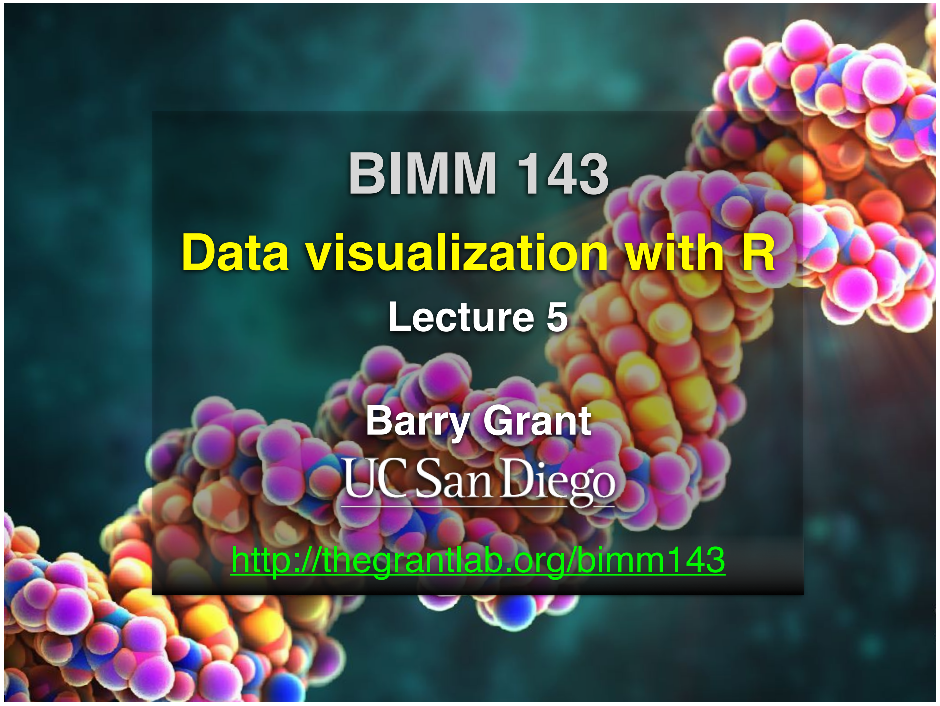

Recap From Last Time:

- 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.

[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.
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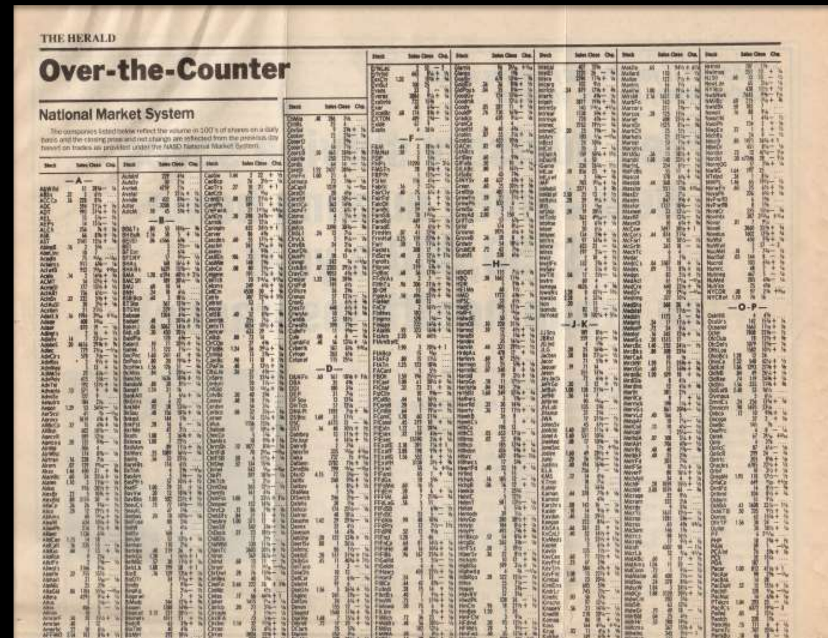
Why visualize at all?

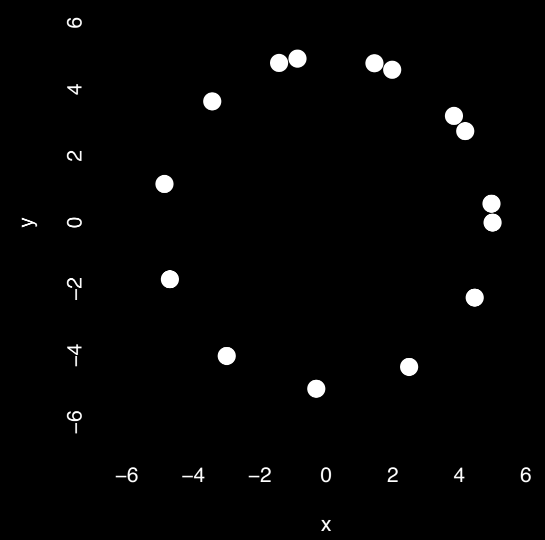

THE HERALD

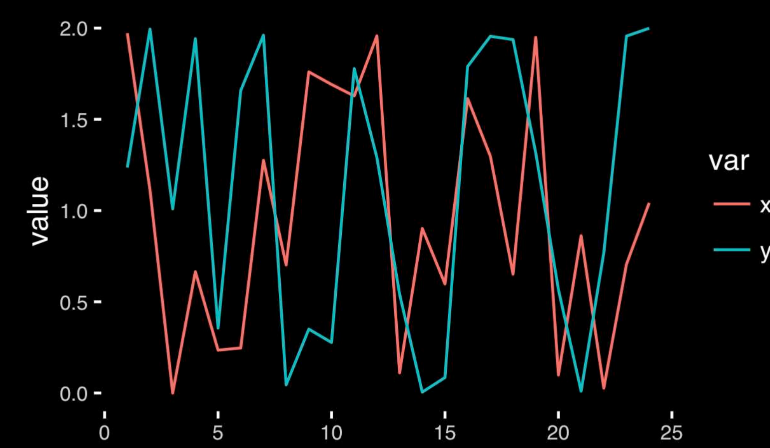
Over-the-Counter

National Market System

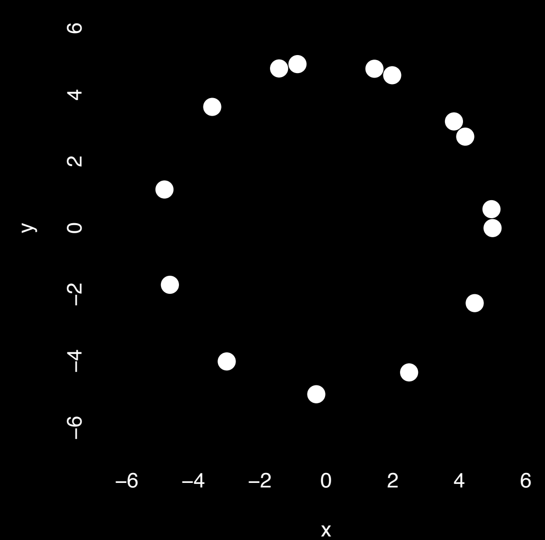
	x	y
1	5.00	0.00
2	4.18	2.75
3	1.98	4.59
4	-0.86	4.92
5	-3.43	3.64
6	-4.86	1.16
7	-4.70	-1.70
8	-2.99	-4.01
9	-0.30	-4.99
10	2.49	-4.34
11	4.46	-2.25
12	4.97	0.57
13	3.84	3.20
14	1.45	4.79
15	-1.42	4.79

	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





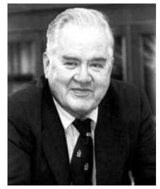
https://bioboot.github.io/bimm143_F18/class-material/05_draw_circle_points/



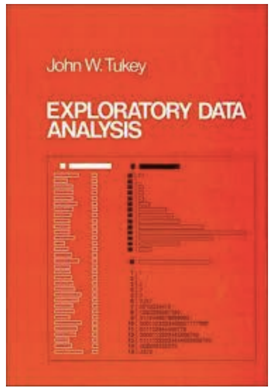
Exploratory Data Analysis

- 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

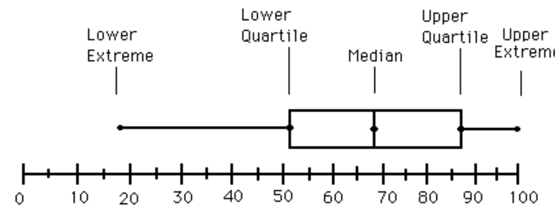


- Based on insights developed at Bell Labs in the 60's
- Techniques for visualizing and summarizing data
- What can the data tell us? (in contrast to "confirmatory" data analysis)
- Introduced many basic techniques:
  - 5-number summary, box plots, stem and leaf diagrams,…
- 5 Number summary:
  - extremes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



Side-note: **boxplots**

- **Box-and-whisker plot** : a graphical form of 5-number summary (Tukey)



`boxplot( rnorm(1000,0) )`

summary(); hist()

The Trouble with Summary Stats

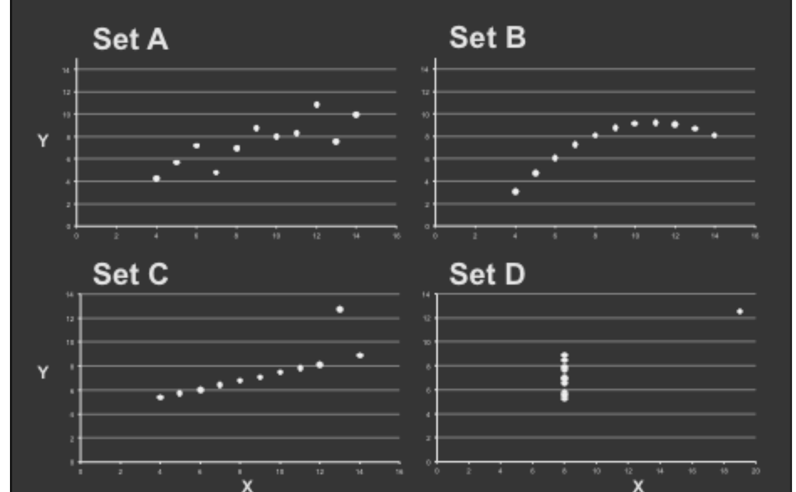
Set A X	Set A Y	Set B X	Set B Y	Set C X	Set C Y	Set D X	Set D Y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.1	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.1	4	5.39	19	12.5
12	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

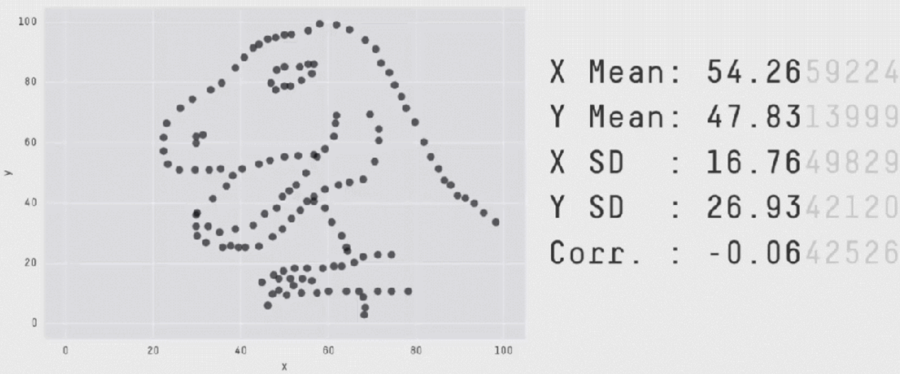
$u_X = 9.0$ $\sigma_X = 3.317$ $Y = 3 + 0.5X$
$u_Y = 7.5$ $\sigma_Y = 2.03$ $R^2 = 0.67$

[Anscombe 73]

Looking at Data



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



Key point: You need to visualize your data!

https://github.com/stephlocke/datasauRus

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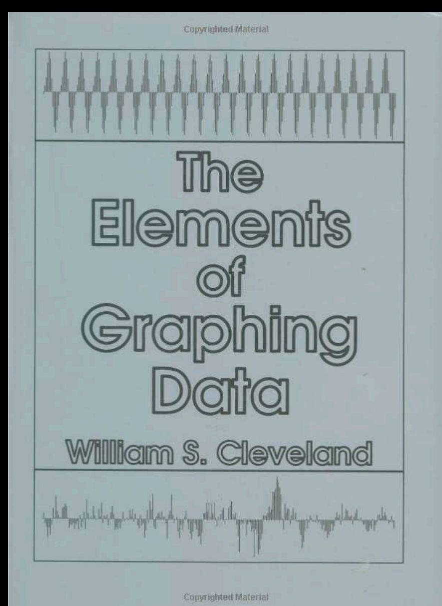

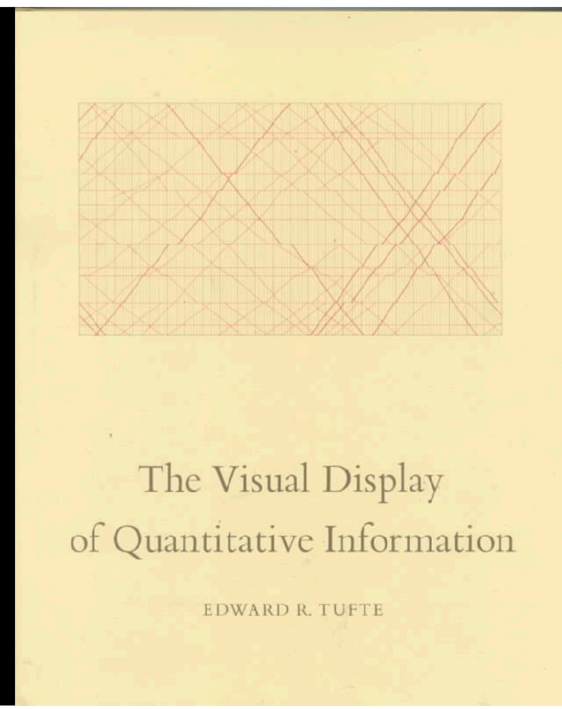

Key Point:
Good visualizations optimize for the human visual system.

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

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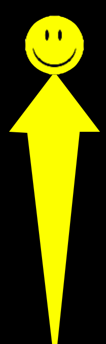

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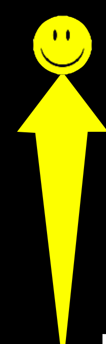

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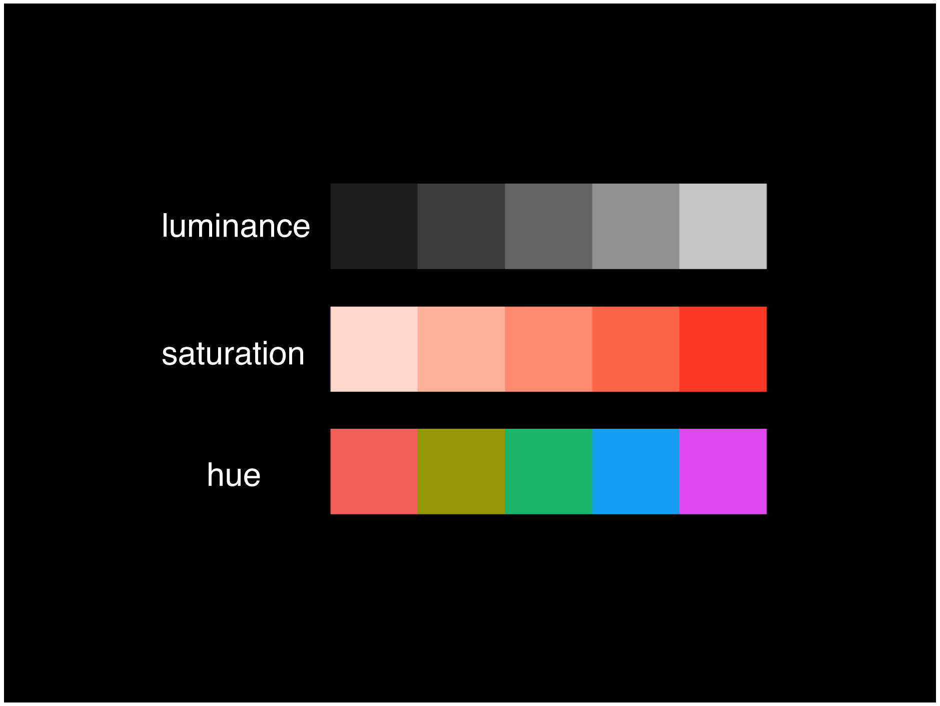
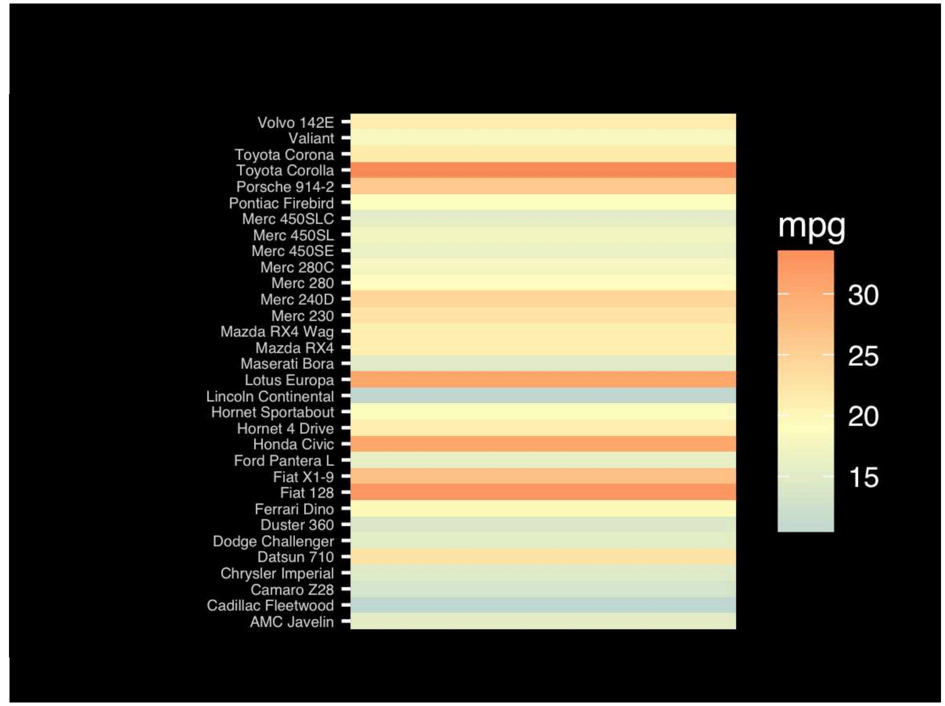

luminance
saturation
hue


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
Mazda RX4
Maserati Bora
Lotus Europa
Lincoln Continental
Hornet Sportabout
Hornet 4 Drive
Honda Civic
Ford Pantera L
Fiat X1-9
Fiat 128
Ferrari Dino
Duster 360
Dodge Challenger
Datsun 710
Chrysler Imperial
Camaro Z28
Cadillac Fleetwood
AMC Javelin
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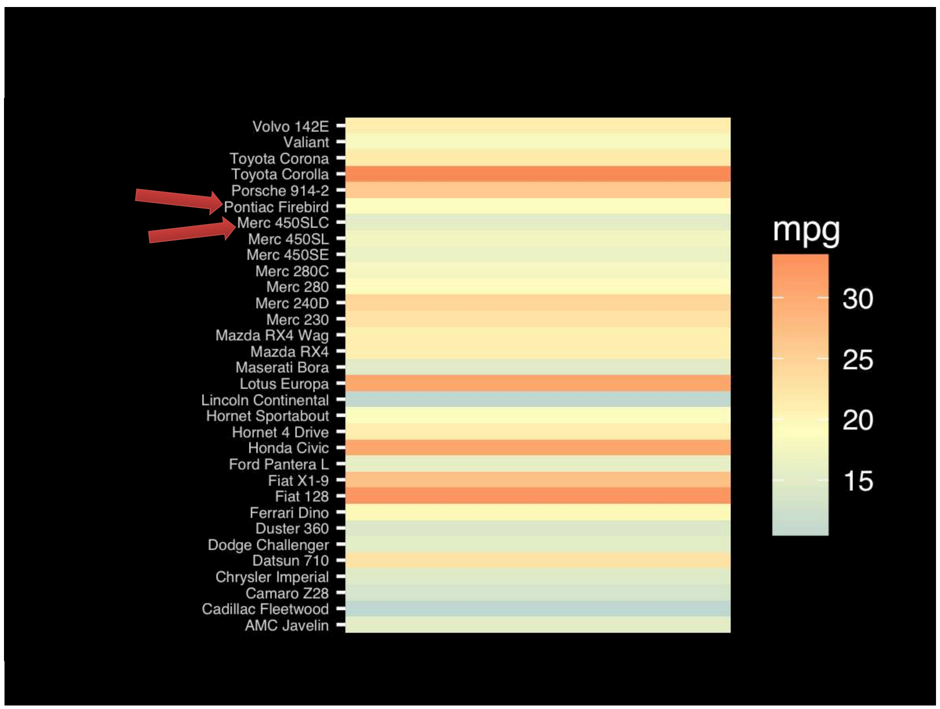
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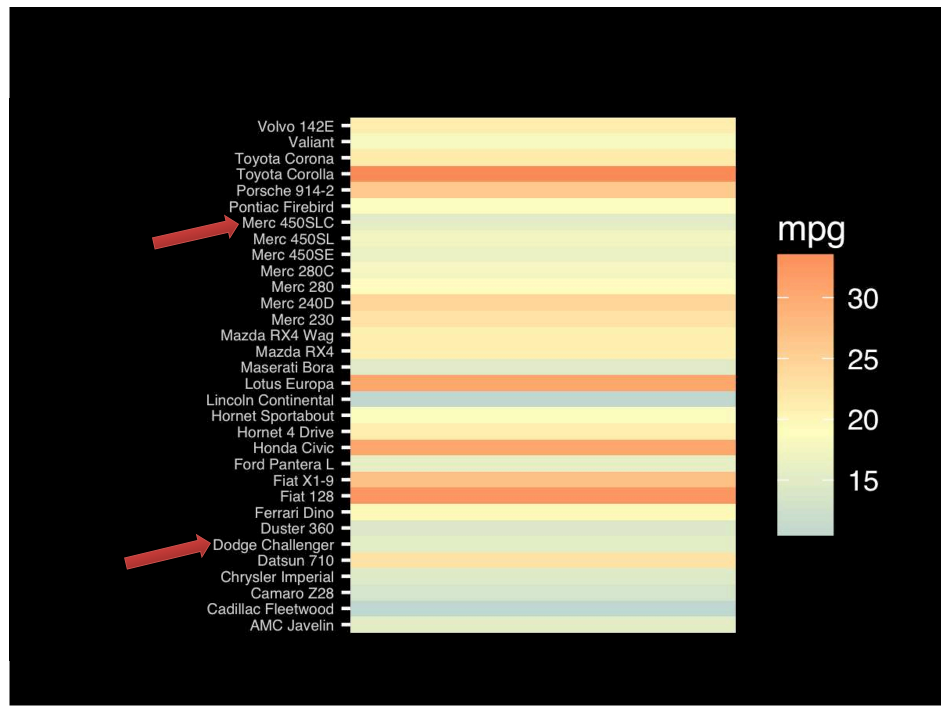
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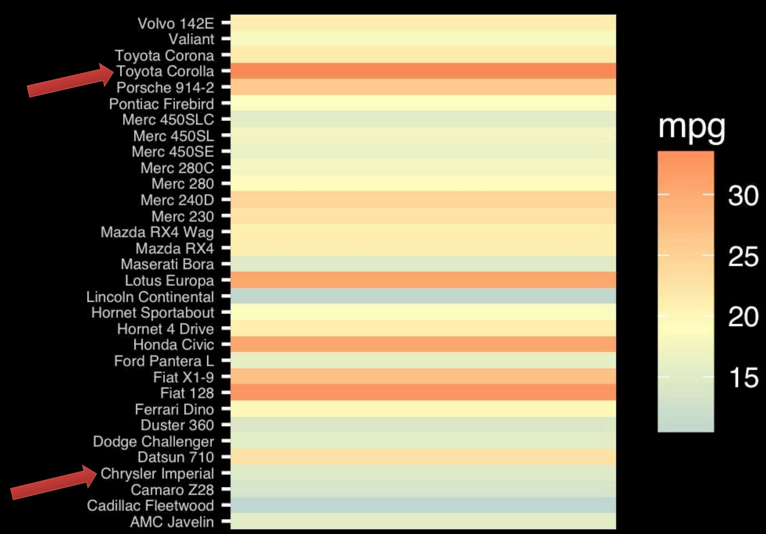
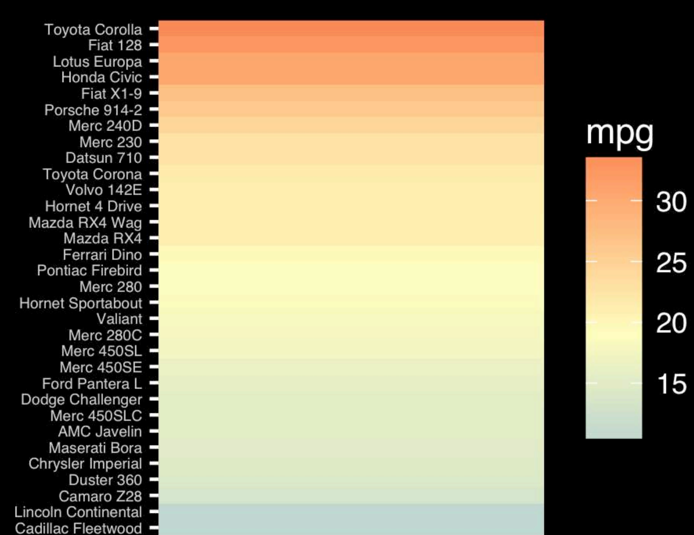
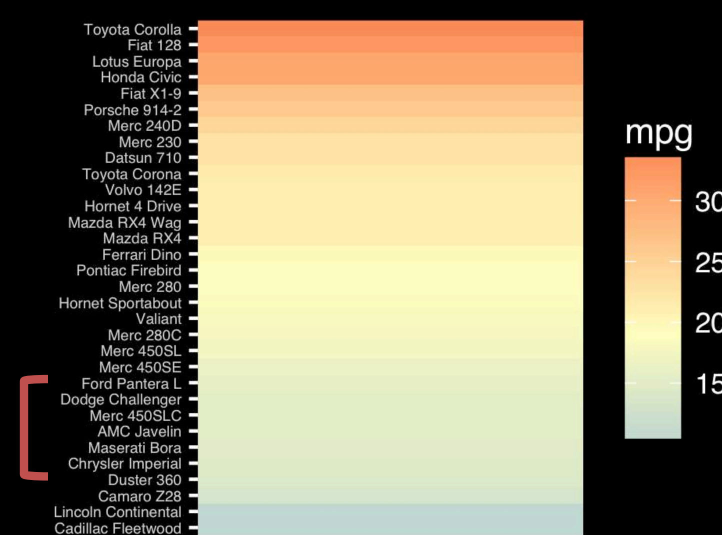
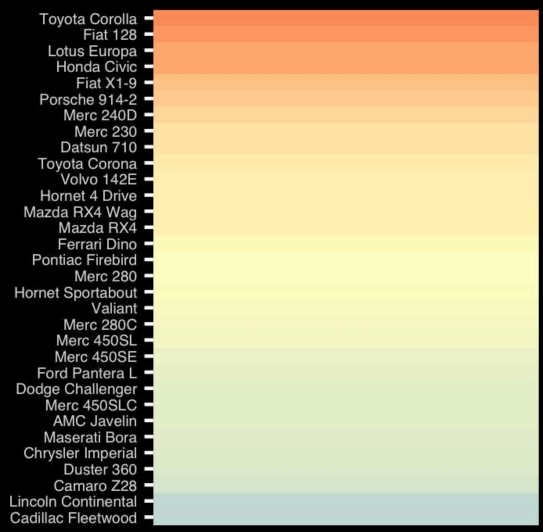


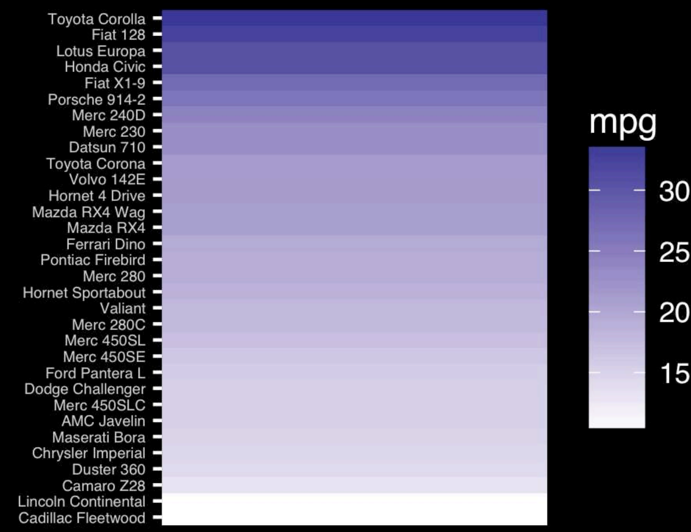
Observation: Alphabetical is almost never the correct ordering of a categorical variable.







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



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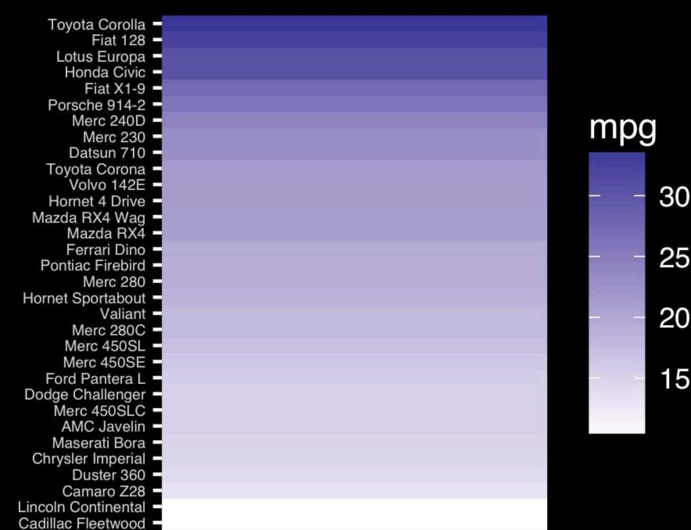

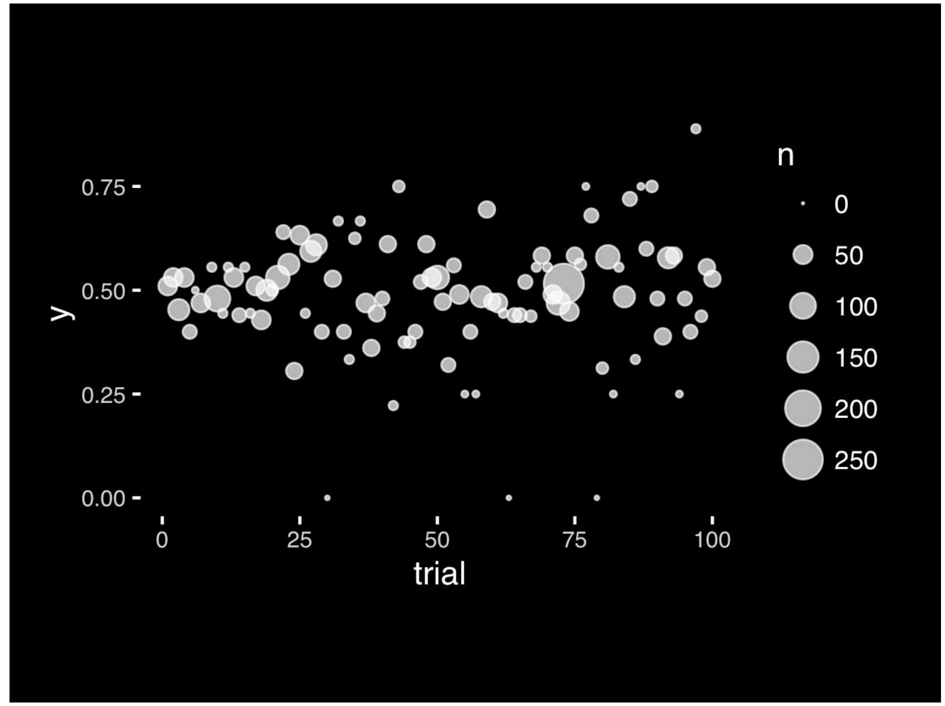

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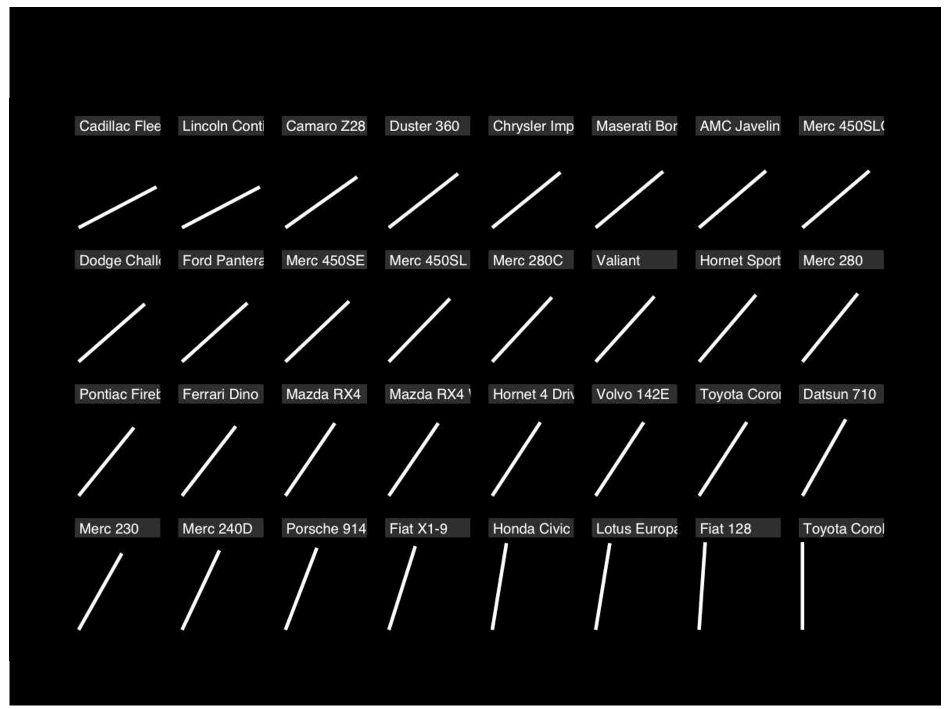
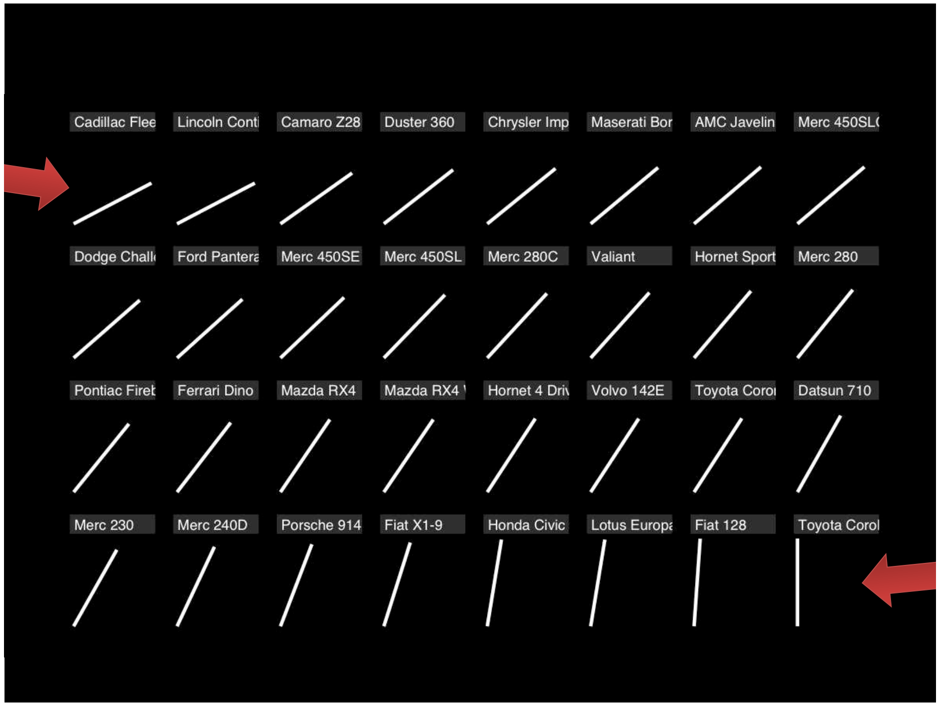
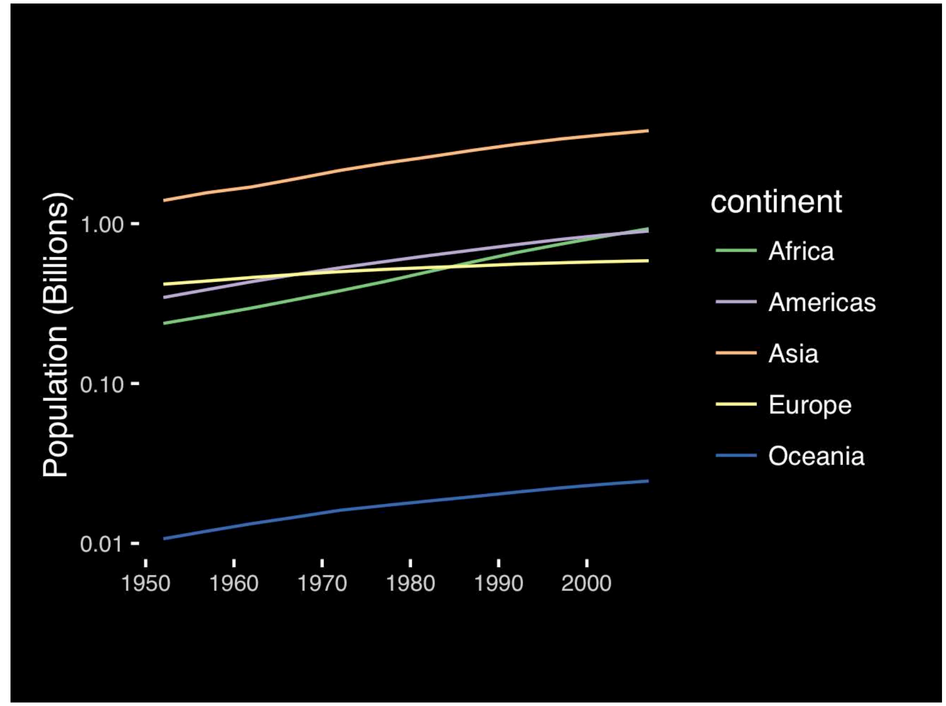
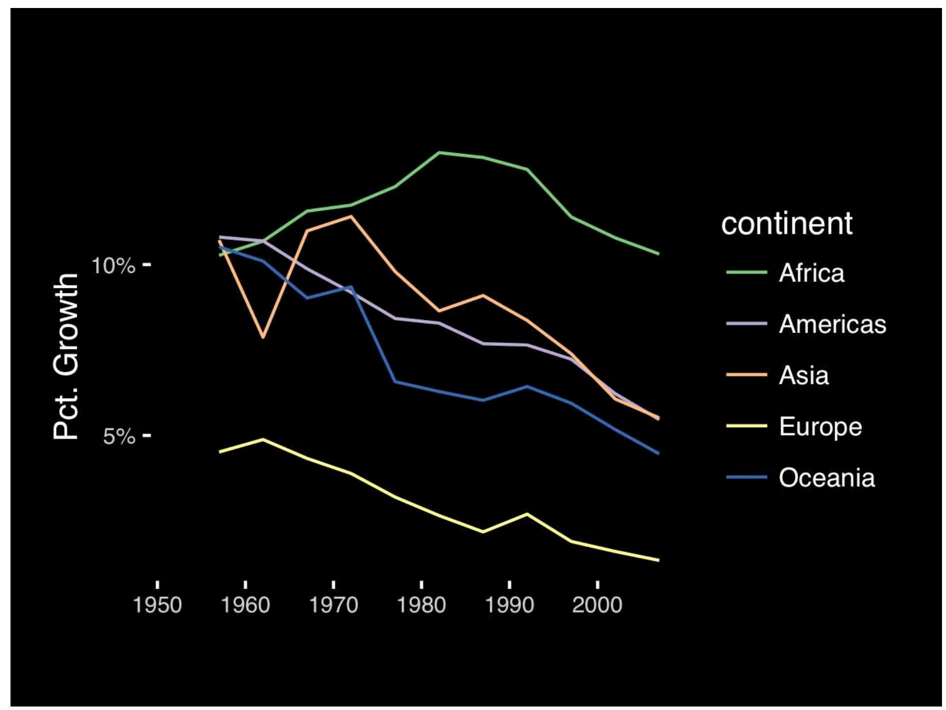






If growth (slope) is important, plot it directly.



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Observation: Pie charts are <u>ALWAYS</u> 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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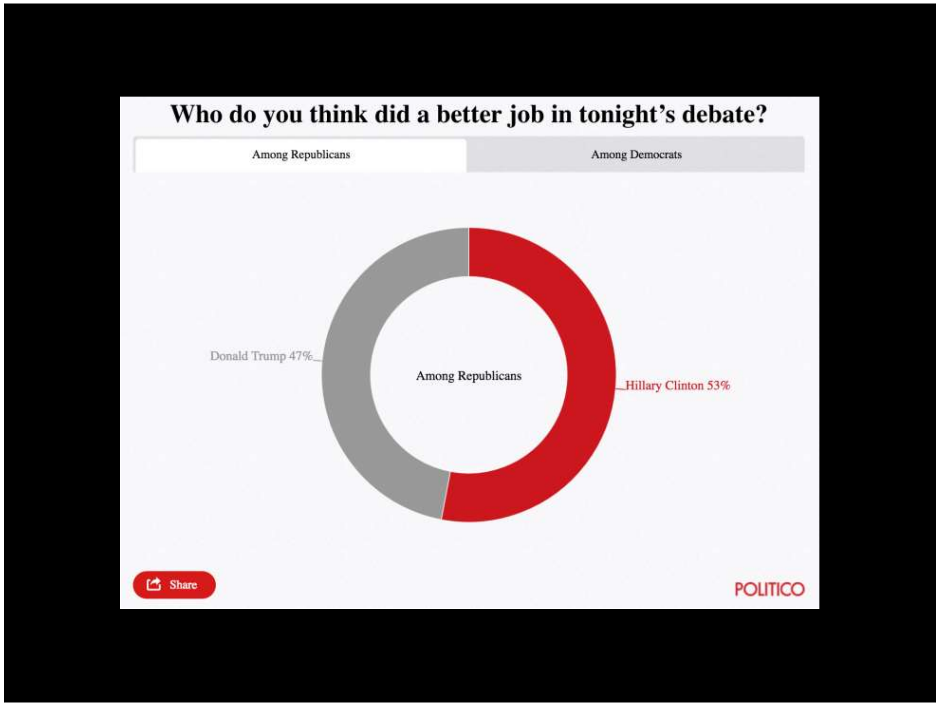

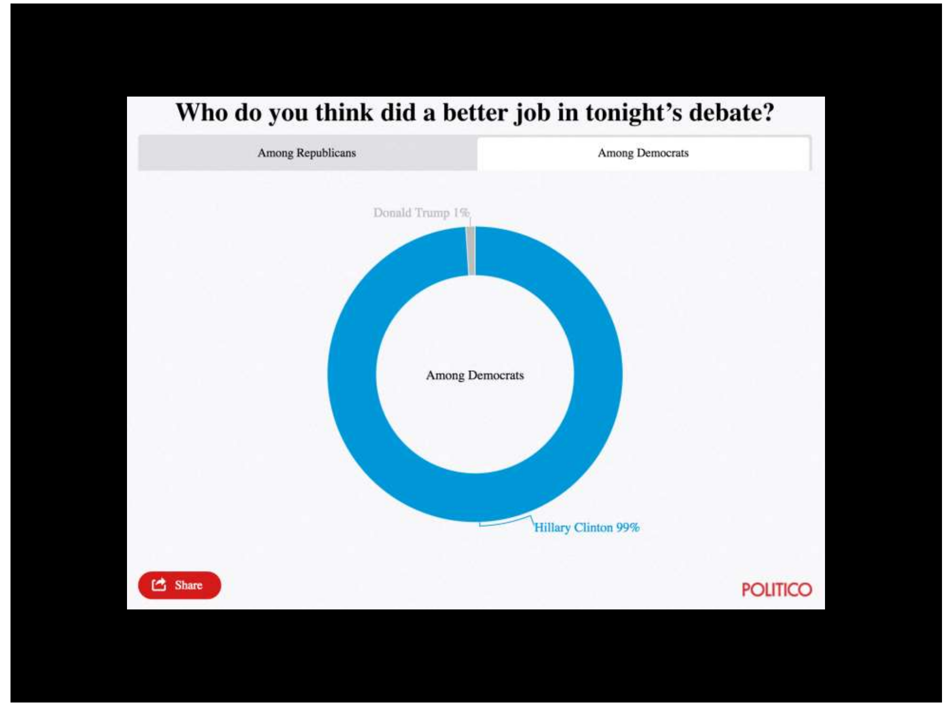

Tables are preferable to graphics for many small data sets. A table is nearly always better than a dumb pie chart; the only thing worse than a pie chart is several of them, for then the viewer is asked to compare quantities located in spatial disarray both within and between pies... Given their low data-density 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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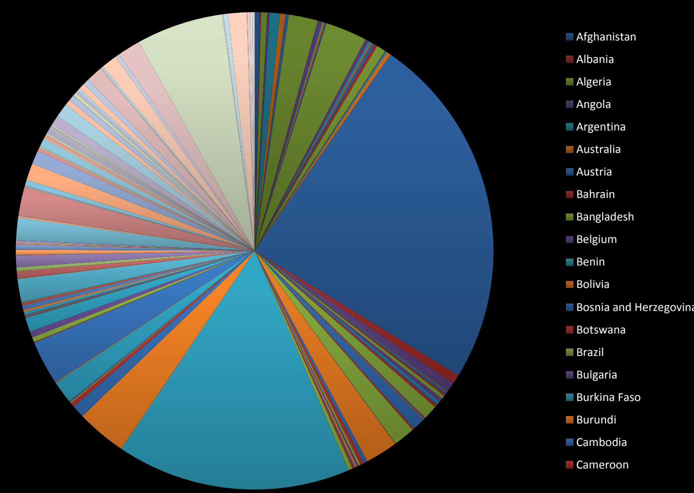
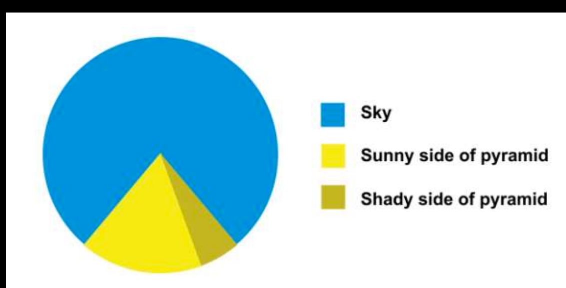
Who do you think did a better job in tonight's debate?

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



All good pie charts are jokes…



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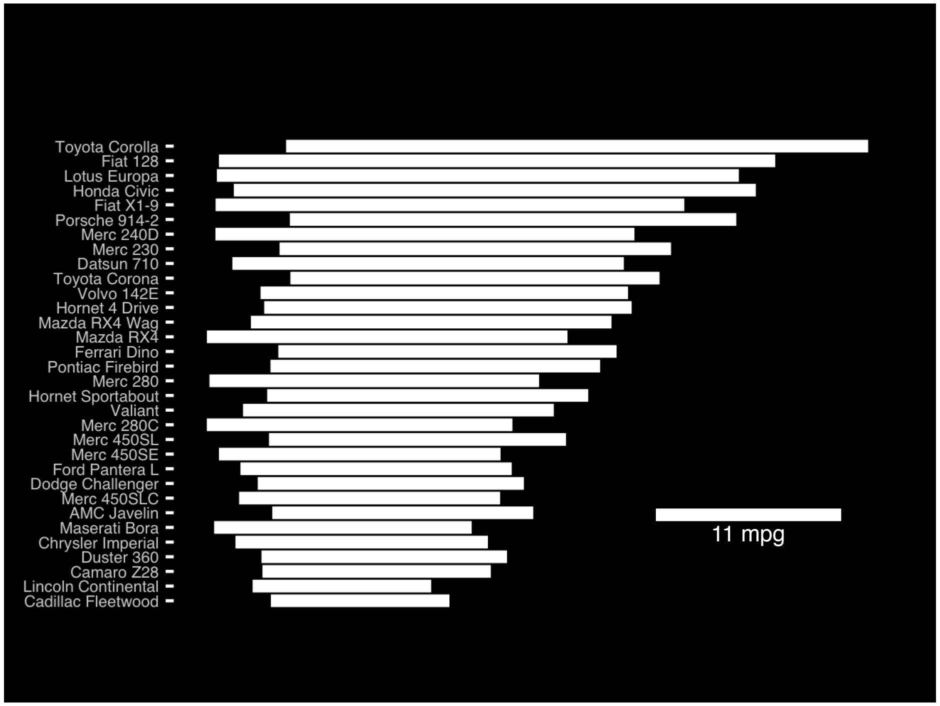

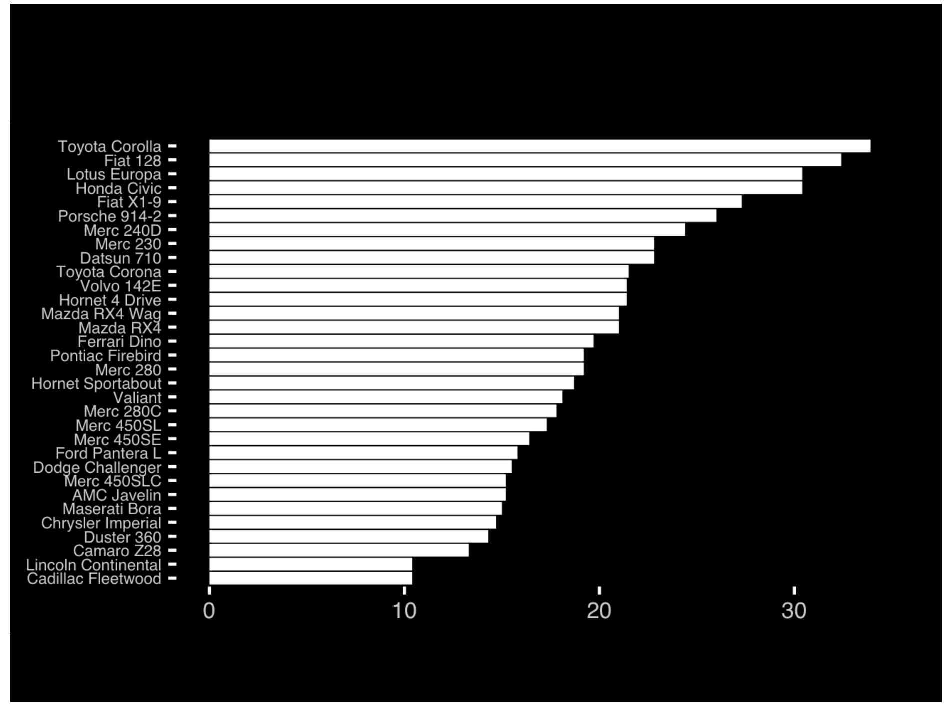

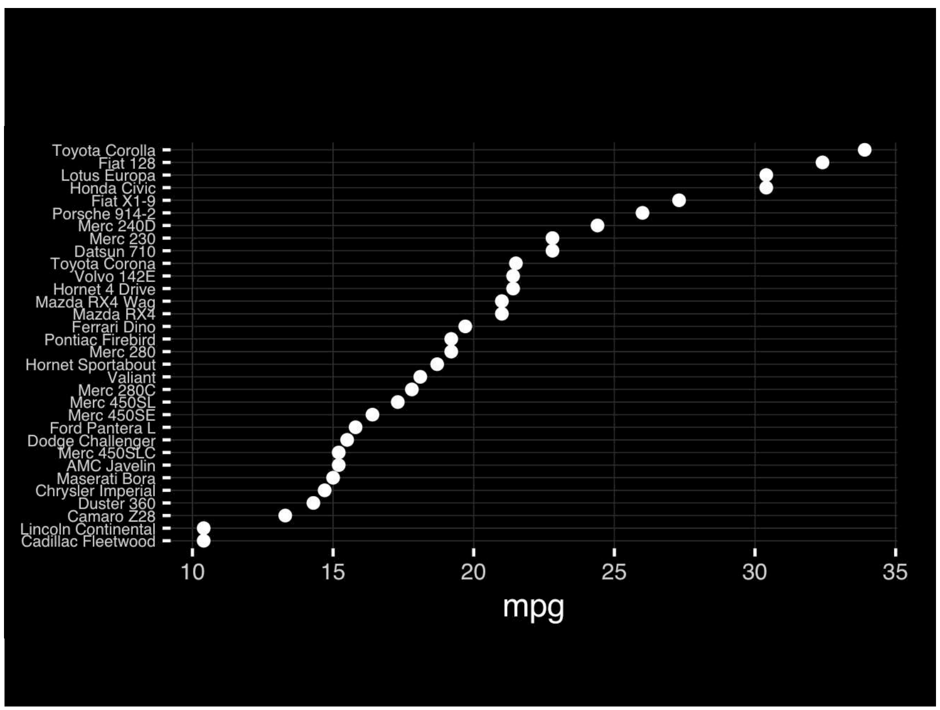

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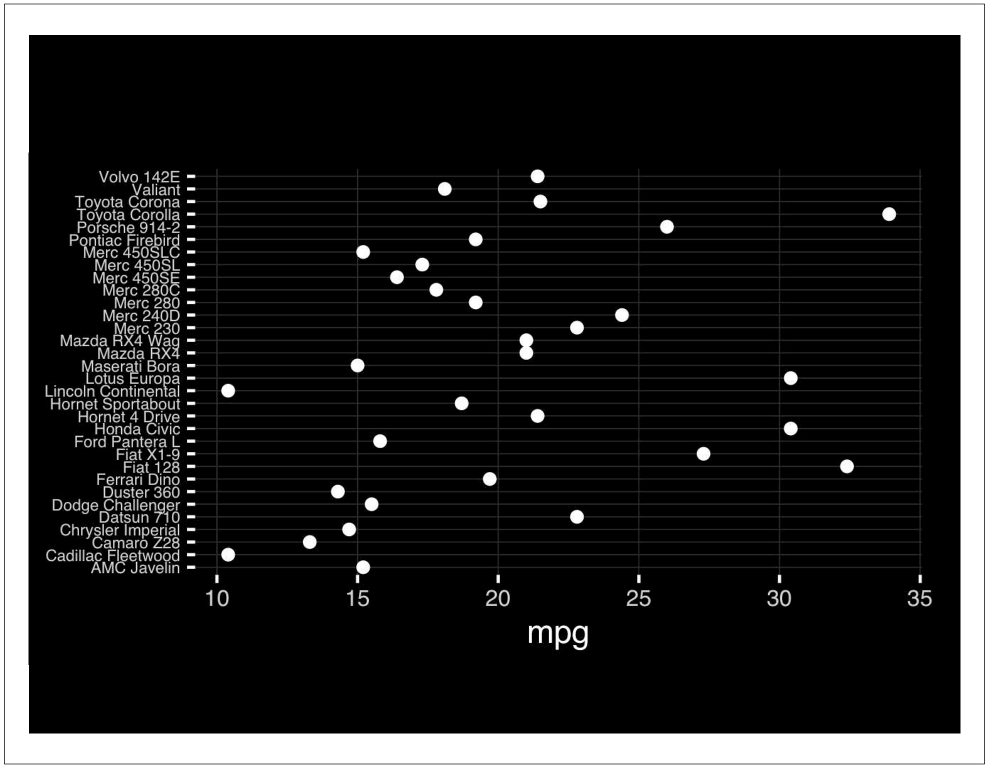
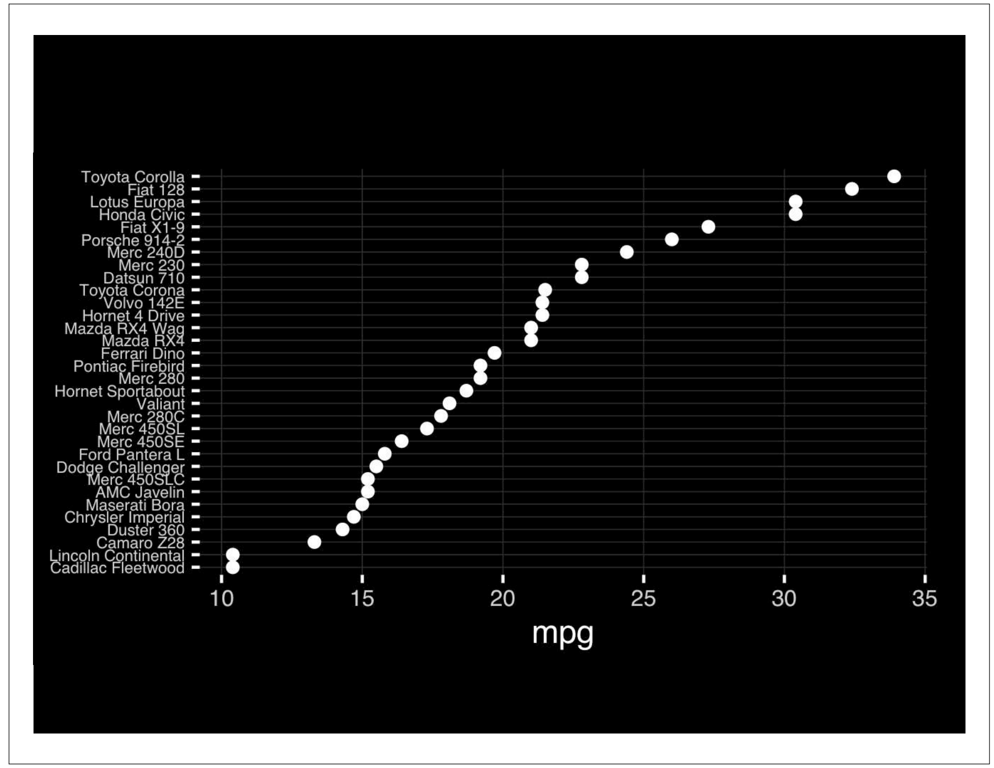
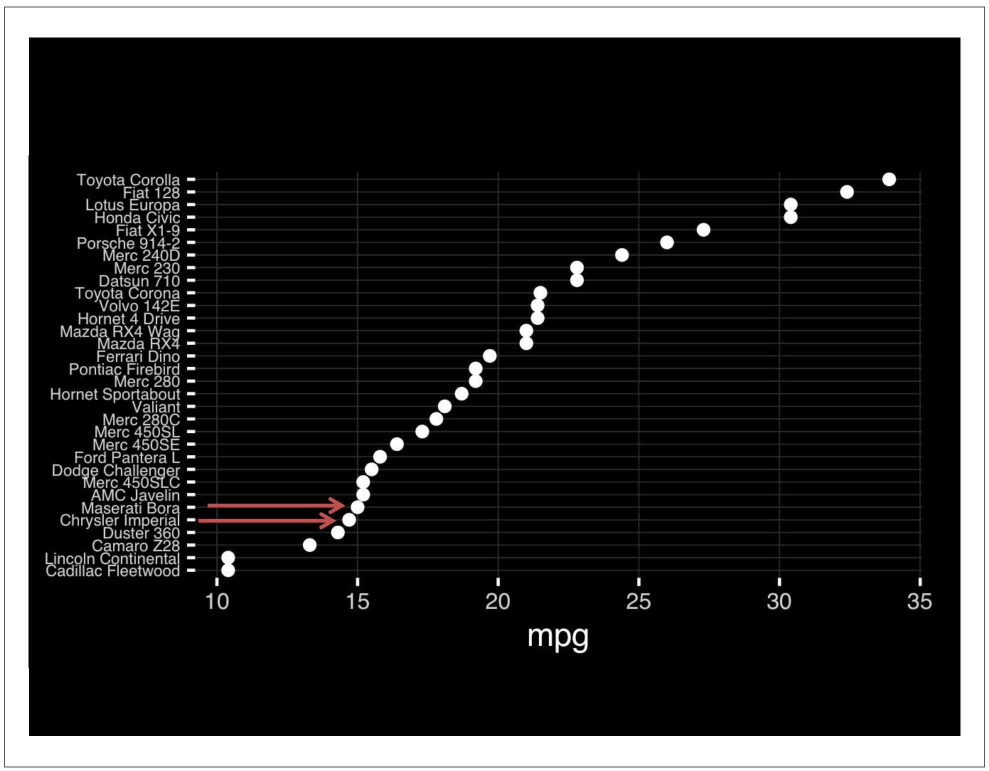
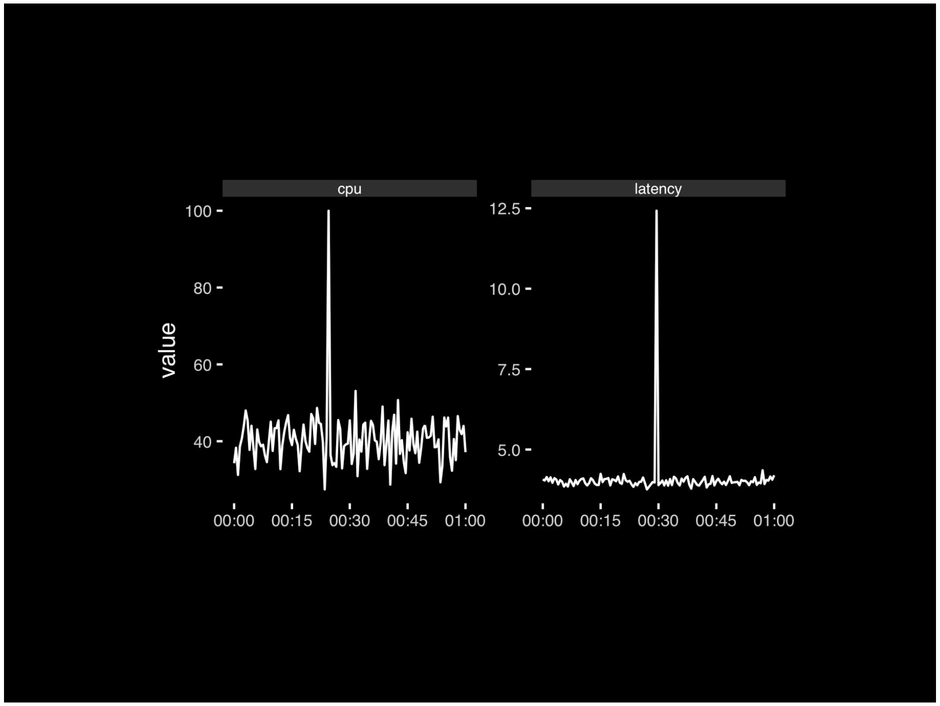
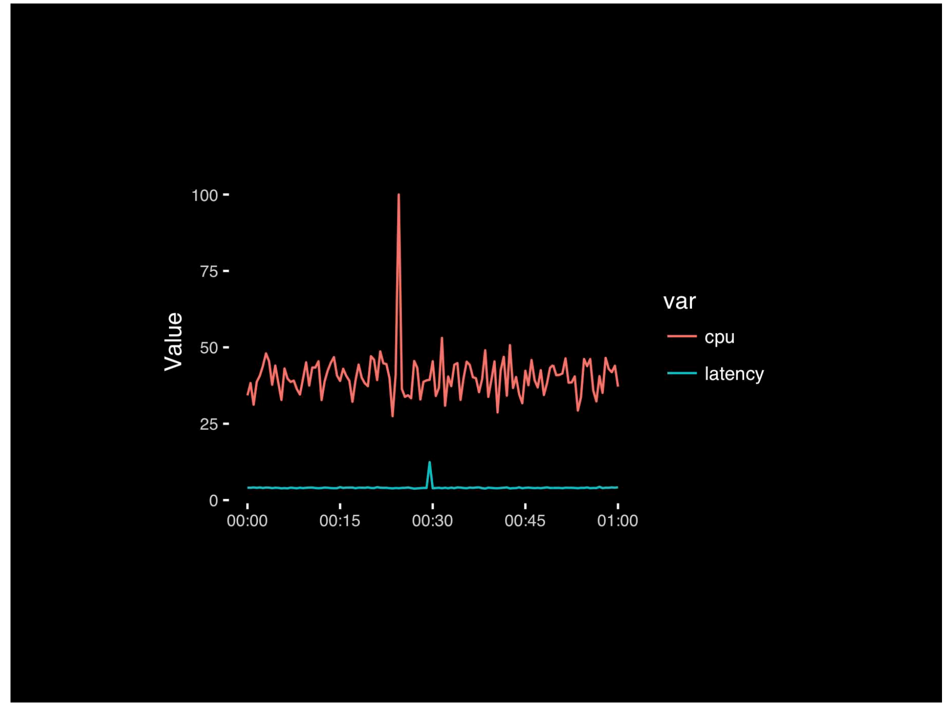


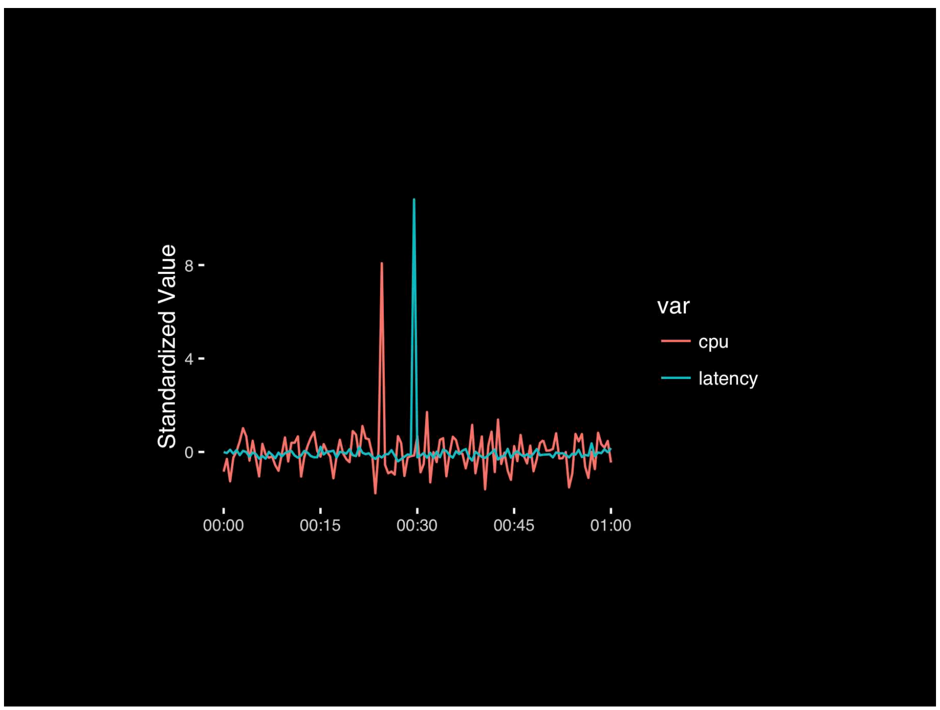




Observation: Comparison is trivial on a common scale.







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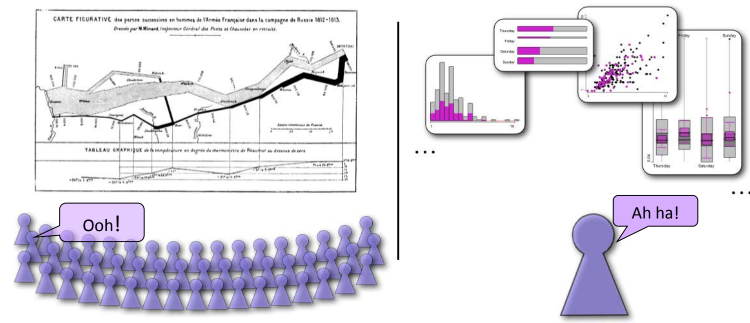
Do it Yourself!

Hands-on

Section 1 only please

Different graphs for different purposes

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



Presentation   Exploration

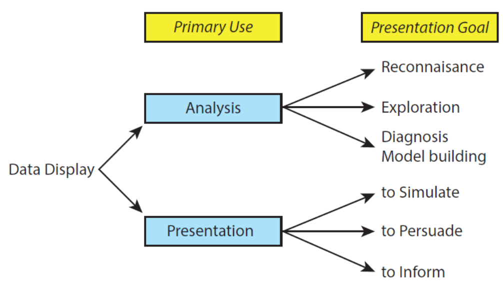
Roles of graphics in data analysis

- Graphs (& tables) are forms of communication:
  - What is the audience?
  - What is the message?

Analysis graphs: design to see patterns, trends, aid the process of data description, interpretation

Presentation graphs: design to attract attention, make a point, illustrate a conclusion

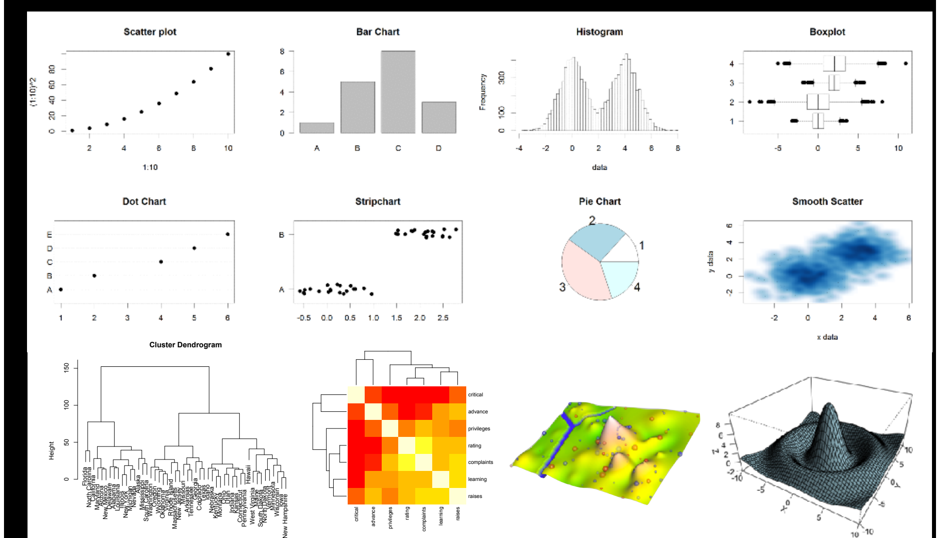
Basic functions of data display



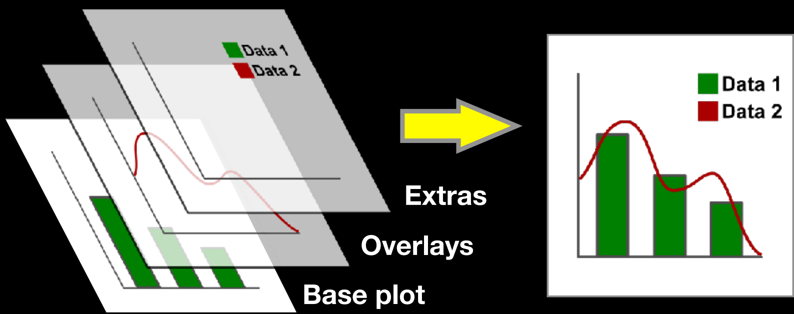
Exploratory (for you!)

Info for others, publications & sharing etc.

Core R Graph Types

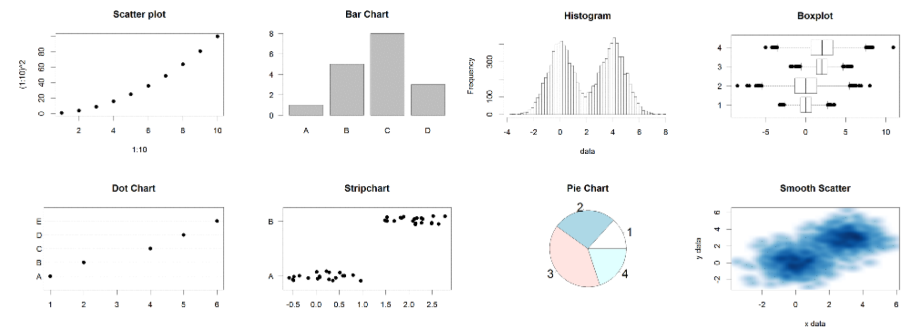


The R Painters Model



Side-Note: "Red and green should never be seen"

Core Graph Types



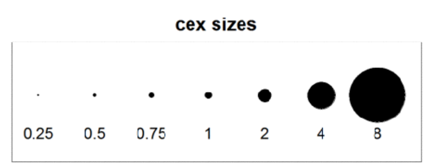
- Local options to change a specific plot
- Global options to affect all graphs

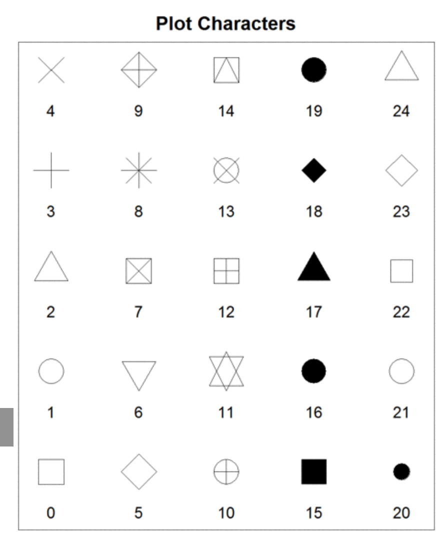
Common Options

- 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

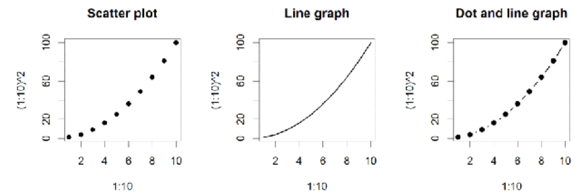




plot(1:5, pch=1:5, cex=1:5)

Plot Type Specific Options

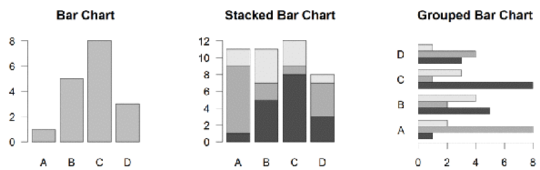
Plot (scatterplots and line graphs)



- 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 )
```

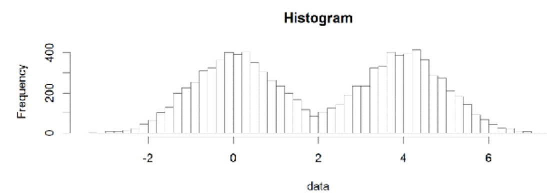
Barplot (bar graphs)



- 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)
```

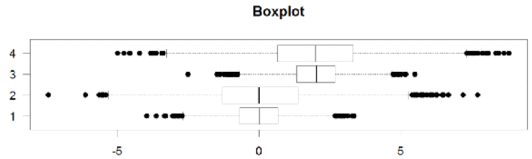
Hist (histograms)



- Input: Vector
- Output: Summary of binned data
- Options:
  - `breaks` Number or limits of bins
  - `probability` Y axis is probability, not freq
  - `labels` Per bin text labels

```
hist( c( rnorm(1000,0), rnorm(1000,4) ), breaks=20 )
```

Boxplot



- Input: Vector, List or formula (`data~factor`)
- Output: Summary of the boxplot parameters
- Options:
  - `range` Sensitivity of whiskers
  - `varwidth` Width represents total observations
  - `horizontal` Plot horizontally

```
boxplot( cbind( rnorm(1000,0), rnorm(1000,4) ) )
```

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
```

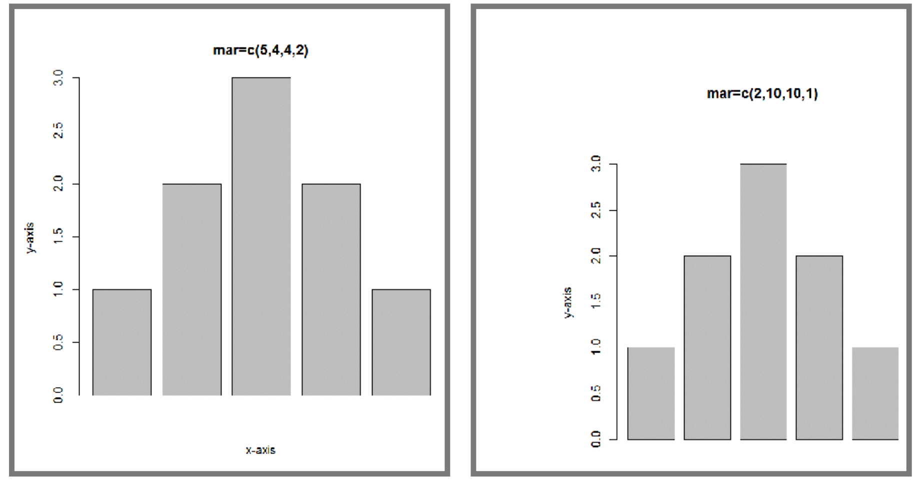
Par examples

- Reading current value
  - `par()$cex`
- Setting a value
  - `par(cex=1.5) -> old.par`
- Restoring a value
  - `par(old.par)`
  - `dev.off()`

Par options

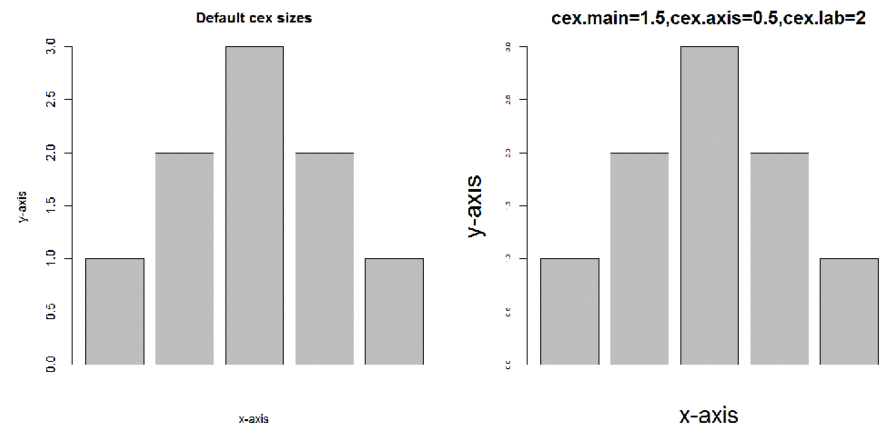
- Margins
  - `mai` (set margins in inches)
  - `mar` (set margins in number of lines)
  - `mex` (set lines per inch)
  - 4 element vector (bottom, left, top, right)
- Warning
  - `Error in plot.new() : figure margins too large`

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



Par options

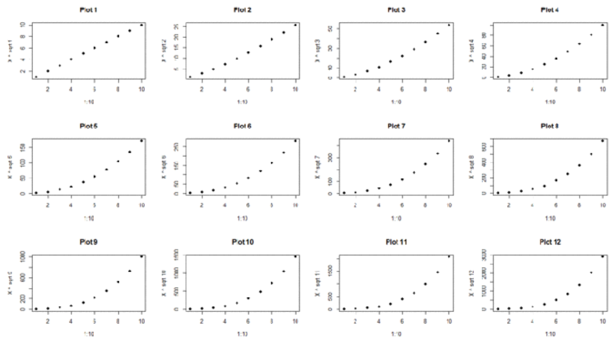
- Fonts and labels
  - `cex` - global char expansion
    - `cex.axis`
    - `cex.lab`
    - `cex.main`
    - `cex.sub`



`par( cex.main=1.5, cex.axis=0.5, cex.lab=2 )`

Par options

- Multi-panel
  - `par( mfrow(rows,cols) )`



par(mfrow(3 , 4))

Do it Yourself!

Hands-on

Section 2 only please

Using Color

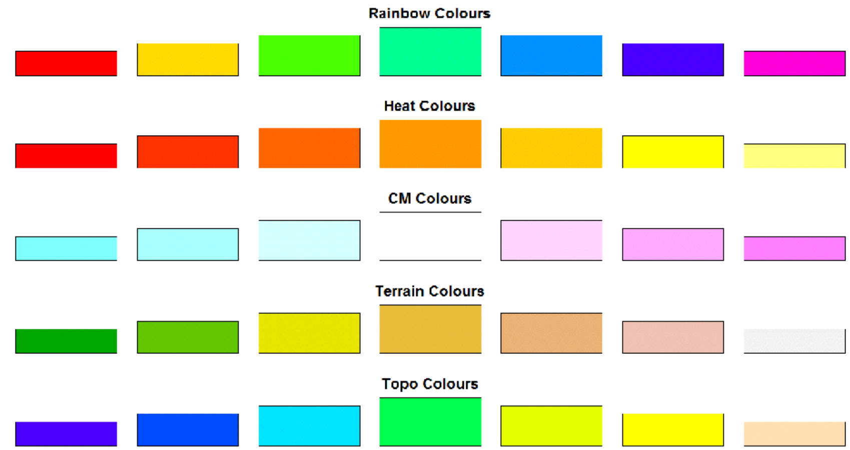
Specifying colors

- Hexadecimal strings
  - `#FF0000` (red)
  - `#0000FF` (blue)
  - `#CC00CC` (purple)
- Controlled names
  - `"red"` `"green"` etc.
  - `colors()`

Built in color schemes

- Functions to generate colors
- Pass in number of colors to make
- Functions:
  - `rainbow()`
  - `heat.colors()`
  - `cm.colors()`
  - `terrain.colors()`
  - `topo.colors()`

`rainbow( 7 )`



`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 **pallete** 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
- Coloring by value
  - Need function to map values to colors

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

Do it Yourself!

Hands-on

Section 3 only please

For next day:

Section 4 Revisited

- Open your previous Lecture5 RStudio **project** (and your saved **R script**)
- Locate and open in RStudio the downloaded file color_to_value_map.r
- This is an example of a poorly written function typical of something you might get from a lab mate that knows some R…

(POOR!) Color Mapping Function

```
map.colors <- function (value,high.low,palette) {
  proportion <- ((value-high.low[1])/(high.low[2]-high.low[1]))
  index <- round ((length(palette)-1)*proportion)+1
  return (palette[index])
}
```

Talking point:
- Can you figure out what this function it is supposed to do?
- What format should the inputs be in order to work?
- How could we improve this function?

Homework!

New **DataCamp** Assignments

- Introduction to R Markdown
- Functions
- Loops

Muddy Point Assessment Form Link