Exercise

DESIGNING EXPERIMENTS

Adapted from Allen Roth's "Designing Experiments" in *Workshop Statistics*

Designing a good experiment is a complicated task. There are many potential problems that could lead a researcher to erroneous conclusions. In critically reviewing studies, it is important to understand some basic principles of experimental design. This exercise will help you understand some of the most important concepts, which are highlighted in bold text. We will be using these terms frequently throughout the semester so be sure to review them.

(Note: Experiments in the physical sciences have principles and complications other than those discussed here. Major difficulties in those fields often involve the choice or design of appropriate equipment.)

1) Suppose that you want to study whether an SAT coaching program actually helps students to score higher on the SAT's, so you gather data on a random sample of students who have attended the program. Suppose you find that 95% of the sample scored higher on the SAT's after attending the program than before attending. Moreover, suppose you calculate that the mean of the improvements in SAT scores was a substantial 120 points.

   a) Explain why you cannot be certain that the SAT coaching *caused* these students to improve on the test.
   b) Suggest some other explanations for their improvement.

   The SAT study illustrates the need for a **controlled experiment** in order to allow one to draw meaningful conclusions about one variable *causing* another to respond in a certain way. The fundamental principle of experimental design is **control**. An experimenter tries to *control* for possible effects of other variables so that differences in one variable of interest can be attributed directly to the other variable of interest.

   The counterpart to a controlled experiment is an **observational study** in which one passively records information about test subjects without actively intervening in the process. It is difficult to draw conclusions about cause from an observational study since the possible effects of other variables – called **confounding variables –** are not controlled.

   A good test for determining whether a study is experimental or observational is to ask whether the subject's actions were different than they would have been had the study not have taken place. That is, were the subjects asked, told or made to do anything that they wouldn't have done otherwise? If so, the study is experimental. If not, it is observational.

   c) Is the SAT study described above an experiment or an observational study? Explain.

One principle experimenters use to establish control is **comparison**. One important flaw in the SAT study is that it lacks a **control group** with which to compare the results of the group that attended the program.

2) Suppose that researchers want to study whether pets provide therapeutic benefits for their owners. Specifically, they decide to investigate whether heart attack patients who own a pet tend to recover more often than those who do not. They randomly select a sample of heart attack patients from a large hospital, determine which have pets, and then check up on them after one year. The researchers compare the proportion of their subjects who have survived and find that 92% of those with pets are still alive while only 64% of those without pets have survived.

   a) Is this study observational or experimental?
   b) Is there a comparison group?
   c) The researchers claim that this experiment strongly suggests that pets play a significant role in the survival of heart attack patients. Are there any other plausible explanations for the results?

This pet therapy study shows that analyzing a comparison group does not guarantee that one will be able to isolate a single **causal mechanism** which explains the observed results. A critical flaw in this study is that the subjects were allowed to decide for themselves whether to keep a pet. When subjects choose whether or not to get the **treatment**, it is called a **self-selected sample**.

Experimenters should try to assign subjects to groups in such a way that any confounding variables tend to be evenly distributed between the groups. A principle of control which provides a simple but usually effective way to achieve this is **randomization**. By randomly assigning subjects to different treatment groups, experimenters increase the probability that confounding variables will balance out between the groups.

3) Suppose that a study is conducted to determine whether taking regular doses of vitamin C increases one's resistance to catching the common cold. The researchers form two groups – subjects in one group are given regular doses of vitamin C while those in the other group are not. Subjects are assigned to the treatment group (get the vitamin) based on the flip of a coin. The health of the subjects is monitored over the winter and the researchers find that 56% of subjects in the treatment group caught at least one cold while 82% of the other subjects caught at least one cold.
   a) Is the study observational or experimental?
   b) Is the principle of comparison applied?
   c) Is the principle of control applied?
   d) Is the study randomized?
   e) What are some confounding variables that could have affected the study? Will the study design effectively reduce their impact?

The design of this study could be improved in one respect. There is a subtle variable that randomization cannot balance out because it is a direct result of being assigned to the treatment group. The very fact that subjects in the vitamin C group realize that they are being given a treatment that researchers suspect may improve their health may *cause* them to remain healthier. This phenomenon has been detected in many human studies and is known as the **placebo effect**.

Experimenters control for this confounding variable by giving the control subjects a fake treatment known as a **placebo**. This method of controlling for the placebo effect is called **blindness** (since the subjects cannot "see" whether they are receiving the real treatment. In some experiments, the researchers must make observations that have a degree of subjectivity. If the researchers know which subjects are getting the treatment this knowledge may subconsciously (or consciously!) affect their judgment. In these cases it is important that whoever does the observing or measuring of outcomes does not know which subjects were in the treatment group. This principle is called **double-blindness**.

4) With members of your group, design a good experiment to determine whether water fluoridation is effective in reducing tooth decay among college students. Be sure to include a description of your sample selection (who your subjects will be), your experimental procedure, and how results will be determined.