ST517 Note Outline 2: Summarizing Data

Notes for Lecture 2.1: Types of Data

Types of Variables (Data)

- Categorical Variable:
    - Example: Do you own a car? (Yes, No)
    - Also called **qualitative**
    - Breaking this down further, a categorical variable can have values that are:
        - Nominal:
        - Ordinal:
- Quantitative Variable:
    - Example: What is your age in years?
    - Breaking this down further, a quantitative variable can have values that are:
        - Discrete:
        - Continuous:
- **Key idea:** Different summaries are appropriate for the different types of variables

Categorical vs. Quantitative

- Distinction should be clear but sometimes care is needed
- Example: Quantitative variables that are categorized
    - Numeric data can be categorized after collection so that either quantitative or categorical data summaries can be used
    - If a numeric variable is collected in categories, it then needs to be treated as categorical
        - Ex: Age, classified as: under 18, 18-44, 45-64,65 years or older

- Example: **Likert data**
    - Ratings are often measured using a Likert scale, for example
        - Options—"Strongly disagree," "Disagree," "Neutral," "Agree," "Strongly Agree"
        - Frequency—"Always," "Often," "Sometimes," "Rarely," "Never"
        - Quality—"Excellent," "Good," "Fair," "Poor," "Very Poor"
    - Inherently categorical but categories are often assigned numeric values and treated as quantitative
        - While common in practice, this approach may be invalid, especially for:
            - Shorter scales (e.g. 5 categories as opposed to 7)
            - Smaller samples
            - Individual items (sometimes called Likert-type data) compared to having several items combined in a composite measure (sometimes called Likert scale data)
        - We will treat Likert data as categorical even if numbers have been assigned, since this is its inherent underlying structure

Exploratory Data Analysis (EDA)

- Visualize, summarize, and examine data
    - Visualize via graphical display
    - Also use numeric summaries to summarize and examine data
- Data cleaning, checking assumptions, look for patterns, missing values, etc.

Graphical Displays

- Quickly tells us the story behind the data
- **Key idea:**
    - Good data visualizations tell the story of the data in a way that is informative, easy to get, and visually appealing
    - Poor data visualizations misrepresent the story of the data, either inadvertently or intentionally
- Graphical Displays for Categorical Variables: Bar (or Mosaic) charts, Pie Charts
- Graphical Displays for Numeric Variables: Histograms, Boxplots, and Scatterplots, Time-series plots, Heat maps

Numeric Summaries

- Allow us to make comparisons

- Simplest numeric summaries for categorical variables: Count or percent in each category, tables
- Some numeric summaries for numeric variables:
    - Measures of Central Tendency: Mean, median

    - Measures of Variability: Variation, standard deviation, range, IQR

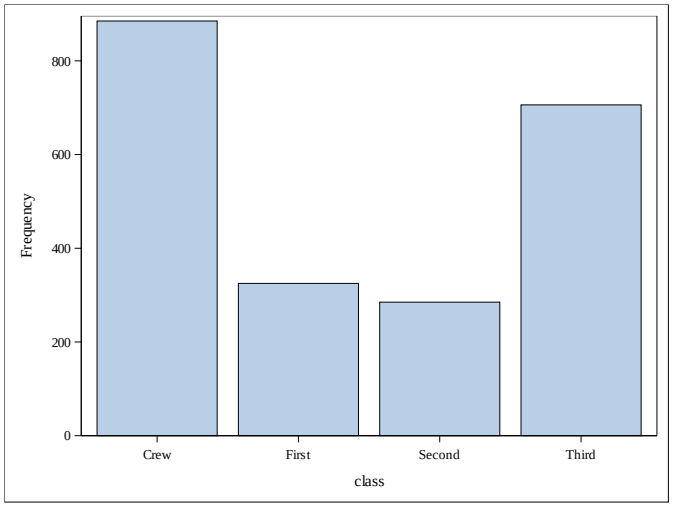
Notes for Lecture 2.2: Graphical Displays & Numeric Summaries for Categorical Data

Numeric Summaries for Categorical Data

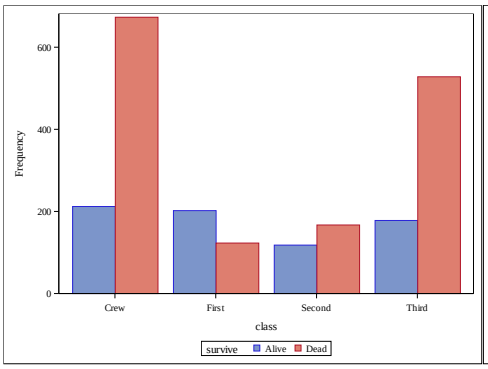
- Count in each category
- Proportion (or percent) in each category
  - Sample proportion: $\hat{p} = \frac{Count}{Sample\ size} = \frac{y}{n}$
- Tables display counts or percent for one or more categorical variables

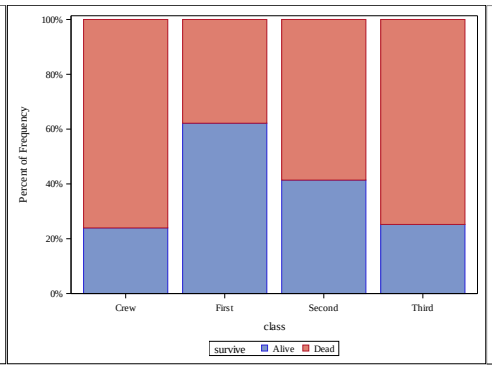
Bar Charts

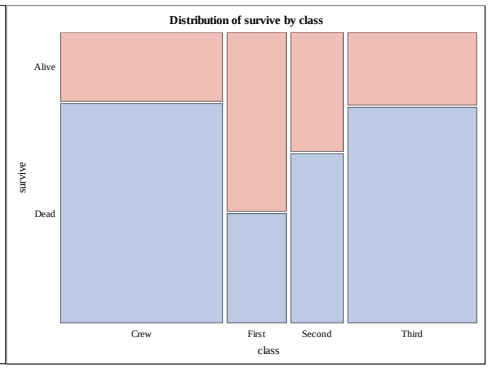
- Useful for displaying one or more categorical variables
- One bar for each category a variable
- Height of bar indicates how many [frequency] *or* percent of units in each category
- Ex (at right): Variable = class on the Titanic; there were over 800 crew members and 300 passengers in 2nd class
- Represent multiple categorical variables with color, using either a…



grouped bar chart, **stacked bar char**, or **mosaic plot**

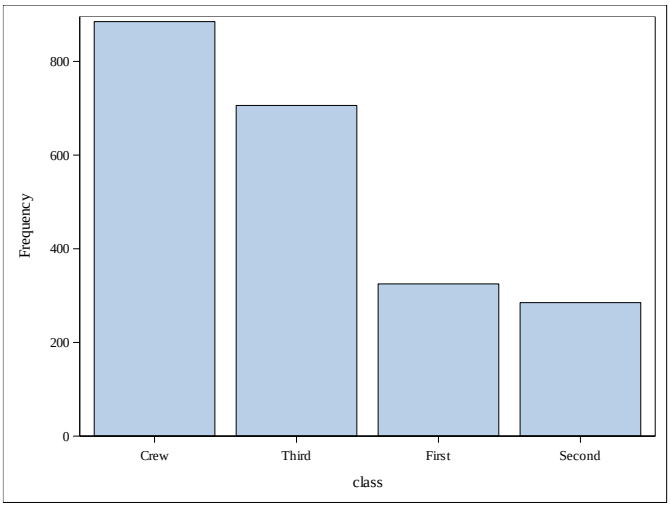




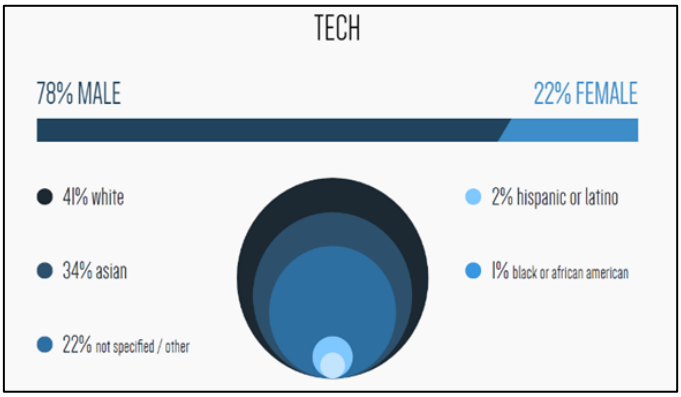


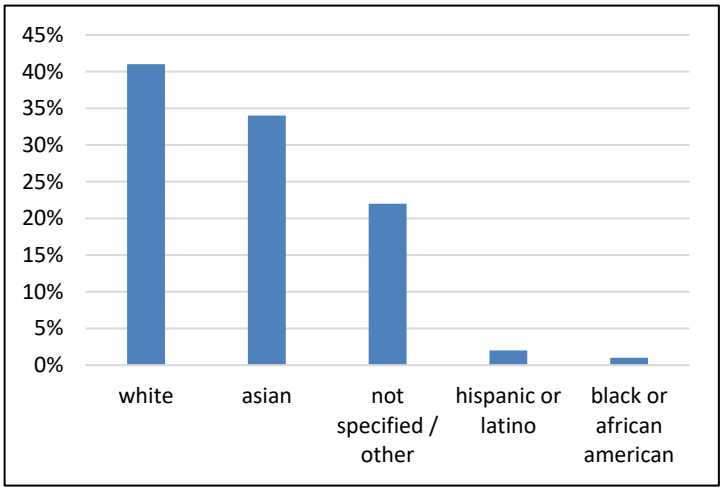
Bar Charts (continued)

- Flexibility in how you arrange bars
  - E.g. alphabetically; by frequency
  - Ordinal variable: arrange bars in order (e.g. S, M,L or L,M,S)

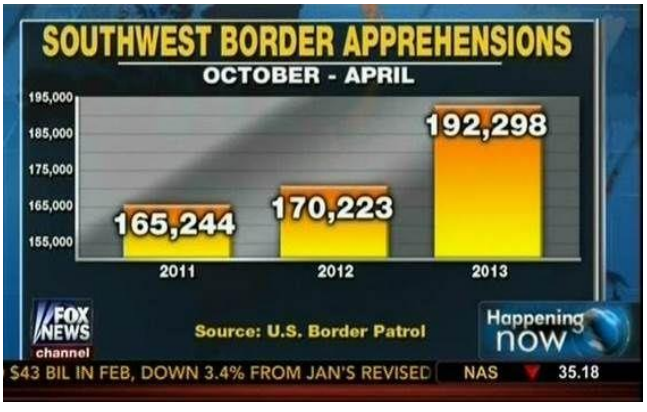


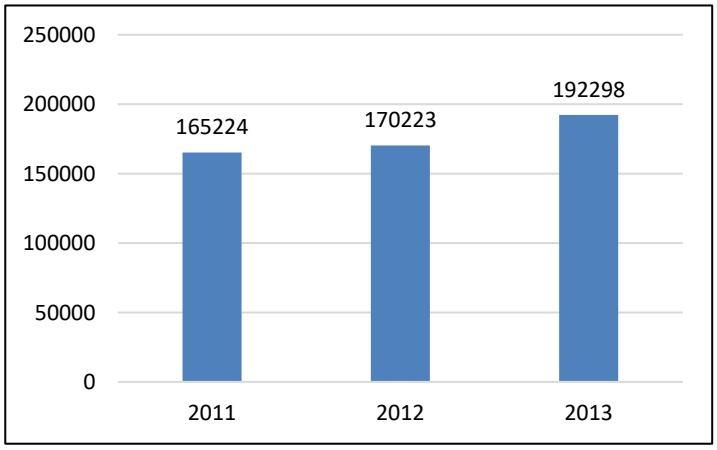
- Caution! Bar charts with other shapes can distort volume or scale, and thus distort the story of the data





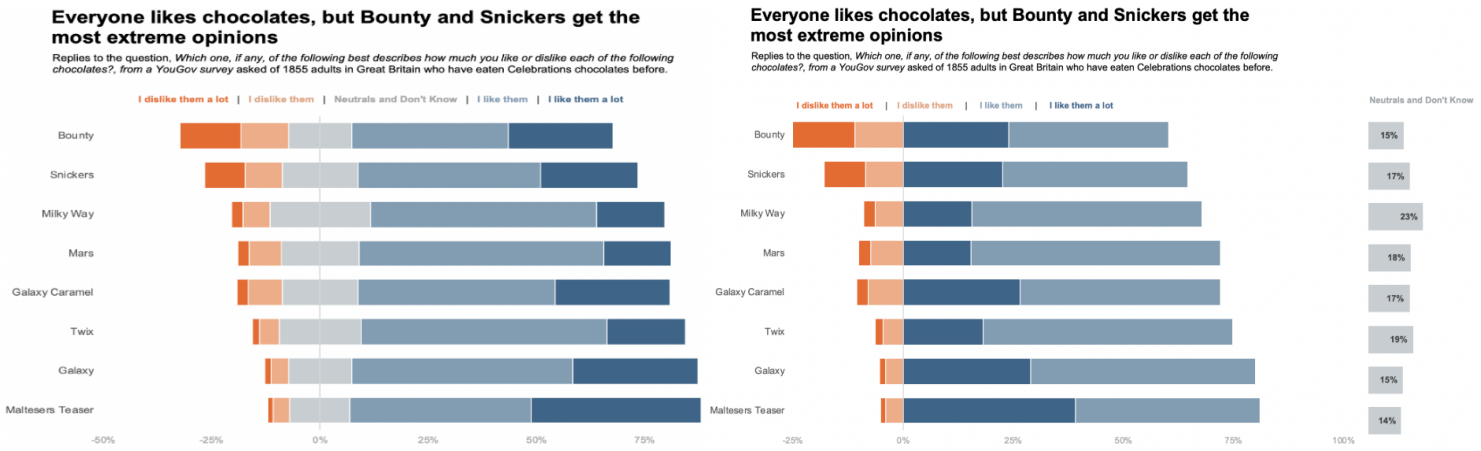
- Caution! Watch for bar charts with the baseline omitted (y-axis truncated)—meaning the y-axis does not start at zero!



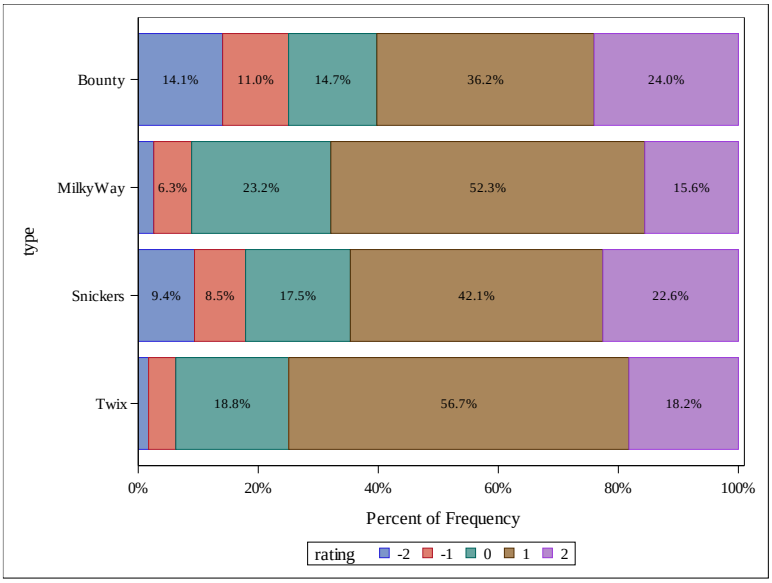


Bar Charts (continued)

- When summarizing Likert data, one recommendation is to use a **diverging stacked bar chart**, either with (right panel of example below) or without (left panel) separate neutrals

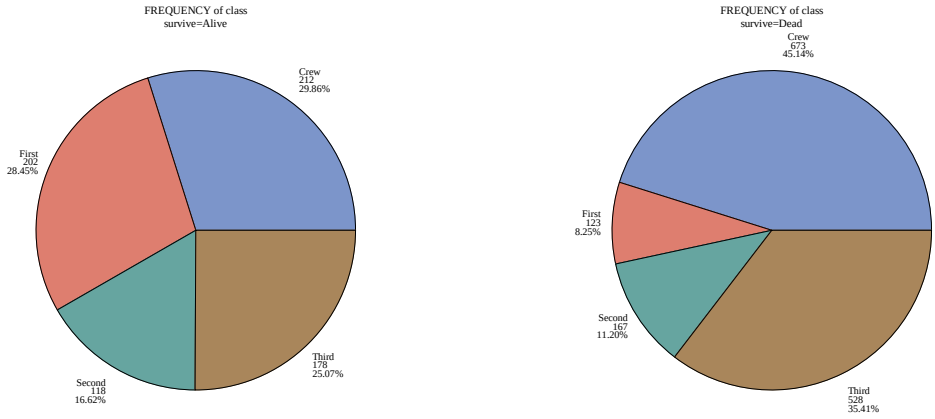


- These charts are not as straightforward to create in SAS, though the source for the above examples shows how to create them in Excel (quite frankly, they are not straightforward to create using Excel either)
- However, a stacked bar chart (where height of the bars is scaled to reach 100%, sometimes called **100% stacked bar charts**) can communication the same information in a way that more easily allows the use to compare and even visually aggregate categories (for example, aggregating "Strongly agree" with "Agree" and "Strongly disagree" with "Disagree")
    - See this article from Chartable for more information
    - Here is an abbreviated (for space) example of a 100% stacked bar chart for the same data from the above example:

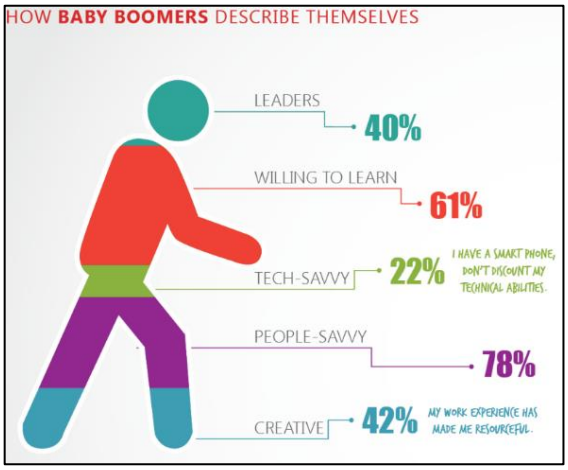


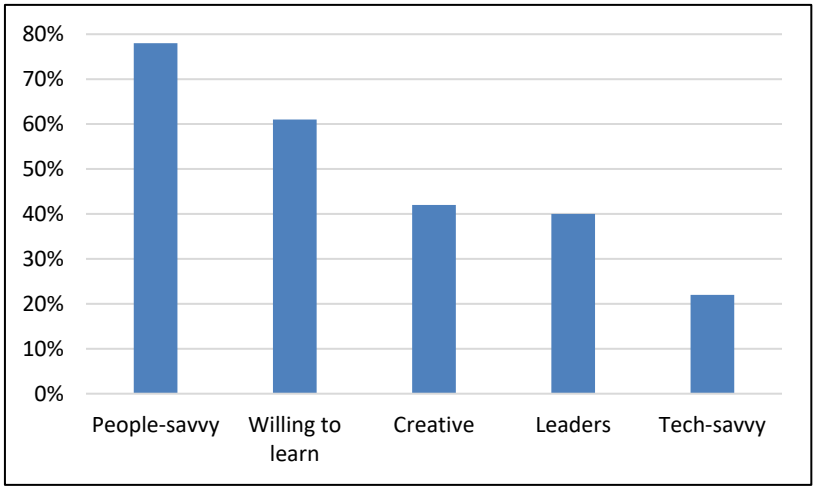
Pie Charts

- Useful for displaying a single categorical variable where categories represent parts of a whole (meaning that units can only fall into a single category so that total percent across all categories is 100%)
- One "wedge" for each category of a variable
- Size of wedge shows percent in each category
- Additional variables cannot be added via color, but you could compare pie charts across different levels of a second categorical variable



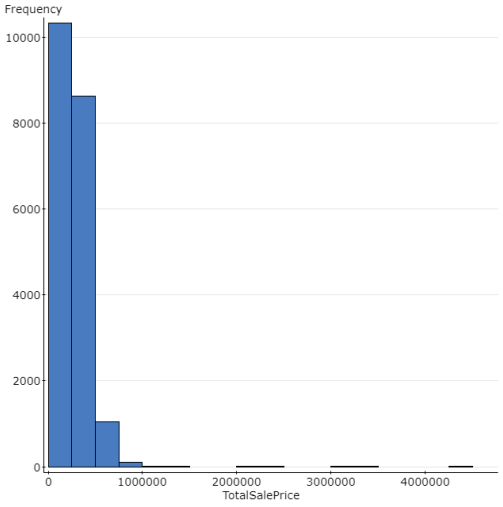
- Caution! Pie charts are often misused! They are used when not appropriate (e.g. when categories add to more than 100%) or visually distorted (e.g. 3-d pie charts, unusual shapes)



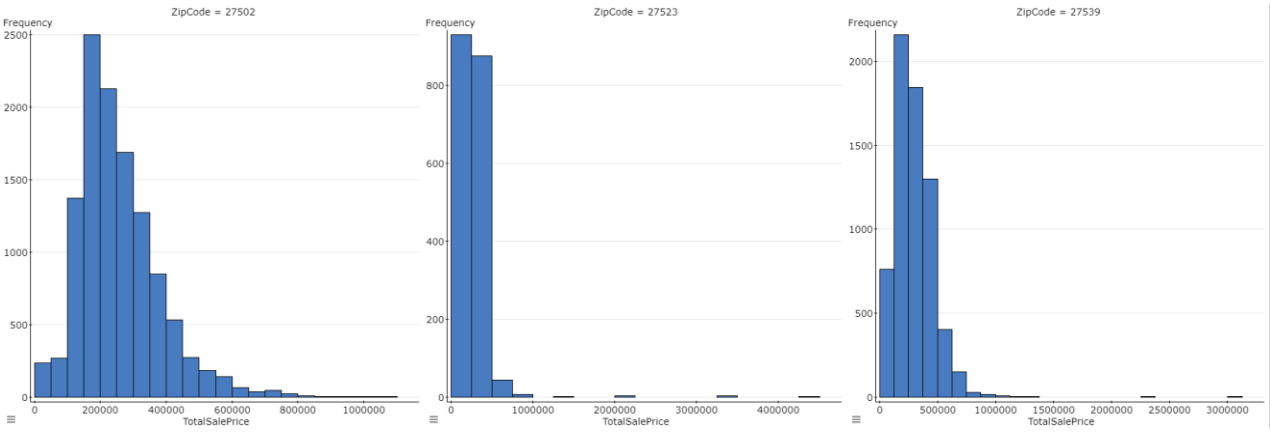


Notes for Lecture 2.3: Graphical Displays for Quantitative Data
Histograms and Distribution

Histograms



- Useful for displaying a single numeric variable
- Horizontal axis shows values of variable
- Bars represent ranges ("bins") of values
- Height of bar indicates how many [frequency] *or* percent of units in each bin
- Ex (at right): variable = sale price for homes in Apex, NC; looking at 1st bar, we see that there were over 10,000 homes that sold for somewhere between $0 and $250,000
- Additional variables cannot be added via color, but you could compare histograms across different levels of a second categorical variable



- Histograms allow us to understand the **<u>distribution</u>** of the data
  - 3 major elements of a distribution:

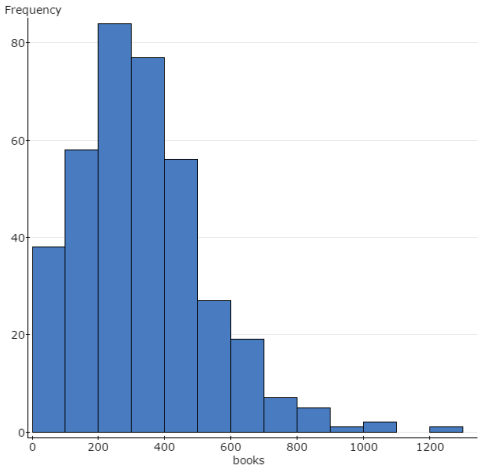
    1.

    2.

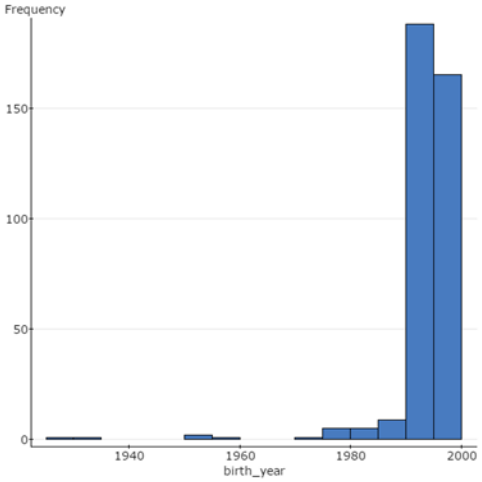
    3.

Shape of Distributions

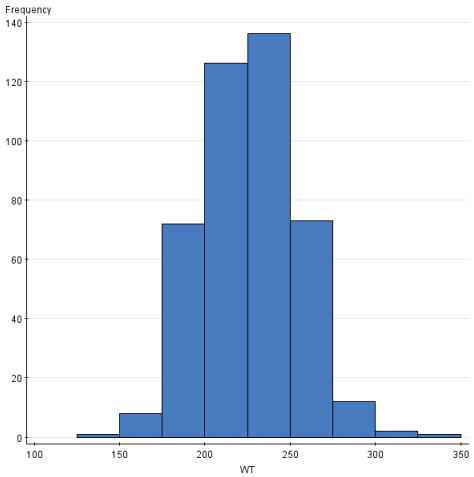
- Skewed Right
  - Long tail to the right
  - Generally because units are stacked up near a lower limit and unlimited on the upper end



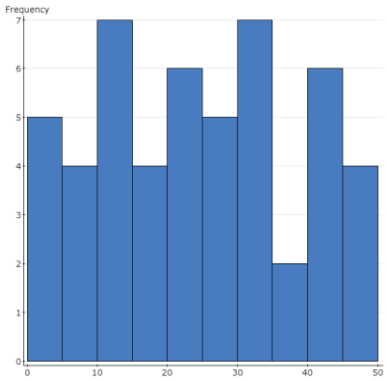
- Skewed Left
  - Long tail to the left
  - Generally because units are stacked up near an upper limit and unlimited on the lower end



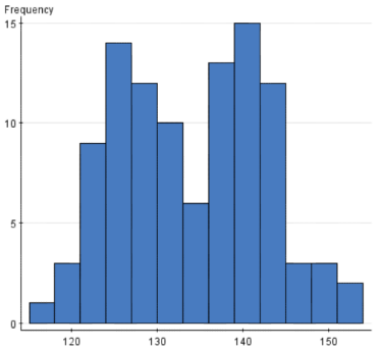
- Symmetric
  - Tails approximately equal in both directions
  - Major cluster far from limits on both ends



Shape of Distributions—Other Things to Consider



- Number of peaks (**<u>modes</u>**)



- Outliers—Unusual values that do not fit with the rest of the pattern
    - E.g. Total sale prices above $2,000,000 or Birth years before 1960
    - Why are they outliers?
        - Data entry errors
        - Invalid data points
        - Actual unusual values
    - How to deal with outliers (if you cannot remove them)?

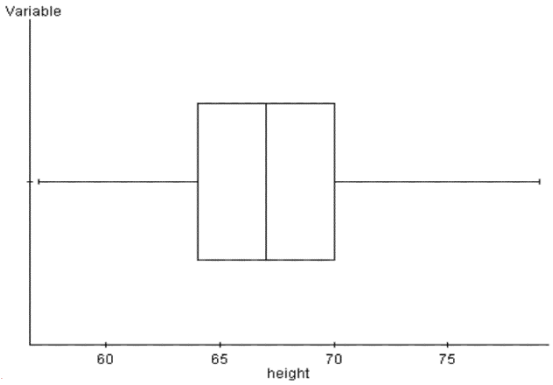
- Caution! Changing the bin width of a histogram can change the features that you see!
    - Bins too wide = may hide features (e.g. bi-modality, outliers)
    - Bins too narrow = too many features, not enough summary (i.e. too spiky)
    - Start with software default but try a few other options as well
    - Consider context
    - Focus on choosing a bin width that communicates the story of the data well

Notes for Lecture 2.4: Graphical Displays for Quantitative Data
Boxplots and Other Graphs

Boxplots

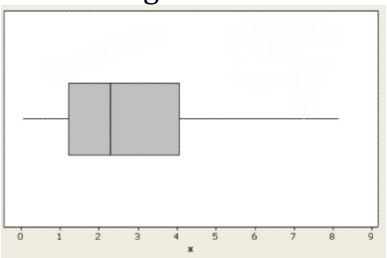
- Good for a first look at the data
- Visual display of the **5 number summary:**

1.
2.
3.
4.
5.

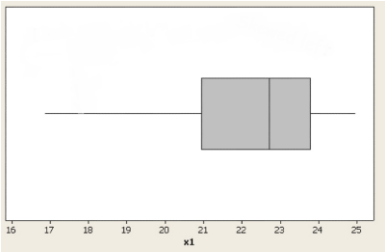


- The middle _____% of the data is located inside of the box
- Can help determine the shape of a distribution

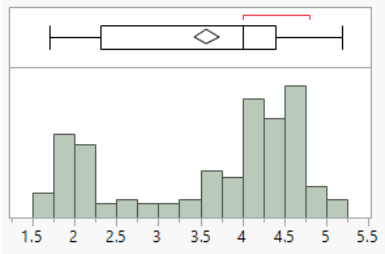
Skewed Right



Skewed Left



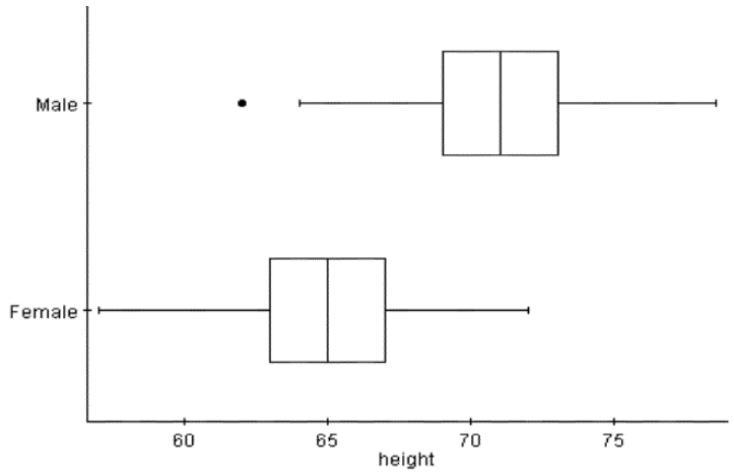
- We cannot determine if a distribution is multimodal from a boxplot



- Computer programs identify outliers
  - Box is not subject to outliers
  - Whiskers extend to largest/smallest non-outliers
  - Uses asterisk or dots to mark outliers

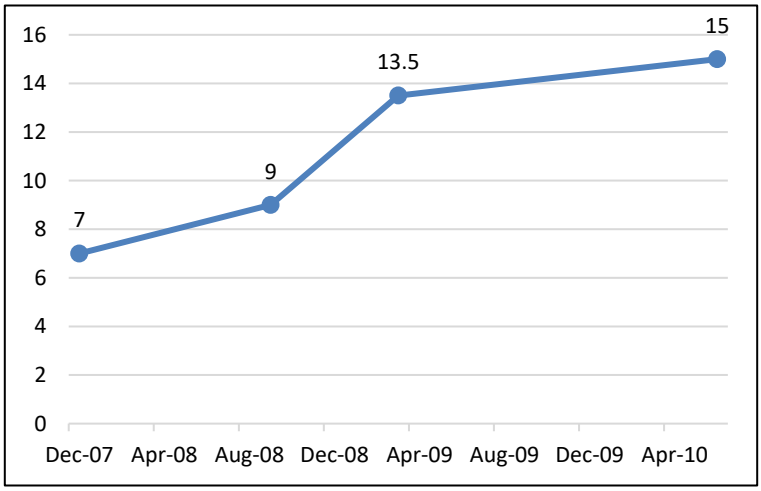
Side-by-side Boxplots

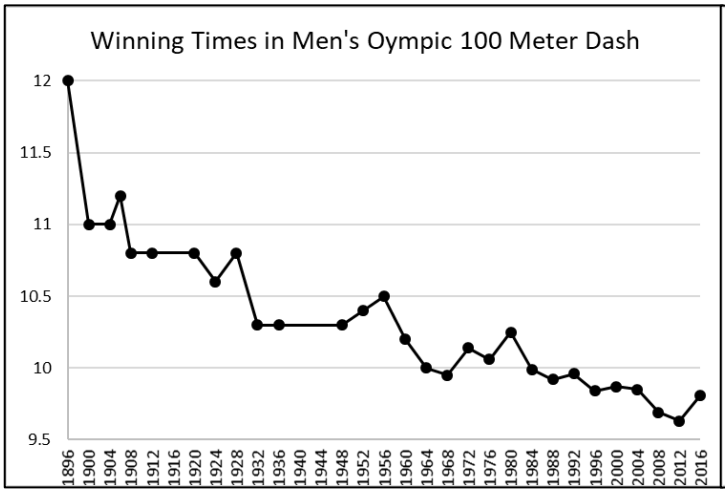
- Way to summarize a quantitative variable within levels of a categorical variable
- Useful for comparing distributions

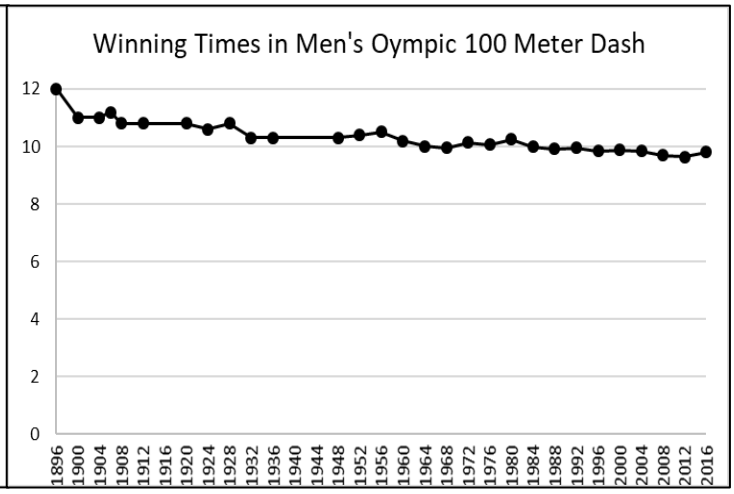


Time Plots

- Special type of scatterplot with *time* on the horizontal access
- **<u>Time series data</u>:** Measurements of a variable taken at regular intervals over time
    - Ex: monthly unemployment, daily market performance, progression of symptoms
    - Plot variable over time to observe trends
- Caution! Watch for time plots with the baseline omitted or otherwise distorted axes

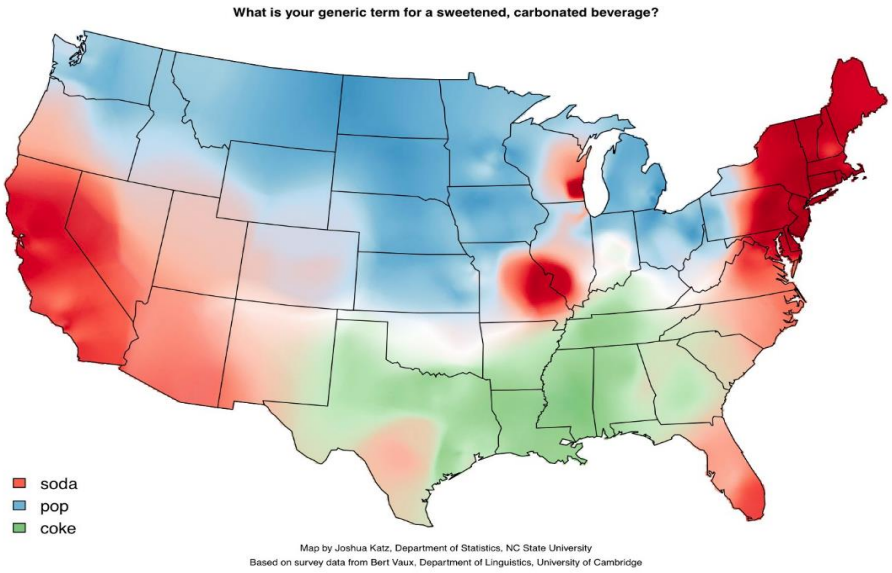




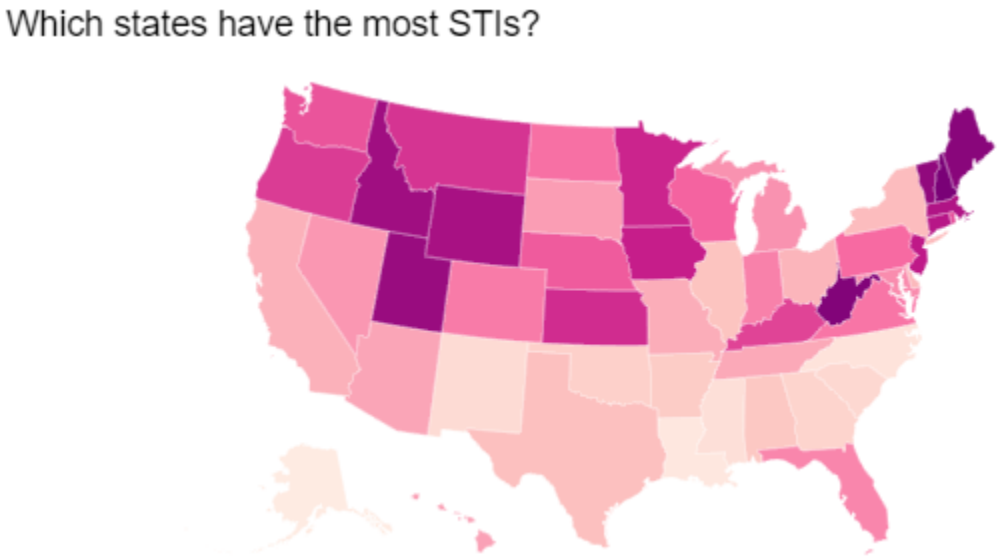


Heat Maps

- Useful for representing a variable that has a spatial element to it
- **<u>Spatial data</u> (<u>Geospatial data</u>)**: Data that involves physical space (e.g. size or shape) or geography (e.g. location)
- Uses color to represent different values of the variable
    - Darker colors indicate a higher or larger values

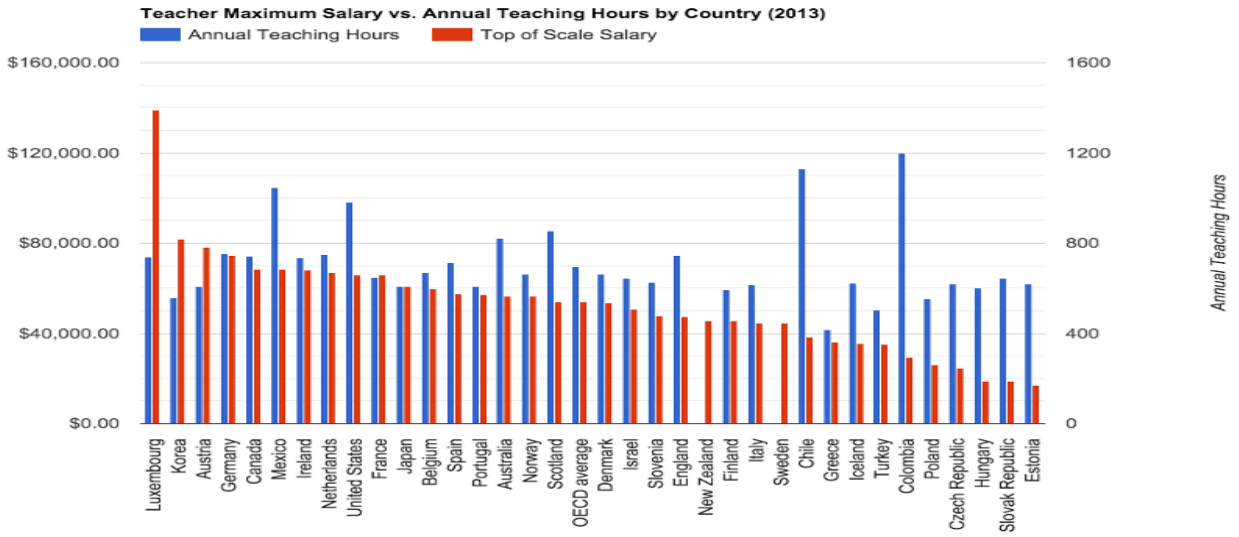


- Caution! Beware of heat maps that go against color convention; these can be confusing (e.g. blue = hot & red = cold) or misleading (e.g. using lighter color to indicate larger values)

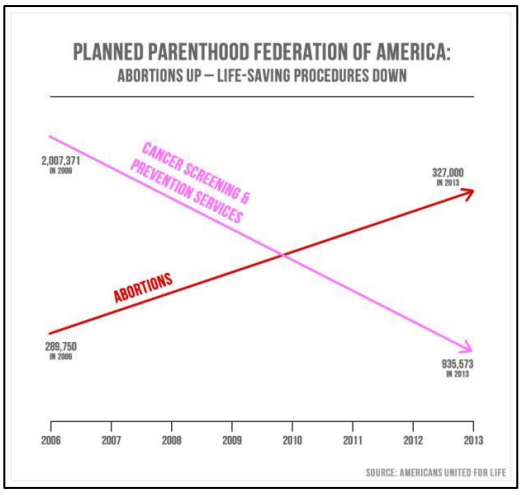


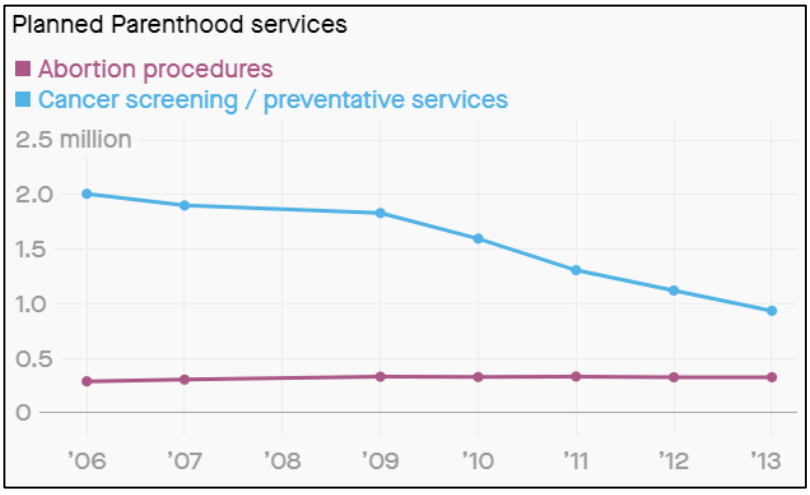
Caution! Graphs with Two Y-axes

- Sometimes variables measured on different scales will be put on the same graph
  - Done to pack a lot of information into a single graph
- Use caution when comparing the variables shown
- Look out for misleading or distorted axes!



- Ex (above): Can't say US has higher working hours than salary—that doesn't make sense! Can say US has longer working hours and lower max salaries than Luxemburg





Notes for Lecture 2.5: Numerical Summaries for Quantitative Data

Measures of Central Tendency

- **Mean**
  - *Population mean*: μ
  - *Sample mean*: $\bar{y} = \frac{\sum_{i=1}^{n} y_i}{n} = \frac{1}{n}\sum_{i=1}^{n} y_i$
  - Interpretation (via example):

- **Median**: Middle value in a data set when values are put in increasing order
  - Interpretation (via example):

- Benefits of the Mean:

- Problems with the Mean:
  - Sometimes misunderstood
  - Sensitive to skewed data

    Skewed Right:

    Skewed Left:

    Symmetric:
  - Sensitive to unusual values:

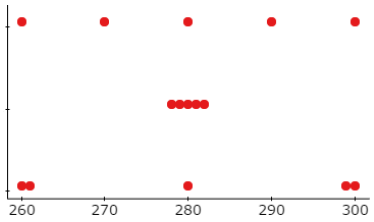
Measures of Variability

- Once we have an idea of a "typical" value, it is good to know about how much the individual values vary around this central value
- Example: 3 distributions with same mean (μ = 280) that look very different

260, 270, 280, 290, 300

278, 279, 280, 281, 282

260, 261, 280, 299, 300



Range	IQR	Std.Dev.

- **Range** = maximum – minimum = Spread of entire dataset
- **Interquartile range**: IQR = Q3 – Q1 = Spread of middle 50%
- **Variance**: Summarizes distance between each individual and the mean
  - *Population Variance:* σ^2
  - *Sample Variance*: $s^2 = \frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n-1}$
- **Standard deviation**: s = square root of the variance
  - Interpretation:
  - Ex (Apex home sale prices): s = 144677.62
- Each measure of variability tells us how inconsistent the data values are

Measures of Variability (continued):

- Measures of variability are most useful for comparing distributions
- Benefits of using variance or standard deviation: Considers values for all individuals in the data set, where range and IQR only consider 2 values
- Problems with using variance:
    - Variance (and standard deviation) are sensitive to unusual values or skew
    - Variance is measured in units squared (e.g. dollars^2); standard deviation is measured in the original units of the problem (e.g. dollars)

What does Standard Deviation Measure?

- Represents the average distance from each point to the mean
- Simple example: A group of employees at a local company are paid by the hour. The amount they are paid for the six workers is \$7, \$8, \$9, \$10, \$12, and \$14.

7 8 9 10 12 14

When to Use Each Numeric Summary

- Mean (average value)

- Median (middle value)

- Range

- IQR

- Standard deviation

Notes for Lecture 2.6: Transformations of Numerical Summaries

Transformations

- Data is often transformed (adjusted, rescaled, standardized) to better represent the values or compare variables
- How will the numeric summaries change?
- **Recall the wage example:** A group of employees at a local company are paid by the hour. The amount they are paid for the six workers is $7, $8, $9, $10, $12, and $14

7 8 9 10 12 14

  - What would happen if we gave everyone a $3 raise?

10 11 12 13 15 17

  - What would happen if we doubled everyone's pay (multiplied by 2)?

14 16 18 20 24 28

Summary: Transformations

- Measures of variability and center respond to transformations differently
- Adding or subtracting:

- Multiplying or dividing: