Data Collection

Nate Wells

Math 141, 2/11/22

Outline

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- Discuss principals of data collection
- Compare and contrast observational studies and random experiments

Section 1

Principles of Data Collection

Populations and Samples

- Every statistical investigation must begin by clearly identifying the **population** to be studied, the **variables** to be measured, and the **sample** from which measurements will be taken.

Sampling

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  - Properties of probability allow us to quantify uncertainty.
  - In isolation, a single random event may seem arbitrary. But in aggregate, a collection of random events is predictable.
- By following basic procedures for randomly selecting a sample, we can be certain that the results fall within a specified margin of the true value a particular percentage of the time.

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  - In fact, it is necessary that such under-representation samples are possible, in order to quantify *extreme* events.

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  - **Convenience**, where "randomization" is performed by selecting a convenient block of individuals in the population (leading to strong correlation between members of the sample)

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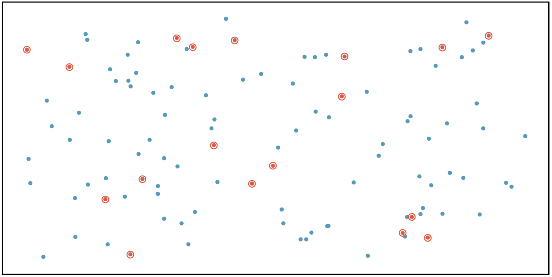
  - What sources of bias are present in this sample?
- Suppose a year later, the restaurant still has 3.5 stars, but now with 1000 reviews. Does the verdict change?
- Suppose a second Thai restaurant opens up nearby, with a yelp rating of 4 stars with 1000 reviews. Can we conclude Portlanders prefer the second restaurant to the first?

Sampling Methods (SRS)

- **SRS**: Randomly select individuals from the population so that each individual has equal likelihood of being selected.



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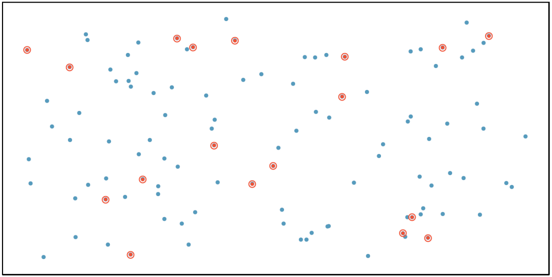

- Advantages:
  - Typically provides better representation compared to larger, non-random samples
  - Relatively simple to implement and analyze
  - Non-biased
  - Provides effective theoretical baseline

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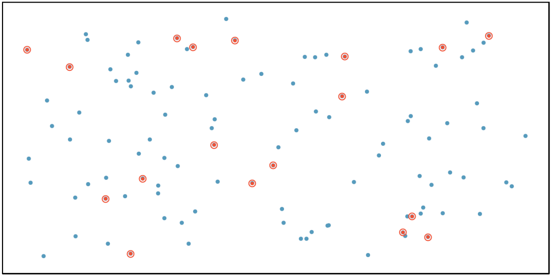

- Disadvantages:
  - May not be as precise as other sampling techniques
  - Can be difficult to perform in practice

Sampling Methods (Stratified)

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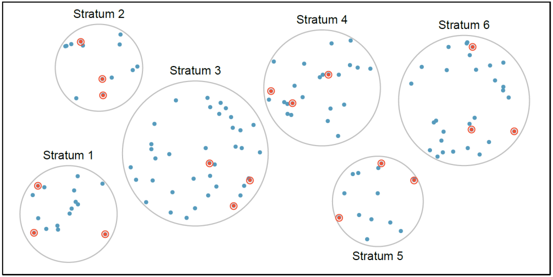

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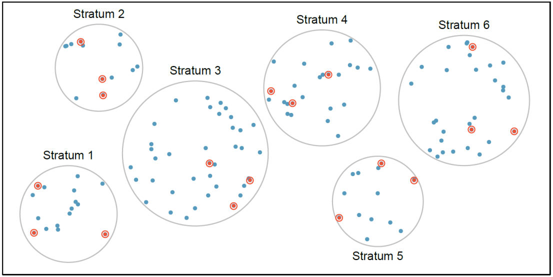

- Advantages:
  - Can be more precise than an SRS, thus requiring lower sample size
  - Hedges against non-representative samples
  - Strata proportions can be adjusted to ensure sufficient data to support analysis

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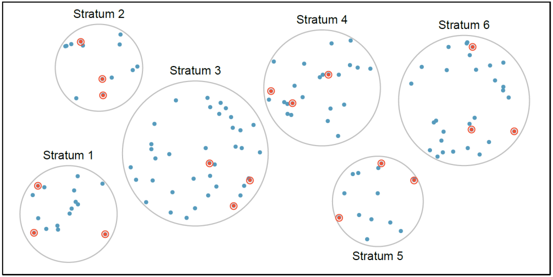

- Disadvantages:
  - Requires more administrative labor in implementation
  - Statistical analysis is more complex
  - Cannot always be implemented

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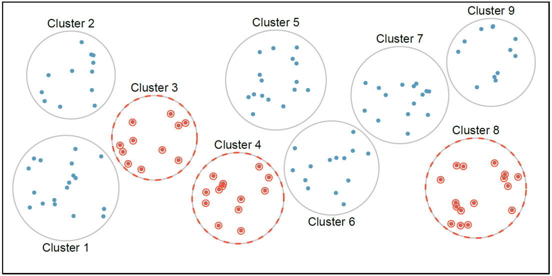

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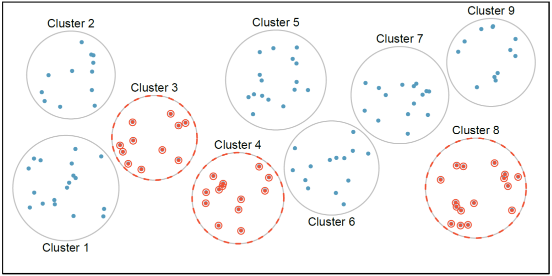

- Advantages:
  - Can be used when it is difficult or impossible to create complete list of population
  - Useful when population is naturally concentrated in heterogeneous groups
  - Often more cost/time effective per sample size than alternatives

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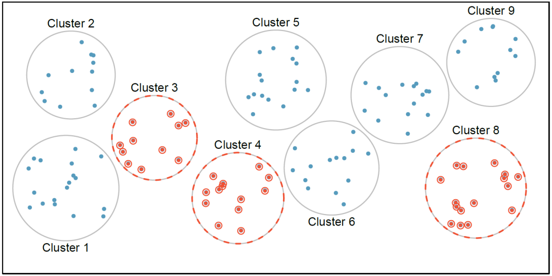

- Disadvantages:
  - Is less precise than simple or stratified sampling
  - Statistical analysis is more complex
  - Cannot always be implemented

Section 2

Assessing Relationships Between Variables

Explanatory and Response Variables

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  1. **Observational studies**, where researchers do not interfere with how data arises.
  2. **Random experiment**, where individuals are assigned to group and a random treatment is assigned.
- Usually, only random experiments may allow researchers to conclude a causal link between explanatory and response variables.

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- If variables X and Y are correlated, there are 4 possible explanations:
  1. Changes in X cause changes in Y
  2. Changes in Y cause changes in X
  3. Changes in a third variable Z cause changes in *both* X and Y
  4. The observed correlation in X and Y is due to chance.

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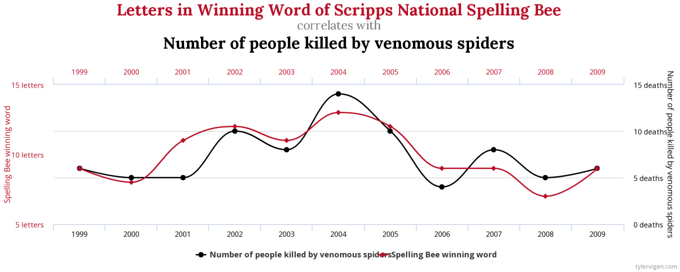

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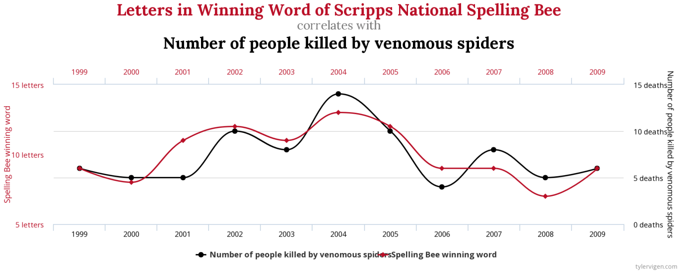

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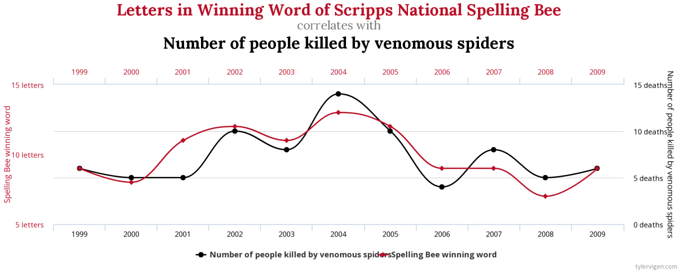

- How do we rule out spurious correlations?
  - Gather more data. If the correlation occurred by chance just due to sampling, the relationship is unlikely to be repeated in an independent sample.

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  - Create models that include possible confounding variables
  - Design experiments that control for possible confounding variables

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- How do you rule out reverse causation?
  - Investigate the temporal order of events.
  - Design an experiment where theorized cause is administered as treatment.

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  In a 1958 article in Nature, (in)famous statistician R. A. Fisher presented a case that smoking ***does not*** *cause lung cancer, arguing that:*

  "If, for example, it were possible to infer that smoking cigarettes is a cause of this disease, it would equally be possible to infer on exactly similar grounds that inhaling cigarette smoke was a practice of considerable prophylactic value in preventing the disease, for the practice of inhaling is rarer among patients with cancer of the lung than with others."

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- Fisher did not disagree with the statistical analysis that smoking and cancer were highly correlated.
- So how do we know that Fisher was wrong? (He was)

Hill's Criteria for Causation

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  1. **Strength** Causal events should have strong correlation.
  2. **Consistency** Different studies should show similar effect.
  3. **Specificity** A single cause should lead to a single effect.
  4. **Temporality** The effect should occur before the cause.
  5. **Gradient** Greater exposure to cause should correspond to greater size of effect
  6. **Plausibility** A plausible mechanism should exist linking cause and effect.
  7. **Coherence** A cause and effect relationship should not conflict with other known relationships
  8. **Experimental Evidence** A cause and effect relationship should be evident in randomized experiment.
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Hill's Criteria for Causation

- In 1965, Austin Bradford Hill outlined 9 criteria for inferring causality:
  1. **Strength** Causal events should have strong correlation.
  2. **Consistency** Different studies should show similar effect.
  3. **Specificity** A single cause should lead to a single effect.
  4. **Temporality** The effect should occur before the cause.
  5. **Gradient** Greater exposure to cause should correspond to greater size of effect
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- Are these *absolutely* necessary to prove causality?
  - No. But they are good guidelines.

Section 3

Experiments and Observational Studies

Principles of Experiment Design

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4. **Blocking**: If variables are suspected to affect response variable, subjects are first grouped into blocks based on these variables.

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- It is suspected that nitrate supplements may effect professional and amateur athletes differently, and so subjects are blocked for pro status:

1. Divide SRS into pro and amateur blocks.
2. Randomly assign pro athletes to treatment and control groups.
3. Similarly, randomly assign amateur athletes to treatment and control groups.
4. Ensure pro/amateur status is equally represented in treatment and control groups.

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  - To study whether high unemployment rate leads to presidential losses for the incumbent party, we cannot create new presidential races.
- Experiments of appropriate size may be prohibitively expensive
  - Experiments of small or moderate size often include uncontrolled confounding variables

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ideal experiment	Random assignment	No random assignment	most observational studies
Random sampling	causal and generalizable	not causal, but generalizable	Generalizability
No random sampling	causal, but not generalizable	neither causal nor generalizable	No generalizability
most experiments	Causation	Association	bad observational studies