Chapter 3 Producing Data

3.1 Introduction

How to get data?

▪**<u>Available data</u>**: from the library and internet

produced in the past for some other purpose but may help answer a present question.

▪**<u>Produce data</u>** : there are two main methods:

- **Observational study**

  Observes individuals and measures variables of interest but does not attempt to influence the responses. The commonest and the most important method is:

  Sampling: collects information about a population by selecting and measuring a sample from the population.

- **Experiment**

  Deliberately imposes some treatment on individuals in order to observe their responses.

Example 1 One 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?

Example 2 Many studies have found that people who drink alcohol in moderation have lower risk of heart attacks than either nondrinkers or heavy drinkers. Does alcohol consumption also improve survival after a heart attack? One study followed 1913 people who were hospitalized after severe heart attacks. In the year before their heart attack, 47% of these people did not drink, 36% drank moderately, and 17% drank heavily. After four years, fewer of the moderate drinkers had died. Is this an observational study or an experiment? Why? What are the explanatory and response variables?

3.2 Design of Experiments

1. Basic Terminologies

Experimental units: the individuals on which the experiment is done. When the units are human beings, they are called **subjects**.

Treatment: a specific experimental condition applied to the units.

Factors: the explanatory variables in an experiment.

Levels of a factor: a specific value of the factor. Each treatment is formed by combining a level of each of the factors.

Example 3 Does regularly taking aspirin help protect people against heart attacks? The Physicians' Health Study (PHS) was a medical experiment that helped answer this question. In fact, the PHS looked at the effects of two drugs: aspirin and beta carotene. The body converts beta carotene into vitamin A, which may help prevent some forms of cancer. 21,996 male physicians were involved in this study. One-fourth of them were assigned to each of the four treatments. On odd-numbered days, the subjects took a white tablet that contained either aspirin or a placebo, a dummy pill that looked and tasted like the aspirin but had no active ingredient. On even-numbered days, they took a red capsule containing either beta carotene or a placebo. The study looked for heart attacks, several kinds of cancer, and other medical outcomes.

(**Example 3 continued**) Results: After several years, 239 of the placebo group but only 139 of the aspirin group had suffered heart attacks. This difference is large enough to give good evidence that taking aspirin does reduce heart attacks. It did not appear that beta carotene had any effect.

Example 4 A manufacturer of food products uses package liners that are sealed at the top by applying heated jaws after the package is filled. The customer peels the sealed pieces apart to open the package. What effect does the temperature of the jaws have on the force required to peel the liner? To answer this question, the engineers prepare 20 pairs of pieces of package liner. They seal five pairs at each of 250º F, 275 º F, 300 º F, and 325 º F. Then they measured the peel strength of each seal.

For the above two examples, **what are the experimental units, factors, levels, treatments, response variables?**

<u>Note</u>: **advantages of experiments over observational studies:**

- In principle, experiments can give good evidence for causation.
- Experiments allow us to study the specific factors we are interested in, while controlling the effects of lurking variables.

2. Principles of Experimental Design

a) Control

A very simple design is one with only a single treatment, which is applied to all of the experimental units. Treatment Observe response

Example 5 "Gastric freezing" is a clever treatment for ulcers in the upper intestine. The patient swallows a deflated balloon with tubes attached, then a refrigerated liquid is pumped through the balloon for an hour. The idea is that cooling the stomach will reduce its production of acid and so relieve ulcers. An experiment reported in the Journal of the American Medical Association showed that gastric freezing did reduce acid production and relieve ulcer pain. Actually, this experiment was poorly designed. The patients' response may have been due to the placebo effect. A later experiment divided ulcer patients into two groups. One group was treated by gastric freezing as before. The other group received a placebo treatment in which the liquid in the balloon was at body temperature rather than freezing. The results: 34% of the 82 patients in the treatment group improved, but so did 38% of the 78 patients in the placebo group.

- **Placebo effect**: the response to a dummy treatment.
- **Bias**: the design of a study is biased if it systematically favors certain outcomes.
- **Control group**: the group of subjects (patients) who receive a sham treatment.

b) Randomization

How can we assign experimental units to treatments in a way that is fair to all of the treatments? The statistician's remedy is to rely on chance to make an assignment that does not depend on any characteristic of experimental units and that does not depend on the judgment of experimenter in anyway.

Randomization: the use of chance to assign experimental units into groups (each treatment).

Example 6 A food company assesses the nutritional quality of a new "instant breakfast" product by feeding it to newly weaned male white rats and measuring their weight gain over a 28-day period. A control group of rats receives a standard diet for comparison. The researchers use 30 rats. Factor? Treatment? …

c) Replication

For a randomized comparative experiment (single factor), there are **two sources of response difference** between two groups (treatment group and control group):

- The treatment does have effect, so it makes the difference.
- The variation due to the play of chance in the randomized assigning of the units.

The strategy to reduce chance variation: use enough experimental units (**replicates**) for each treatment.

Statistical significance: An observed effect so large that is would rarely occur by chance.

Summary of **Principles of Experimental Design**:

- **Control**: control the effects of lurking variables on the response, most simply by comparing two or more treatments.
- **Randomize**: use impersonal chance to assign experimental units to treatments.
- **Replication**: replicate each treatment on many units to reduce chance variation in the results.

3. How to Randomize

Two ways to do randomization: by software or a table of random digits (Table B).

Random Digits: A table of random digits is a list of the digits 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 that has the following properties:

i) The digit in any position in the list has the same chance of being any one of 0-9.

ii) The digits in different positions are independent in the sense that the value of one has no influence on the value of any other.

Consequences of the previous basic properties i) and ii):

- Any pair of random digits has the same chance of being any of the 100 possible pairs: 00, 01, 02, …, 98, 99.
- Any triple of random digits has the same chance of being any of the 1000 possible triples: 000, 001, 002, …, 998, 999.
- … And so on for groups of four or more random digits.

Example 7 (example 6 continued) using Table B to randomly assign rats to treatments.

Two steps of randomization:

- Assign labels to the experimental units.
- Use Table B to select labels at random.

Basic rules of randomization:

- All labels of experimental units must be the same length.
- Using the shortest possible labels----one digit for 9 or fewer units, two digits for 10 to 100 units, and so on.
- You may read digits from Table B in any order. To be simple, we will use reading along rows for this course.

Completely randomized design: all experimental units are allocated at random among all treatments.

Example 8 Doctors identify "chronic tension-type headaches" as headaches that occur almost daily for at least six months. Can antidepressant medications or stress management training reduce the number and severity of these headaches? Are both together more effective than either alone? Investigators compared four treatments: antidepressant alone, placebo alone, antidepressant plus stress management, and placebo plus stress management. Outline the design of the experiment. The headaches sufferers named below have agreed to participate in the study. Use Table B at line 130 to randomly assign the subjects to the treatments.

Acosta	Duncan	Han	Liang	Padilla	Valasco
Asihiro	Durr	Howard	Maldonado	Plochman	Vaughn
Bennett	Edwards	Hruska	Marsden	Rosen	Wei
Bikalis	Farouk	Imrani	Montoya	Solomon	Wilder
Chen	Fleming	James	0'Brian	Trujillo	Willis
Clemente	George	Kaplan	Ogle	Tullock	Zhang

4. Cautions about experimentation

Double-blind: neither the subjects nor the experimenters know which treatment any subject would receive in an experiment.

- Double-blind could reduce bias.

Lack of realism: the most serious potential weakness of experiments.

5. Block designs

A **block** is a group of experimental units or subjects that are known before the experiment to be similar in some way that is expected to affect the response to the treatment.

A **block design** is an experimental design that random assignment of units to treatments is carried out separately within each block.

Matched pairs design --- a special block design with only two treatments.

Example 9 Are cereal leaf beetles more strongly attracted by the color yellow or by the color green? Agriculture researchers want to know, because they detect the presence of the pests in farm fields by mounting sticky boards to trap insects that land on them. The board color should attract beetles as strongly as possible. We must design an experiment to compare yellow and green by mounting boards on poles in a large filed of oats.

Example 9 (continued)

The experimental units are locations within the field far enough apart to represent independent observations. We erect a pole at each location to hold the boards. The locations vary widely in the number of beetles present. For example, the alfalfa that borders the oats on one side is a natural host of the beetles, so locations near the alfalfa will have extra beetles. This variation among experimental units can hide the systematic effect of the board color.

A matched pair design: we mount boards of both colors on each pole. The observations (numbers of beetles trapped) are matched in pairs from the same poles. We compare the number of trapped beetles on a yellow board with the number trapped by the green board on the same pole. Because the boards are mounted one above the other, we select the color of the top board at random. Just toss a coin for each board – if the coin falls heads, the yellow boards in mounted above the green board.

Block design can have blocks of any size.

Example 10 The progress of a type of cancer differs in women and men. A clinical experiment to compare three therapies for this cancer therefore treats gender as a blocking variable. Two separate randomizations are done, one assigning the female subjects to the treatments and the other assigning the male subjects. Note that there is no randomization involved in making up the blocks.

Example 11 Twenty overweight females have agreed to participate in a study of the effectiveness of four reducing regimens, A, B, C, and D. The researcher first calculates how overweight each subject is by comparing the subject's actual weight with her "ideal" weight. The subjects and their excess weights in pounds are

Birnbaum	35	Festinger	24	Loren	32	Obrach	30	Stall	33
Brown	34	Hernandez	25	Mann	28	Rodriguez	30	Tran	35
Brunk	30	Jackson	33	Moses	25	Santiago	27	Wilansky	42
Dixon	34	Kendall	28	Nevesky	39	Smith	29	Williams	22

The response variable is the weight lost after eight weeks of treatment. Because the initial amount overweight will influence the response variable, a block design is appropriate.

(a) Arrange the subjects in order of increasing excess weight. Form five blocks by grouping the four least overweight, then the next four, and so on.

(b) Use Table B to do the required random assignment of subjects to the four reducing regimens separately within each block.