**Experiment Design Notes**

We will discuss how to design an experiment for the express purpose of investigating the __________ of different ________________ on a ____________________.

**Motivating example: Group 6 experiment from Fall 2007—first paragraph of their report**

The purpose of this experiment is to determine the effect of the number of Mentos and the initial volume of Diet Coke on the percent of soda volume lost. A reaction occurs when Mentos are added to a bottle of diet coke. Consequently, the coke erupts out of the top of the bottle resulting in volume loss. The idea of the experiment is to apply a varying amount of Mentos to a varying initial amount of soda and record the volume lost. In our experiment, we include three different sizes of Diet Coke bottles: 20 ounces, 1 liter, and 2 liters. Each experimental unit will be given either four Mentos or eight Mentos. To measure the response variable, the remaining liquid is poured into a measuring utensil and volume is recorded. This volume is subtracted from the initial volume, which represents the volume lost.

The data:

<table>
<thead>
<tr>
<th>Volume</th>
<th>Intial volume</th>
<th>% volume lost Mentos</th>
</tr>
</thead>
<tbody>
<tr>
<td>0591 mL</td>
<td>0.565</td>
<td>0.57</td>
</tr>
<tr>
<td>0591 mL</td>
<td>0.526</td>
<td>0.577</td>
</tr>
<tr>
<td>0591 mL</td>
<td>0.54</td>
<td>0.558</td>
</tr>
<tr>
<td>1000 mL</td>
<td>0.561</td>
<td>0.587</td>
</tr>
<tr>
<td>1000 mL</td>
<td>0.532</td>
<td>0.539</td>
</tr>
<tr>
<td>1000 mL</td>
<td>0.519</td>
<td>0.559</td>
</tr>
<tr>
<td>2000 mL</td>
<td>0.475</td>
<td>0.537</td>
</tr>
<tr>
<td>2000 mL</td>
<td>0.565</td>
<td>0.615</td>
</tr>
<tr>
<td>2000 mL</td>
<td>0.537</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**Response variable**

- The variable or outcome of interest.
- We may want to maximize it or minimize it.
- In the experiment design context, it is believed that changes in the value of the response variable—that is, the variability in the response—may be affected by changes in one or more other variables that will be called factors.
- There can be more than one
- We will focus on quantitative (and mostly continuous) response variables

In this example: _______________________
Factor
• A variable that the experimenter believes may cause variability in the response variable(s) of interest.
• It can be either qualitative (categorical) or quantitative.
• Though a quantitative variable, in general, can be discrete (number of mentos) or continuous (initial volume), in the factorial experiment context, quantitative variables are examined only for a discrete number of values (note three distinct values of initial volume).

Synonyms: __________________________________________
These words are more general, while the word factor is specifically used in the context of experiment design

Levels (of a factor): __________________________________________

In this example:
How many factors are in the experiment? ____
What are the factors, and what are their levels?
Write in Factor (level1, level2, ...) form (we will always write it this way)

Treatment:
• any combination of the levels of one factor with the levels of every other factor

How many treatments in the example? ____
What are the treatments? ________________________________

Experimental unit:
• The units to which we “apply” the treatments, or
• The units created under certain treatment conditions (e.g., concrete block created using a certain process)
• If this is a human experiment, we call them subjects.
• The thing that is replicated (more on this later)
• Sometimes it’s hard to figure out what the experimental unit is, and a big mistake is having only one experimental unit.
In this example:
What are the experimental units? __________________________
How many replicates per treatment? _____
Any other comments about this experiment?

Factorial experiment:
• a study in which the goal is to determine the effects of two or more factors (each with two or more levels) on a response variable.

Complete (or full) factorial experiment:
• We observe every combination of the levels of each factor (what we will do in this class)

Fractional factorial experiment:
• we observed some combinations, but not all
• Can save a lot of money and yet still give much information about effects of factors on response
• You need to take a more advanced class to learn how to do this, or consult a statistician who knows these methods.

Do in-class exercise identifying parts of an experiment.

Variability in the value of the response variable can occur for two reasons:

1. ____________________________
   1.1. Because the values of the factors varied, the response may vary.
   1.2. This is called the "signal."
   1.3. This is what we are interested in quantifying, if it exists.

2. ____________________________
   2.1. **Definition:** Variability among observed values of the response variable for experimental units that receive the same treatment.
   2.2. This is also called noise, and it can keep us from detecting the signal if we don’t minimize it.
   2.3. The word error does not imply that something was done wrong. We just use the term experimental error for noise.
We will use the following example to talk about what this means.

Example 3: Group 11 project Fall 2007

The purpose of this experiment is to determine the effect of paper weight and airplane model on hang time for paper airplanes. We will be using three different paper weights: heavy (construction paper), medium (printer paper), and light (notebook paper). We will be using two different models of planes, though the specific models we used are not important only that we used two different models. The response variable is hang time in seconds. Hang time is the time an object, in this case the paper airplane, stays in the air. This experiment is of interest because it brings to question how much gravity affects the airtime of a paper airplane through the weight of the paper used and how much the lift of a paper airplane affects is airtime also through the size of the wings determined by the model used.

The group members (not their real names): Bob, Sue, Joe, Dave

(In paragraph five, this group told me that the one of the airplane models was called the “dart” model, and the other was called the “glider”, and they hypothesized that the glider would have a greater hang time.)

The data:

<table>
<thead>
<tr>
<th>Paper Type</th>
<th>Model One</th>
<th>Model Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>1.04</td>
<td>0.96</td>
</tr>
<tr>
<td>One</td>
<td>1.44</td>
<td>2.74</td>
</tr>
<tr>
<td>One</td>
<td>3.36</td>
<td>1.47</td>
</tr>
<tr>
<td>Two</td>
<td>0.93</td>
<td>1.42</td>
</tr>
<tr>
<td>Two</td>
<td>1.01</td>
<td>1.14</td>
</tr>
<tr>
<td>Two</td>
<td>2.25</td>
<td>1.76</td>
</tr>
<tr>
<td>Three</td>
<td>1.9</td>
<td>0.94</td>
</tr>
<tr>
<td>Three</td>
<td>2.04</td>
<td>1.04</td>
</tr>
<tr>
<td>Three</td>
<td>2.04</td>
<td>1.04</td>
</tr>
</tbody>
</table>

Why are the three numbers that got Treatment 1 all different? Why are the three numbers that got Treatment 2 all different? ________________________________

Sources of experimental error:

1. __________________________________________
   • No two people, paper towels, concrete blocks, lab rats, paper airplanes, are exactly alike.

   In example:
2. If the same experimental unit is measured more than once, will the value be the same?
   - If two different researchers measure the same experimental unit, will they get the same value?

   **In example:**

3. When two experimental units are assigned the same treatment, do they get *exactly* the same treatment?

   **In this example:**

4. Variables that are not intended to be part of the treatment, but they affect the response variable

   **In this example:**