Chapter 9

Producing Data: Experiments
How Data are Obtained

◆ Observational Study
  – Observes individuals and measures variables of interest but does not attempt to influence the responses
  – Describes some group or situation
  – Sample surveys are observational studies

◆ Experiment
  – Deliberately imposes some treatment on individuals in order to observe their responses
  – Studies whether the treatment causes change in the response.
Experiment versus Observational Study

Both typically have the goal of detecting a relationship between the explanatory and response variables.

◆ Experiment
  – create differences in the explanatory variable and examine any resulting changes in the response variable (cause-and-effect conclusion)

◆ Observational Study
  – observe differences in the explanatory variable and notice any related differences in the response variable (association between variables)
Why Not Always Use an Experiment?

- Sometimes it is unethical or impossible to assign people to receive a specific treatment.
- Certain explanatory variables, such as handedness or gender, are inherent traits and cannot be randomly assigned.
Confounding

The problem:

- in addition to the explanatory variable of interest, there may be other variables (explanatory or lurking) that make the groups being studied different from each other
- the impact of these variables cannot be separated from the impact of the explanatory variable on the response
Confounding

The solution:
- **Experiment**: randomize experimental units to receive different treatments (possible confounding variables should “even out” across groups)
- **Observational Study**: measure potential confounding variables and determine if they have an impact on the response (may then *adjust* for these variables in the statistical analysis)
Question

A study of cell phones and the risk of brain cancer looked at a group of 469 people who have brain cancer. The investigators matched each cancer patient with a person of the same sex, age, and race who did not have brain cancer, then asked about use of cell phones. Result: “Our data suggest that use of handheld cellular telephones is not associated with risk of brain cancer.” Is this an observational study or an experiment? Why? What are the explanatory and response variables?
Question

An educational software company wants to compare the effectiveness of its computer animation for teaching about supply and demand curves with that of a textbook presentation. The company tests the economic knowledge of a number of first-year college students, then divides them into two groups. One group uses the animation, and the other studies the text. The company retests all the students and compares the increase in economic understanding in the two groups. Is this an experiment? Why or why not? What are the explanatory and response variables?
Experiments: Vocabulary

- **Subjects**
  - individuals studied in an experiment

- **Factors**
  - the explanatory variables in an experiment

- **Treatment**
  - any specific experimental condition applied to the subjects; if there are several factors, a treatment is a combination of specific values of each factor
Case Study

Effects of TV Advertising

Objective:
To determine the effects of repeated exposure to an advertising message (may depend on length and how often repeated)
Case Study

- **subjects**: a certain number of undergraduate students
- all subjects viewed a 40-minute television program that included ads for a digital camera
Case Study

- some subjects saw a 30-second commercial; others saw a 90-second version
- same commercial was shown either 1, 3, or 5 times during the program
- there were two factors: length of the commercial (2 values), and number of repetitions (3 values)
Case Study

- the 6 combinations of one value of each factor form six treatments

<table>
<thead>
<tr>
<th>Factor A: Length</th>
<th>1 time</th>
<th>3 times</th>
<th>5 times</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 seconds</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>90 seconds</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

subjects assigned to Treatment 3 see a 30-second ad five times during the program.
Case Study

- after viewing, all subjects answered questions about: recall of the ad, their attitude toward the camera, and their intention to purchase it – these were the response variables.
Comparative Experiments

- Experiments should *compare* treatments rather than attempt to assess the effect of a single treatment in isolation.

In other words, always use control group(s).
Randomized Comparative Experiments

- Not only do we want to compare more than one treatment at a time, but we also want to make sure that the comparisons are fair: *randomly* assign the treatments
  - each treatment should be applied to similar groups or individuals (removes lurking vbls)
  - assignment of treatments should not depend on any characteristic of the subjects or on the judgment of the experimenter
Experiments: Basic Principles

- **Randomization**
  - to balance out lurking variables across treatments

- **Placebo**
  - to control for the power of suggestion

- **Control group**
  - to understand changes not related to the treatment of interest
Double-Blind Experiments

- If an experiment is conducted in such a way that neither the subjects nor the investigators working with them know which treatment each subject is receiving, then the experiment is double-blinded
  - to control response bias (from respondent or experimenter)
Completely Randomized Design

- In a *completely randomized design*, all the subjects are allocated at random among all of the treatments.
  - can compare any number of treatments (from any number of factors)
Statistical Significance

- If an experiment (or other study) finds a difference in two (or more) groups, is this difference really important?
- If the observed difference is larger than what would be expected just by chance, then it is labeled **statistically significant**.
- Rather than relying solely on the label of statistical significance, also look at the actual results to determine if they are practically important.
Example: Do antioxidants prevent cancer?

People who eat lots of fruits and vegetables have lower rates of colon cancer than those who eat little of these foods. Fruits and vegetables are rich in “antioxidants” such as vitamins A, C, and E. Will taking antioxidants help prevent colon cancer? A medical experiment studied this question with 864 people who were at risk of colon cancer. The subjects were divided into four groups: daily beta-carotene, daily vitamins C and E, all three vitamins every day, or daily placebo. After four years, the researchers were surprised to find no significant difference in colon cancer among the groups.
Example: Do antioxidants prevent cancer?

(a) What are the explanatory and response variables in this experiment?
(b) Outline the design of the experiment. Use your judgment in choosing the group sizes.
(c) The study was double-blind. What does this mean?
(d) What does “no significant difference” mean in describing the outcome of the study?
(e) Suggest some lurking variables that could explain why people who eat lots of fruits and vegetables have lower rates of colon cancer. The experiment suggests that these variables, rather than the antioxidants, may be responsible for the observed benefits of fruits and vegetables.
Pairing or Blocking

- Pairing or blocking
  - to reduce the effect of variation among the subjects
  - different from a completely randomized design, where all subjects are allocated at random among all treatments
Matched Pairs Design

- Compares two treatments

- Technique:
  - choose pairs of subjects that are as closely matched as possible
  - randomly assign one treatment to one subject and the second treatment to the other subject

- Sometimes a “pair” could be a single subject receiving both treatments
  - randomize the order of the treatments for each subject
Block Design

- A **block** is a group of individuals that are known before the experiment to be similar in some way that is expected to affect the response to the treatments.

- In a **block design**, the random assignment of individuals to treatments is carried out separately within each block.
  - a single subject could serve as a block if the subject receives each of the treatments (in random order)
  - matched pairs designs are block designs
Compare effectiveness of three television advertisements for the same product, knowing that men and women respond differently to advertising.

- Three treatments: ads (need three groups)
- Two blocks: men and women
Pairing or Blocking: Example from Text

Men, Women, and Advertising

Assignment to blocks is not random

Subjects

Women

Random assignment

Group 1 → Ad 1
Group 2 → Ad 2
Group 3 → Ad 3

Compare reaction

Men

Random assignment

Group 1 → Ad 1
Group 2 → Ad 2
Group 3 → Ad 3

Compare reaction
Athletes taking oxygen

We often see players on the sidelines of a football game inhaling oxygen. Their coaches think this will speed their recovery. We might measure recovery from intense exertion as follows: Have a football player run 100 yards three times in quick succession. Then allow three minutes to rest before running 100 yards again. Time the final run. You plan an experiment using 25 football players as subjects. Discuss the design of such an experiment to investigate the effect of inhaling oxygen during the rest period.