Lecture 1: Laying the Foundations + Terminology

Chapters 1.1-1.2

Goals for Today

- Go over the syllabus
- Show some fun examples
- Discuss how to evaluate the efficacy of a treatment
- Describe the different kinds of variables we'll consider

What is statistics?

(Direct from text) The general scientific process of investigation can be summed up as follows:

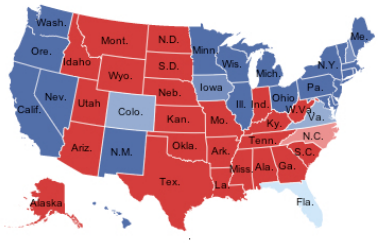
1. Identify the scientific question or problem
2. Collect relevant data on the topic
3. Analyze the data
4. Form a conclusion and communicate it

Statistics concerns itself with points 2 through 4.

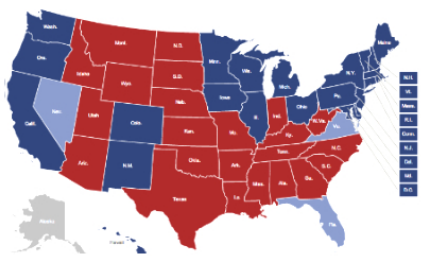
Your Majors

Biology	Economics
11	5
History	Environmental Studies
4	3
Mathematics	Psychology
3	3
Biochem and Molecular Biology	Chemistry
2	2
International Policy Studies	Linguistics
2	2
Undecided	Anthropology
2	1
Economics/Mathematics	Environmental Studies-Hist
1	1
Environmental Studies-Pol Sci	Physics
1	1
Sociology	
1	

Example: 2012 Election - Nate Silver's Predictions vs Actual Results



Nate Silver's Map



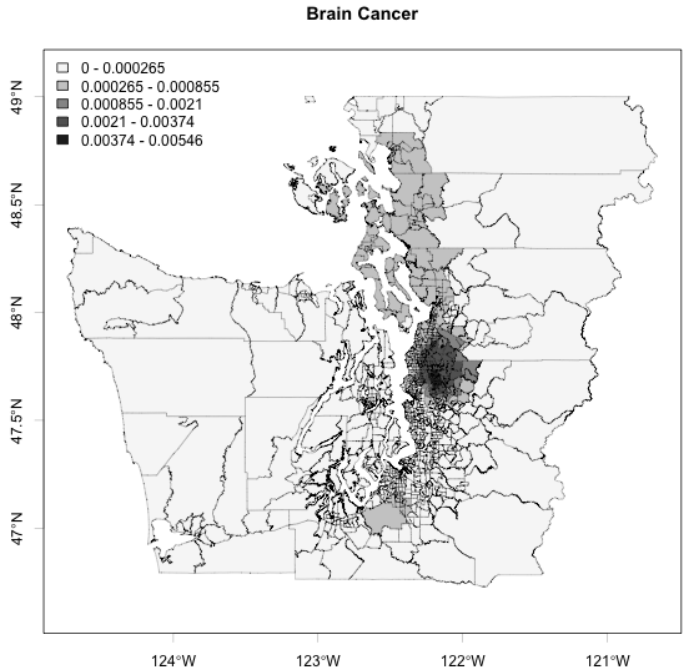
The Actual Map

Example: Brain & Breast Cancer in Western Washington

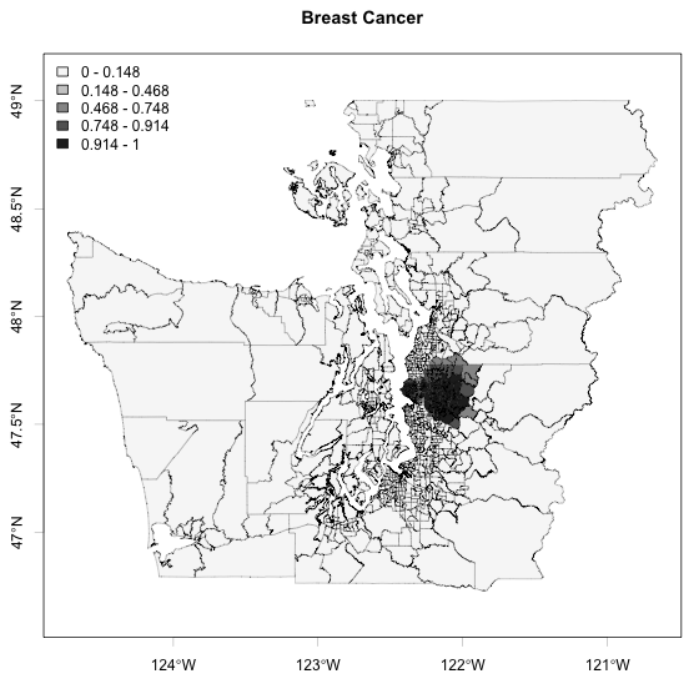
My PhD dissertation involved detecting cancer "clusters": areas of residual spatial variation of disease risk.

We modeled the (Bayesian) probability of cluster membership for each of the $n = 887$ census tracts in Western Washington in 2000, using cancer data from 1995–2005, controlling for age, race, and gender.

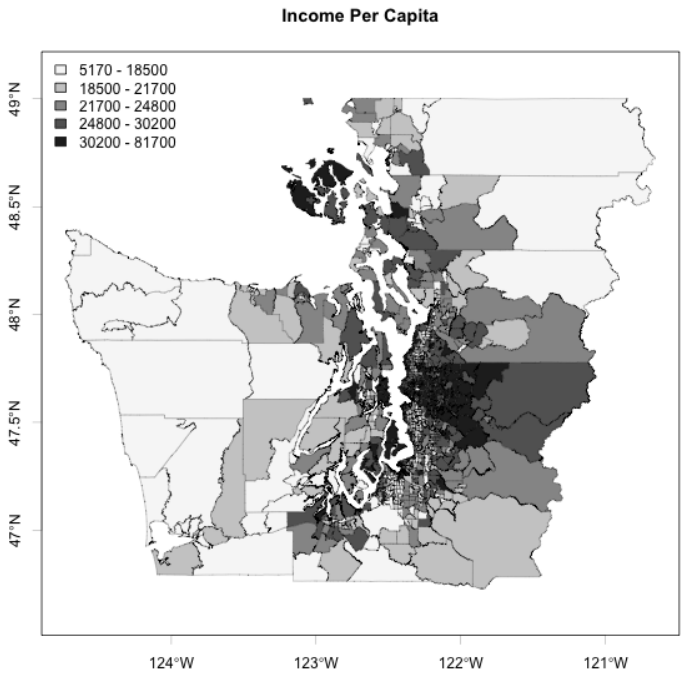
Brain Cancer Controlling for Age, Race, & Gender



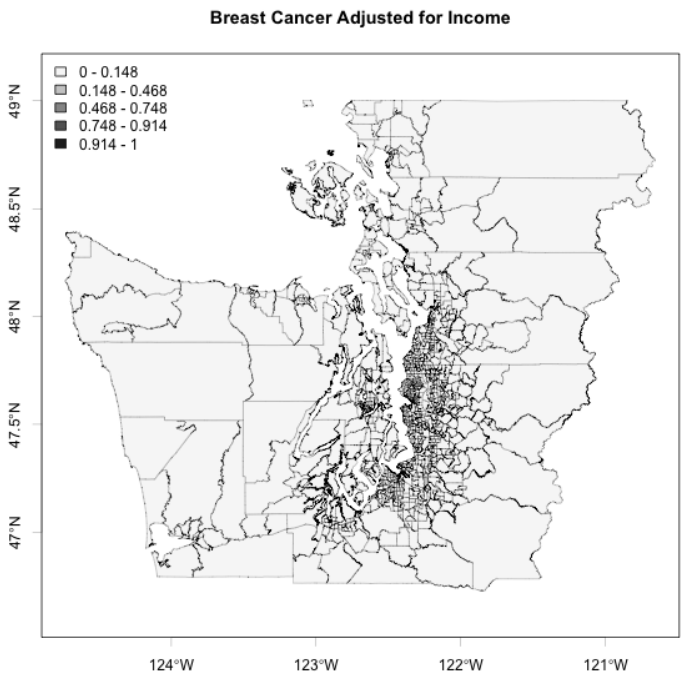
Breast Cancer Controlling for Age, Race, & Gender



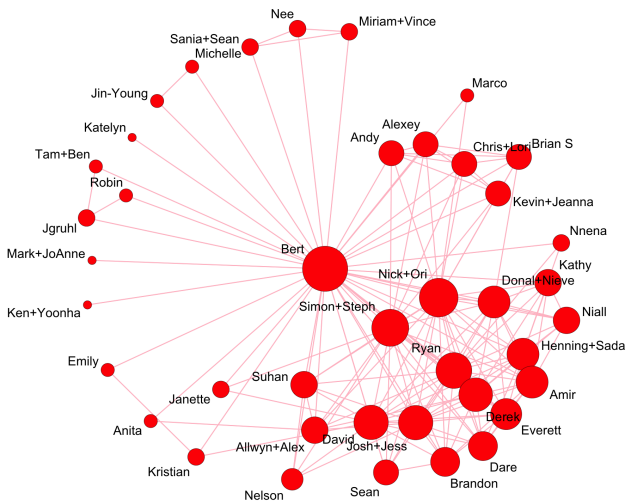
Income per Capita Quintiles



Breast Cancer Adjusted for Income as Well



Example: Social Network Display of a Recent Party I Had



Say we want answer the following questions:

- Does a new kind of cognitive therapy alter levels of depression in patients?
- Or you question the effectiveness of antioxidants in preventing cancer.
- Will reassuring potential new users to a gambling website that we won't spam them increase the sign-up rate?

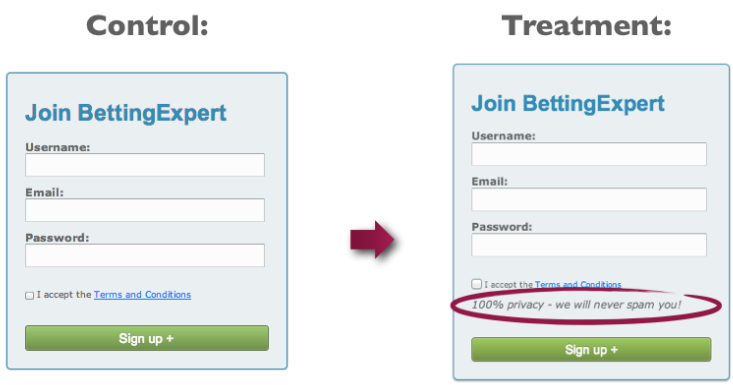
Evaluating the efficacy of a 'treatment'

In all the above cases, you are questioning the efficacy of a treatment/intervention. One way to evaluate the efficacy is via an experiment where you define

- A control group: the "business as usual" baseline group
- A treatment group: the group that receives/is subject to the treatment/intervention

and make comparisons.

Website Experiments



Example of a treatment vs control

Two other examples in the media of late

- Facebook's tinkering with user's emotions (link)
- OkCupid's admission that they experiment on human beings (link)

Variables

A variable is a description of any characteristic whose value may change from one unit in the population to the next:

Data

At its simplest, data are presented in a data table or matrix where (almost always) each

- row corresponds to cases or units of observation/analysis
- column represents the variables corresponding to a particular observation

It is almost always the case that

- n is the number of observations
- p is the number of variables

Data Summaries

Consider the variable "federal spending per capita" in each of the 3,143 counties in the US. One can hardly digest this:

```
   [1]   6.068095   6.139862   8.752158   7.122016   5.130910   9.973062   9.311835  15.439218
   [9]   8.613707   7.104621   6.324061  10.640378   9.781442   8.982702   6.840035  20.330684
  [17]   9.687698  11.080738   7.839761   9.461856   9.650295   7.760627  25.774791  13.948106
  ...
[3121]   7.520731  10.246400   3.106800  17.679572   4.824044   7.247212   8.484211   8.794626
[3129]   9.829593   8.100945  17.090715   4.855849   6.621378  22.587359  10.813260  11.422522
[3137]   9.580265   4.368986   5.062138   6.236968   4.549105   8.713817   6.694784
```

Data Summaries

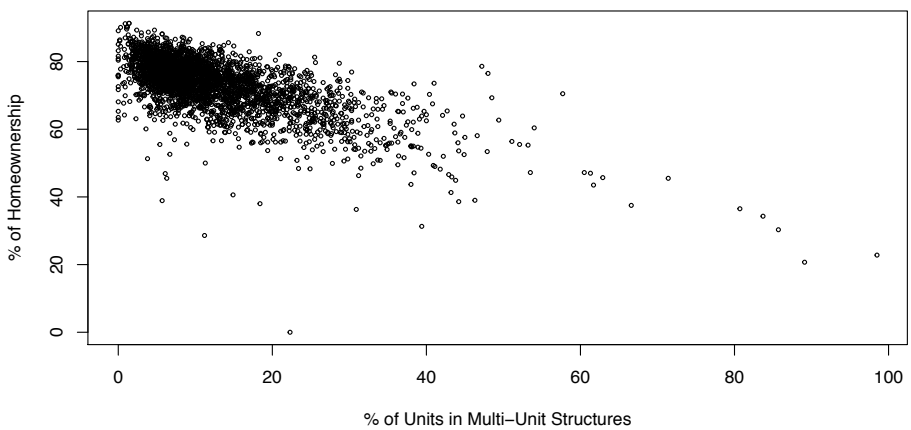
We can't interpret all the data at once; we need to boil it down via summary statistics, single numbers summarizing a large amount of data.

Using the `summary()` command in `R`:

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
  0.000   6.964   8.669   9.991  10.860 204.600       4
```


Relationships between variables

We can best display the relationship between two variables using a scatterplot AKA bivariate plot:



Relationships between variables

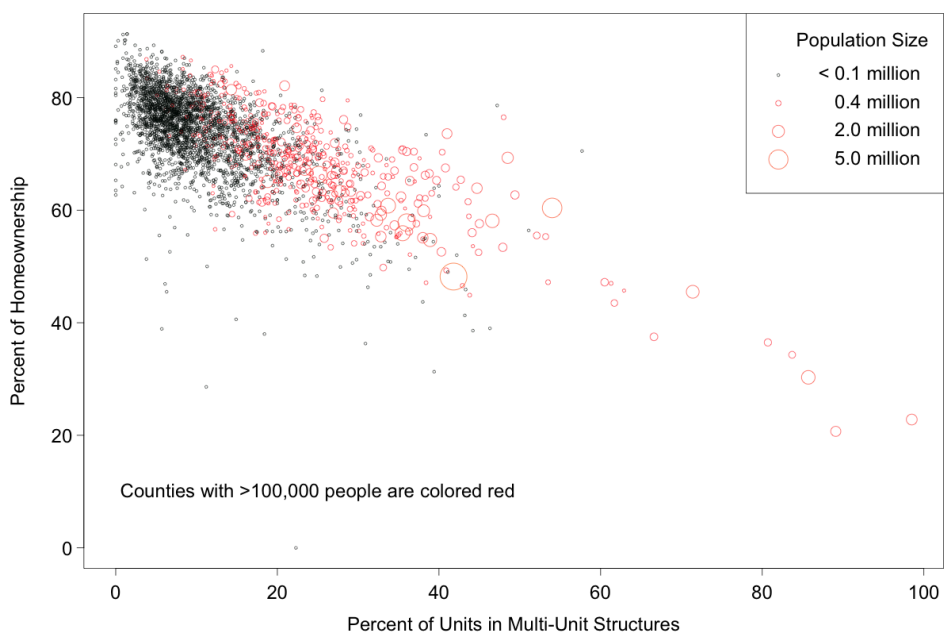
Almost always we are interested in the relationship between two or more variables.

A pair of variables are either related in some way (associated) or not (independent). No pair of variables are both associated and independent.

We can have either a negative association (as the value of one variable increases, the other decreases) or a positive association.

Relationships between variables

We can consider a third variable in the previous plot.



Lecture 2: Sampling and Bias

Chapter 1.3

Goals for Today

- Understand important considerations about data collection, in particular sampling.
- Food for thought about the next lecture: explanatory/response variables and causality.

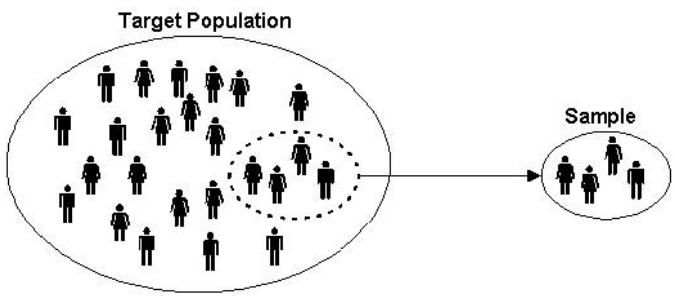
Populations and Samples

We want to make statements about some aspect of a study/target population.

1. What proportion of Oregonians smoke?
2. What are the sexual behaviors of males and female Americans in 1948?
3. What proportion of the Reed community believes they have personally experienced offensive, hostile, or intimidating conduct on campus?

Populations and Samples

It is often not feasible to collect data for every case in the population. If so, we take a sample of cases.



If the sample is representative of the desired population then our results will be generalizabile.

Populations and Samples

So say we take a representative sample of 1000 Oregonians and poll their smoking habits. We can then generalize the results to the entire population of Oregon.

One example of a non-representative sample is a biased sample.

How do we take a representative sample? In its simplest form, you need to randomly sample from the entire population. But this is easier said than done.

Comment on the Representativeness of These Samples:

1. The Royal Air Force wants to study how resistant their airplanes are to bullets. They study the bullet holes on all the airplanes on the tarmac after an air battle against the Luftwaffe (German Air Force).
2. I want to know the average income of Reed graduates in the last 10 years. So I get the records of 10 randomly chosen Reedies. They all answer and I take the average.
3. Imagine it's 1993 i.e. almost all households have landlines. You want to know the average number of people in each household in Portland. You randomly pick out 500 phone numbers from the phone book and conduct a phone survey.
4. You want to know the prevalence of illegal downloading of TV shows among Reed students. You get the emails of 100 randomly chosen Reedies and ask them "How many times did you download a pirated TV show last week?"

Statistics in Society: Alfred Kinsey

In the mid 20th century, biologist/sexologist Alfred Kinsey wanted to study human sexuality.

At the time sexuality was an extremely taboo subject, very little research had been conducted at that point and Kinsey was astonished at the public's general ignorance.

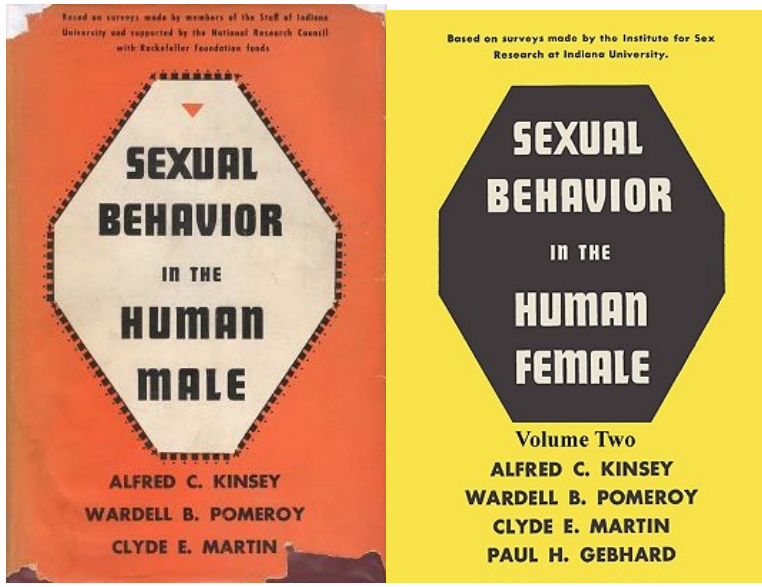
Statistics in Society: Kinsey's Questions/Research Problem

What type of questions was Kinsey interested in? Using his 300 question survey, he hoped to address...

1. What percentage of Americans engaged in premarital and extramarital sex?
2. What were the homosexual tendencies of American males?
3. How common were oral sex and masturbation?
4. ...

Statistics in Society: Kinsey Reports

The results were published two books on human sexual behavior known as the "Kinsey Reports": Sexual Behavior in the Human Male (1948) and Female (1953).



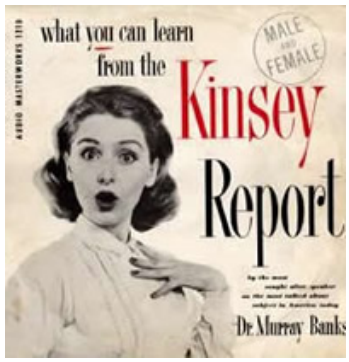
Statistics in Society: Conclusions of Kinsey Reports

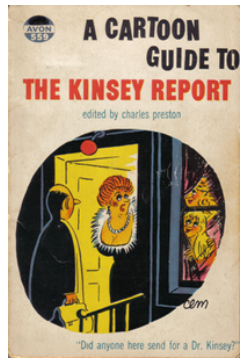
Kinsey claimed, among other things

1. 85% of white men had had premarital sex, 50% had had extra-marital sex
2. Kinsey wrote in 1948 that one in ten white men were more or less, exclusively homosexual for at least three years between the ages of 16 and 55.
3. Kinsey reported that oral sex was very common (70% of couples did it), masturbation was very common (almost 63%/92% of women/men did it)

Statistics in Society: Reaction to Kinsey Reports

Needless to say, people were taken quite aback.





There was also a huge conservative backlash against the reports.

Statistics in Society: Kinsey's Methods

What were his data collection methods? How did he sample his data? Focusing on the male report, my understanding is that

1. He did in fact base his conclusions on a very large sample size of 5300 males.
2. He sought out volunteers to answer his 300 question survey.
3. He recruited new people by asking previous respondents if they knew other people. This led to a large proportion of his sample to include prison populations and male prostitutes.

What could be some issues?

Response of the American Statistical Association

The American Statistical Association criticized the sampling procedure. In particular, John Tukey, one of the most eminent statisticians of the time, said

> *"A random selection of three people would have been better than a group of 300 chosen by Mr. Kinsey."*

Even though the Kinsey Report was groundbreaking and contributed much to the field of sexology by bringing many topics to the forefront, Kinsey's statements were not generalizable to the general public.

Reed Campus Climate Survey

During the 2012-2013 academic year Reed contracted Rankin & Associates Consulting to conduct the Campus Climate Survey to "examine the learning, living, and working environment at Reed College."

On page v and iii of the Executive Summary:
http://www.reed.edu/institutional_diversity/campus_climate.html

Examples of Different Types of Bias:

Moral of the Story

For you:

1. the consumer of statistics: Ask yourself what was the study design?
   - Who is the study population?
   - Who are the respondents and how were they selected?
2. the producer of statistics: think about how you will collect your data beforehand. If you want your results to generalize beyond just your sample to your study population, your sampling scheme has to as representative as feasible.

Explanatory and Response Variables

Example: A medical doctor pours over some his patients' medical records and observes:

$\Longrightarrow$

He then posits the following causal relationship:

- Explanatory variable: sleeping with shoes on
- Response variable: waking up with headaches

What's wrong with hypotheses?

Lecture 3: Observational Studies + Randomized Experiments + Confounding + Simpsons's Paradox

Chapter 1.4

Goals for Today

- We illustrate the difference between
  - an observational study
  - a randomized experiment, where the treatment is assigned at random.
- Introduce the notion of confounding AKA lurking variables
- Discuss Simpson's Paradox (not in textbook).

Going Back to Previous Example

Going back to the study on

$\Longrightarrow$

- The explanatory variable was: sleeping with your shoes on
- The response variable was: waking up with a headache
- The doctor hypothesized a causal relationship

Confounding Variable AKA Lurking Variable

This is an example of confounding. A confounding variable affects both the explanatory and response variable. So if:

Controlling for Potential Confounding

One way to control for (i.e. take into account) confounding is to do an exhaustive search for all such variables. This is not always practical.

Another way is via an experiment where we randomly assign individuals to a treatment or a control group in a randomized experiment.

Back to Shoes and Headaches

So imagine we recruit 10,000 people for our study and randomly assign 5000 people to each of:

- Treatment: sleep with shoes on
- Control: sleep with shoes off

In this table

Group	n	# with headache
Treatment	5000	n_1
Control	5000	n_2
Total	10,000	$n_1 + n_2$

n_1 and n_2 won't be very different.

Observational Studies vs Randomized Experiments

The key word from the study design above was randomly assign.

- Observational studies: a study where researchers have no control over who receives the treatment
- Randomized experiments: a study where researchers not only have control over who receives the treatment, but also make the assignments at random.

Observational Studies vs Randomized Experiments

Conclusion: The study introduced at the end of the last lecture is an observational study, so we cannot conclude that wearing shoes when you sleep causes you wake up with a headache.

Mantra: Correlation is not causation Just because two variables appear to be associated/correlated, does not mean that one is causing the other.

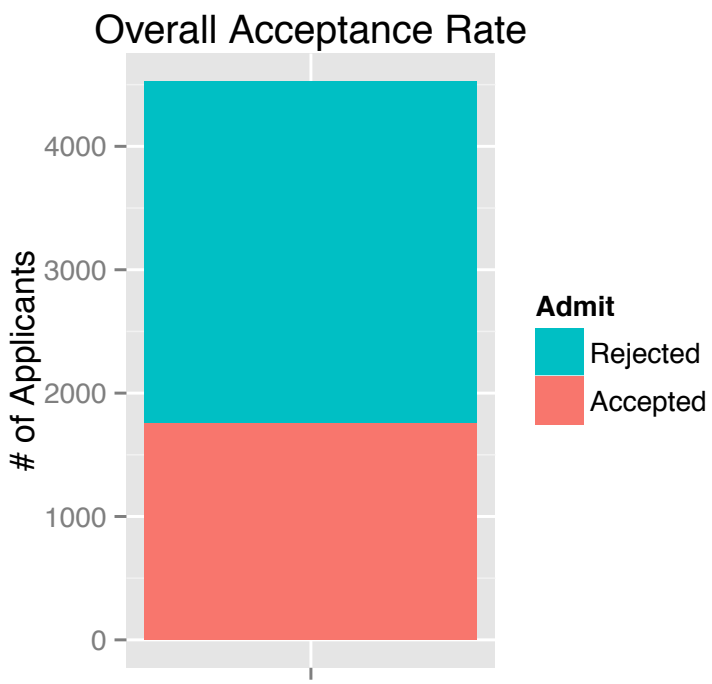
- Spurious correlations: http://www.tylervigen.com/
- Saturday Morning Breakfast Cereal: http://www.smbc-comics.com/?id=3129

Well-Known Example of Confounding

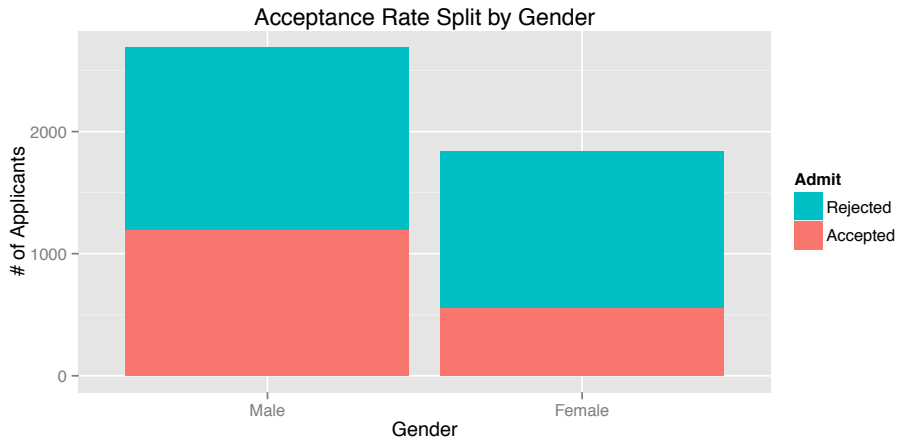
A famous example of an unaccounted for confounding variable having serious repercussions was when the UC Berkeley was sued in 1973 for bias against women who had applied for admission to graduate schools.

Let's consider the $n = 4526$ people who applied to the 6 largest departments.

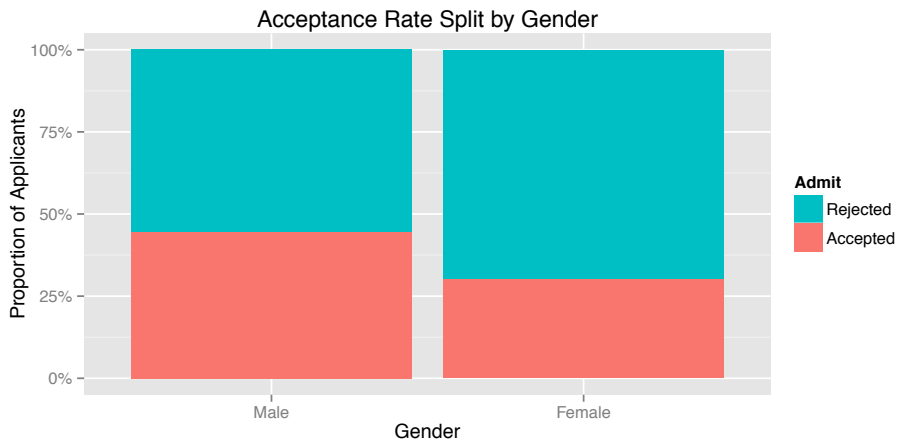
Of the $n = 4526$ applicants:



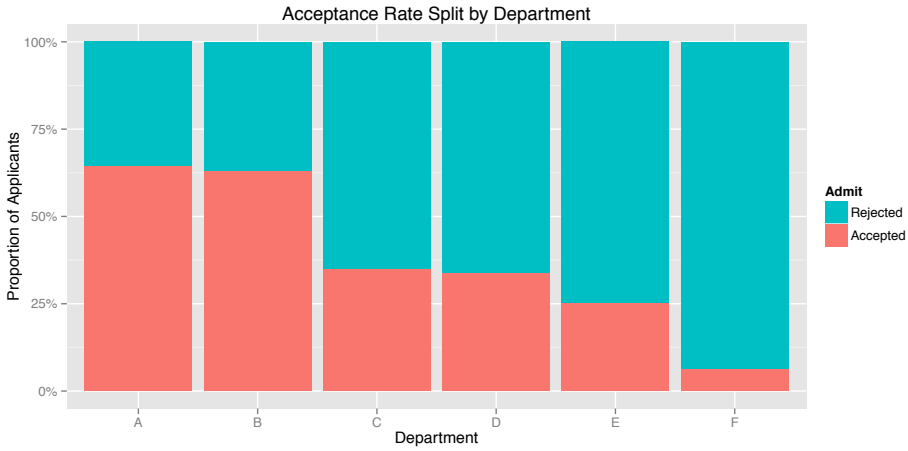
Split the counts by gender:



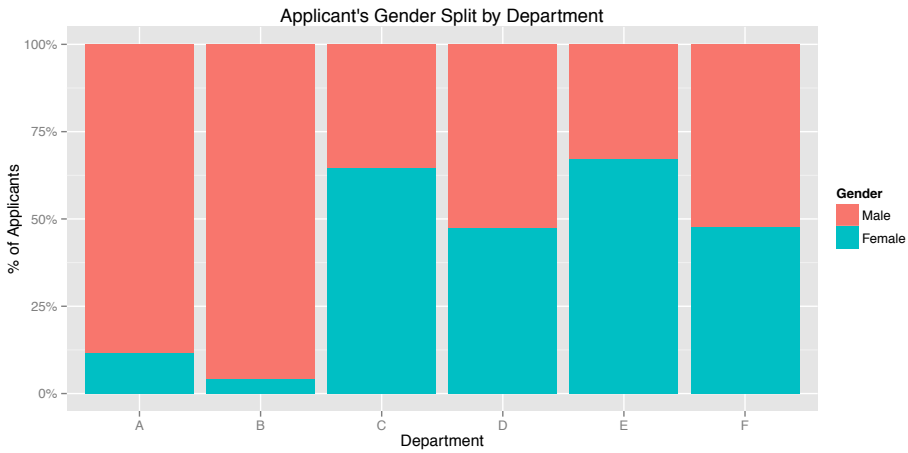
Look at proportions instead of counts:



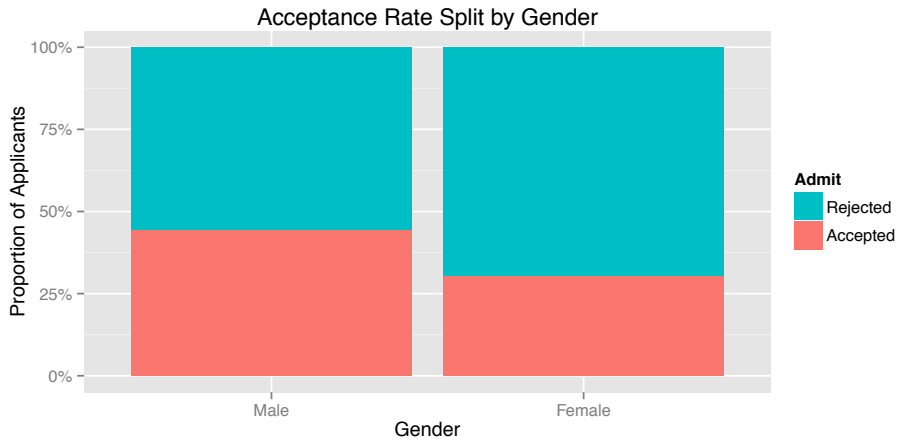
What was the "competitiveness" of departments?



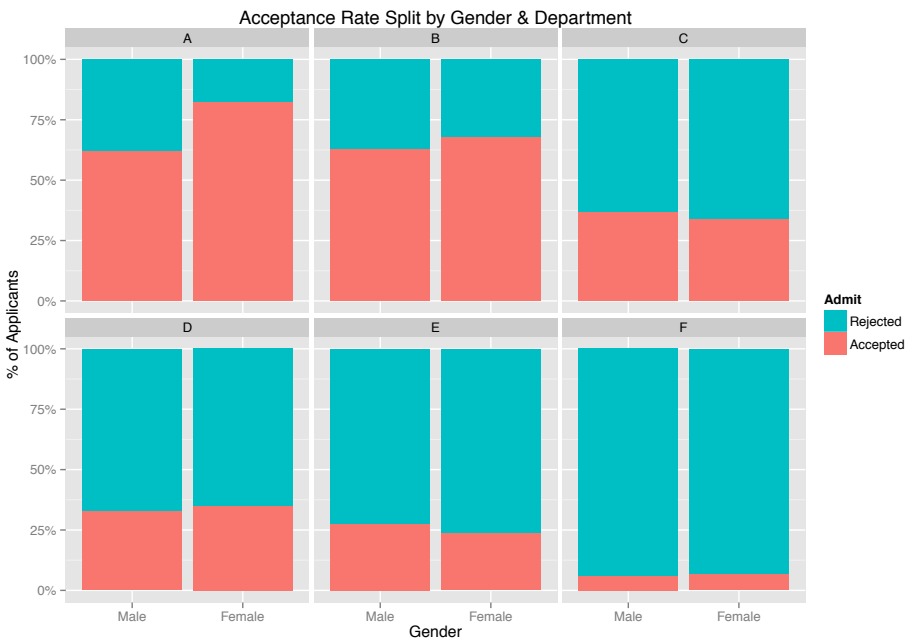
Where were the women applying?



So while in aggregate things looked like this:



You need to account for department!



Bickel et al.'s (1975) Explanation

There was the presence of a confounding variable: competitiveness of applying to the department, which is a function

- number of applicants
- number of available slots

So it wasn't that departments were discriminating against women, rather:

- women tended to apply to departments with high competition and hence lower admission rates, primarily the humanities.
- men tended to apply to departments with low competition and hence higher admission rates, primarily the sciences.

Bickel et al.'s (1975) Explanation

In fact, Bickel et al. found that "If the data are properly pooled...there is a small but statistically significant bias in favor of women."

This was the exact opposite claim of the lawsuit. This is known as Simpson's Paradox.

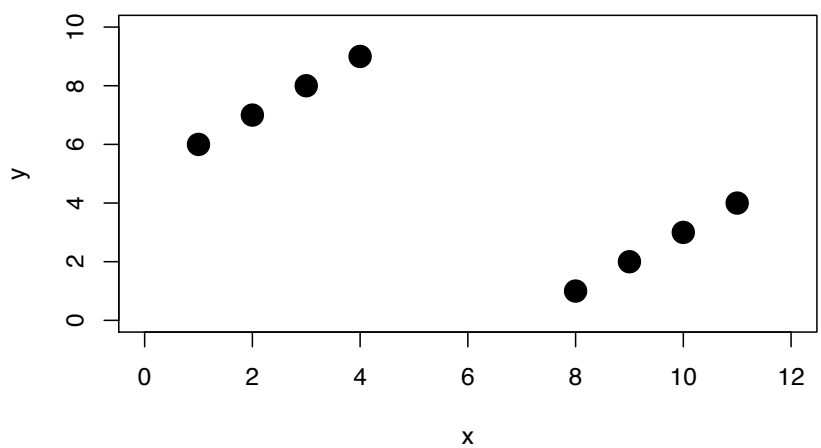
Simpson's Paradox

(From Wikipedia) Simpson's paradox occurs when a trend that appears in different groups of data disappears when these groups are combined, and the reverse trend appears for the aggregate data.

This is due to a confounding variable.

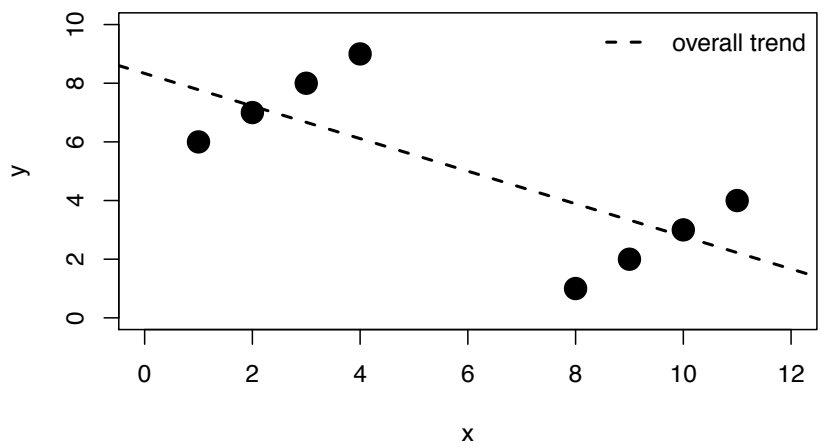
A Graphical Illustration of Simpson's Paradox

Say we have the following points:



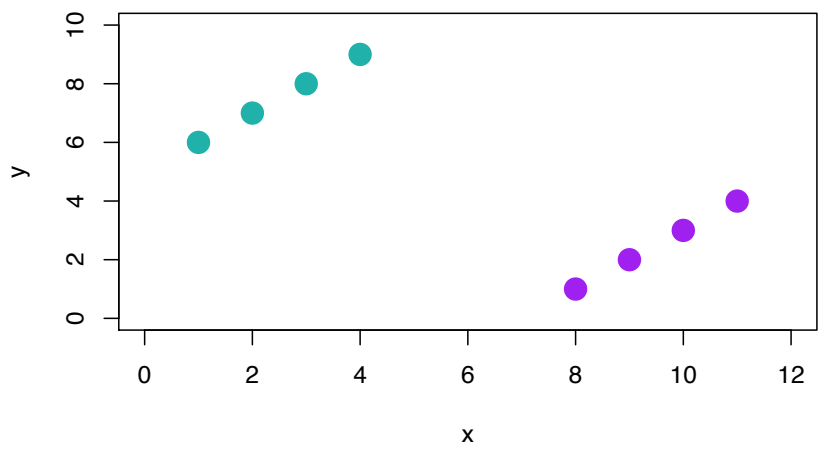
A Graphical Illustration of Simpson's Paradox

Overall, if we fit a single line, the explanatory variable x is negatively related with the outcome variable y:



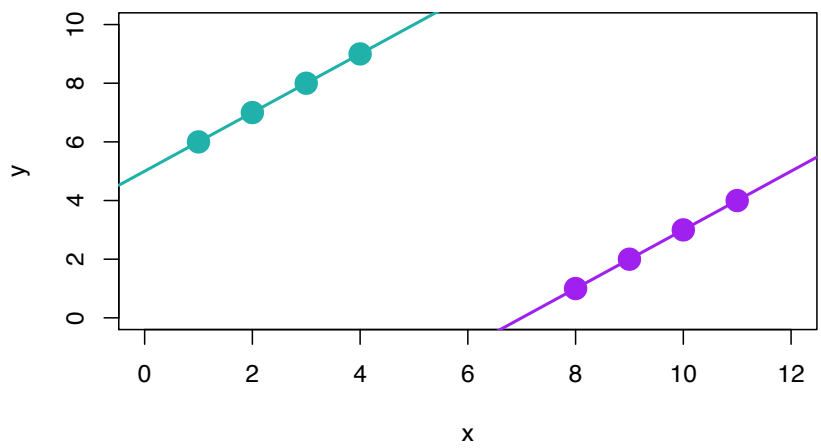
A Graphical Illustration of Simpson's Paradox

But say we consider a confounding variable, in this case color, and fit two separate lines for each group:



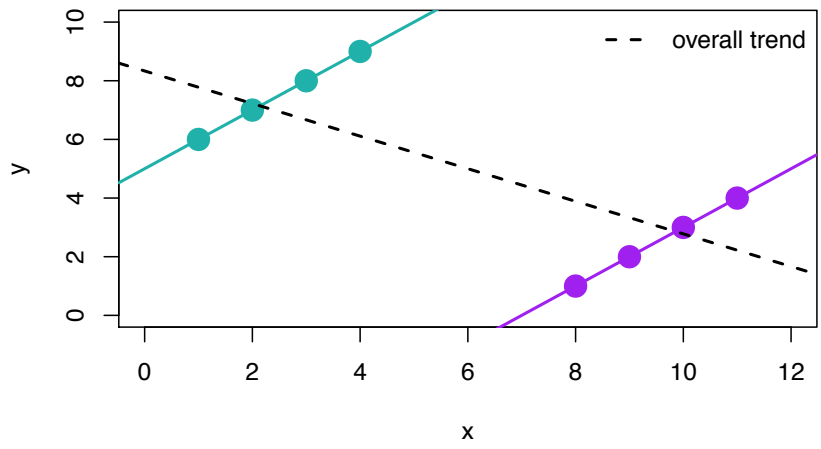
A Graphical Illustration of Simpson's Paradox

The subgroups now exhibit a positive relationship!



A Graphical Illustration of Simpson's Paradox

i.e. the trend in aggregate is the reverse of the trend in the subgroups (teal & purple).



Bickel et al.'s (1975) Conclusion

"The bias in the aggregated data stems not from any pattern of discrimination on the part of admissions committees, which seem quite fair on the whole, but apparently from prior screening at earlier levels of the educational system."

"Women are shunted by their socialization and education toward fields of graduate study that are generally more crowded, less productive of completed degrees, and less well funded, and that frequently offer poorer professional employment prospects."

The original paper can be found here.

Next time

We will discuss

- Specific types of sampling beyond just simple random sampling, as this is not always feasible
- Experimental design: some key principles to keep in mind when evaluating the efficacy of treatments.

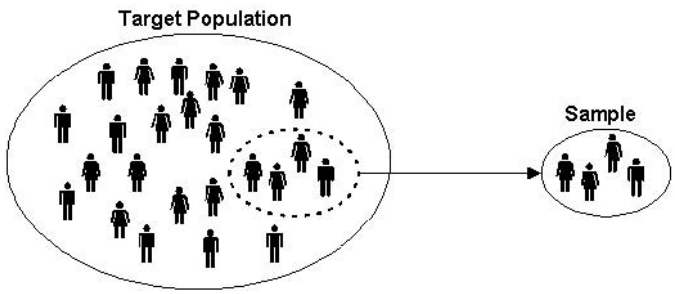
Lecture 4: Sampling Methods + Design of Experiments

Chapter 1.4.2 + 1.5

Goals for Today

- Discuss different types of sampling
- Designing experiments
- Very important example: clinical trials
- Example of my own designed experiment: Fried Chicken Face Off

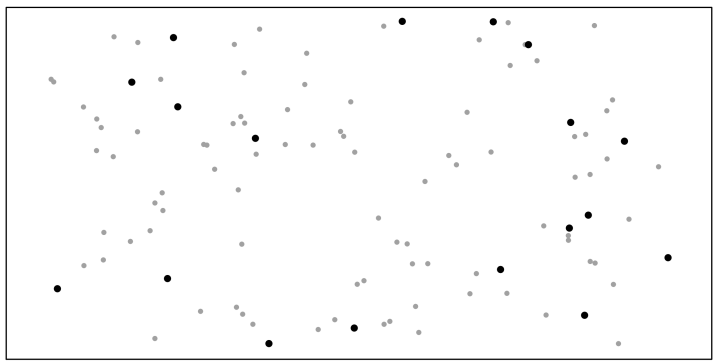
Recall from Lecture 1.3: Population and Samples



If the sample is representative of the desired population then our results are generalizable.

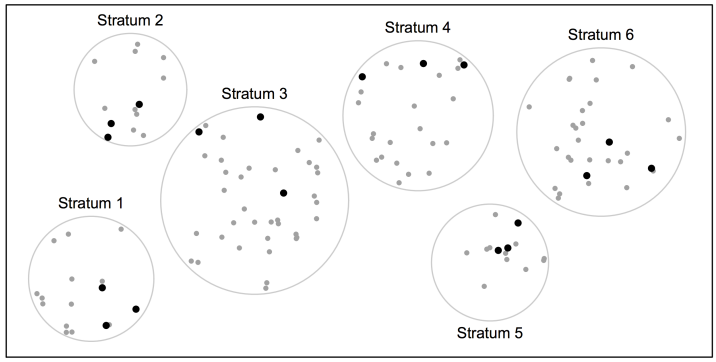
How do we take a representative (i.e. unbiased) sample? You randomly sample from the population.

1. Simple Random Sampling



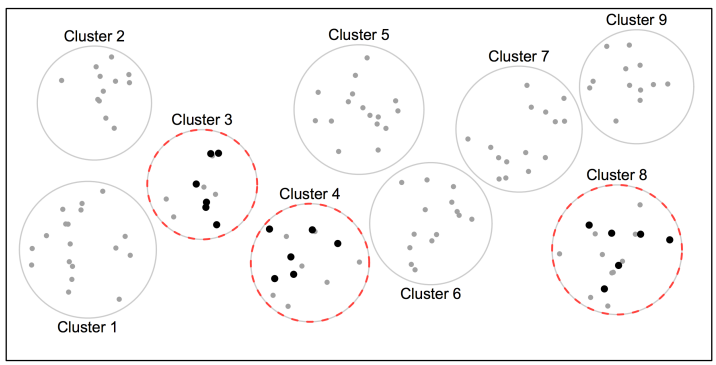
Most granular sampling: Where every individual in the population has the same probability of being sampled. Here, all dots are members of the population, and the bolder dots are sampled.

2. Stratified Sampling



Divide and conquer: The population is divided into strata, and we sample from each strata. For example, each strata could be a census tract in Oregon, and we sample 3 individuals from each strata.

3. Cluster Sampling



Two stage sampling: Very similar to stratified sampling in its process, except that there is no requirement to sample from every cluster. First the clusters in red were chosen at random, and then we sample from them.

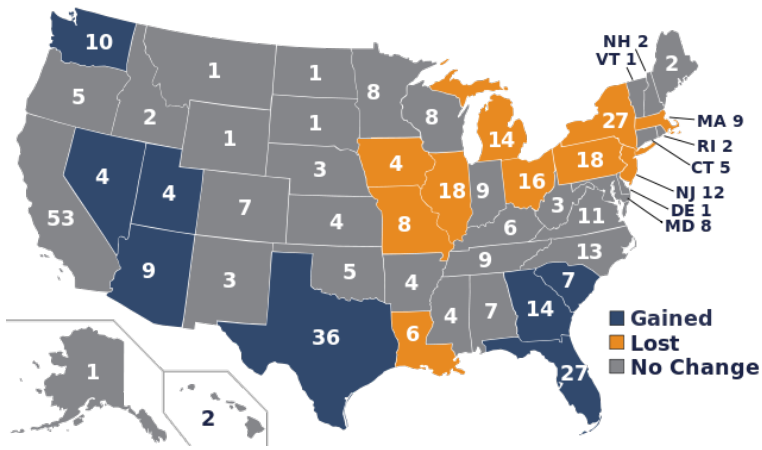
Three Different Types of Sampling

1. Simple random sampling: most granular sampling
2. Stratified sampling: divide and conquer
3. Cluster sampling: two-stage sampling

The mathematics behind the stratified and cluster sampling are more complicated to account for the hierarchies involved. Ex: for stratified sampling use the Horvitz-Thompson estimator.

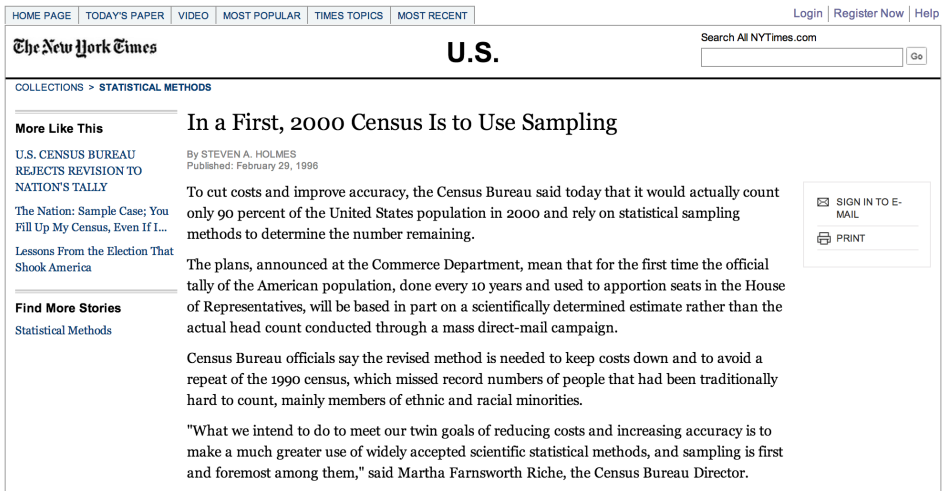
Statistics in Society: The US Census

The purpose of the decennial US census is congressional apportionment: the 435 seats in the US House of Representatives get distributed to the 50 states in proportion to their population. After the 2010 census:



Statistics in Society: The US Census

President Bill Clinton's administration planned on using sampling in the 2000 census. In an article dated in 1996:



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Statistical Methods

In a First, 2000 Census Is to Use Sampling

By STEVEN A. HOLMES
Published: February 29, 1996

To cut costs and improve accuracy, the Census Bureau said today that it would actually count only 90 percent of the United States population in 2000 and rely on statistical sampling methods to determine the number remaining.

The plans, announced at the Commerce Department, mean that for the first time the official tally of the American population, done every 10 years and used to apportion seats in the House of Representatives, will be based in part on a scientifically determined estimate rather than the actual head count conducted through a mass direct-mail campaign.

Census Bureau officials say the revised method is needed to keep costs down and to avoid a repeat of the 1990 census, which missed record numbers of people that had been traditionally hard to count, mainly members of ethnic and racial minorities.

"What we intend to do to meet our twin goals of reducing costs and increasing accuracy is to make a much greater use of widely accepted scientific statistical methods, and sampling is first and foremost among them," said Martha Farnsworth Riche, the Census Bureau Director.

SIGN IN TO E-MAIL

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Statistics in Society: The US Census

However, Article I, Section 2 of the US Constitution states: *The actual Enumeration shall be made within three Years after the first Meeting of the Congress of the US, and within every subsequent Term of ten Years...*

As such, the Supreme Court ruled 5-4 in 1999 that

- sampling could not "under any circumstances" be used to reapportion U.S. House seats
- could be used for other purposes such as redrawing state legislative districts or allocating federal funds to cities and states

Statistics in Society: The Census

THE WALL STREET JOURNAL.

U.S. EDITION Friday, May 15, 2009 As of 4:42 PM EDT

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POLITICS | May 15, 2009, 4:42 p.m. ET

Census Nominee Rules Out Statistical Sampling in 2010

Article | Comments

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By TIMOTHY J. ALBERTA

WASHINGTON—President Barack Obama's nominee to head the Census Bureau on Friday ruled out using statistical sampling to adjust the results of the 2010 census, quelling Republican concerns and making his confirmation likely next week.

Robert Groves, director of the University of Michigan's Survey Research Center and a former Census Bureau official, is an expert on statistical sampling, the practice of extrapolating a larger population from a smaller slice of it. Proponents of sampling say it helps produce a more accurate tally of the population, especially when it comes to traditionally undercounted groups, such as minorities living in urban areas.

But many Republican lawmakers insist that sampling violates the Constitution, which calls for an "actual Enumeration" of the population every 10 years. Critics also say the use of sampling would politicize the traditionally nonpolitical Census Bureau.

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Principles Of Designing Experiments

Switching gears...

(Wikipedia) In general usage, design of experiments (DOE) or experimental design is the design of any information-gathering exercises where variation is present, whether under the full control of the experimenter or not.

However, in statistics, these terms are usually used for controlled experiments: experiments where there is a control and treatment group.

Principles Of Designing Experiments

Clinical Trials

To evaluate the efficacy of a drug, they must be subject to a clinical trial. The gold standard for a clinical trial is randomized controlled trial. i.e. randomized control and treatment groups.

Example of Mine: Ezell's Famous Chicken

In Seattle's Central District lies

From Wikipedia: Oprah Winfrey called it her favorite fried chicken. There are a number of photos of her on the wall of the original restaurant proclaiming her love of the chicken. It is also said she has the chicken flown to her in Chicago when she has a craving.

Example of Mine: Ezell's Famous Chicken

One day I was raving about Ezell's Chicken. My friend Nick accused me of being another person "buying into the hype"; that if people were subjected to a blinded taste test, Ezell's would fare no better than KFC. So...

vs

We set up a "Fried Chicken Face Off" where we would have individuals try both kinds of chicken and rate which one they liked more.

Design of Experiment Principles in Place

Goal: Evaluate which kind of chicken, Ezell's or KFC, that people prefer in a blinded taste test. (Not if participant can determine which chicken came from which restaurant.)

Question: What principles of the design of experiments should be put in place to this end?

Design of Experiment Principles in Place

The design principles we put in place:

- Single blinded: The taster doesn't know which (Ezell's or KFC) chicken they are eating, but the server does.
- Randomizing which kind of meat (wing, breast, leg) between tasters. Each taster would try two kinds of meat.
- Controlling for which kind of meat within a taster: i.e. if you eat a KFC wing, you will necessarily eat an Ezell's wing
- Randomizing which order of chicken you eat: KFC first or not

Design of Experiment Principles in Place

The design principles we put in place:

- Controlling for temperature: hence we're picking a place that is central to both Ezell's and KFC given the traveling required.
- Controlling for visual look: We thought blind-folds were a bit excessive
- Controlling for kind of batter: we can't do KFC crispy chicken b/c Ezell's doesn't have that type of batter. This is a limitation of the study b/c some feel the crispy chicken is better, but we have no choice.
- Just one replicate of each kind of meat.

Results

Final score: KFC 8, Ezell's 4.
Some notes:

- Even though people were "blinded", most knew which the two pieces were from KFC.
- People generally felt the chicken meat from Ezell's was better, and this was magnified as the chicken went cold.
- However, they felt the skin was better at KFC. Given that fried chicken is what it is b/c of the skin, people voted for KFC.
- Future metrics need to consider the chicken and the skin separately, as well as the "overall experience" scores. i.e. this face off should be viewed as a pilot study

Caution: Grad Students NOT at Work

Next time

Examining and visualizing numerical data

Lecture 5: Visualizing Numerical Data

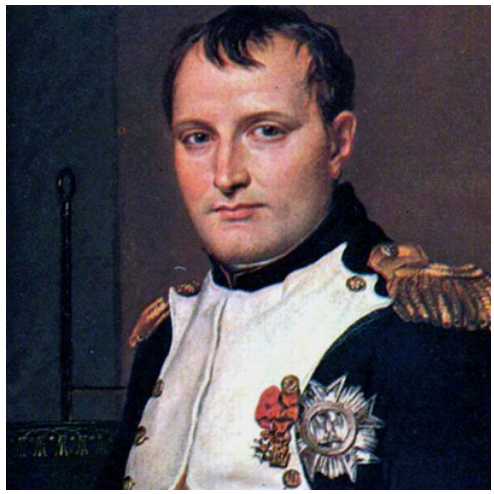
Chapter 1.6 + 1.7

Goals for Today

- Visualizing numerical data
  - Two famous historical examples of data visualization
  - Reed's 2013 entering class
- Histograms
- Measures of Central Tendency: Mean, Median, and Mode
- Measure of Spread: Sample variance and sample standard deviation

Famous Example 1: Napoleon's March on Russia in 1812

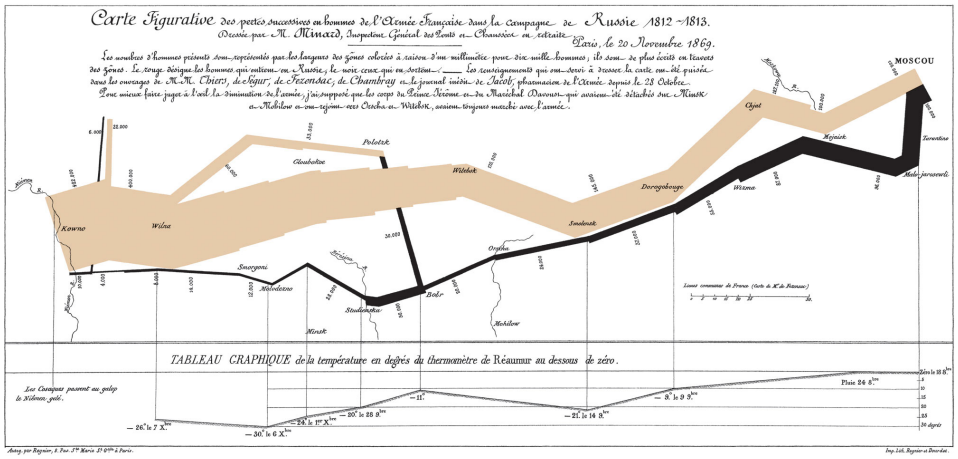
In 1812, Napoleon led a French invasion of Russia, at one point marching on Moscow.



Famous Example 1: Napoleon's March on Russia in 1812

The advance and retreat on Moscow was an unmitigated disaster:

Famous Example 1: Napoleon's March on Russia in 1812



Famous Example 1: Napolean's March on Russia in 1812

Why is this visualization big deal?

On a two-dimensional page, it displays 6 variables (in others words, 6 dimensions of information) at once:

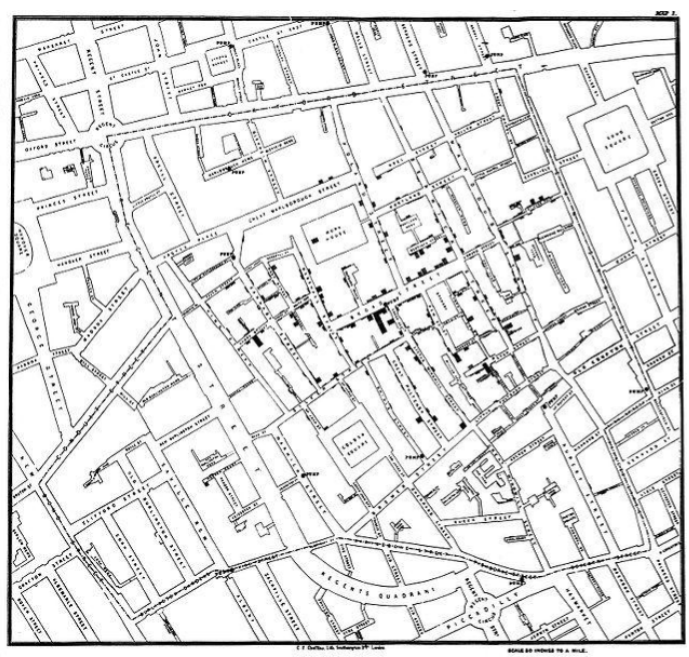
Famous Example 2: 1854 Broad Street Cholera Outbreak

On August 31 1854, an epidemic of cholera began in the Soho neighborhood of London. Over the next three days 127 people near Broad Street had died.

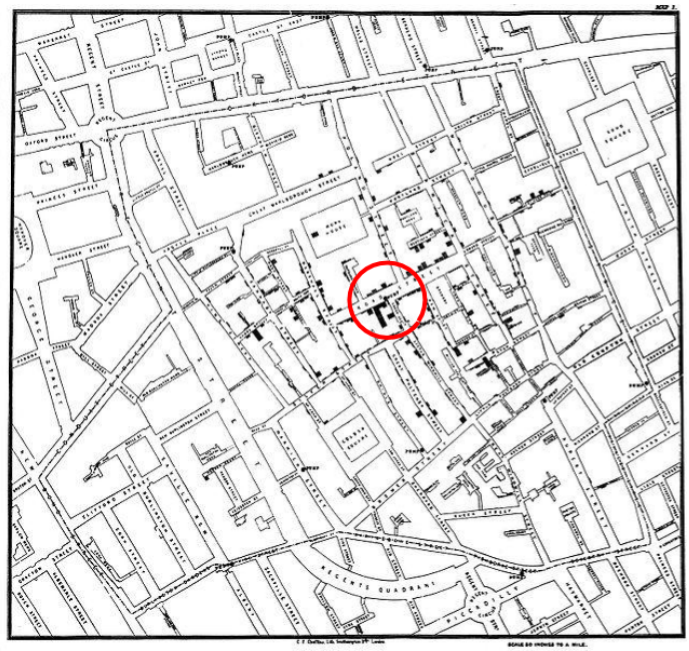
Dr. John Snow, a physician, was a student of the disease. (From Wikipedia) Snow was a skeptic of the then-dominant miasma theory that stated that diseases such as cholera or the Black Death were caused by pollution or a noxious form of "bad air."

Snow created the following map to investigate:

Famous Example 2: 1854 Broad Street Cholera Outbreak



Famous Example 2: 1854 Broad Street Cholera Outbreak



Famous Example 2: 1854 Broad Street Cholera Outbreak

He identified the source of the outbreak as water from the Broad Street Pump, which was near a cesspit that began to leak.

This led to discovering that cholera was transmitted by food and water being contaminated by fecal matter and not via the air. This was a watershed moment in the emerging field of epidemiology.

Histograms

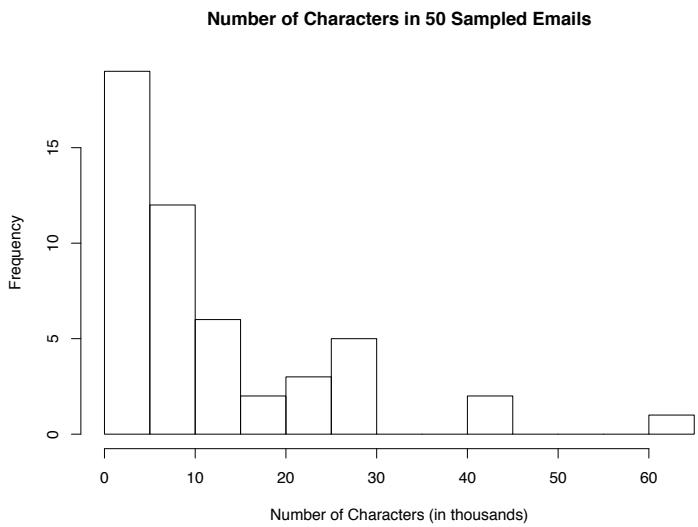
In the `openintro` package, the `email50` dataset contains a random sample of 50 emails, in which researchers try to identify emails as spam. One variable is the # of characters:

Characters (in 1000's)	0-4.999	5-9.999	10-14.999	...	60-64.999
Count	19	12	6	...	1

So each of the intervals 0-5, 5-10, 10-15, etc. are buckets/bins and we count the number of emails in each bucket/bin.

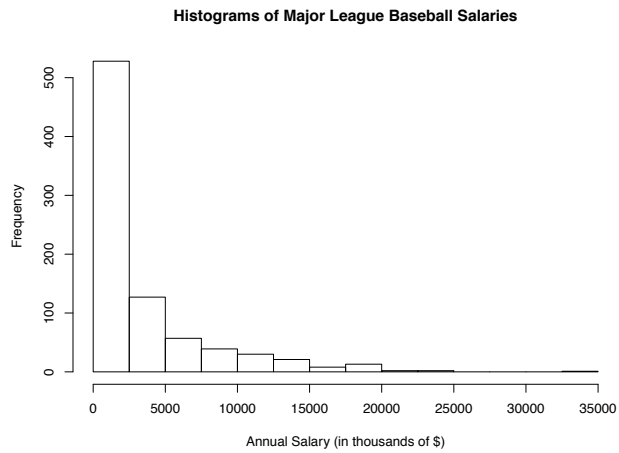
Histograms

Histograms provide a description of the shape of the distribution of data.



Skew and Long Tail

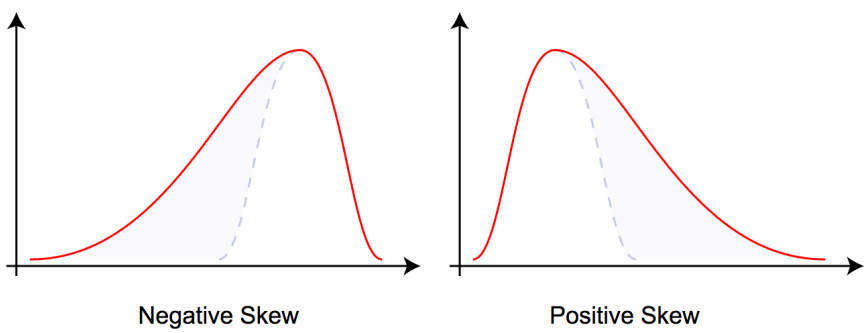
Also in the `openintro` package is MLB salary data in 2010. If we plot a histogram:



The data has a long tail to the right: data is right-skewed. i.e. a small number of players who make a VERY large amount of money.

Trick to Remembering Which Skew is Which

- Long tail to the right: data is right-skewed AKA positively-skewed
- Long tail to the left: data is left-skewed AKA negatively-skewed



Reed's 2013 US-Originating Entering Class

What can we do about skewed data?

http://rpubs.com/rudeboybert/reed2013

Mean

The mean, AKA average, is a common way to measure the center of the data. So for example, the mean of 1, 2, 5, 3, and 7 is

$$\frac{1+2+5+3+7}{5} = 3.6$$

We label the sample mean $\overline{x}$ (pronounced "x bar"):

$$\overline{x} = \frac{x_1 + x_2 + \ldots + x_n}{n}$$

where $x_1, x_2, \ldots, x_n$ are the n observed/sampled values.

Median

The median, however, is the middle number.

Two cases:

- Odd number of values: the median of (1, 3, 5, 8, 10) is 5.
- Even number of values: the median of (1, 3, 5, 8) is the average of the middle two values: $\frac{3+5}{2} = 4$

But why use the median at all?

Mean vs Median: Imaginary Scenario

- Say at company X, there 5 employees: the CEO and everyone else.
- The CEO earns \$1000 an hour, while the others earn \$20, \$21, \$30, and \$40 an hour.
- The employees complain that they are paid too little.
- The CEO counters that the mean hourly salary is $\overline{x} = \frac{20+21+30+40+1000}{5} = 222.20$ an hour, which is really high.

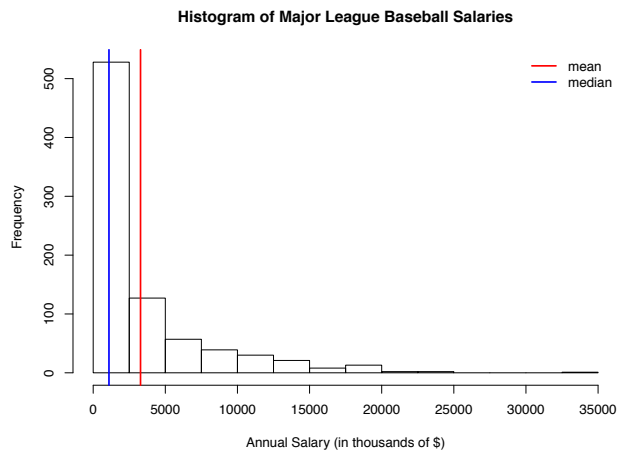
Mean vs Median: Imaginary Scenario

The CEO's extreme salary is inflating the mean. A more appropriate measure is the median hourly salary of 30.

Medians are less sensitive to (i.e. more robust to) outliers than the mean.

Ex: the "median home price" is typically used, because it isn't as sensitive as the mean to the few very expensive houses.

Mean vs Median: Back to MLB Salary Data

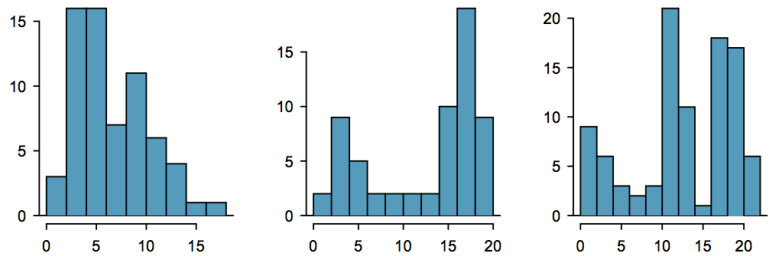


Mode

A mode is the value that appears the most often in a data set. So out of (1, 3, 3, 5, 6), the modal value is 3.

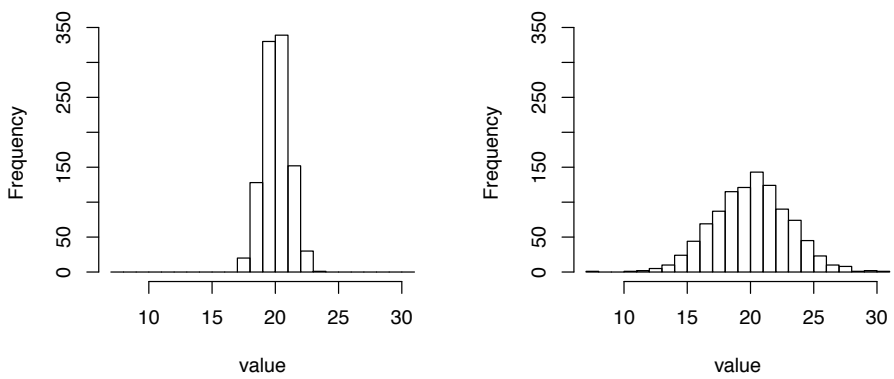
Modes also describe peaks, but this can get subjective.

A distribution can be unimodal, bimodal, or multimodal:



Measure of Spread

Next, consider the following two histograms: Both have mean of about 20. What is the difference between them?



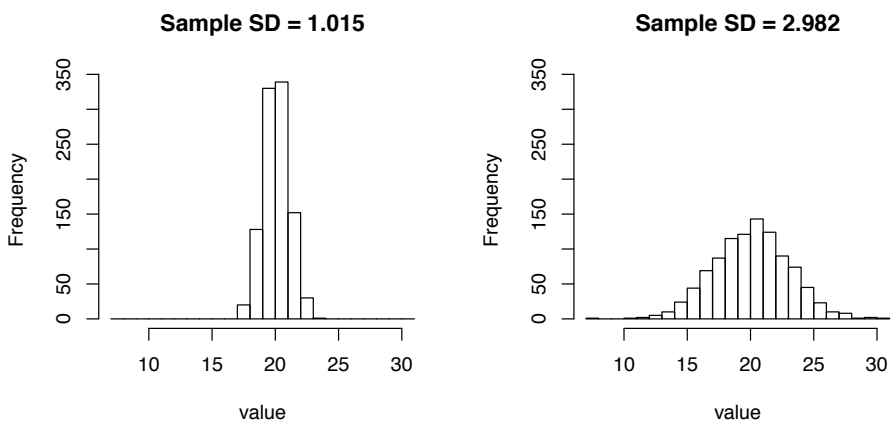
Measure of Spread

We need a measure of spread/variability. The sample variance s^2 is roughly the average squared distance from the mean.

The sample standard deviation s is the square root of the sample variance. The sample standard deviation is useful when considering how close the data are to the mean.

Measure of Spread

Back to example:



How to Compute the Sample Standard Deviation

Read section 1.6.4. The formula really doesn't make much intuitive sense, but is the way it is due to mathematical convenience. Fortunately there is an `R` command that computes it for you: `sd()`

Next Time

- Another simple data visualization tool: boxplots
- Examining/Visualizing Categorical Data

Lecture 6: Visualizing Numerical and Categorical Data

Chapter 1.6+1.7

Goals for Today

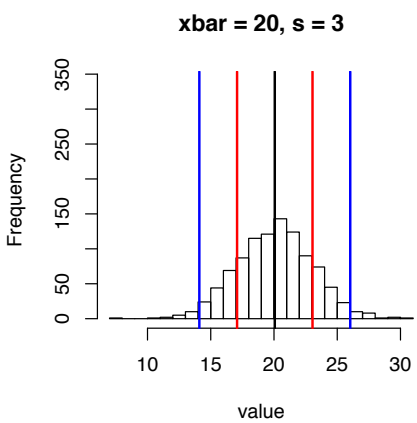
- Rule of thumb for standard deviations
- Population vs sample mean/variance/standard deviations
- Percentiles and Quartiles
- Boxplots
- Piecharts, barplots, mosaicplots

Rule of Thumb for Standard Deviations

If the data distribution is bell-shaped, then

- about $\frac{2}{3}$ of the data will be within one SD of the mean (book says 70%).
- about 95% of the data will be within two SD.

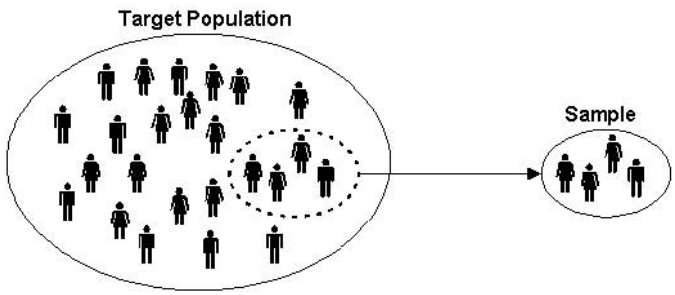
Example



- black line is mean $\overline{x}$
- red lines mark about $\frac{2}{3}$:
  $[\overline{x} - s, \overline{x} + s] =$
  $[20 - 3, 20 + 3] = [17, 23]$.
- blue lines mark about 95%:
  $[\overline{x} - 2s, \overline{x} + 2s] =$
  $[20 - 6, 20 + 6] = [14, 26]$.

Population vs Sample Mean/Variance/Standard Deviation

Recall the notion of taking a representative sample from a study/target population. Say we are interested in the income of the individuals.



Population vs Sample Mean/Variance/Standard Deviation

- The sample mean $\overline{x}$ is the mean income of the 4 sampled people.
- The population mean μ is the mean income of all 24 people in the target population.
- We say $\overline{x}$ estimates μ. If the sample is representative, then $\overline{x}$ estimates μ with high accuracy i.e. it is unbiased.

Population vs Sample Mean/Variance/Standard Deviation

	True Population Value	Sample Value
Mean	μ	$\overline{x}$
Variance	σ^2	s^2
Standard Deviation	σ	s

The sample value is used to estimate the (true) population value.

Percentiles

A percentile (%'ile) indicates the value below which a given %'age of observations fall.

SAT Scores from 2012
http://media.collegeboard.com/digitalServices/pdf/research/SAT-Percentile-Ranks-2012.pdf

So for example, if you scored 700 in critical reading, 95% of college-bound seniors who took the test did worse.

Quartiles

Quartiles split up the data into 4 intervals, each with about one quarter of the data:

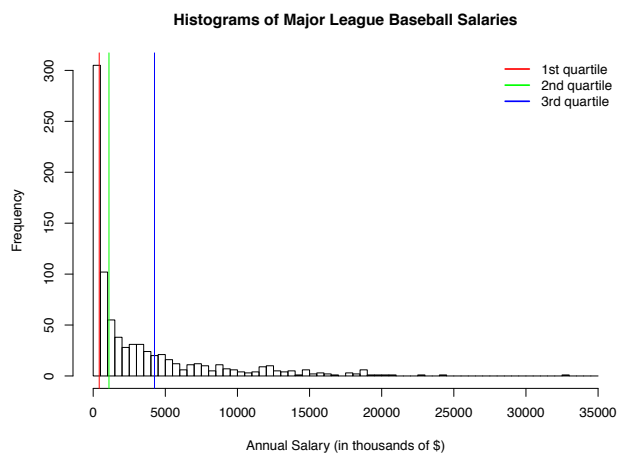
- The lower quartile is the 25th %'ile
- The median is the 50th %'ile
- The upper quartile is the 75th %'ile

The interquartile range (IQR) is another measure of the spread of a sample:

$$\text{IQR} = \text{upper quartile} - \text{lower quartile}$$

MLB Data Quartiles

```
 Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
400.0   418.3  1094.0  3282.0  4250.0 33000.0
```



The IQR is (3rd Quartile - 1st Quartile) = 4250.0 - 418.3 = 3831.7 i.e the distance between the red and blue line.

Robust Statistics (Chapter 1.6.6)

Robust estimates are statistics where extreme observations (outliers) have less effect on their values, i.e. are more resistant to their effect. The median and IQR are two examples.

Example: Old scoring system in figure skating: drop the highest & lowest scores and then take the average.

Say we have a figure skater who gets judged by countries V-Z:

Country	V	W	X	Y	Z
Score	4.0	5.2	5.2	5.3	6.0

Drop the 4.0 and 6.0, then the final score is: $\frac{5.2+5.2+5.3}{3} = 5.23$

Boxplots

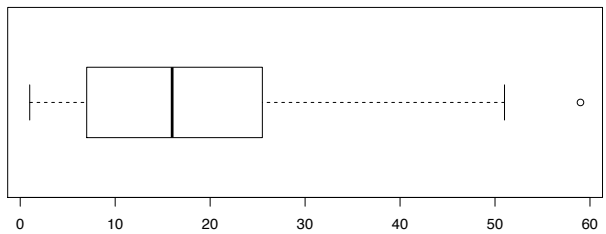
Boxplots are visual summaries of a sample $x_1, \ldots, x_n$ that bring to light unusual values (potential outliers):

Example: # US Forces casualties in the war in Afghanistan for each month from 2008-2009:

7, 1, 7, 5, 16, 28, 20, 22, 27, 16, 1, 3, 14, 15, 13, 6, 12, 24, 44, 51, 37, 59, 17, 17

Boxplots

```
Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
1.00    7.00   16.00   19.25   24.75   59.00
```



US Forces casualties in Afghanistan for each month 2008–2009

Page 29 of text describes the length of the whiskers: they capture data that is no more than $1.5 \times IQR$ of both ends of the box.

Outliers Are Relatively Extreme

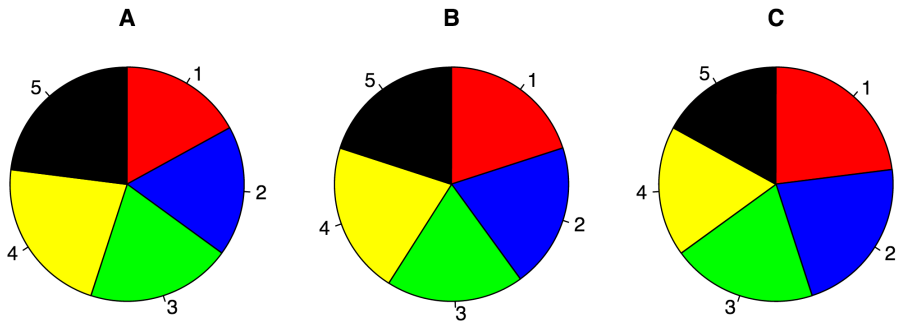
An outlier is an observation that appears extreme relative to the rest of the data.

Why it is important to look for outliers? Examination of data for possible outliers serves many useful purposes, including

- Identifying strong skew in the distribution.
- Identifying data collection or entry errors.
- Providing insight into interesting properties of the data.

Piecharts

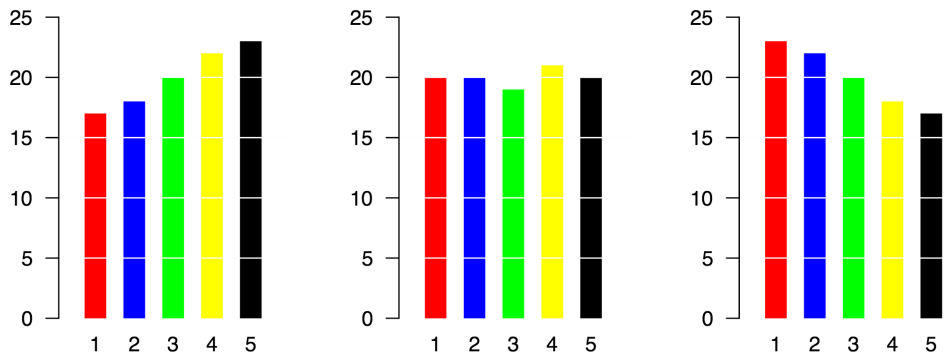
Say we have the following piecharts represent the polling from a local election with five candidates (1-5) at three different time points A, B, an C:



Answer the following questions:

- In the first race, is candidate 5 doing better than candidate 4?
- Who did better between time A and time B, candidate 2 or candidate 4?

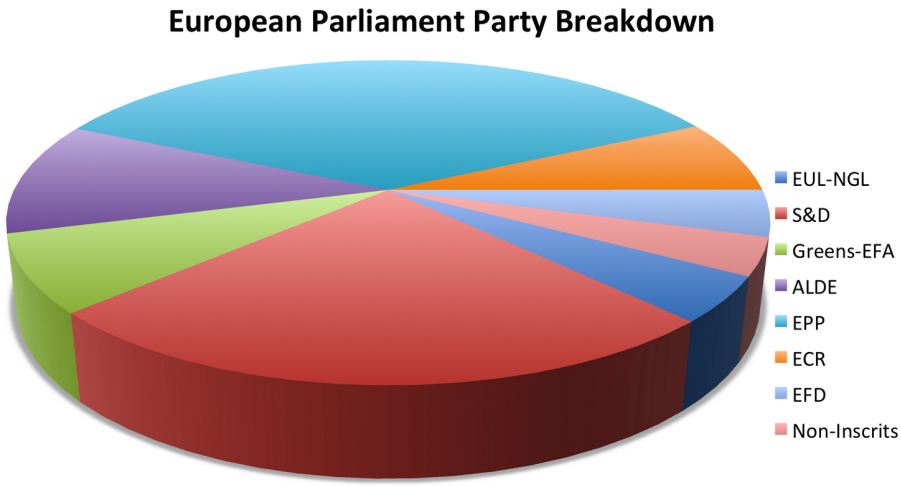
Barplots Instead



Answers:

- Candidate 5 is doing better than 4
- Between A and B, candidate 2 went from about 17% to 20% while candidate went from about 22% to 21%. So candidate 2 did better

3D Piecharts Can Be Deceiving



EEP (teal) has 266 seats, whereas S&D (red) has 190 seats.

Titanic Survival Data

Typing `data(Titanic)` in R loads the survival and death counts, split by each of the following categories:

- Class: 1st, 2nd, 3rd, or crew (4 levels)
- Gender (2 levels)
- Age: Child or adult (2 levels)

i.e. $4 \times 2 \times 2 = 16$ possible groups to consider.

Questions

- What was the effect of class (1st, 2nd, 3rd, crew) on your chances of survival?
- Did the "women and children" first lifeboat policy hold?

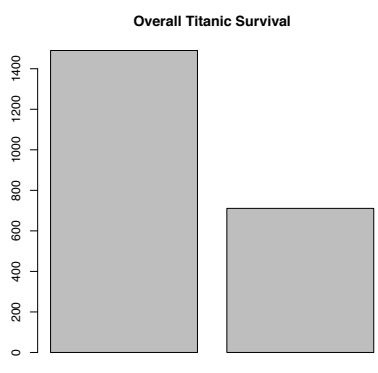
Frequency Table

A table summarizing a single categorial variable is called a frequency table. Overall:

Died	1490
Survived	711
Total	2201

Barplot

Barplots are ways to display categorial variables:



Contingency Table

A table that cross-classifies two categorical variables is a contingency table. Now let's split survival by class: 1st, 2nd, 3rd, and crew.

Before:

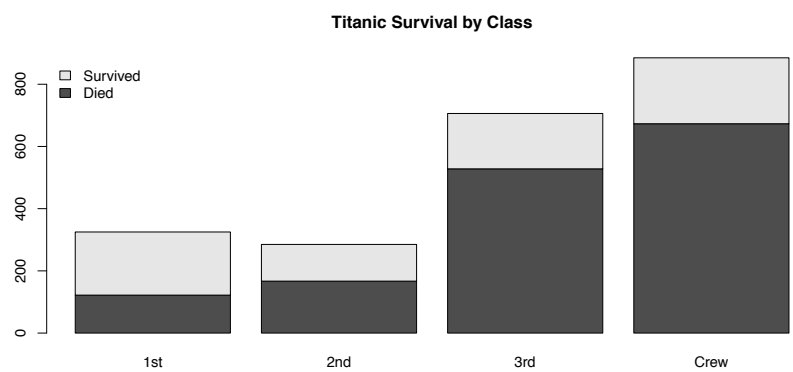
Died	1490
Survived	711
Total	2201

After:

	1st	2nd	3rd	Crew	Total
Died	122	167	528	673	1490
Survived	203	118	178	212	711
Total	325	285	706	885	2201

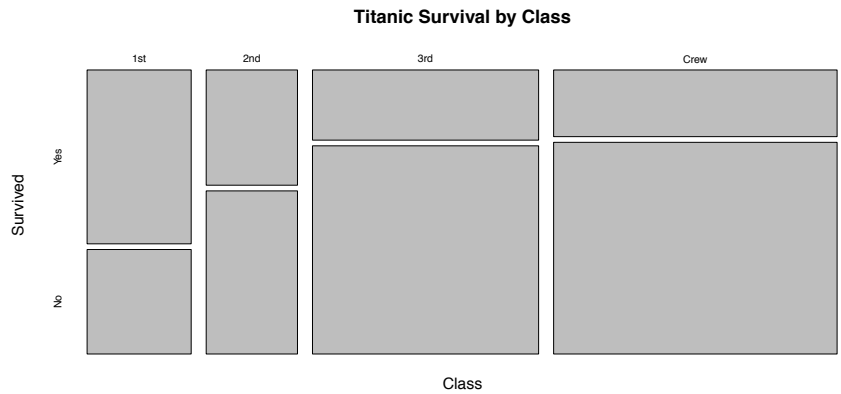
Stacked Barplot

Stacked barplots are one way to display values from a contingency table:



Mosaic Plots

Mosaic plots are similar, but the widths of the bars now reflect proportions:



Stacked Barplots

Using the `ggplot2` package, we can plot survivals by class, age, and gender all at once.

Standardized/Normalized Stacked Barplots

Instead of raw counts, we can expand each bar to reflect proportions (i.e. standardize/normalize them).