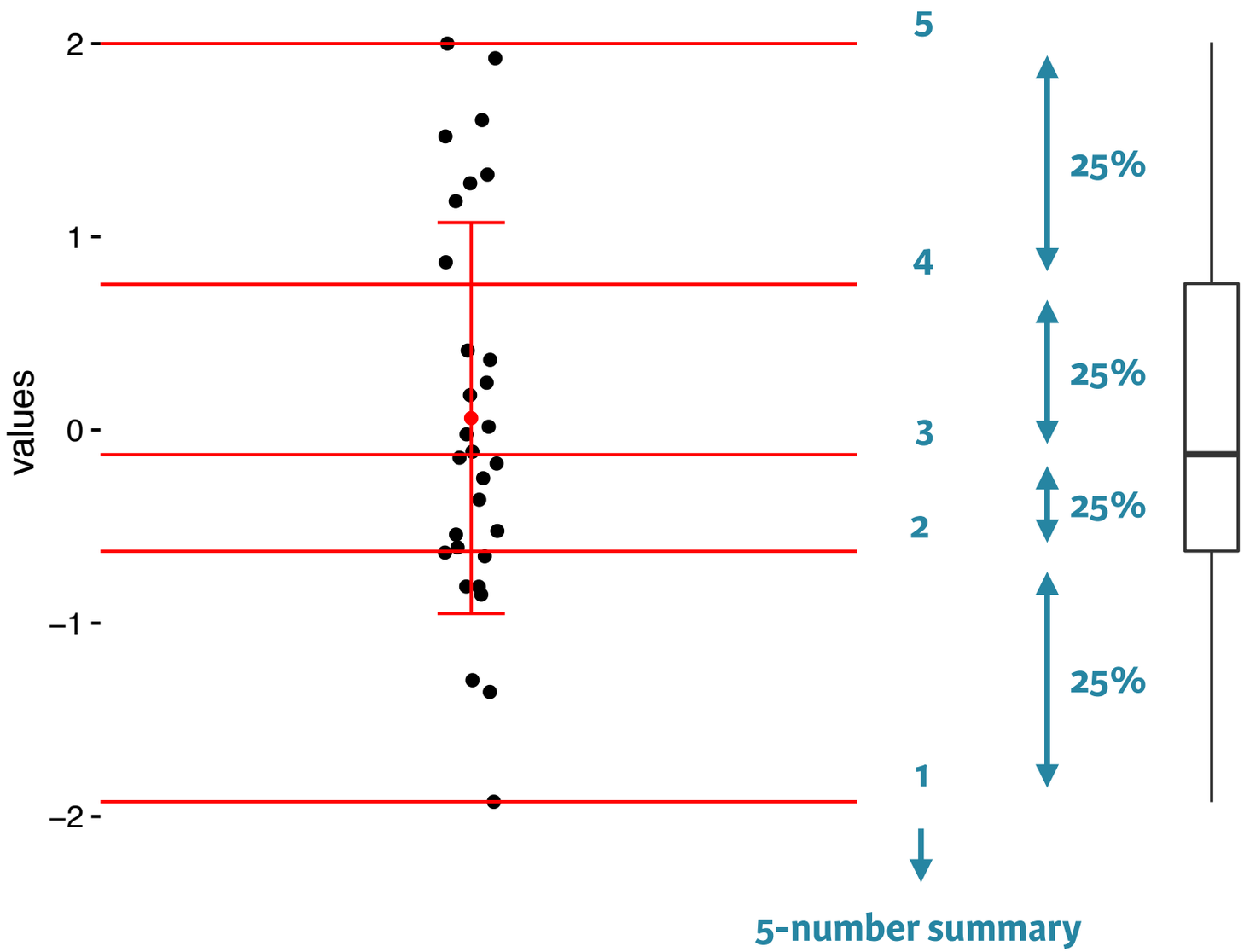

Side-note: **boxplot**

Graphical form of the 5 number summary!

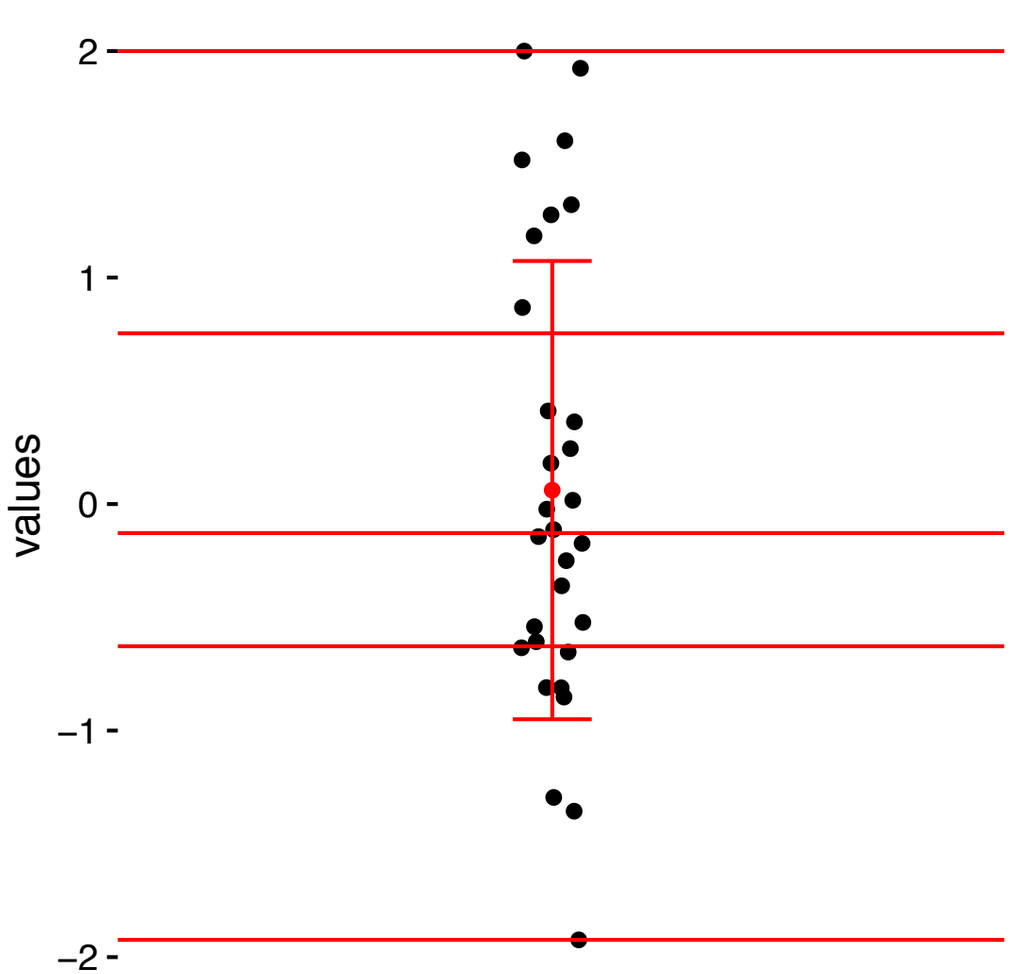


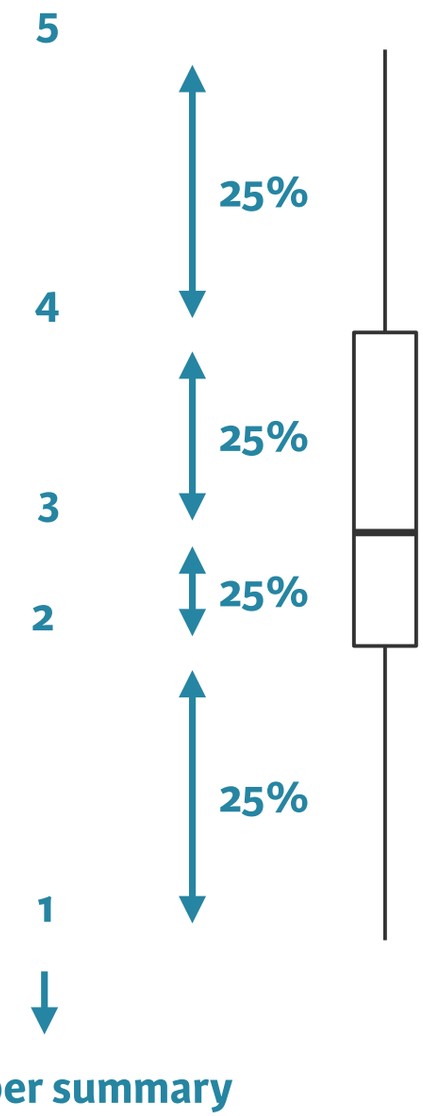

```
x <- rnorm(1000)

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!





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

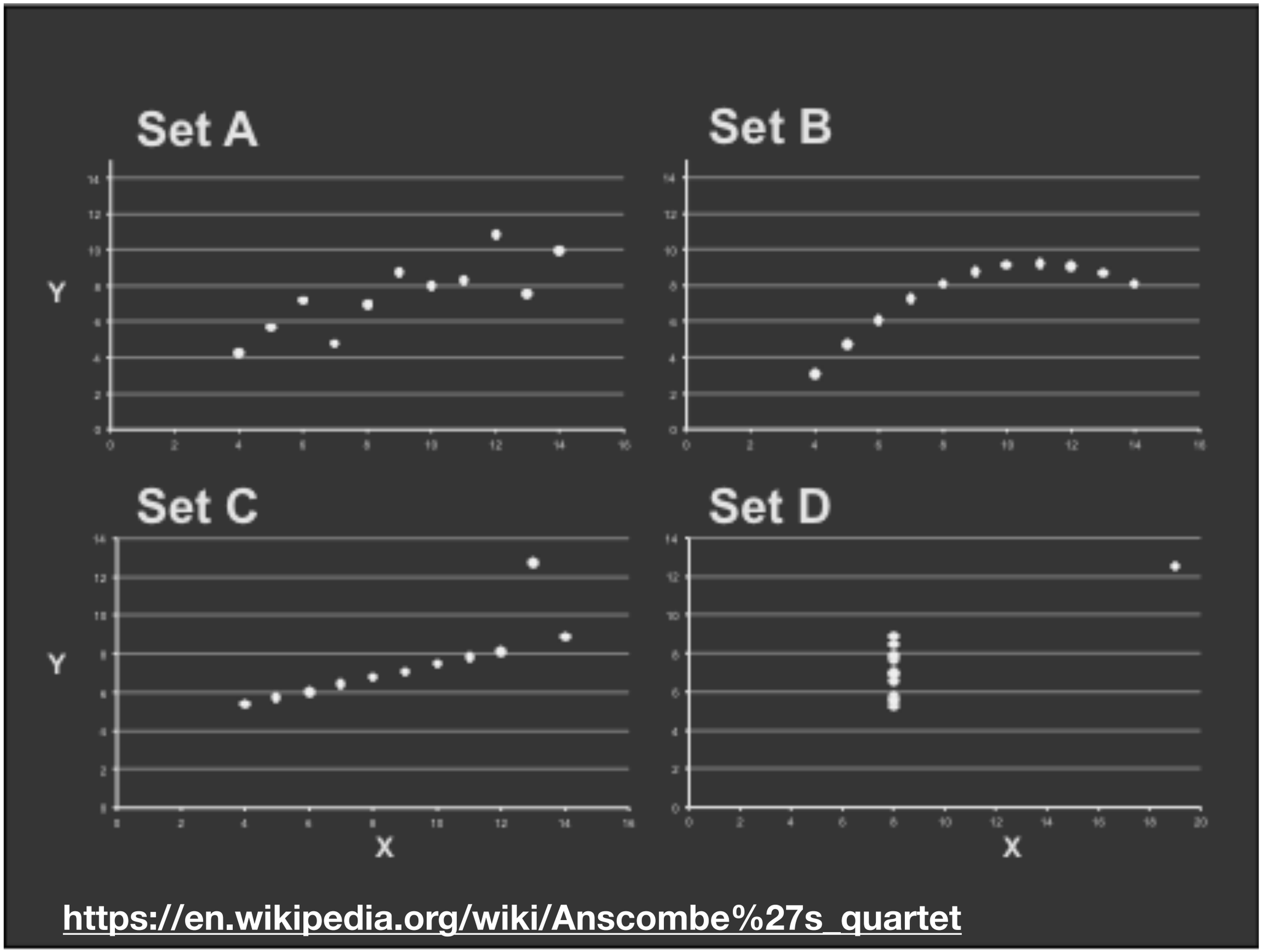
Summary Statistics Linear Regression

$u_X = 9.0$ $\sigma_X = 3.317$ $Y = 3 + 0.5\ X$

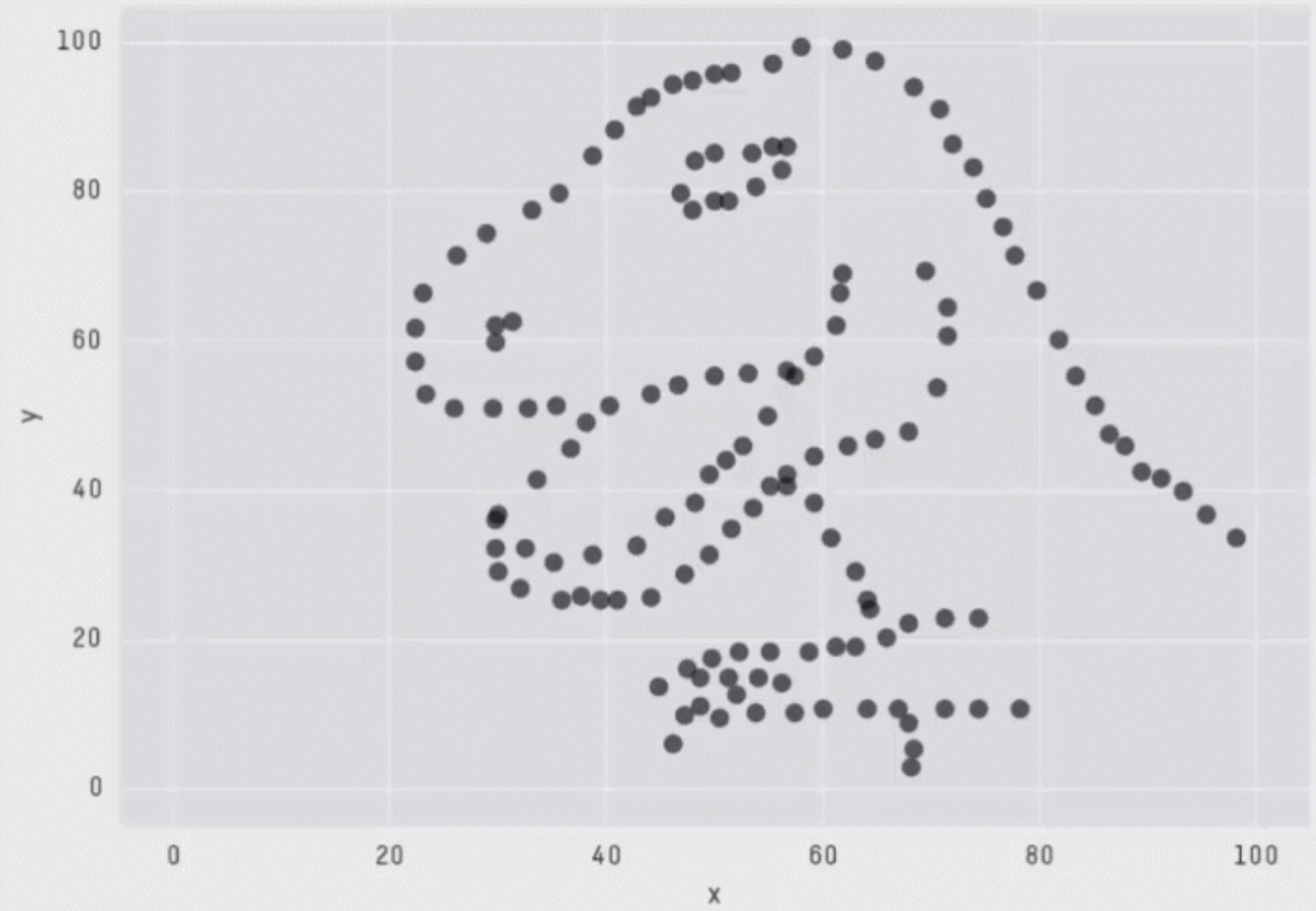
$u_Y = 7.5$ $\sigma_Y = 2.03$ $R^2 = 0.67$

[Anscombe 73]

Looking at Data



https://en.wikipedia.org/wiki/Anscombe%27s_quartet



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

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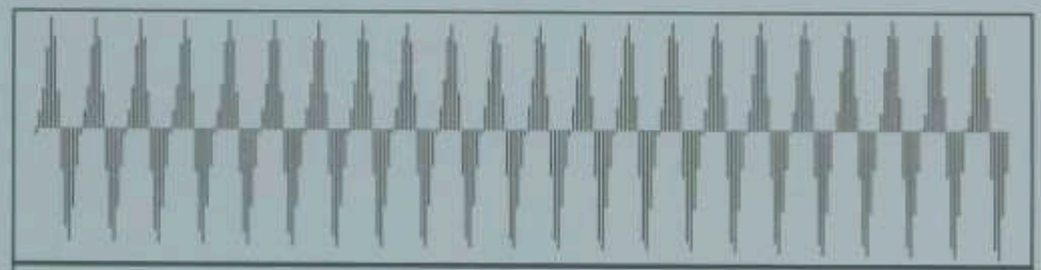
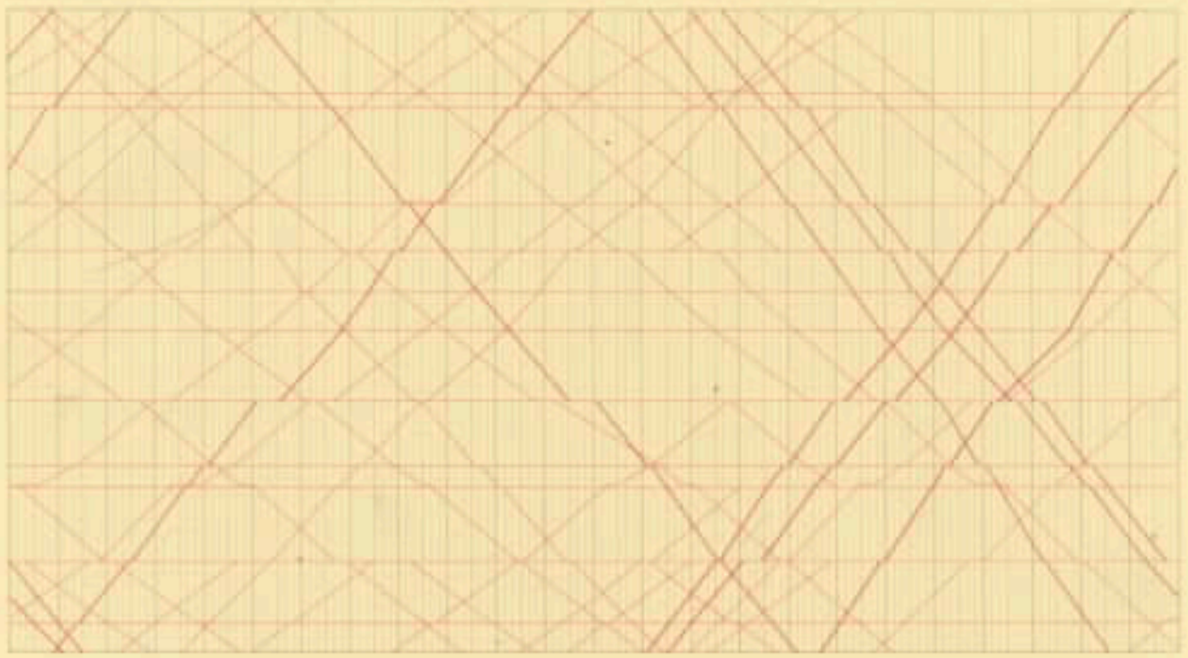


The Elements of Graphing Data

William S. Cleveland



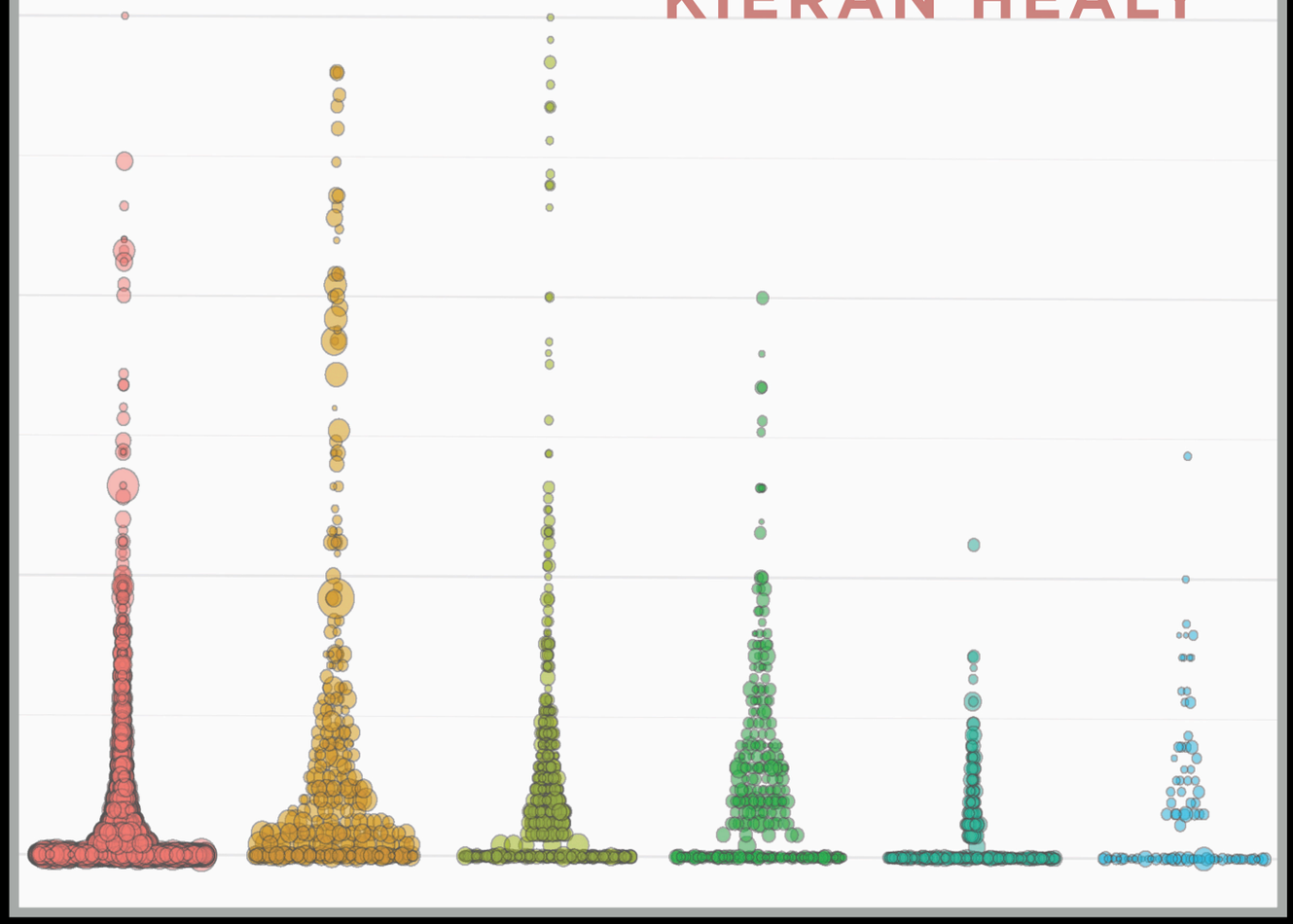
The Visual Display of Quantitative Information

EDWARD R. TUFTE

DATA VISUALIZATION

A PRACTICAL INTRODUCTION

KIERAN HEALY



http://socviz.co/

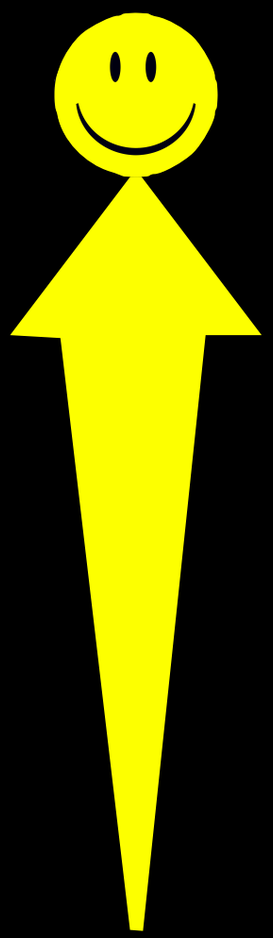
Key Point:

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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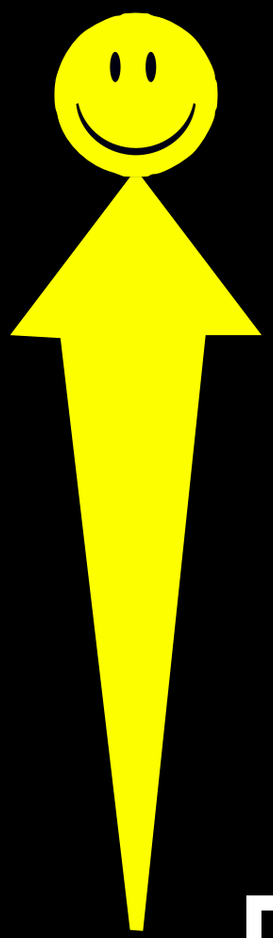

- Position along a common scale
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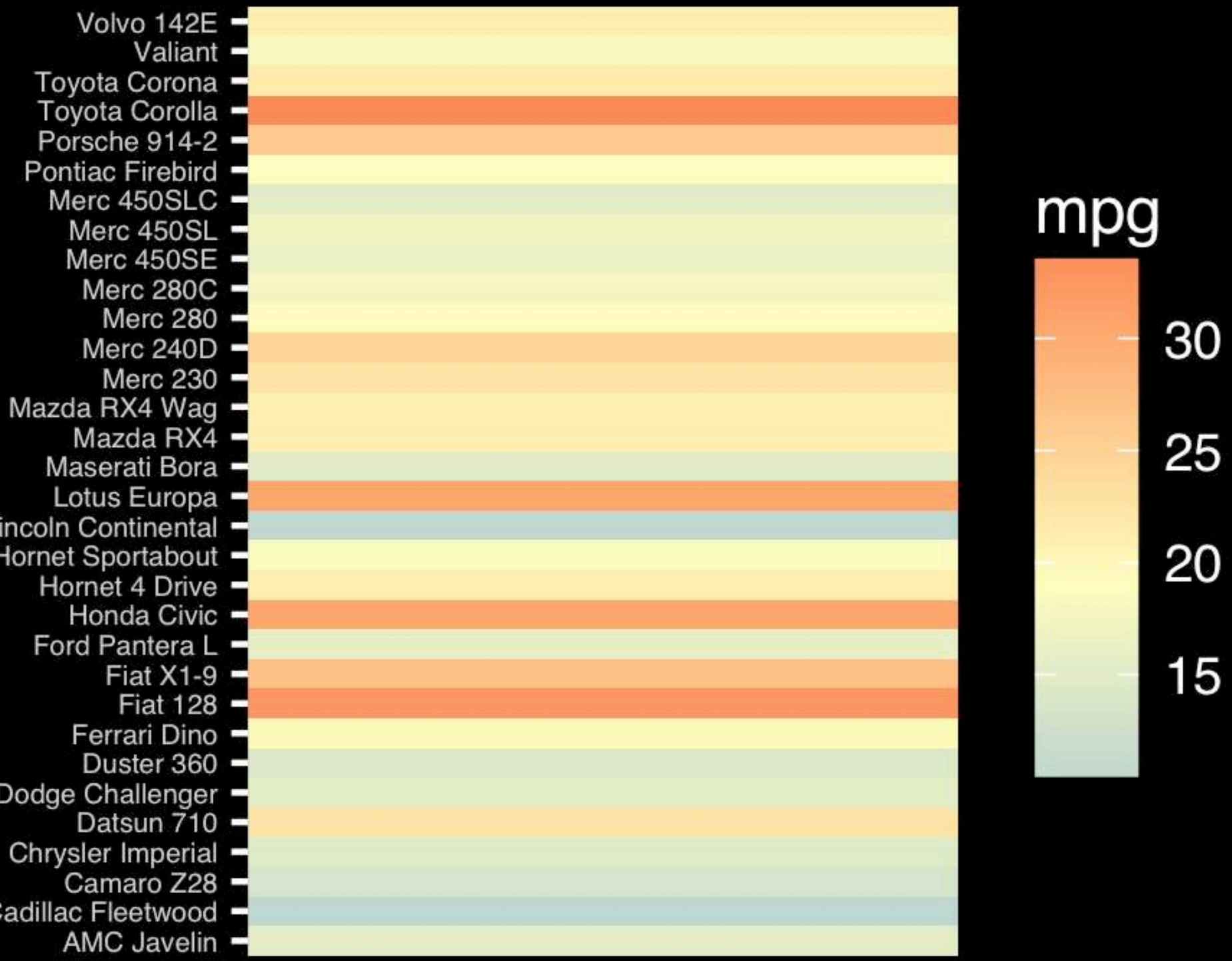
- Area
- Volume or Density or **Color saturation/hue**

luminance

saturation

hue


Volvo 142E
Valiant
Toyota Corona
Toyota Corolla
Porsche 914-2
Pontiac Firebird
Merc 450SLC
Merc 450SL
Merc 450SE
Merc 280C
Merc 280
Merc 240D
Merc 230
Mazda RX4 Wag
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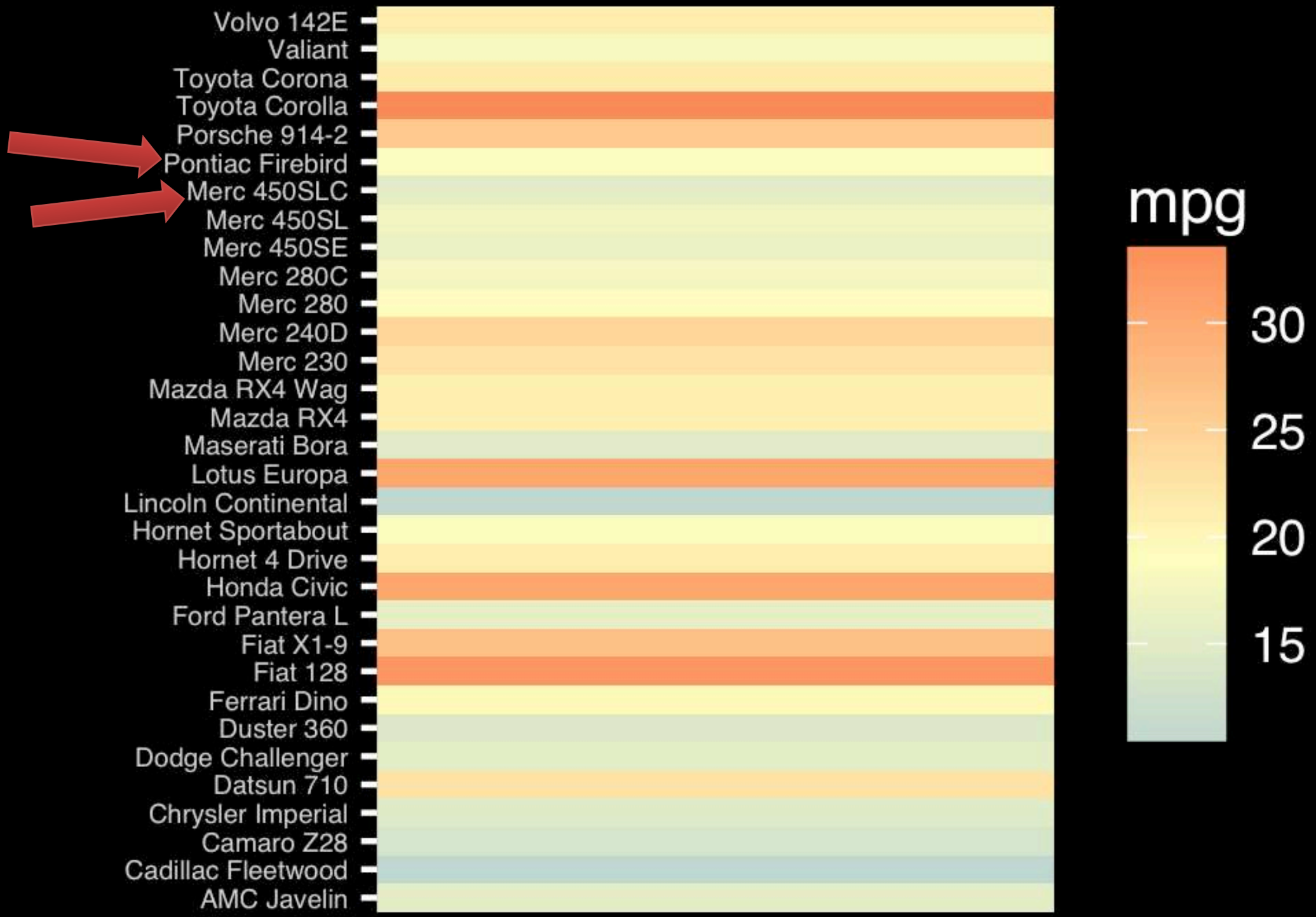
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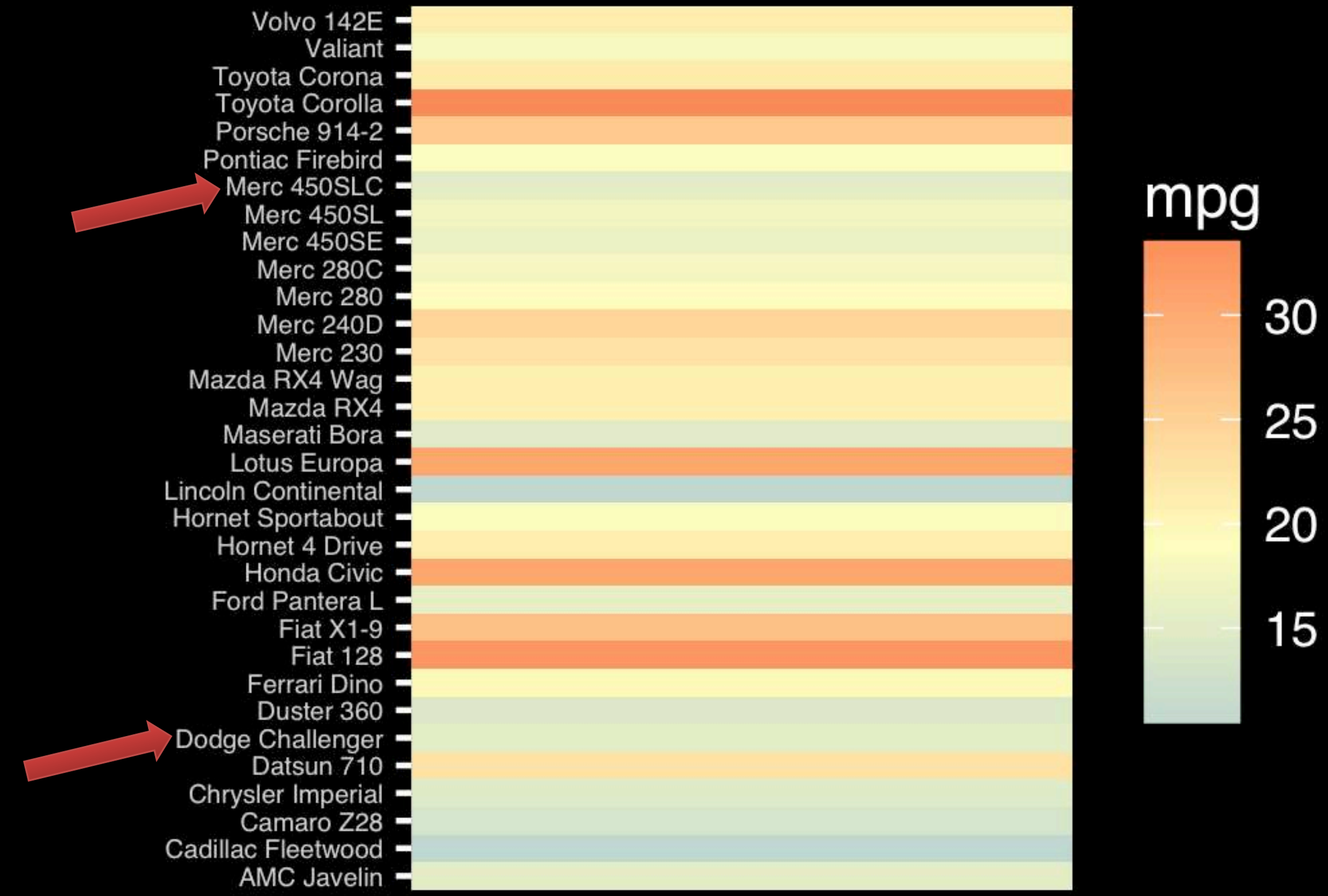
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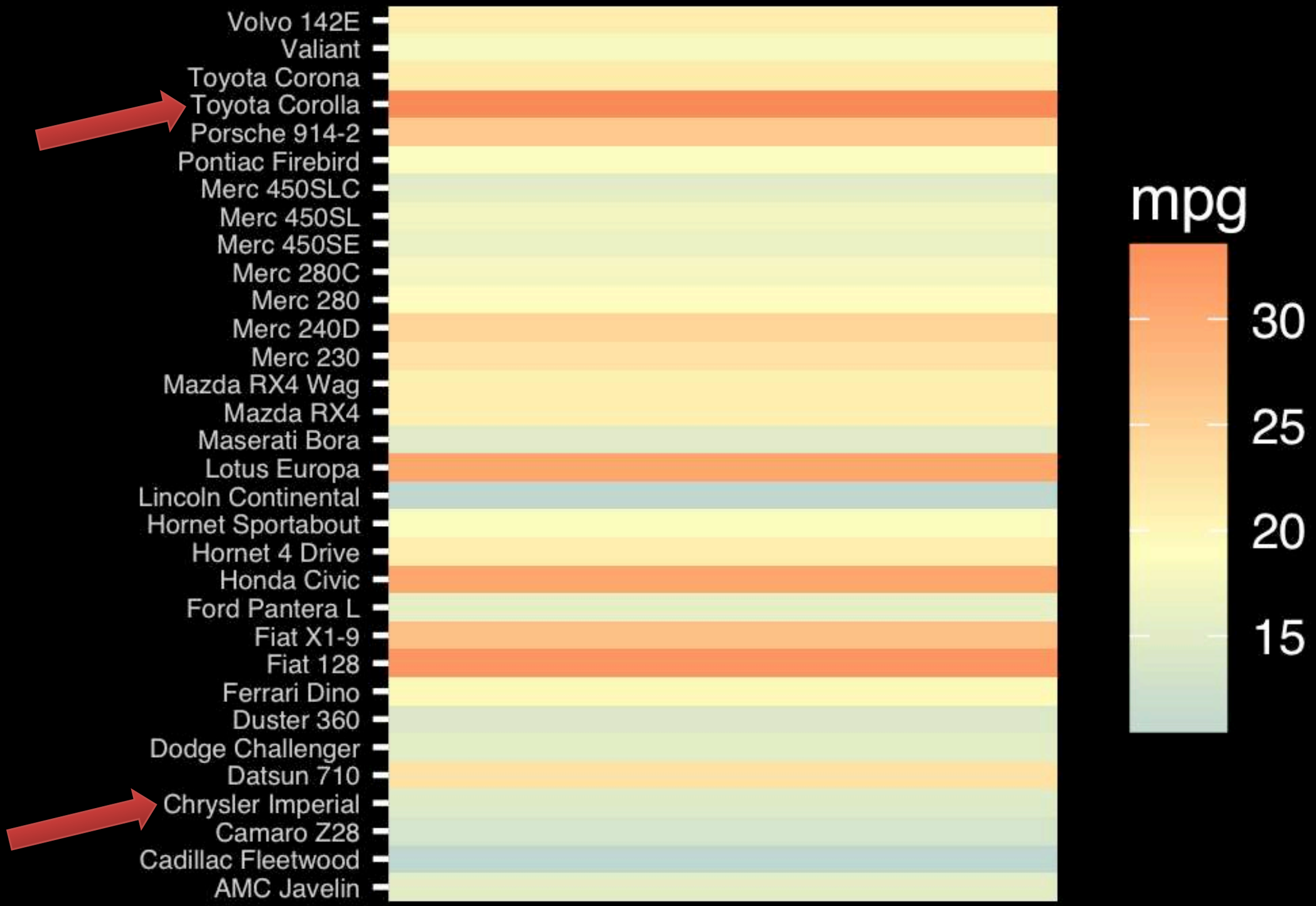
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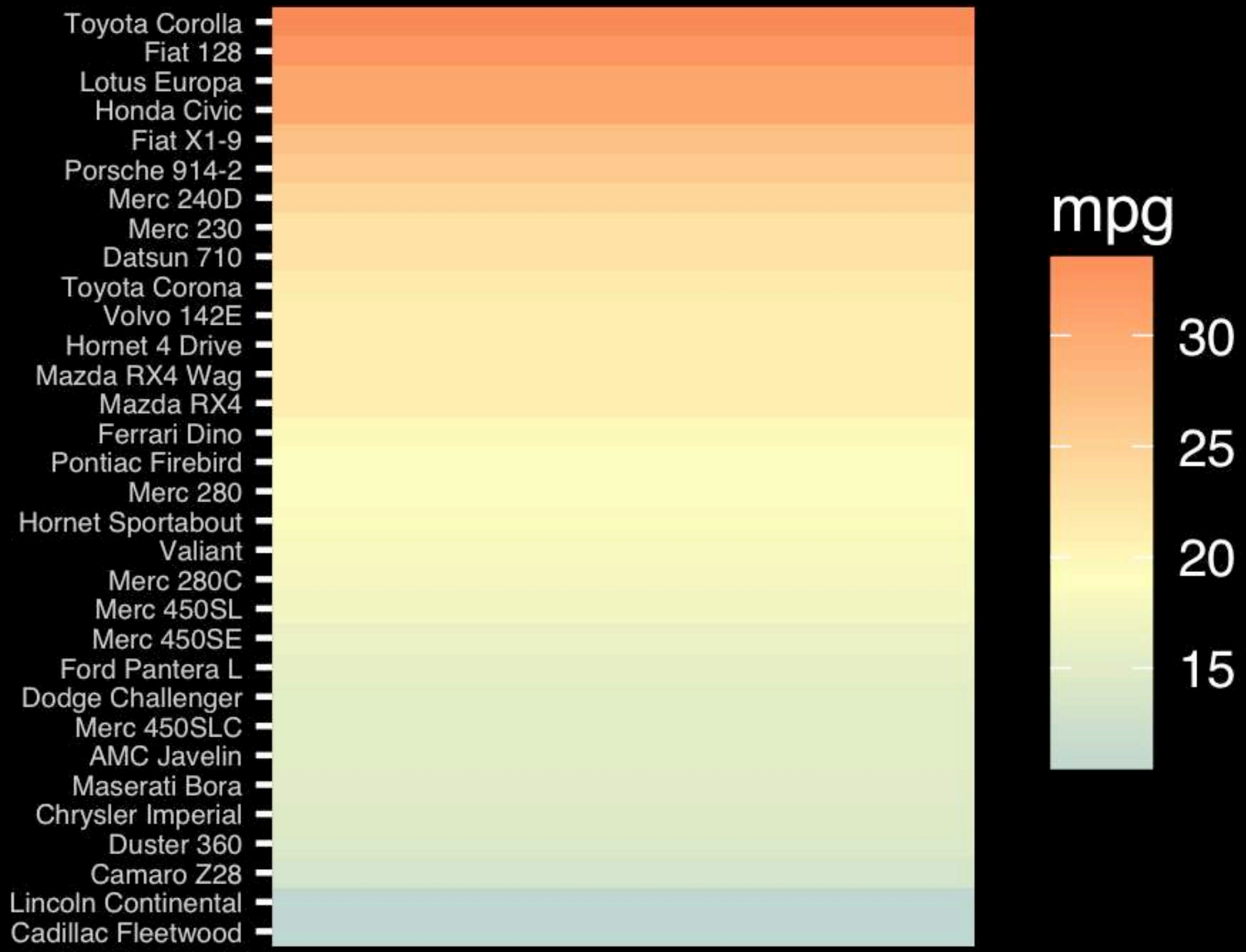
Observation: Alphabetical is almost never the correct ordering of a categorical variable.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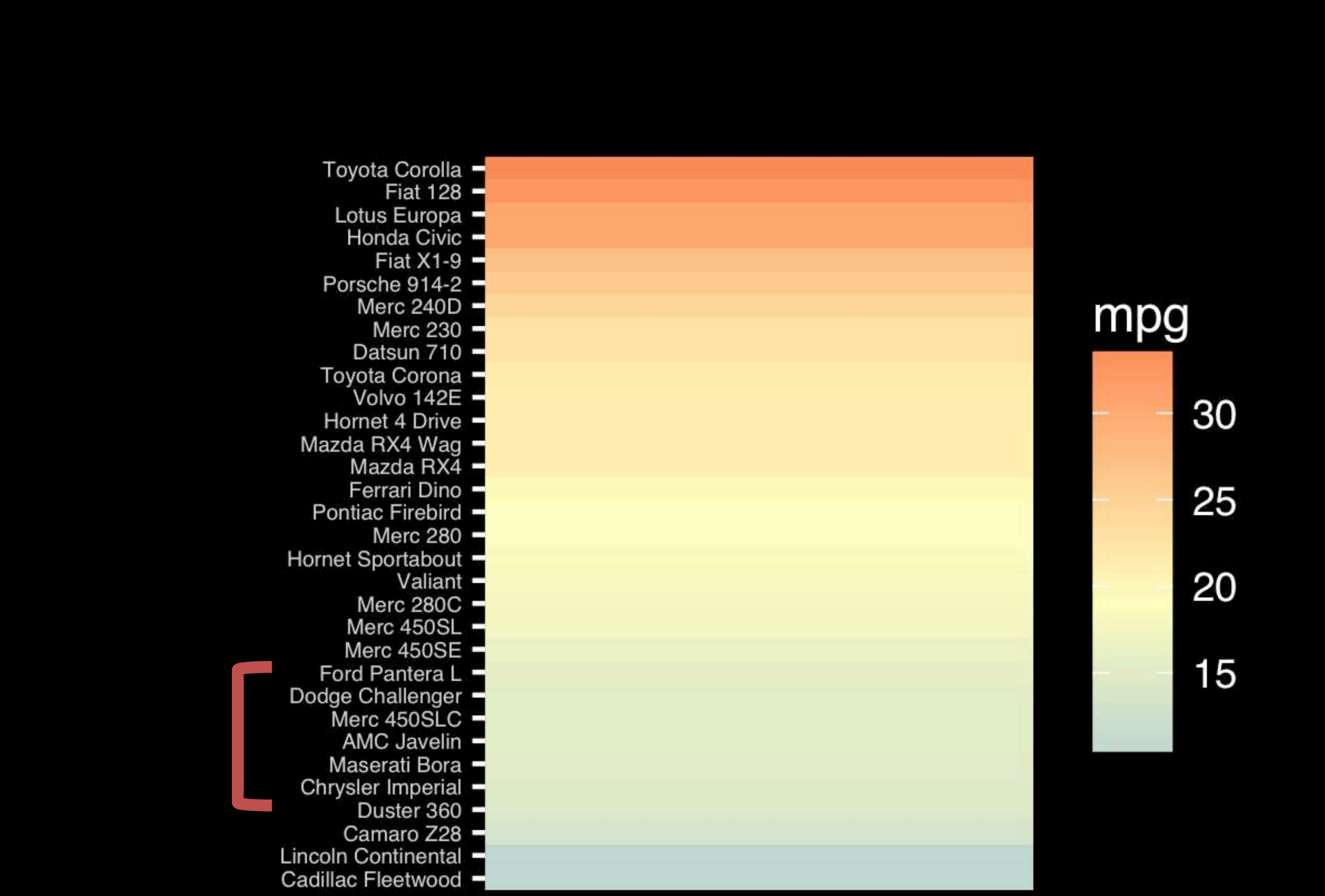
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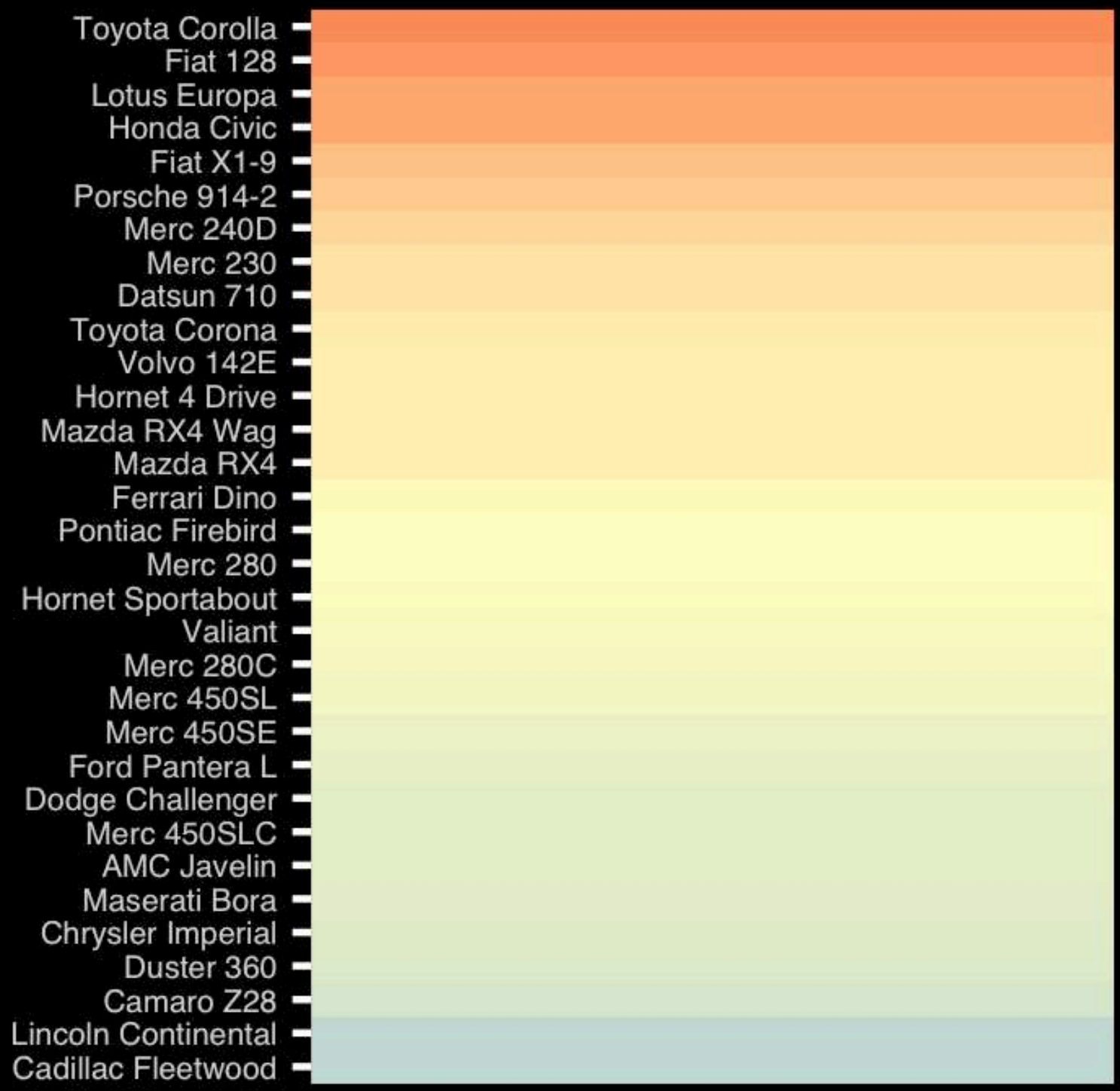
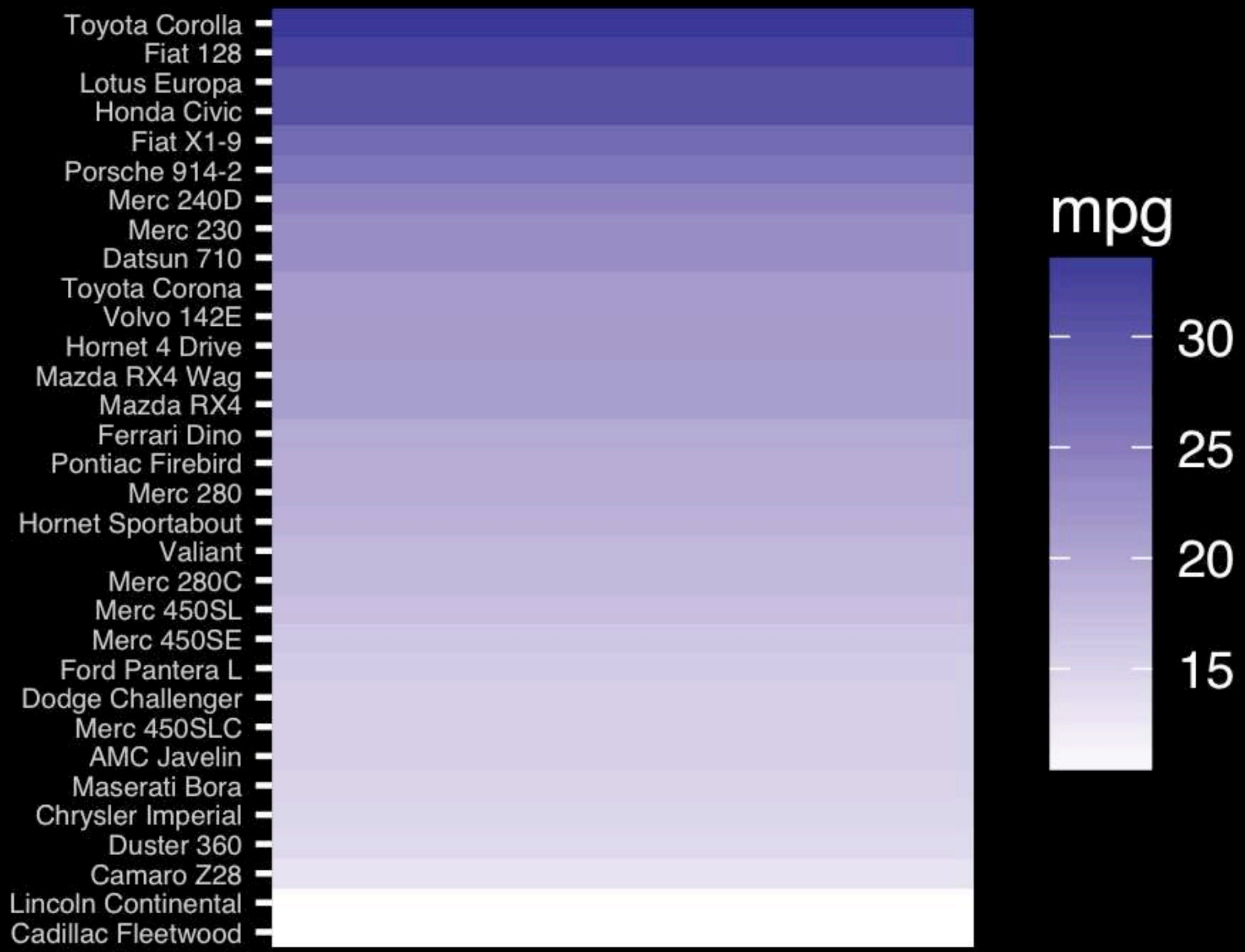


If we did not have the legend would you know which was low or high mpg?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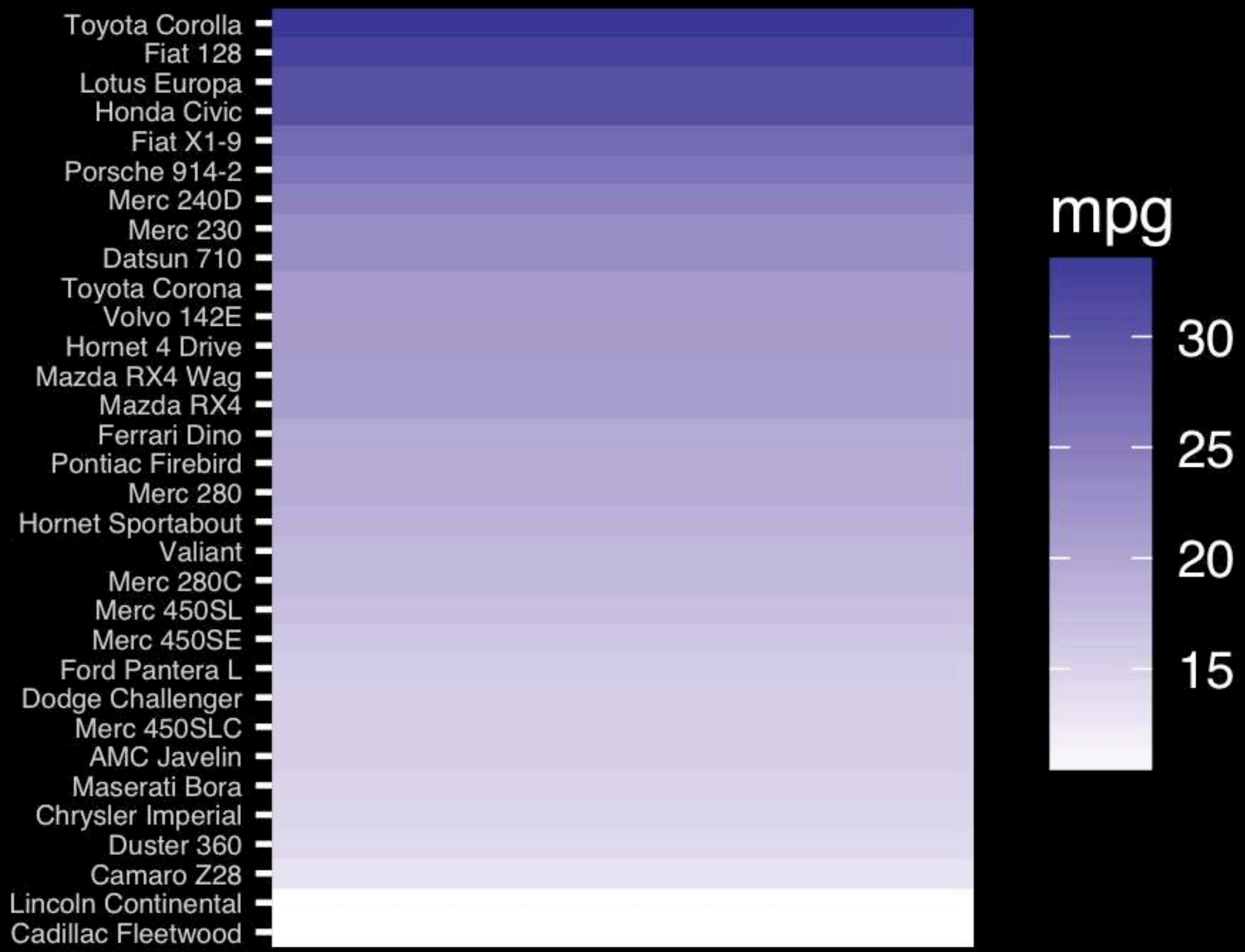
- **Area**
- Volume or Density or Color saturation/hue


Toyota Corolla
Fiat 128
Lotus Europa
Honda Civic
Fiat X1-9
Porsche 914-2
Merc 240D
Merc 230
Datsun 710
Toyota Corona
Volvo 142E
Hornet 4 Drive
Mazda RX4 Wag
Mazda RX4
Ferrari Dino
Pontiac Firebird
Merc 280
Hornet Sportabout
Valiant
Merc 280C
Merc 450SL
Merc 450SE
Ford Pantera L
Dodge Challenger
Merc 450SLC
AMC Javelin
Maserati Bora
Chrysler Imperial
Duster 360
Camaro Z28
Lincoln Continental
Cadillac Fleetwood
mpg
30
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Honda Civic
Merc 230
Hornet 4 Drive
Pontiac Firebird
Merc 280C
Dodge Challenger
Chrysler Imperial
Cadillac Fleetwood
Lotus Europa
Merc 240D
Volvo 142E
Ferrari Dino
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Fiat X1-9
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Mazda RX4 Wag
Merc 280
Merc 450SL
Merc 450SLC
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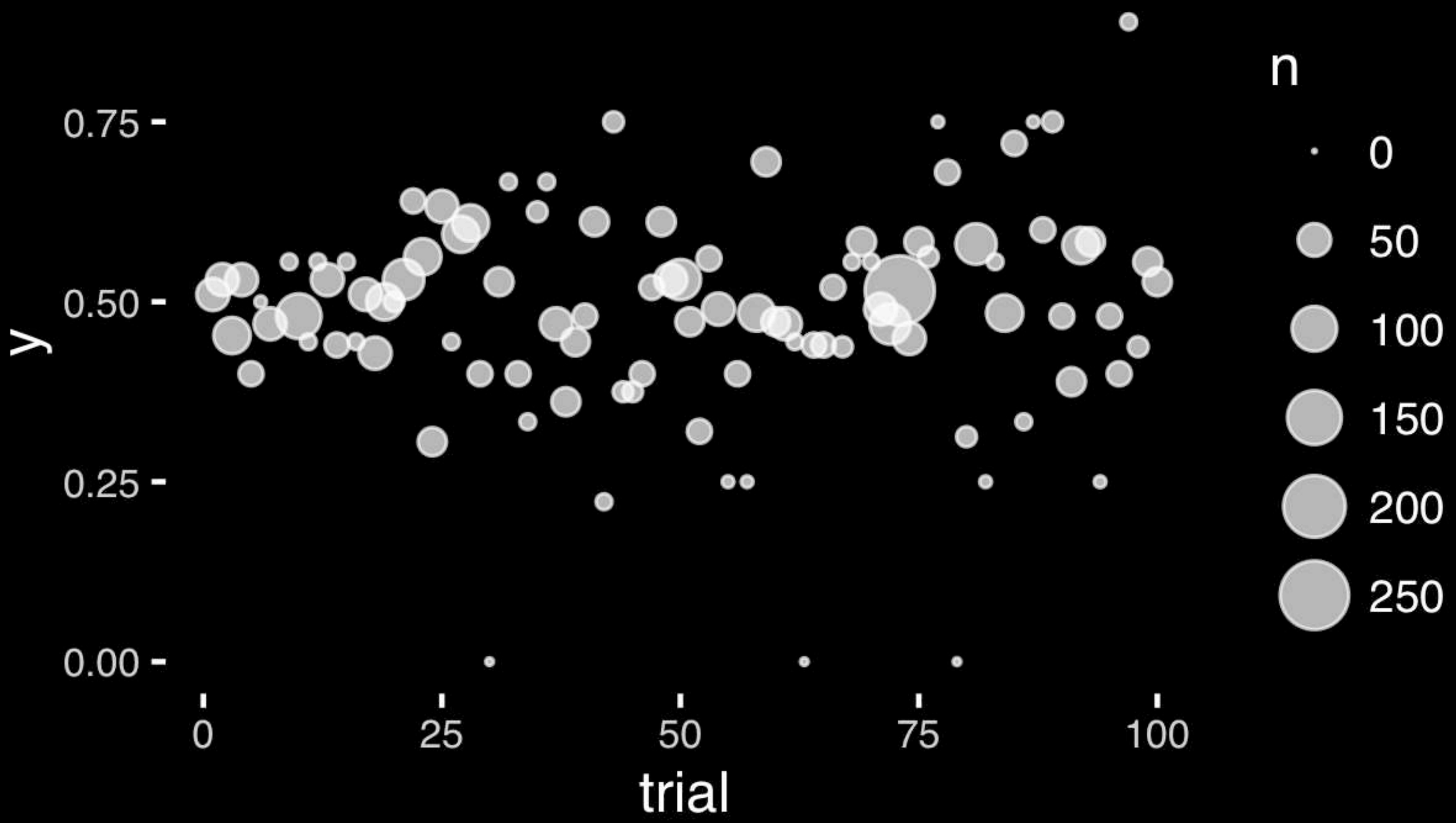
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50
75
100
trial

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

Cadillac Flee

Lincoln Conti

Camaro Z28

Duster 360

Chrysler Imp

Maserati Bor

AMC Javelin

Merc 450SL(

Dodge Chall(

Ford Pantera

Merc 450SE

Merc 450SL

Merc 280C

Valiant

Hornet Sport

Merc 280

Pontiac Fireb

Ferrari Dino

Mazda RX4

Mazda RX4 \

Hornet 4 Driv

Volvo 142E

Toyota Coro(

Datsun 710

Merc 230

Merc 240D

Porsche 914

Fiat X1-9

Honda Civic

Lotus Europa

Fiat 128

Toyota Corol

Cadillac Flee

Lincoln Conti

Camaro Z28

Duster 360

Chrysler Imp

Maserati Bor

AMC Javelin

Merc 450SL(

Dodge Chall(

Ford Pantera

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Merc 280C

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Hornet Sport

Merc 280

Pontiac Fireb

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Volvo 142E

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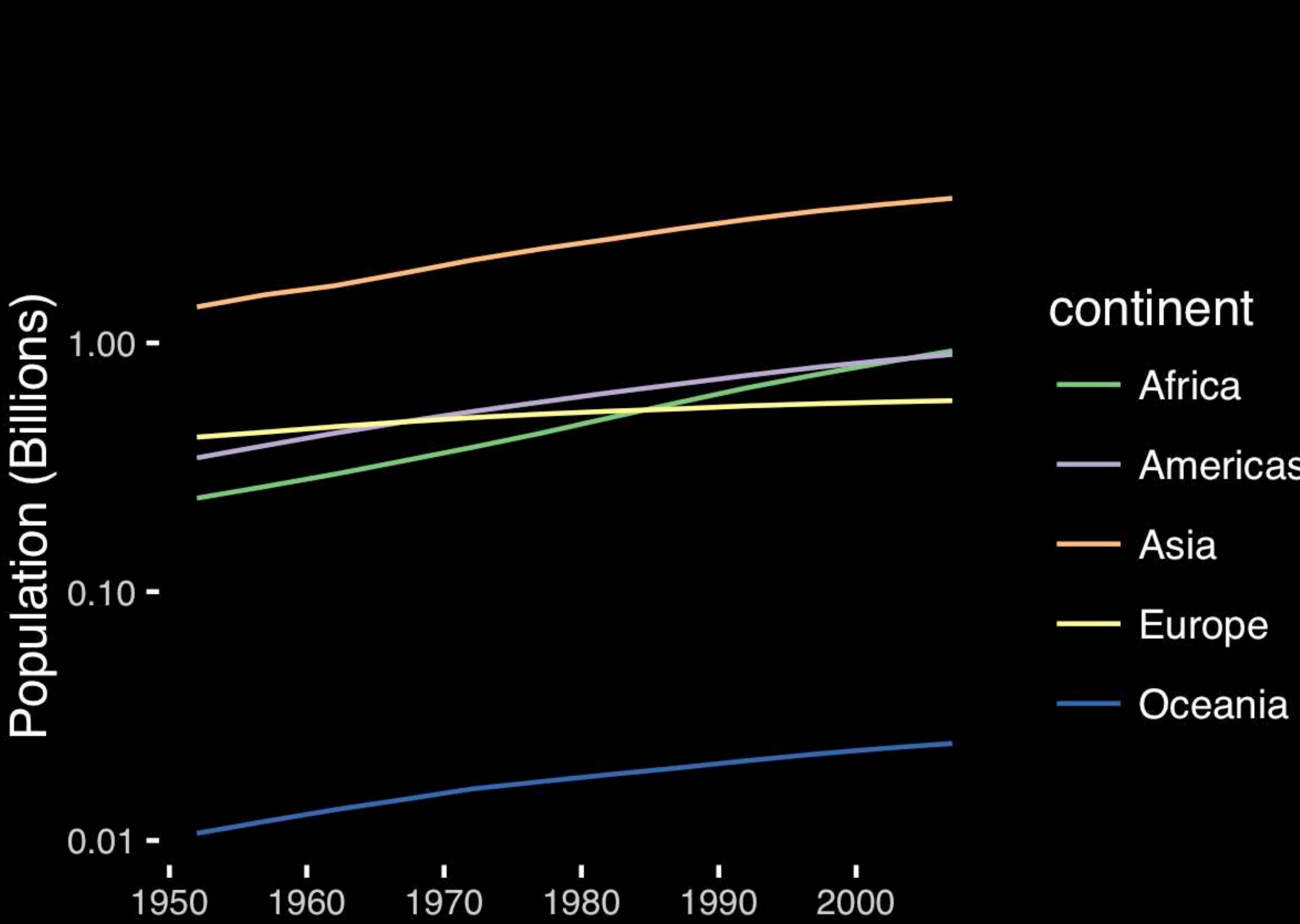
Honda Civic

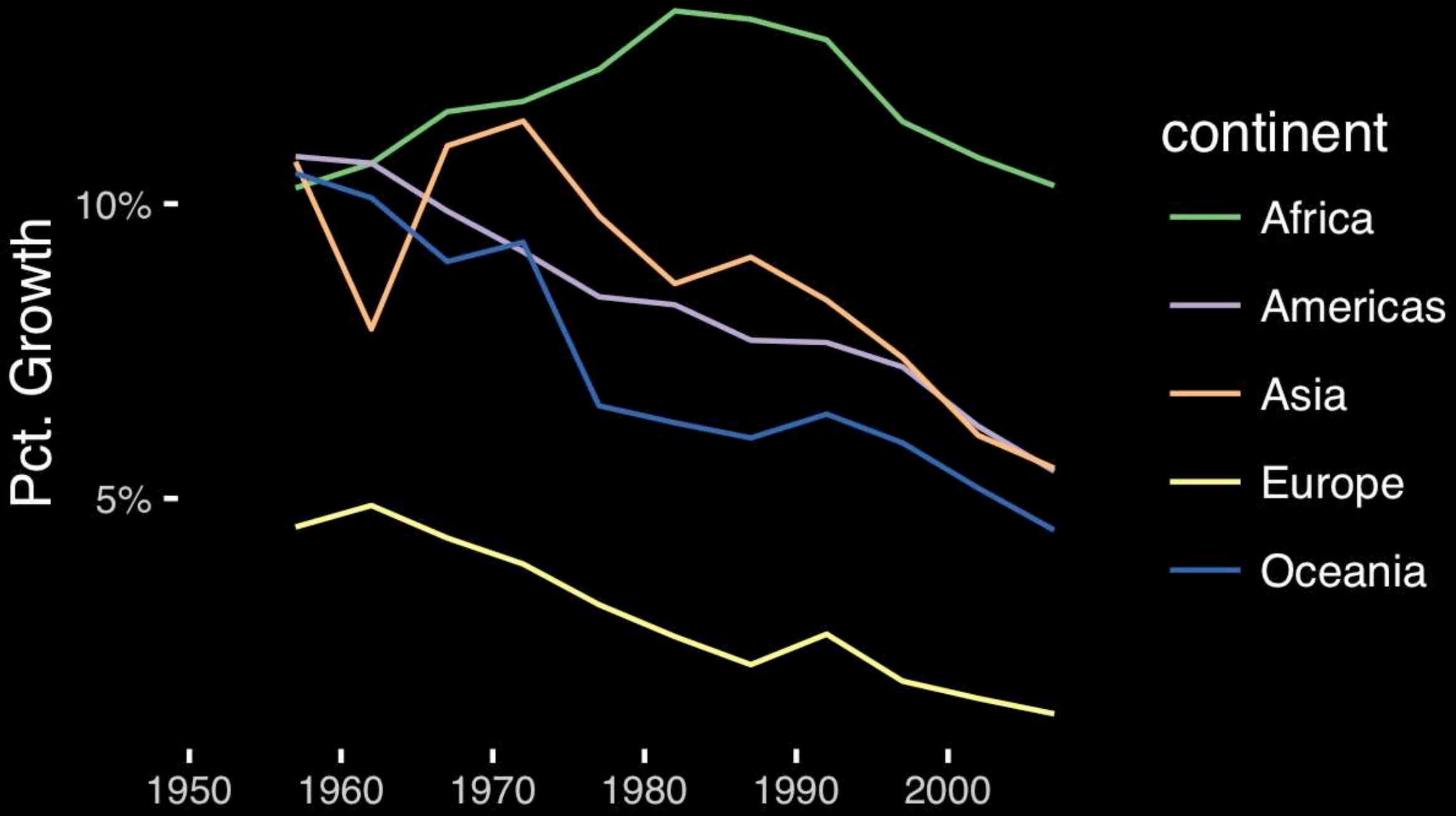
Lotus Europa

Fiat 128

Toyota Corol


Population (Billions)
1.00
0.10
0.01
1950
1960
1970
1980
1990
2000
continent
Africa
Americas
Asia
Europe
Oceania

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


Pct. Growth
10%
5%
1950
1960
1970
1980
1990
2000
continent
Africa
Americas
Asia
Europe
Oceania

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

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

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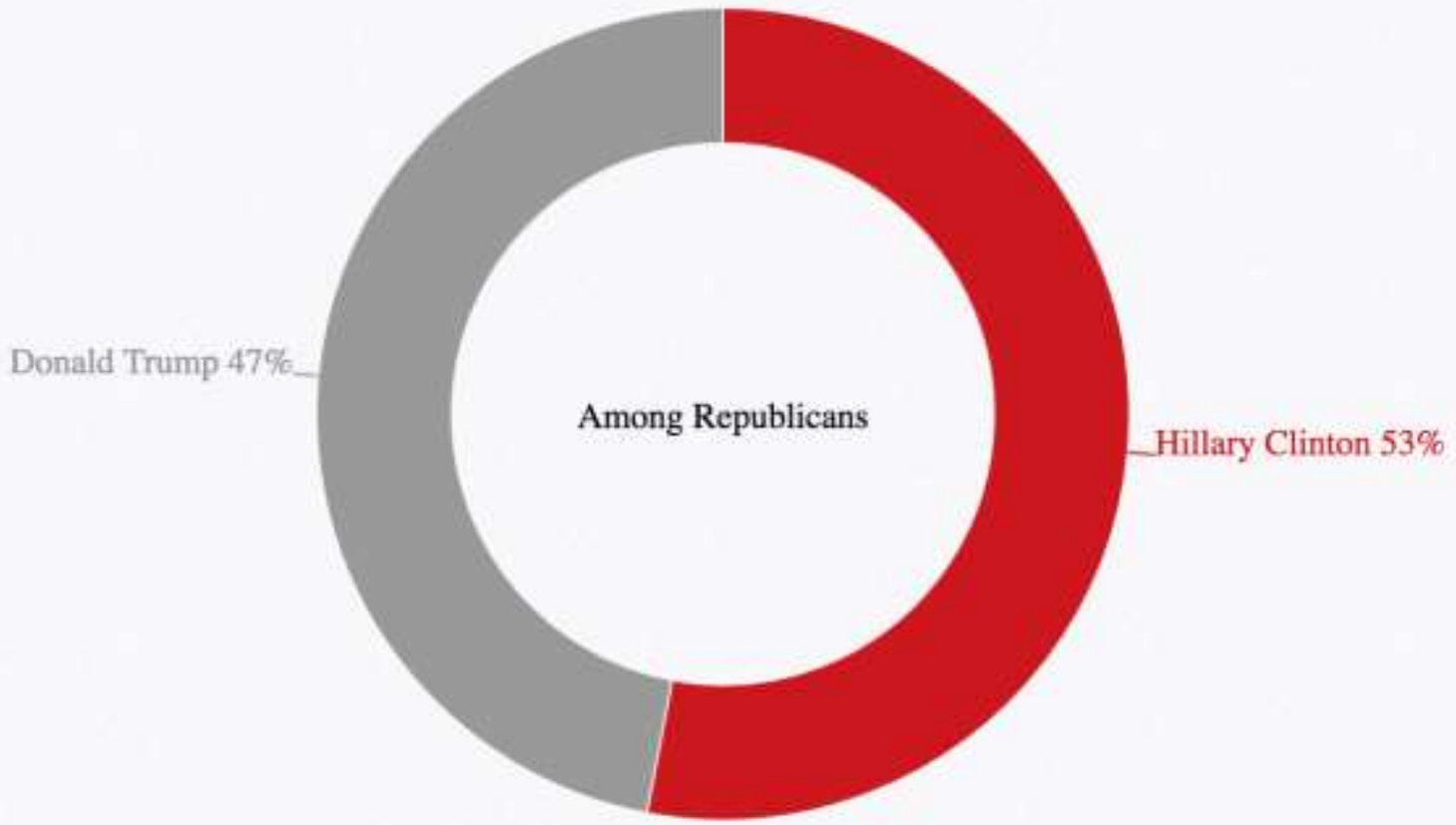
http://blog.codahale.com/2006/04/29/google-analytics-the-goggles-they-do-nothing/

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

Among Republicans | Among Democrats

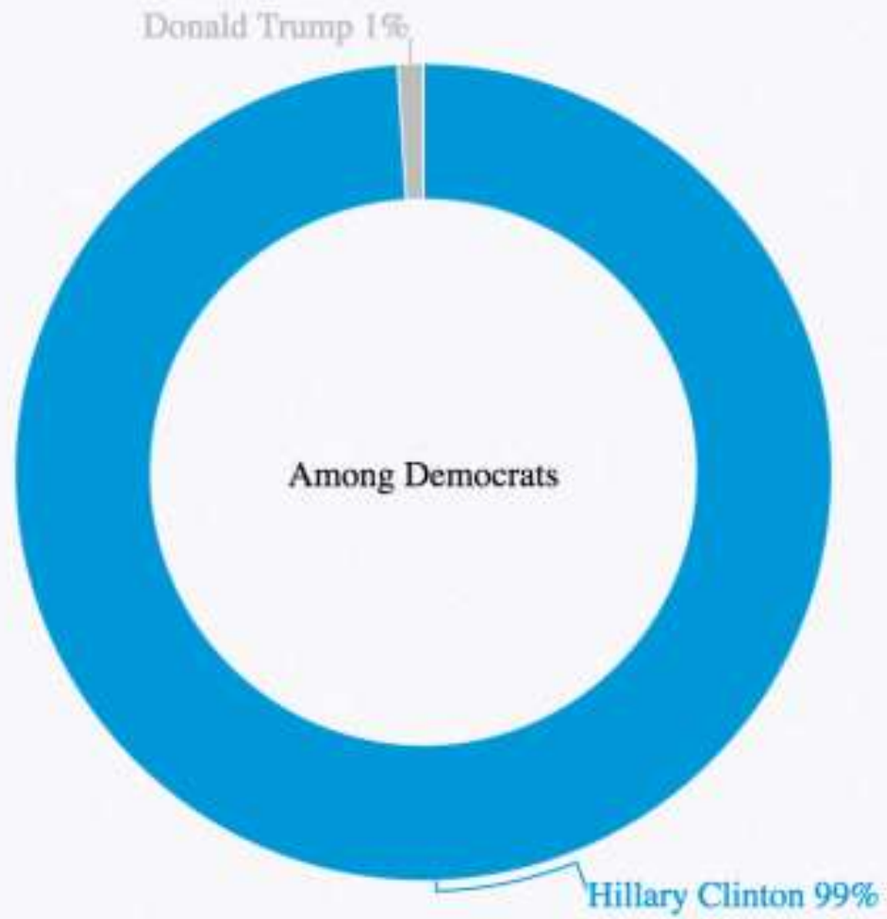


Share

POLITICO

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

Among Republicans | Among Democrats



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.**

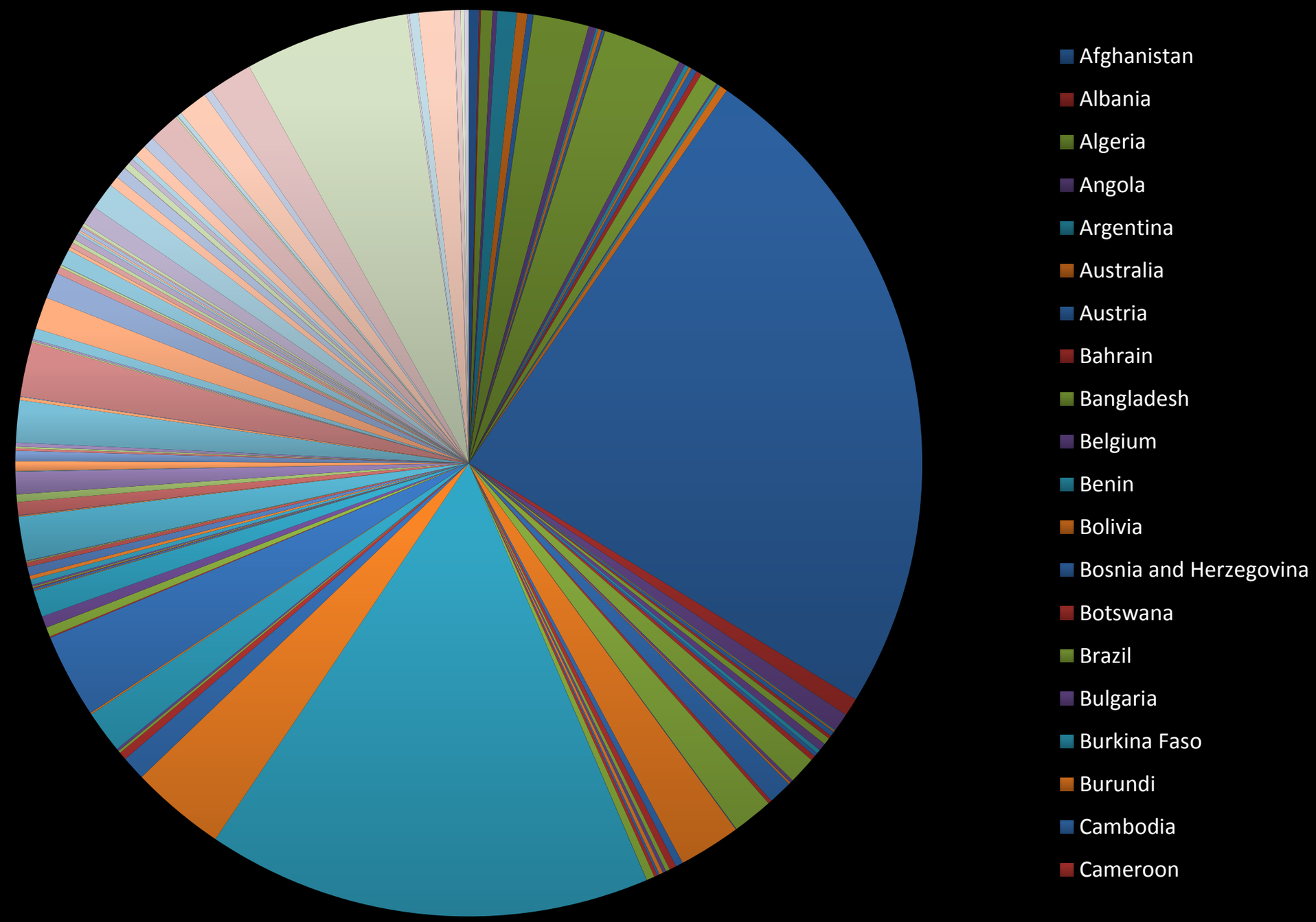
-Edward Tufte, The Visual Display of Quantitative Information

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.

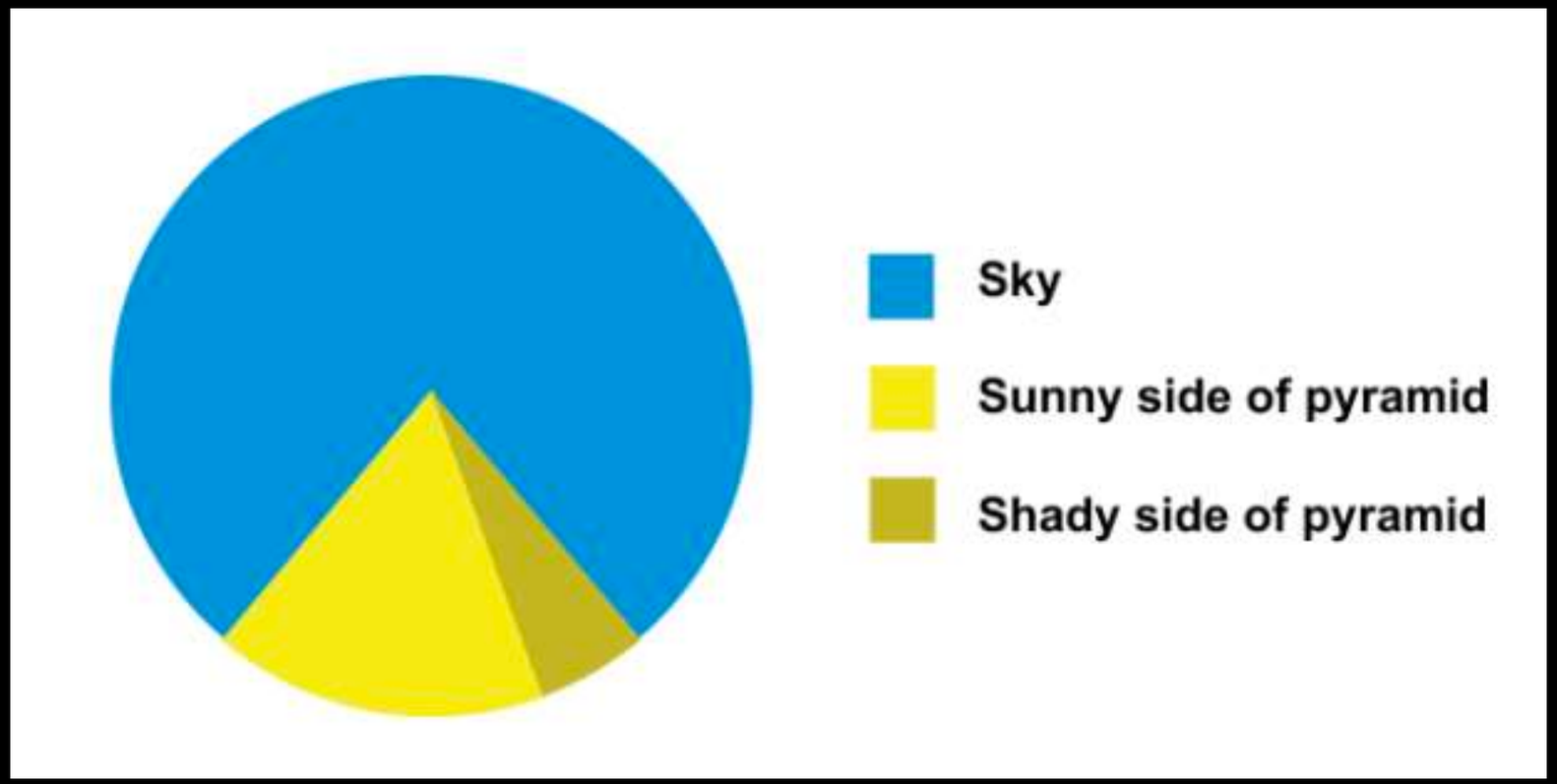
-Edward Tufte, The Visual Display of Quantitative Information

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

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


Afghanistan
Albania
Algeria
Angola
Argentina
Australia
Austria
Bahrain
Bangladesh
Belgium
Benin
Bolivia
Bosnia and Herzegovina
Botswana
Brazil
Bulgaria
Burkina Faso
Burundi
Cambodia
Cameroon

All good pie charts are jokes…



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- Length
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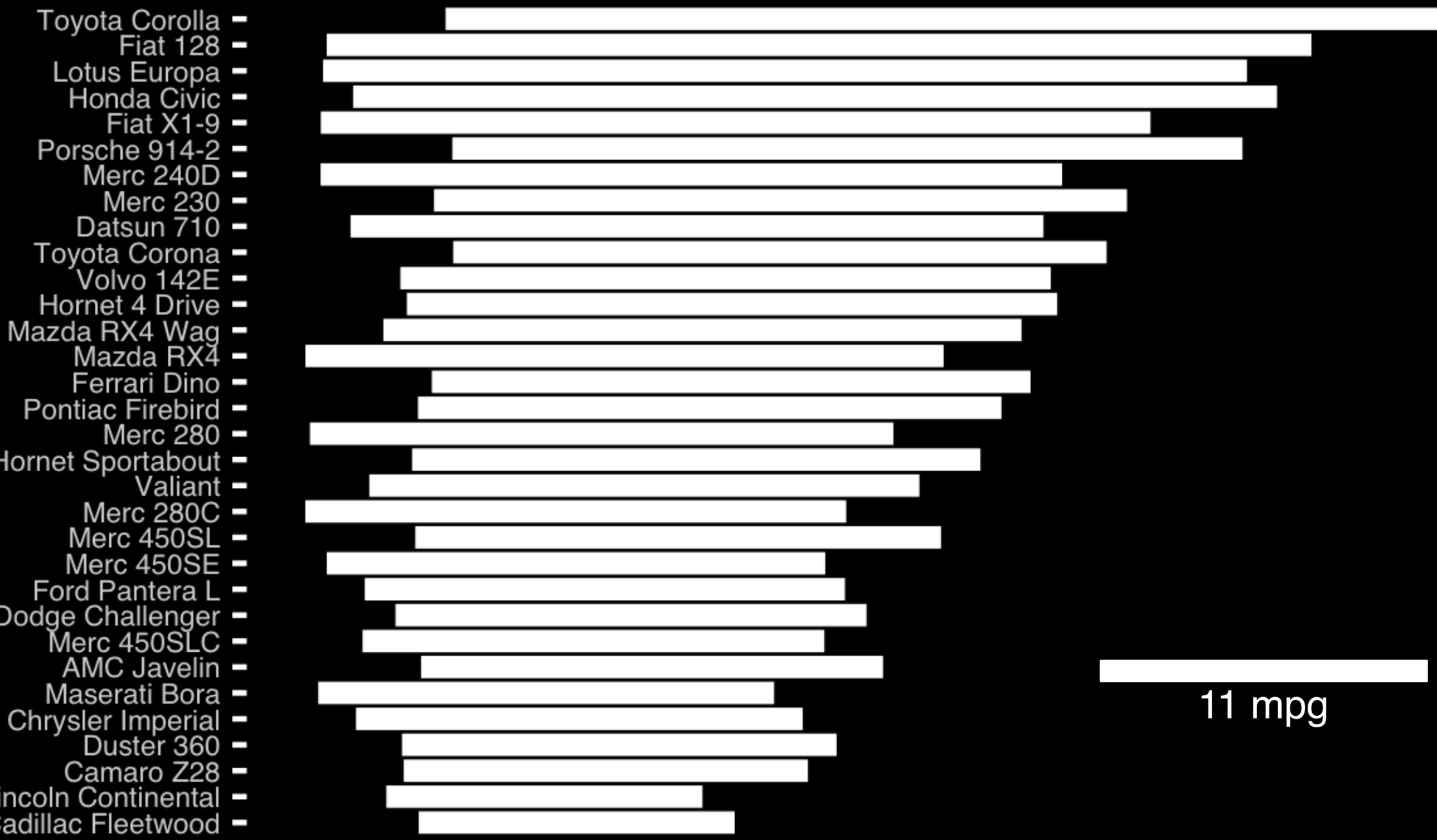
Toyota Corolla
Fiat 128
Lotus Europa
Honda Civic
Fiat X1-9
Porsche 914-2
Merc 240D
Merc 230
Datsun 710
Toyota Corona
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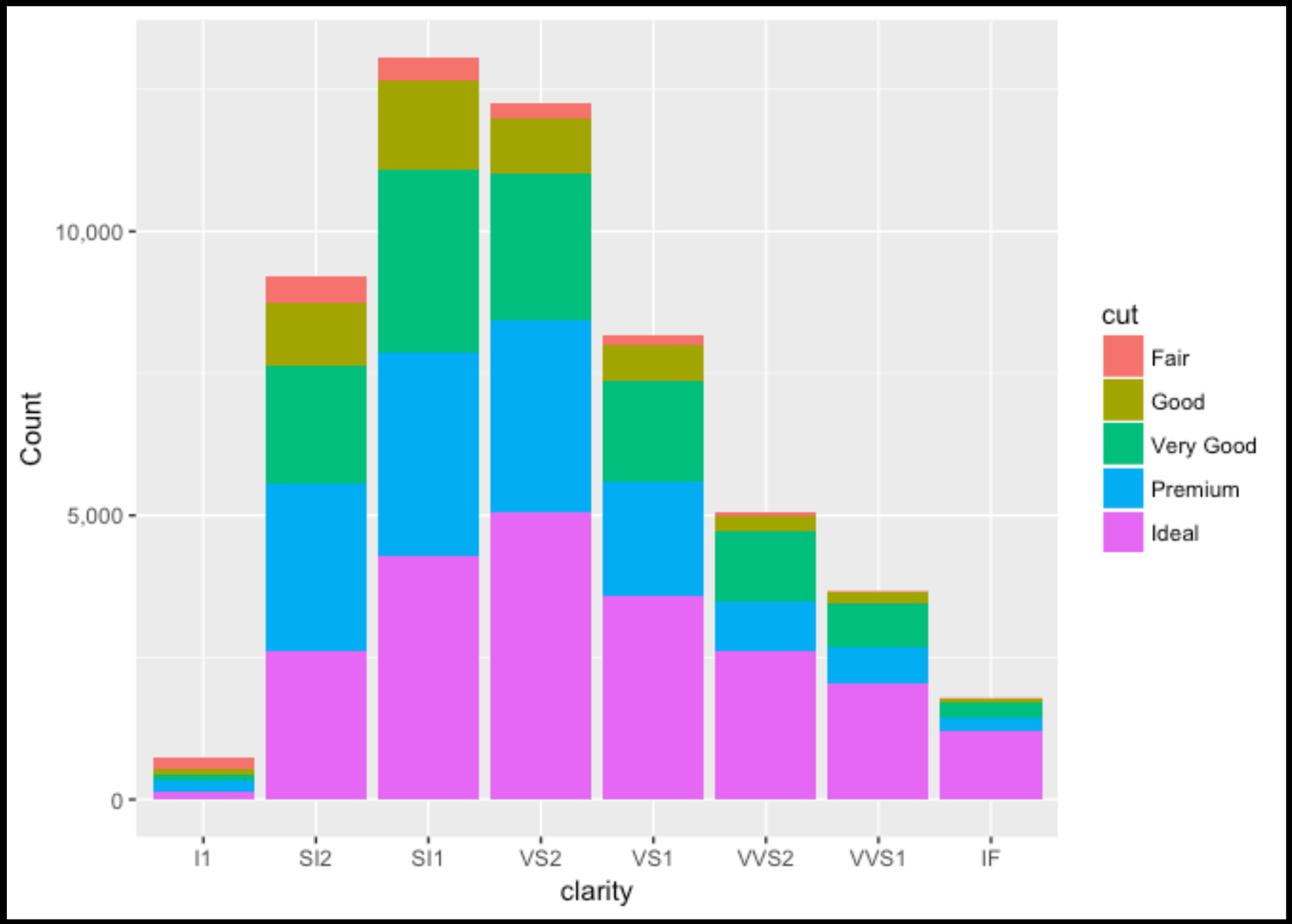
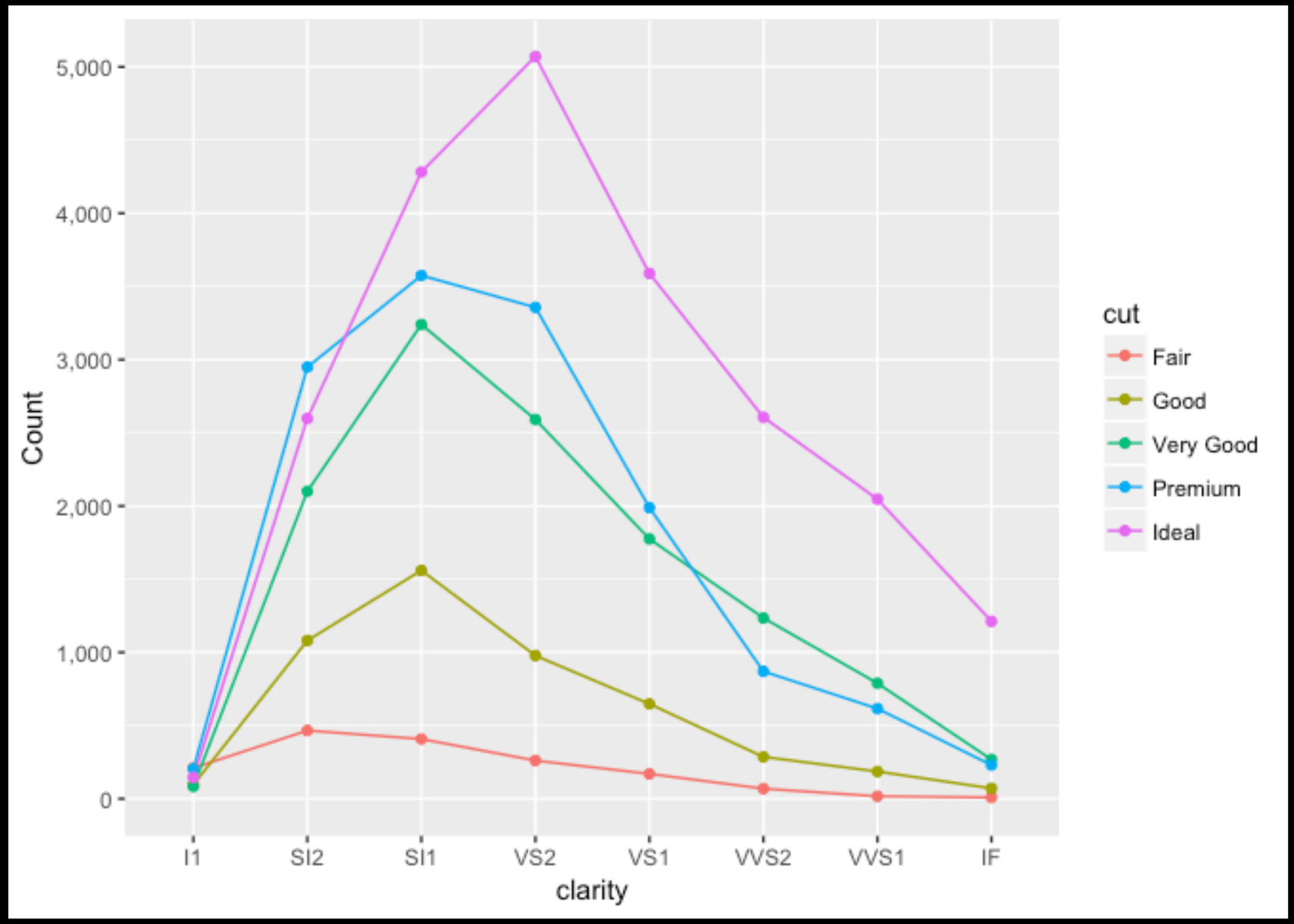
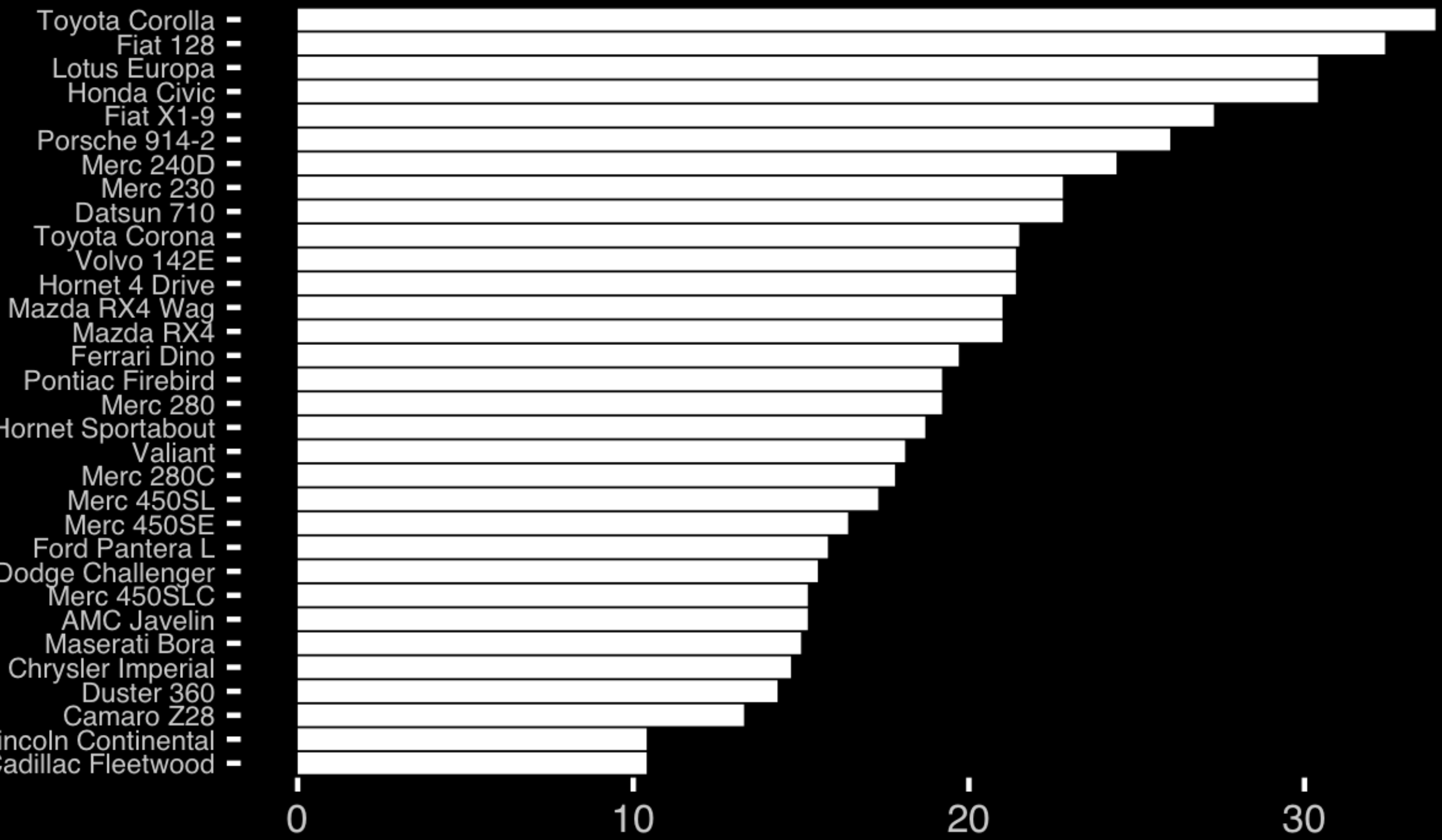
Merc 450SL
Merc 450SE
Ford Pantera L
Dodge Challenger
Merc 450SLC
AMC Javelin
Maserati Bora
Chrysler Imperial
Duster 360
Camaro Z28
Lincoln Continental
Cadillac Fleetwood
11 mpg

Stacked anything is nearly always a mistake



This is much better...




Toyota Corolla
Fiat 128
Lotus Europa
Honda Civic
Fiat X1-9
Porsche 914-2
Merc 240D
Merc 230
Datsun 710
Toyota Corona
Volvo 142E
Hornet 4 Drive
Mazda RX4 Wag
Mazda RX4
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Merc 450SE
Ford Pantera L
Dodge Challenger
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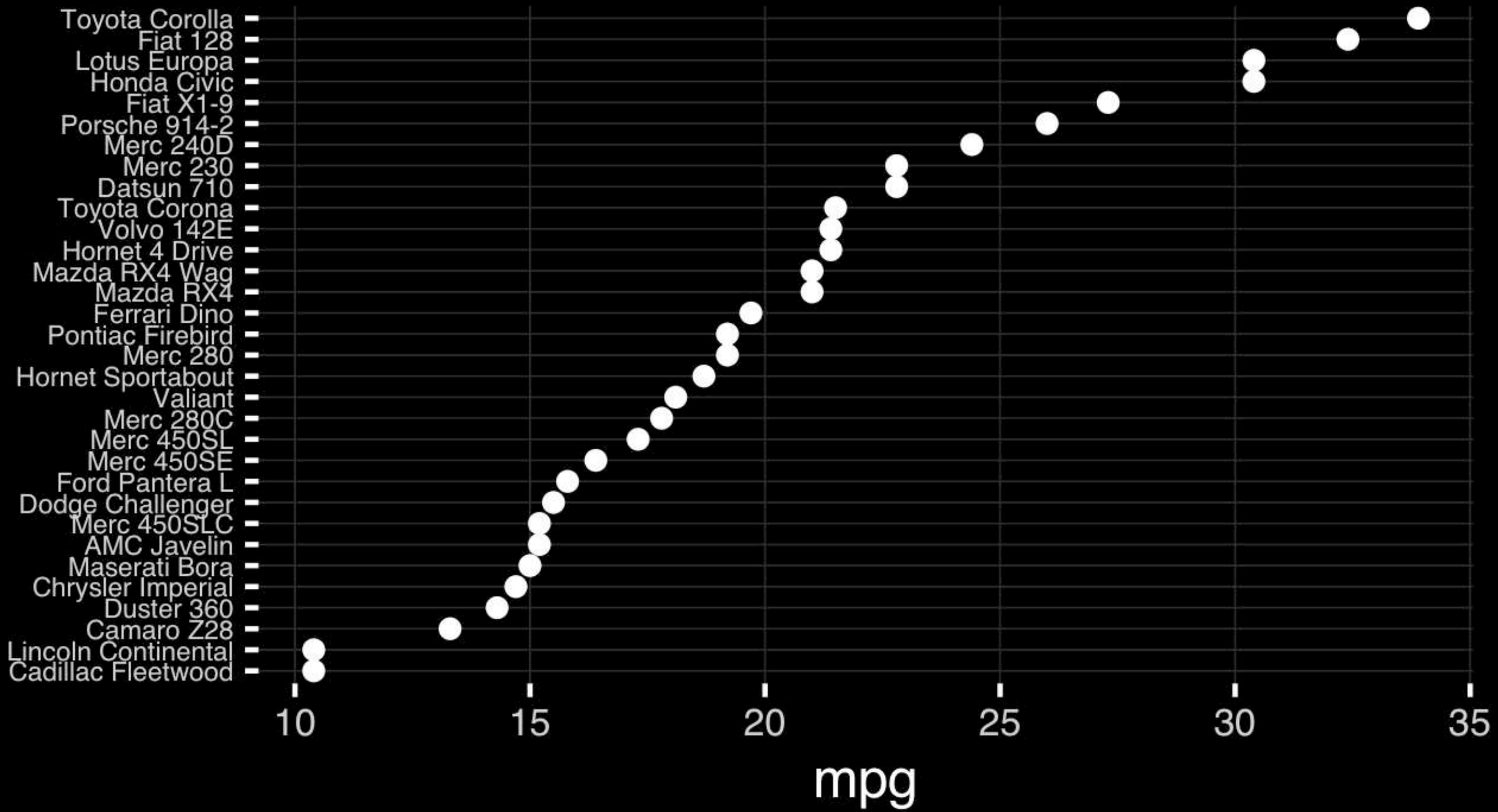
Toyota Corolla
Fiat 128
Lotus Europa
Honda Civic
Fiat X1-9
Porsche 914-2
Merc 240D
Merc 230
Datsun 710
Toyota Corona
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Merc 280
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Merc 280C
Merc 450SL
Merc 450SE
Ford Pantera L
Dodge Challenger
Merc 450SLC
AMC Javelin
Maserati Bora
Chrysler Imperial
Duster 360
Camaro Z28
Lincoln Continental
Cadillac Fleetwood
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mpg

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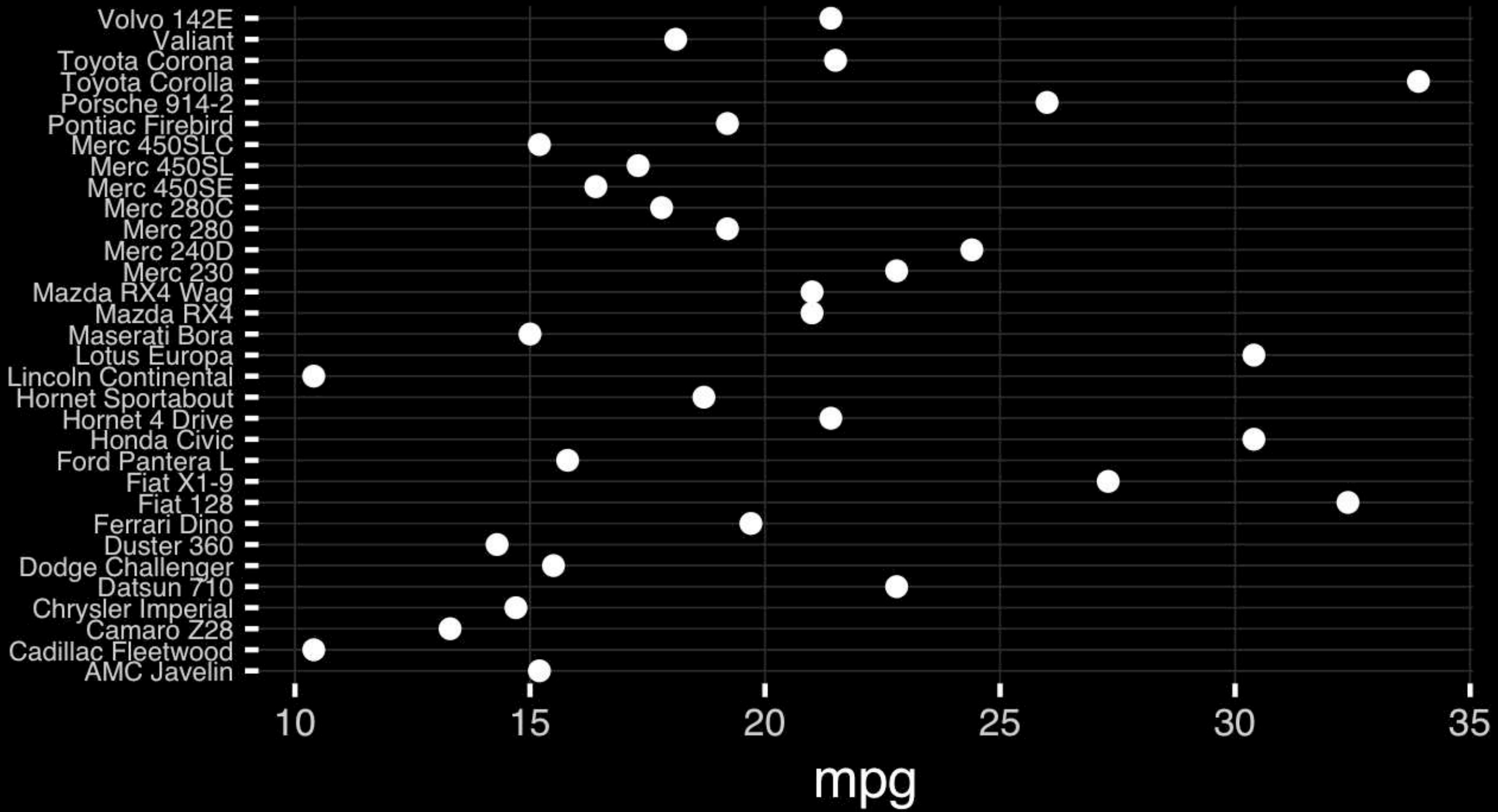
Volvo 142E
Valiant
Toyota Corona
Toyota Corolla
Porsche 914-2
Pontiac Firebird
Merc 450SLC
Merc 450SL
Merc 450SE
Merc 280C
Merc 280
Merc 240D
Merc 230
Mazda RX4 Wag
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Maserati Bora
Lotus Europa
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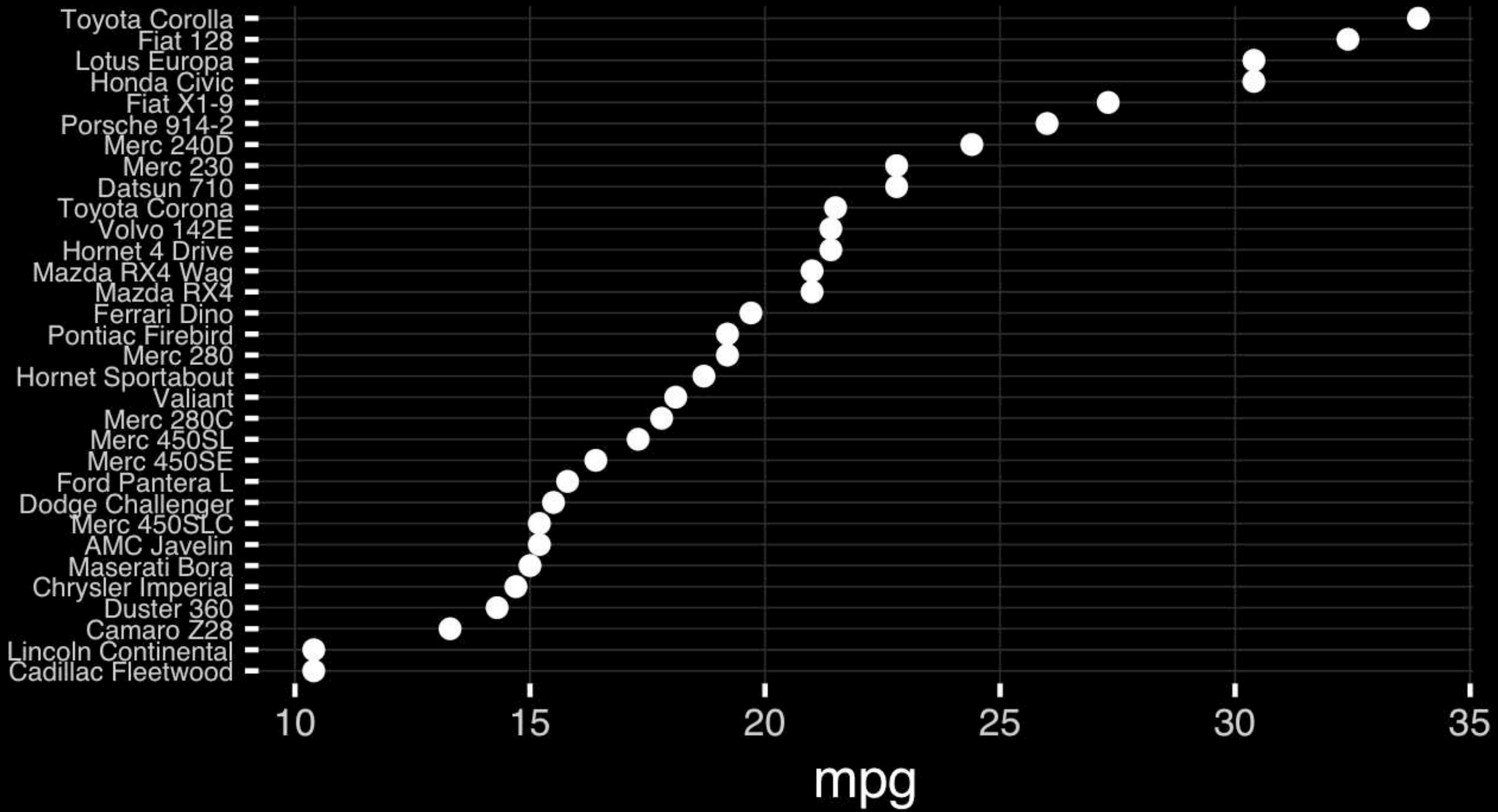
Toyota Corolla
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Ford Pantera L
Dodge Challenger
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Maserati Bora
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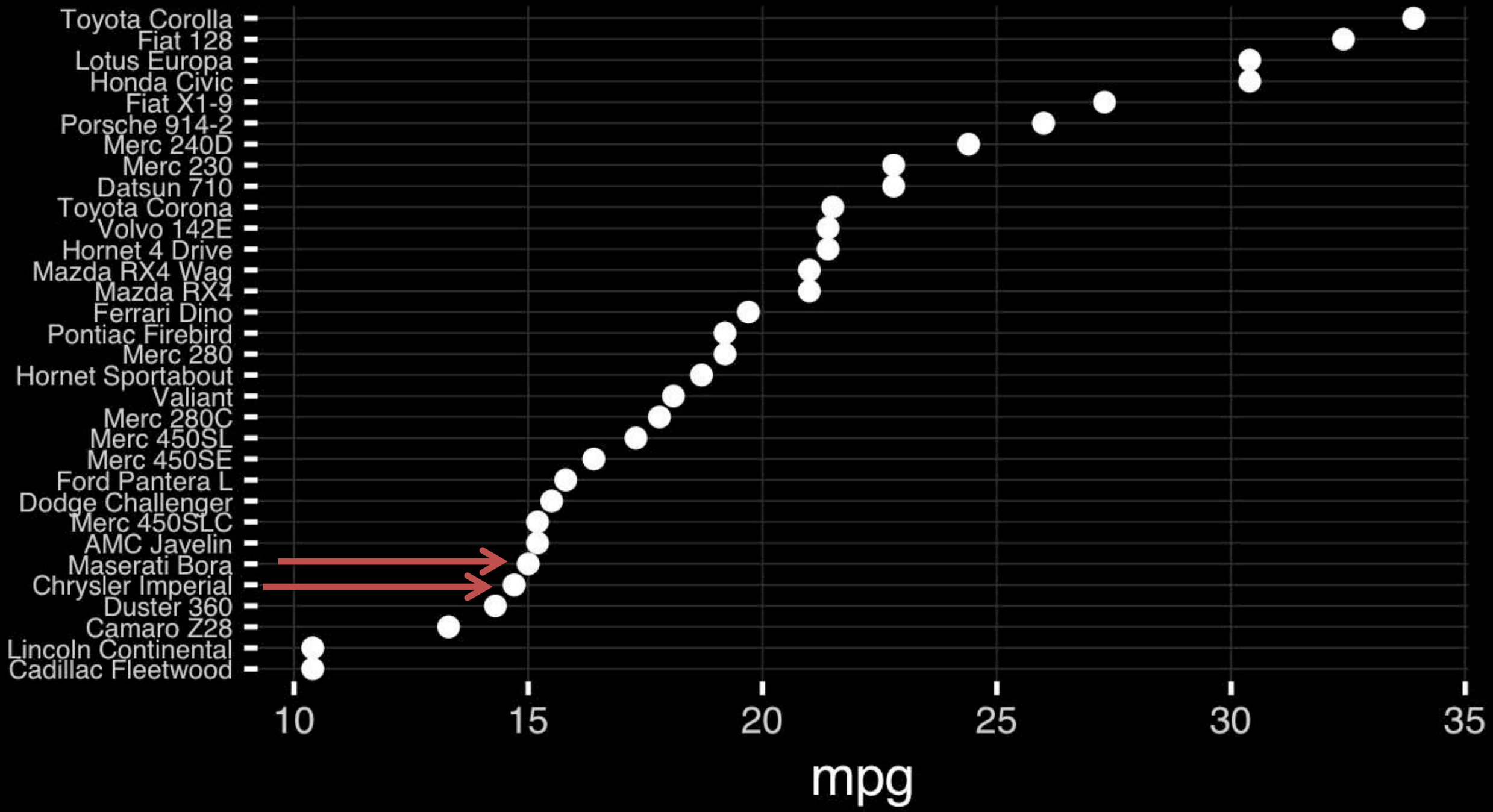
Toyota Corolla
Fiat 128
Lotus Europa
Honda Civic
Fiat X1-9
Porsche 914-2
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AMC Javelin
Maserati Bora
Chrysler Imperial
Duster 360
Camaro Z28
Lincoln Continental
Cadillac Fleetwood
10
15
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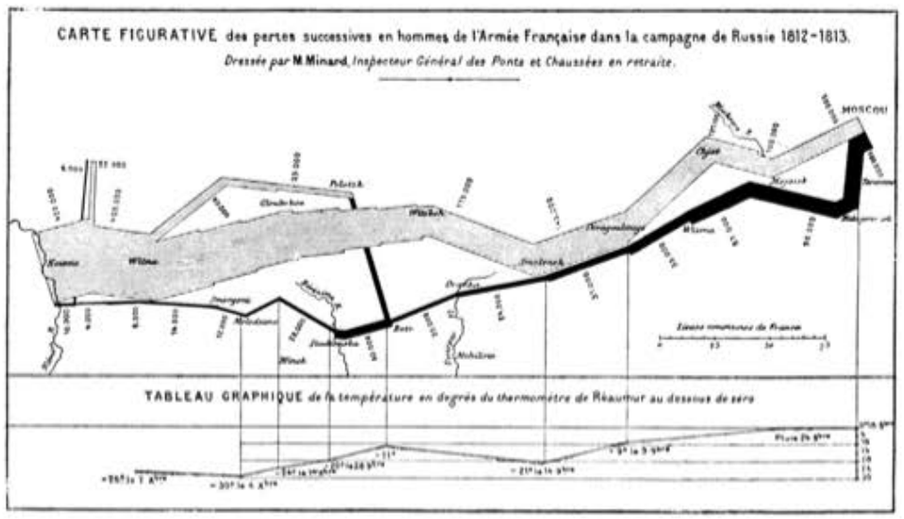
Observation: Comparison is trivial on a common scale.

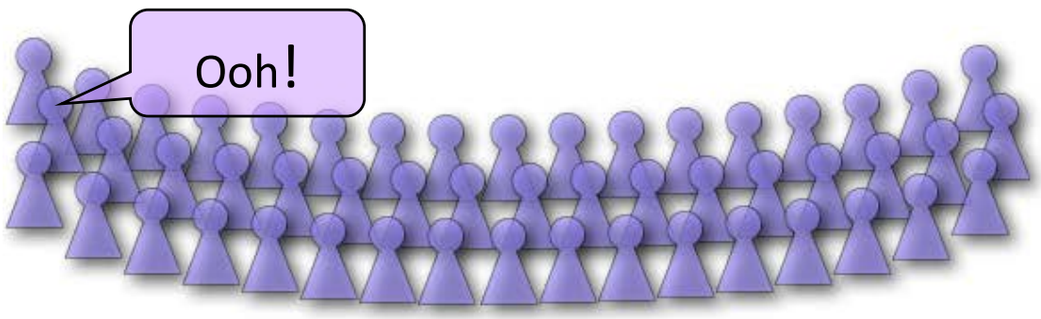
Today's Learning Goals

- 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**, **dendrograms** 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**.

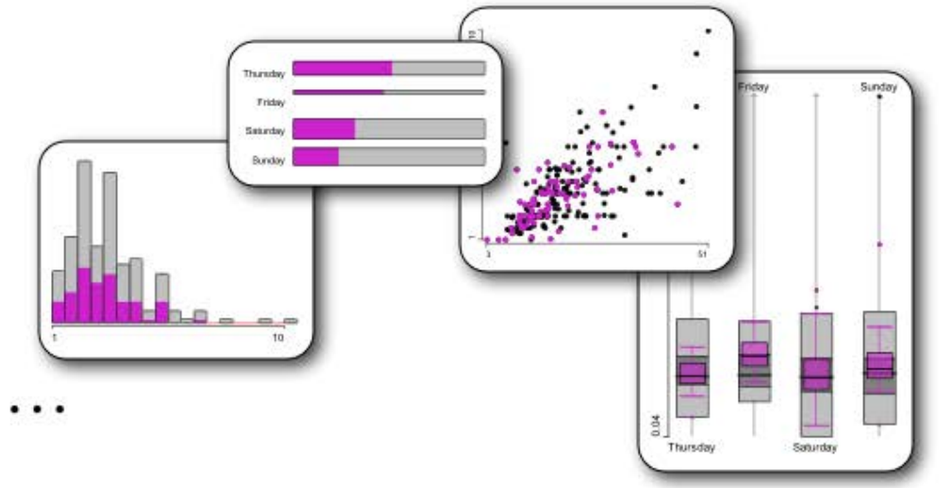
Different graphs for different purposes

Exploratory graphs: many images for a narrow audience (you!)
Presentation graphs: single image for a large audience





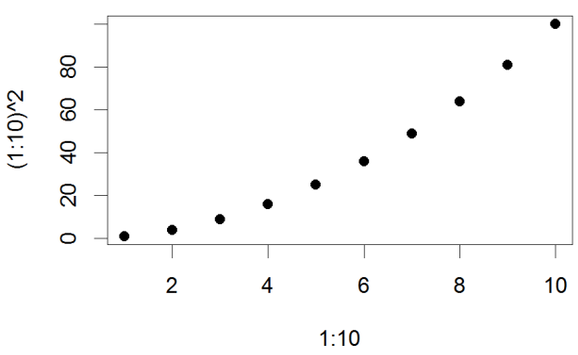
Presentation



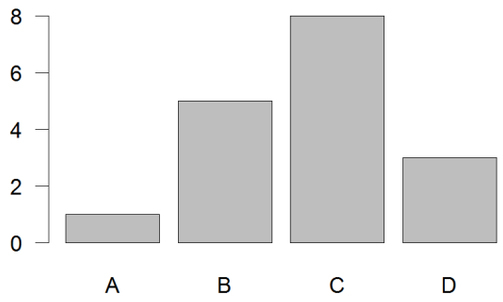
Exploration

Core R Graph Types

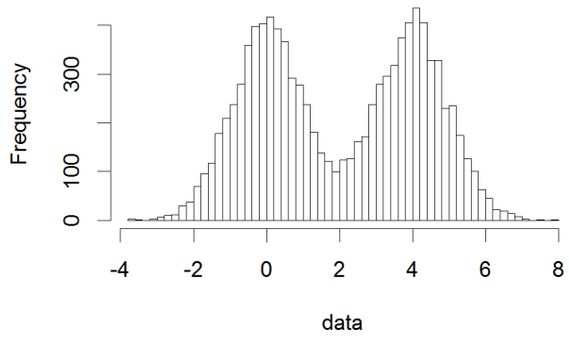
Scatter plot



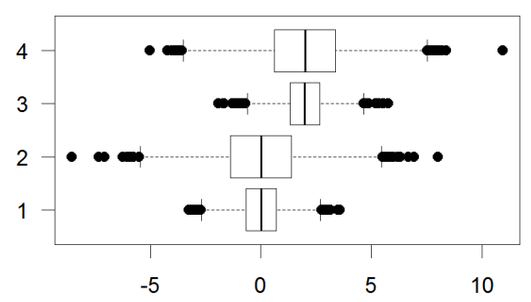
Bar Chart



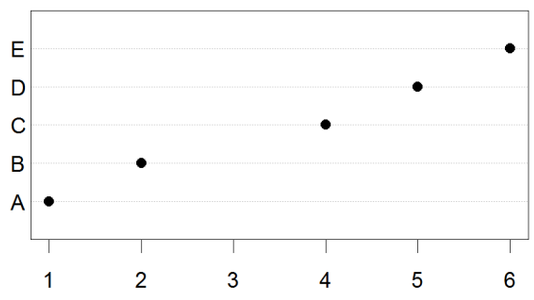
Histogram



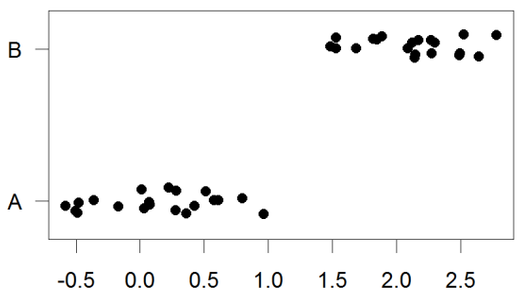
Boxplot



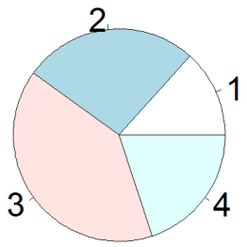
Dot Chart



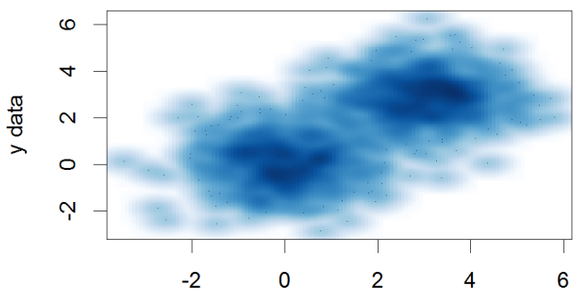
Stripchart



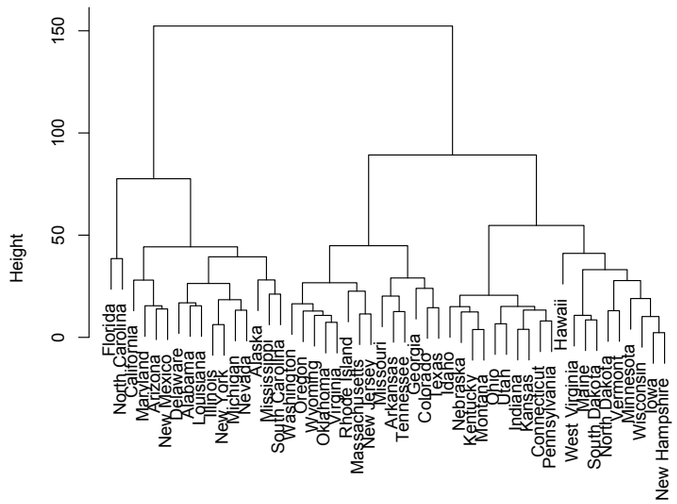
Pie Chart

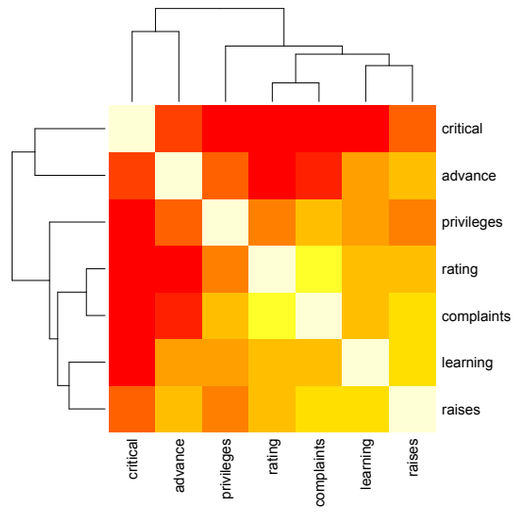


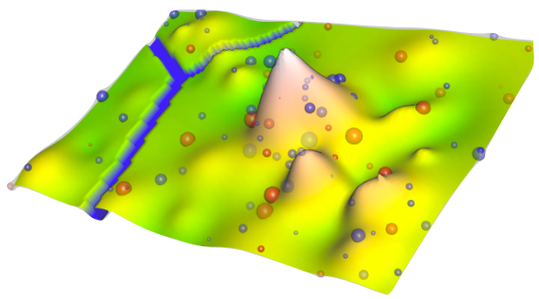
Smooth Scatter

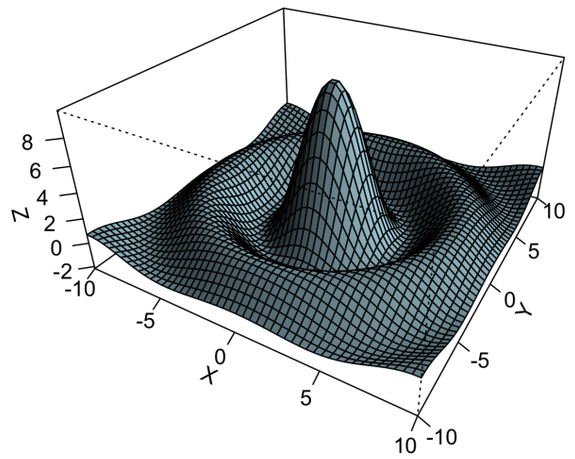


Cluster Dendrogram

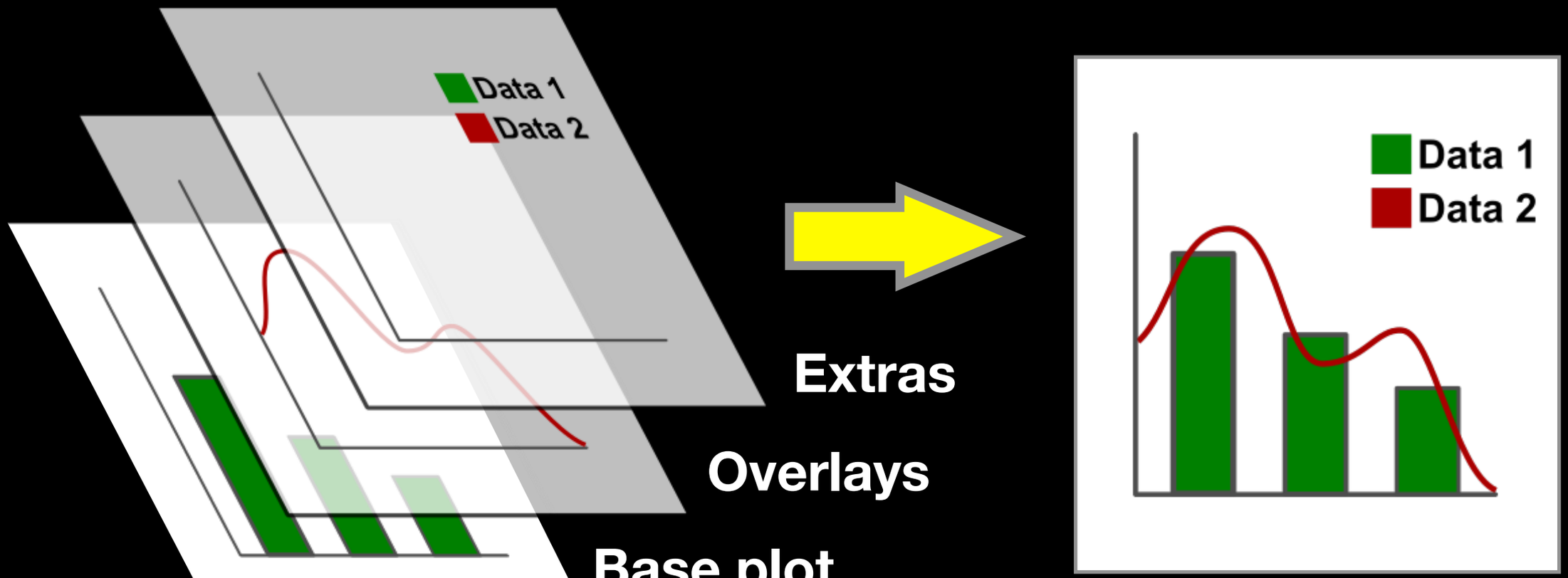








The R Painters Model



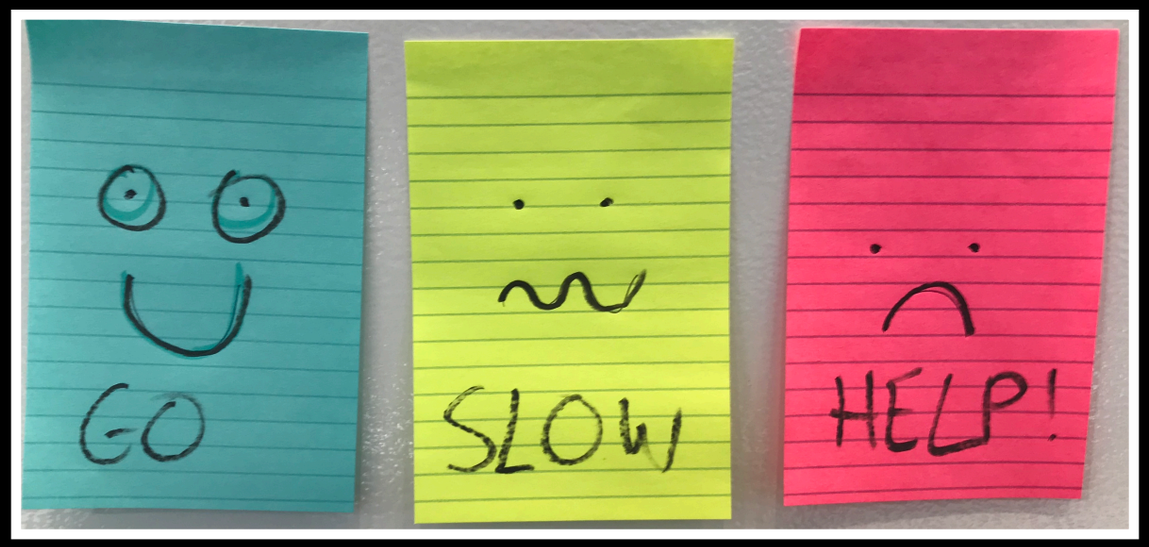
Side-Note: “Red and green should never be seen”

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**.



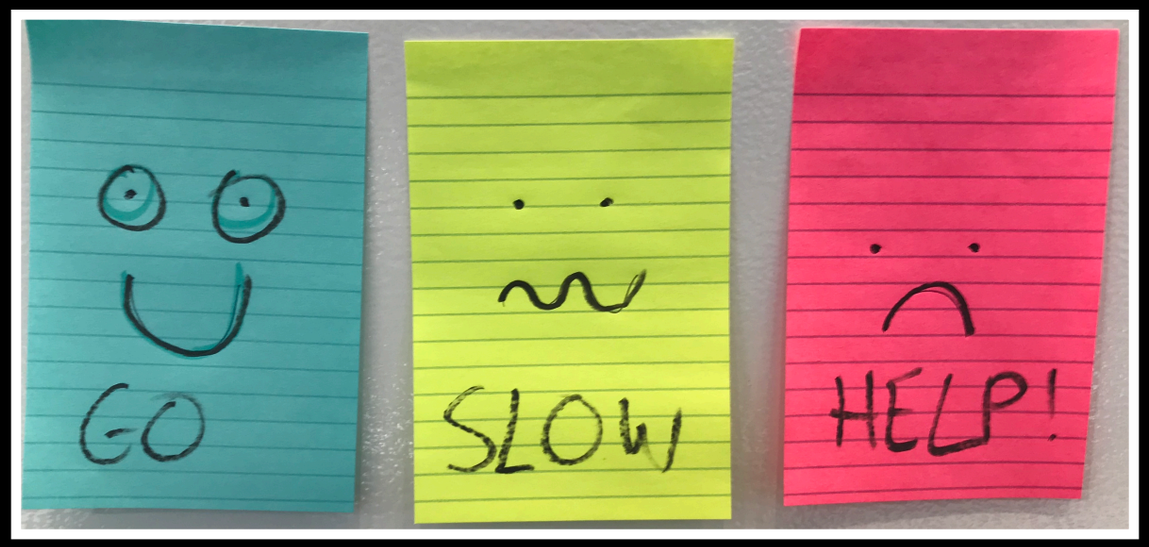
Do it Yourself!

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,
- Create and save an R Script called class05.R in your project directory

Do it Yourself!



Hands-on

Section 2 Notes

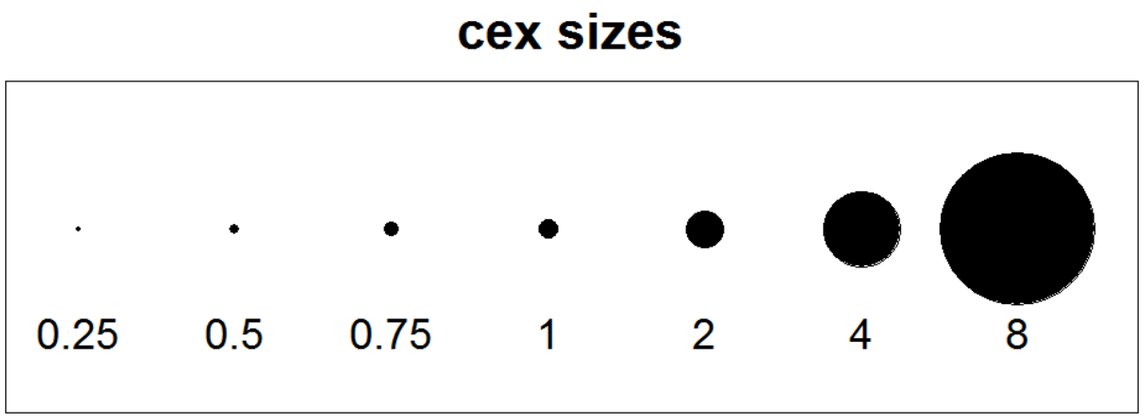
- Focus on Sections 2A & 2B (scatterplots & barplots) in the lab **handout**.
- Try Section 2C (histograms) if you have time.
- See notes on the following slides...

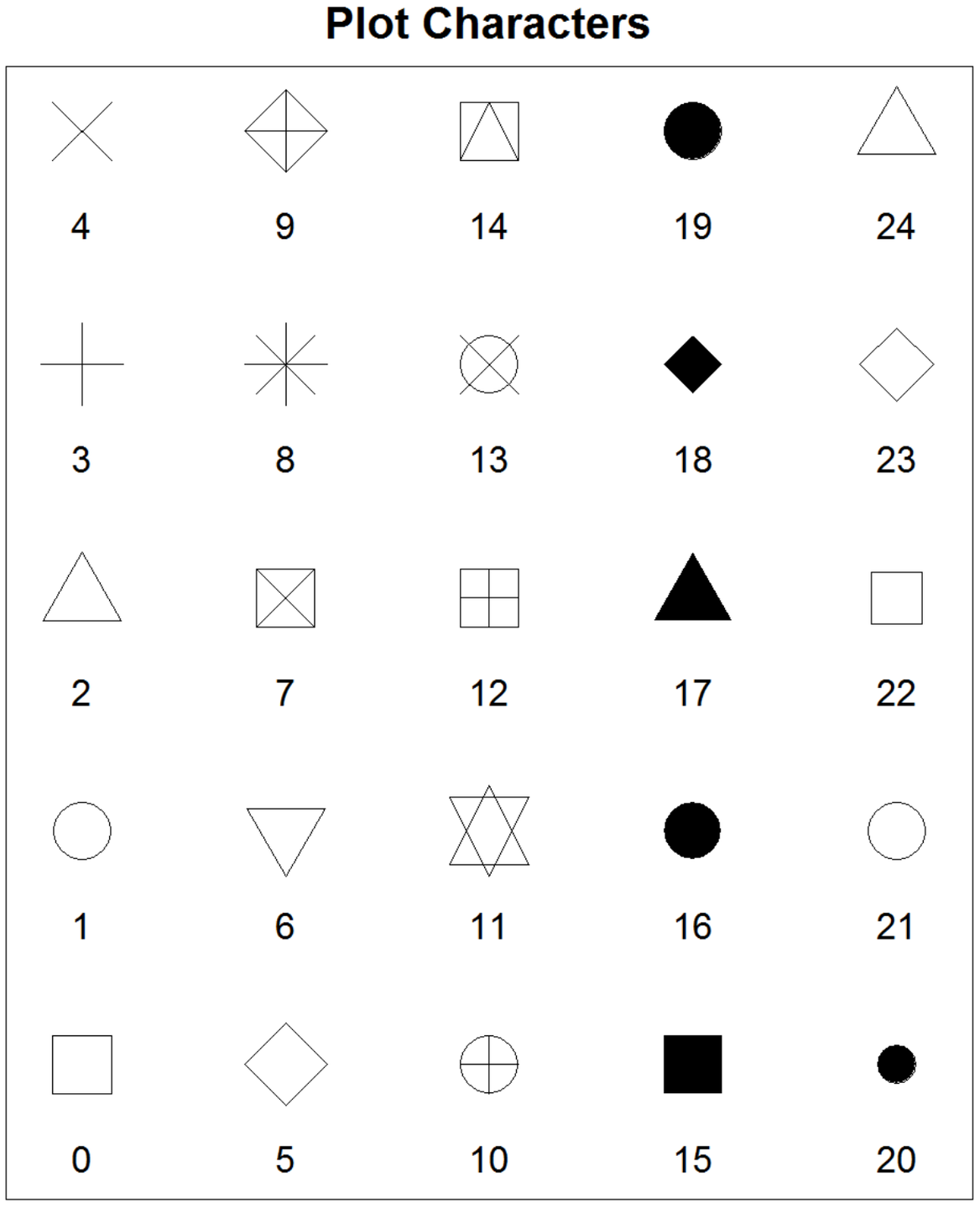
Common Options

- 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

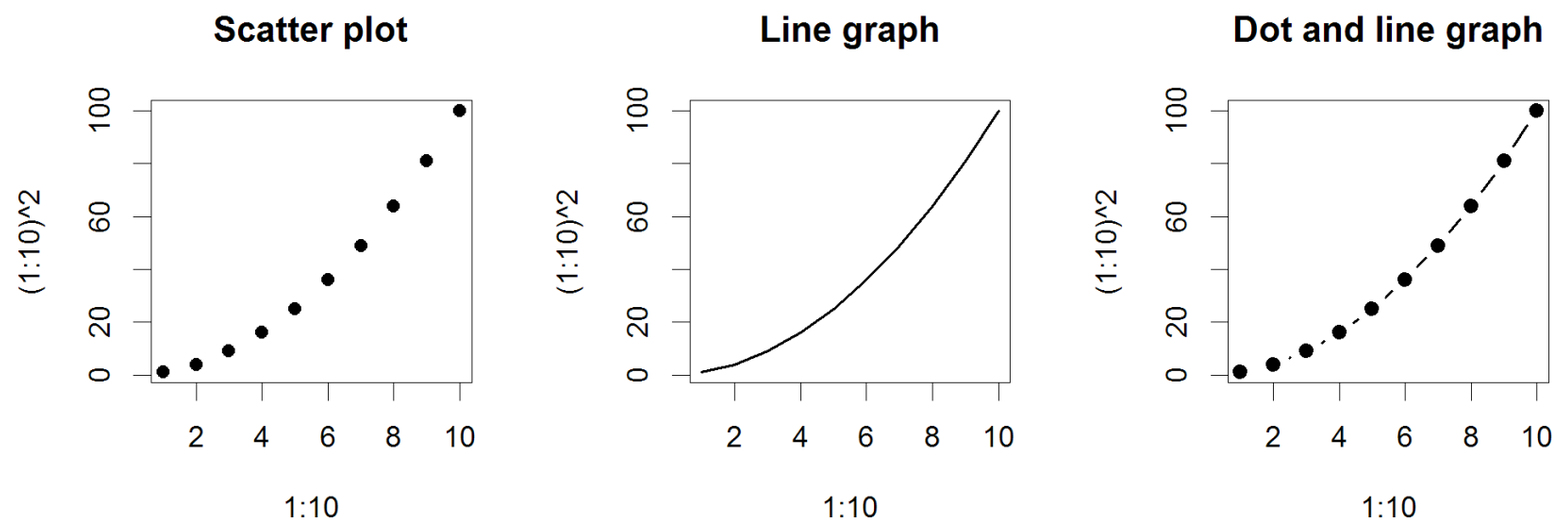





```
plot( 1:5, pch=1:5, cex=1:5 )
```

Plot Type Specific Options

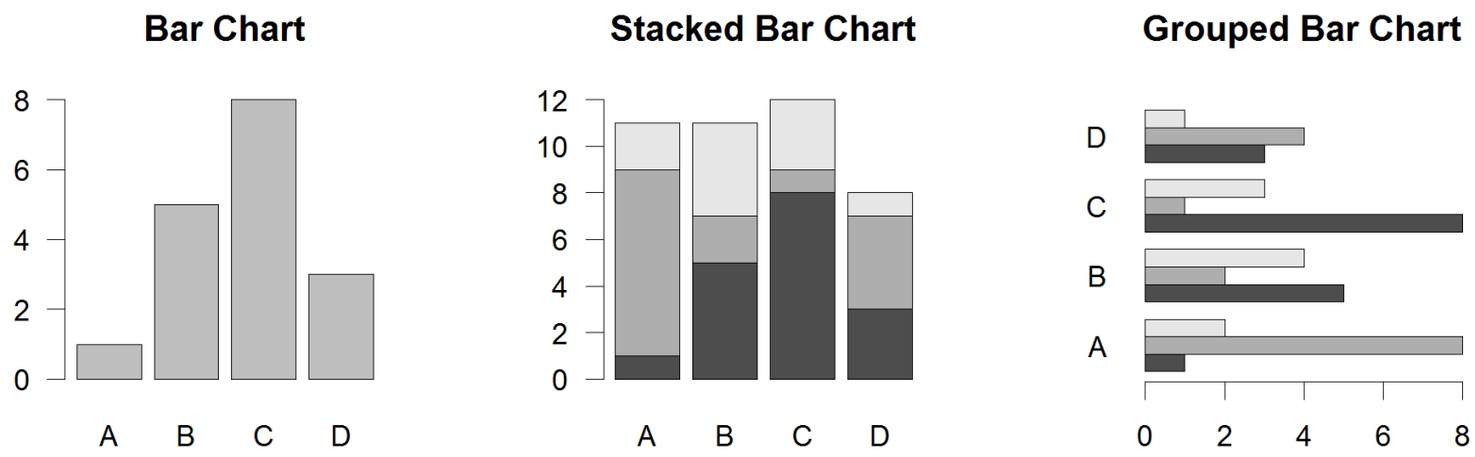
Plot (scatterplots and line graphs)



- 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

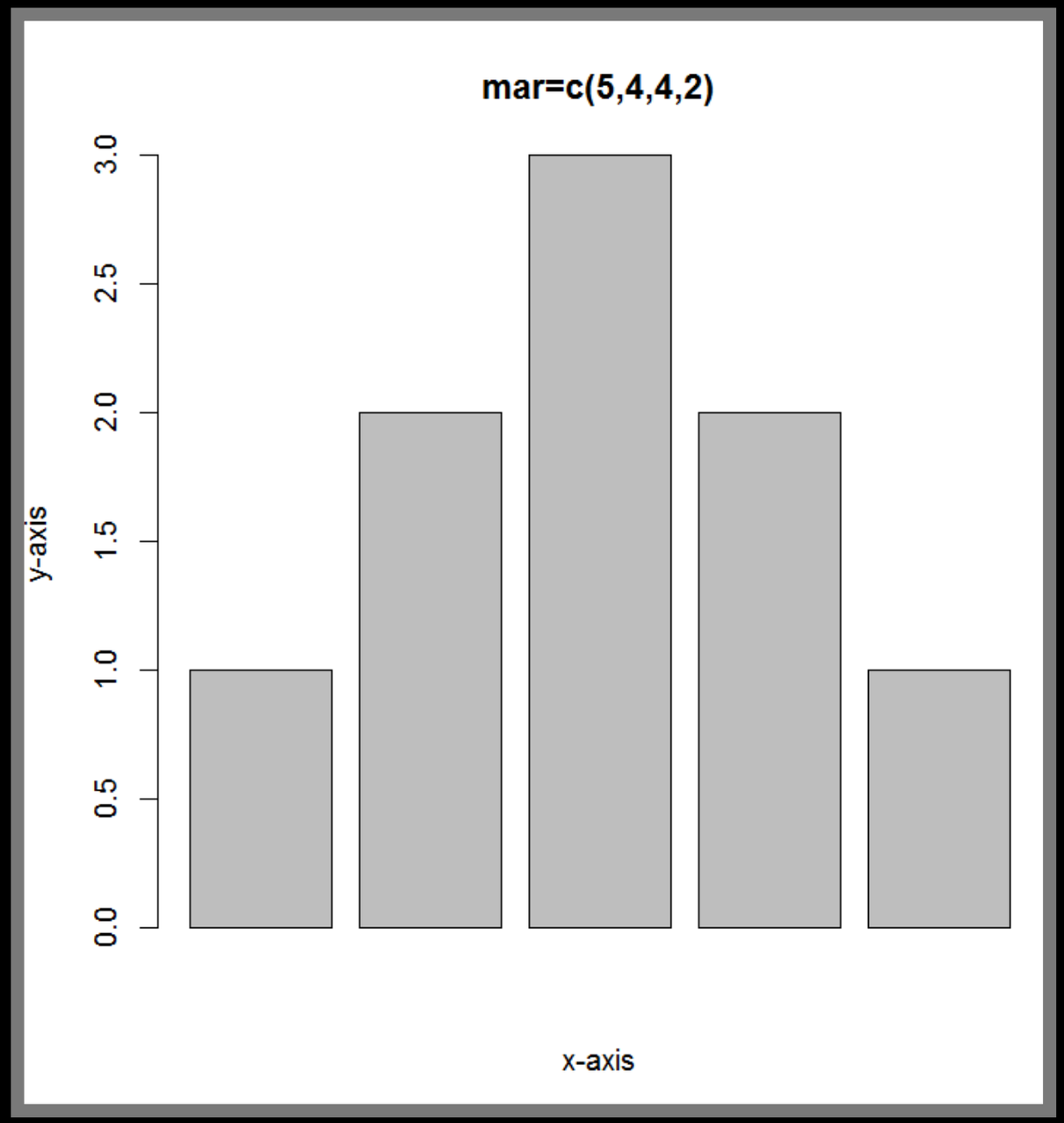
- Many par options can also be passed to individual plots

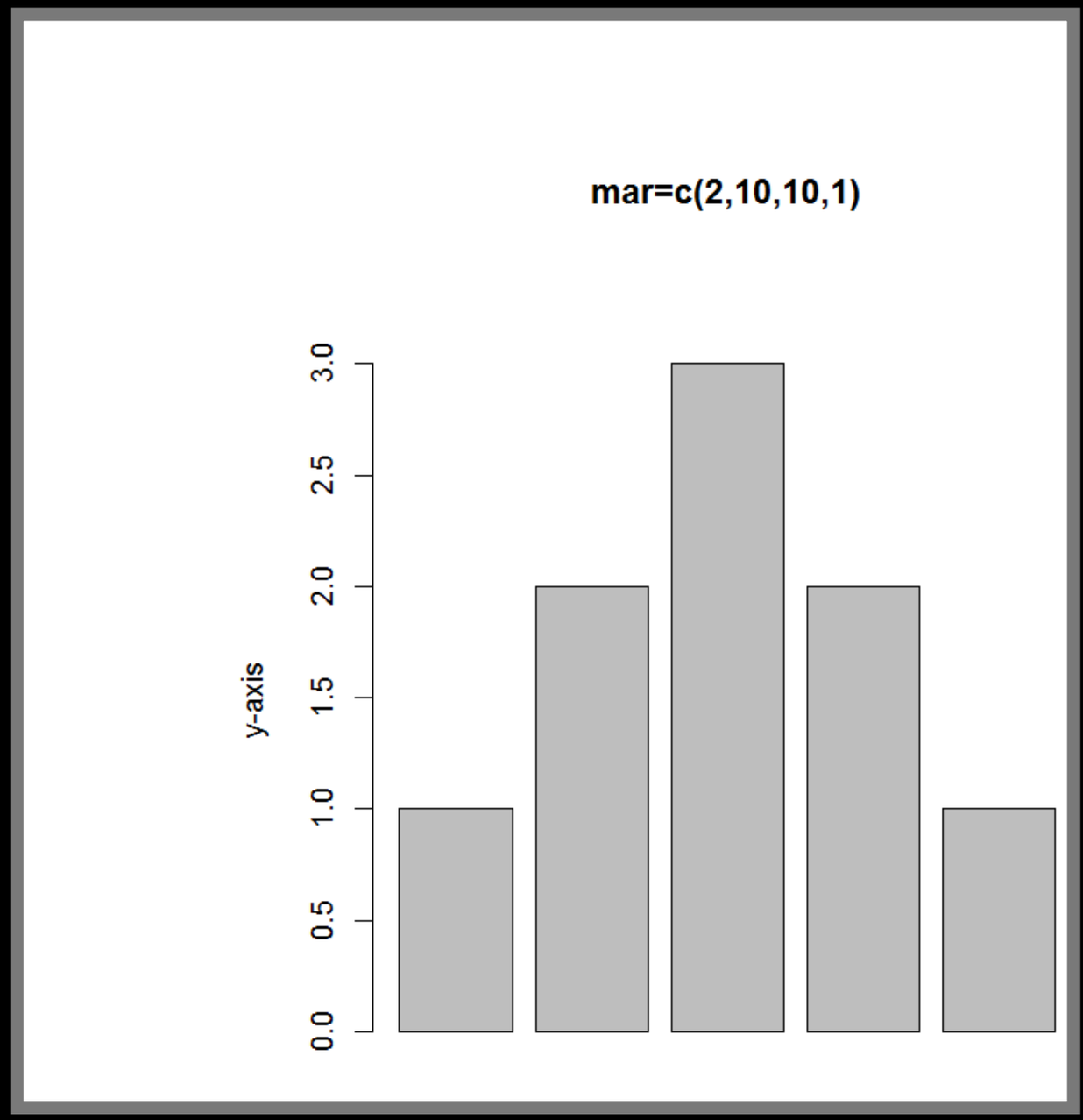
```
?par
```

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)





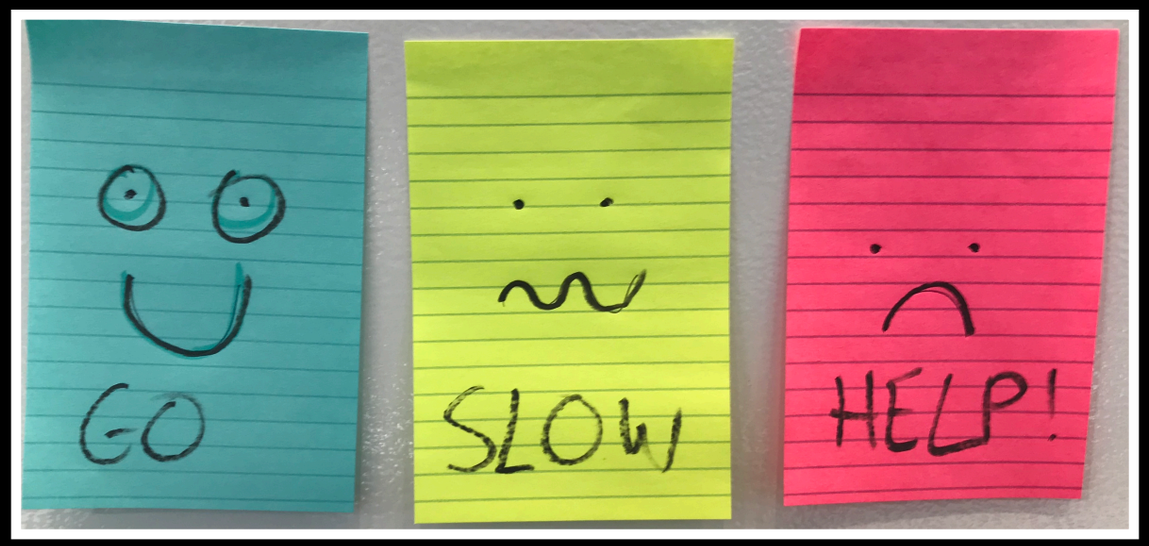

```
par( mar=c(2, 10, 10, 1) )
barplot(x)
```

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))

Do it Yourself!



Hands-on

Section 3 using color:

- 3A. Providing color vectors
- 3B. Coloring by value
- 3C. Dynamic use of color

Finally we will make a lab report!

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 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
    - `palette()`
    - `palette(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** Assignments

- **RStudio IDE (Pt 1)**
- **Intermediate R**
  - Conditionals and Control Flow
  - Functions
  - Loops

Muddy Point Assessment Form Link

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