Section 4.2 - Experiments

There are two different ways to produce/gather data in order to answer specific questions:

1. Observational Studies
   *Observes individuals* and measures variables of interest but does not attempt to influence the responses.

   **Retrospective vs. Prospective**

   ![Diagram showing past data vs. observe future]

2. Experiments
   Deliberately *impose some treatment* on individuals in order to observe their responses.

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**Determine if the below situations are observational studies or experiments—and why.**

1. Over a 4-month period, among 30 people with bipolar disorder, patients who were given a high dose (10g/day) of omega-3 fats from fish oil improved more than those given a placebo.

   *Experiment - treatment (omega-3 or not) was imposed*

2. The leg muscles of men aged 60 to 75 were 50% to 80% stronger after they participated in a 16-week, high-intensity resistance-training program twice a week.

   *Observational - part. chose to do the training, no treatment was imposed*

3. Among a group of disabled women aged 65 and older who were tracked for several years, those who had a vitamin B12 deficiency were twice as likely to suffer severe depression as those who did not.

   *Observational - no treatment was imposed — just observed health conditions*
4. In 2001 a report in the *Journal of the American Cancer Institute* indicated that women who work at nights have a 60% greater risk of developing breast cancer. Researchers based these findings on the work histories of 763 women with breast cancer and 741 women without the disease.

   observational – no treatment was imposed
   (not forced to work @ night)

5. In 2002, the journal *Science* reported that a study of women in Finland indicated that having sons shortened the lifespan of mothers by about 34 weeks per son, but that daughters helped to lengthen the mothers’ lives. The data came from church records from the period 1640 to 1870.

   observational – no treatment imposed
   (can’t dictate the sex of child)

6. Some gardeners prefer to use non-chemical methods to control insect pests in their gardens. Researchers have designed two kinds of traps, and want to know which design will be more effective. They randomly choose 10 locations in a large garden and place one of each kind of trap at each location. After a week, they count the number of bugs in each trap.

   experiment – treatment (kind of trap) was imposed

In any study (observational or experiment) we have at least two variables. These are the *response* and the *explanatory* variables.

**Response Variable(s)** - measures the outcome of the study - we measure these

**Explanatory Variable(s)** - may explain or influence changes in another variable
For each of the previous 6 examples, identify the explanatory and response variables.

1. RV: bipolar improvement  EV: omega-3 consumption
2. RV: leg strength       EV: training program type
3. RV: mental health     EV: B12 levels
4. RV: presence of breast-cancer  EV: work history
5. RV: lifespan          EV: sex of child
6. RV: # of insects caught  EV: trap design

Observational studies of the effect of one variable on another often fail because of confounding between the explanatory variable and one or more lurking variables.

**Definition:**

A lurking variable is a variable that is not among the explanatory or response variables in a study but that may influence the response variable.

Confounding occurs when two variables are associated in such a way that their effects on a response variable cannot be distinguished from each other.
Lurking Variables:
Influences change in the two variables of interest creating the impression of an association between them. Often with observational studies.

Confounding Variables:
Often with experiments - you can't tell which variable had an affect on the response. For example: suppose you are interested in whether or not fertilizer helps your lawn grow better. You spread fertilizer on half of your lawn which just so happens to be the sunny half. You can't determine if it was the sun or the fertilizer that caused a change in how the lawn looks compared to the non-fertilizer/non-sun side.

Subjects or participants - the individuals studied in the experiment (usually only called this when they are people - otherwise an experimental unit)

Factors - the explanatory variables in an experiment

Levels - which specific values that the experimenter chooses to test for a given factor

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
**EXAMPLE:** A study published in the New England Journal of Medicine (March 11, 2010) compared two medicines to treat head lice: an oral medication called *Ivermectin* and a topical lotion containing malathion. Researchers studied 812 people in 376 households in seven areas around the world. Of the 185 randomly assigned to *Ivermectin*, 171 were free from head lice after two weeks compared to only 151 of the 191 households randomly assigned to malathion. Identify the experimental units, explanatory and response variables, and the treatments in this experiment.

**experimental units:** households

**E.V.:** head lice treatment

**R.V.:** presence of head lice

**treatments:** *Ivermectin*, malathion

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**EXAMPLE:** Does adding fertilizer affect the productivity of tomato plants? How about the amount of water given to the plants? To answer these questions, a gardener plants 24 similar tomato plants in identical pots in his greenhouse. He will add fertilizer to the soil in half of the pots. Also, he will water 8 of the plants with 0.5 gallons of water per day, 8 of the plants with 1 gallon of water per day and the remaining 8 plants with 1.5 gallons of water per day. At the end of three months he will record the total weight of tomatoes produced on each plant. Identify the explanatory and response variables, experimental units, and list all the treatments.

**exp. units:** tomato plants

**E.V.:** amt. of water, fertilizer use

**R.V.:** total weight of tomatoes

**treatments:**

- **levels**
  - *no fert. + 0.5 gal*
  - *fert. + 0.5 gal*
  - *no fert. + 1 gal*
  - *fert. + 1 gal*
  - *no fert. + 1.5 gal*
  - *fert. + 1.5 gal*

- **levels**
  - *no fert.*
  - *fert.*
  - *no fert.*
  - *fert.*

- **levels**
  - *no fert.*
  - *fert.*
  - *no fert.*
  - *fert.*
**How to Experiment Well:**
*The Randomized Comparative Experiment*

The remedy for confounding is to perform a *comparative experiment* in which some units receive one treatment and similar units receive another. Most well designed experiments compare two or more treatments.

Comparison alone isn’t enough, if the treatments are given to groups that differ greatly, *bias* will result. The solution to the problem of bias is *random assignment.*

**Definition:**
In an experiment, *random assignment* means that experimental units are assigned to treatments at random, that is, using some sort of chance process.
A chemical engineer is designing the production process for a new product. The chemical reaction that produces the product may have higher or lower yield depending on the temperature and the stirring rate in the vessel in which the reaction takes place. The engineer decides to investigate the effects of combinations of two temperatures (50°C and 60°C) and three stirring rates (60 rpm, 90 rpm, and 120 rpm) on the yield of the process. She will process twelve batches of the product at each combination of temperature and stirring rate.

(a) What are the experimental units and the response variable in this experiment?

<table>
<thead>
<tr>
<th>batches of new product</th>
<th>RV: yield</th>
</tr>
</thead>
</table>

(b) How many factors are there? What are the levels?

<table>
<thead>
<tr>
<th>2</th>
<th>50°C, 60°C</th>
<th>60 rpm, 90 rpm, 120 rpm</th>
</tr>
</thead>
</table>

(c) What are the treatments?

<table>
<thead>
<tr>
<th>50°C, 60 rpm</th>
<th>60°C, 90 rpm</th>
<th>60°C, 120 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>50°C, 90 rpm</td>
<td>50°C, 120 rpm</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>60°C, 60 rpm</td>
<td>60°C, 90 rpm</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>60°C, 120 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
</tr>
</tbody>
</table>

(d) How many individuals are required for the experiment?

\[ 6 \times 12 = 72 \]

Outline the design of the chemical reaction experiment.
### Four Principles of Experimental Design

1. **Control**  
   - sources of variation - experimental factors and other sources (not necessarily a control group - use comparison)

2. **Randomize**  
   - helps to equalize the effects of unknown or uncontrollable sources among all experimental units  
   - if you do not randomize you CANNOT use statistical techniques to draw conclusions

3. **Replicate**  
   - two kinds  
     - use multiple subjects in order to determine the variation among the responses  
     - experimental units need to represent the population so that the experiment could be replicated with other representative samples

4. **Block (not required)**  
   - use when attributes of the experimental units that are NOT being studied might affect the outcomes  
   - similar to strata when sampling

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**Comparative experiments** - reduce bias by controlling the effects of lurking variables by comparing the effects of more than one treatment rather than assessing a single treatment in isolation

**Control Group** - in a comparative experiment the group that is NOT receiving the experimental treatment

**Completely randomized design** - a randomized comparative experiment that assigns subjects or individuals to ALL treatment groups randomly (SRS)
Placebos and the Placebo Effect

- "treatment" that is designed to have no effect (sugar pill, etc)
- the act of receiving a treatment can affect the response

placebo - pain dropped 2 pts
med - pain dropped 5 pts

**EXAMPLE:** Eye cataracts are responsible for over 40% of blindness around the world. Can drinking tea regularly slow the growth of cataracts? We can't experiment on people so we use rats as subjects. Researchers injected 18 young rats with a substance that causes cataracts. One group of the rats also received black tea extract; a second group received green tea extract; and a third got a placebo, a substance with no effect on the body. The response variable was the growth of cataracts over the next six weeks. They found that both tea extracts did slow cataract growth. Outline the design of this completely randomized experiment. Use the table of random digits, starting at line 124, to assign rats to treatments.

- label rats 00-17
- reading 2 digits @ a time, skip repeats +
  #s > 17.
- First 6 to green tea, next 6 to black tea, remaining 6 to placebo
Randomized Block Designs - subjects are placed into blocks based on some similarity that is known prior to the experiment and is expected to affect the response to the treatments. Within each block the subjects are randomly assigned to treatments.

EXAMPLE:
Anne is an avid baker who would like to compare two different chocolate chip cookie recipes (A and B). So, she recruits 10 volunteer taste testers (not a hard task!) to rate each type of cookie on a scale from 1 (very bad) to 5 (very good). She will make 10 of each type of cookie, for a total of 20. Each cookie tray will only hold 10 cookies, so she will use two trays and bake them at the same time in the same oven, one sheet on the lower rack and one sheet on the upper rack. As an avid baker, Anne knows that cookies often bake differently depending on which rack they are on. Outline the design of a randomized blocked experiment.

[Diagram of cookie baking process]

20 cookies → upper 10 cookies → measure → compare fastness
20 cookies → lower 10 cookies → A (5) → B (5)
Blinding

When using blinding in an experiment we have to keep in mind the two groups of people who interact regularly throughout the experiment.

(1) Subjects - those receiving the treatment
(2) Those administering the treatment and measuring the response

Single-Blind Experiments - When one and only one of the groups above know which treatment each subject is receiving.

Double-Blind Experiments - Neither the subjects nor the people who interact with them know which treatment each subject is receiving.

Matched Pairs design -
- A completely randomized design that compares two treatments
- Subjects are grouped in pairs that are as closely matched as possible and receive different treatments which are assigned randomly within the pair.
- Sometimes these pairs are actually a single subject who receives both treatments and therefore serve as their own control. In this case the order the treatments are received is randomized.
- The effect of the treatments is then compared within each pair.

FOR EXAMPLE: the standard Coke vs. Pepsi taste test

Can you think of another example?

complete a task w/musica w/out

Twin studies
Which of the following statements are true?

I. A completely randomized design offers no control for lurking variables.

II. A randomized block design controls for the placebo effect.

III. In a matched pairs design, participants within each pair receive the same treatment.

(A) I only
(B) II only
(C) III only
(D) All of the above.
(E) None of the above.

The idea of a randomized comparative experiment is to give good evidence that differences in the treatments actually cause the differences we see in the response.

An observed effect that is SO large that it would rarely occur by chance is called statistically significant.

**Statistically significant association (from a well-designed experiment) DOES imply causation**