A FOODIE'S DILEMMA

Lab 3: Variability Due to the Measuring Instrument

INTRODUCTION

Sources of variability are everywhere. We observe differences in people such as varying heights, weights, hair colors, and personalities. We experience personal differences such as changes in commute times or levels of happiness. These *variables* change from one observation to the next. A study of a variable usually begins by measuring several observations to create a set of data. Measuring can be straight forward, such as using a scale to determine the weight of a person in pounds. In other cases, measurement is more complex. In psychology, for example, there are many ways to evaluate happiness. One possibility is a questionnaire containing questions regarding happiness. In these settings, the questionnaire is known as the **measuring instrument**. Regardless of the nature of the data being collected, a measuring instrument is always used to measure the variable.

In addition to true differences among observations, variability can result from the measuring instrument itself. Consider a ten item multiple-choice test versus a 25 item multiple-choice test as two possible measuring instruments for student knowledge where both 100 point tests cover the same content. If the same set of students takes both tests, much of the variability in the scores will likely be due to true differences in student knowledge. However, the amount of variability present in the ten item test will probably be different from the amount of the variability for the 25 item test even for the same group of students. We might also find that the average score is higher on one test than the other for the same group of students. Some of the differences that occur on the exam scores are due to the measuring instrument. In this lab, variability introduced by the measuring instrument is explored.

QUESTIONS FOR THOUGHT

1. What are three different ways to measure body temperature? Include at least one measurement that treats body temperature as a categorical variable and at least one that treats body temperature as a quantitative variable.
2. What are three different ways to measure happiness? Include at least one measurement that treats happiness as a categorical variable and at least one that treats happiness as a quantitative variable.
3. What kinds of descriptive statistics would you use to summarize data if happiness were treated as a categorical variable?
4. What kinds of descriptive statistics would you use to summarize data if happiness were treated as quantitative variable?

SETTING

Have you ever found yourself in this scenario: you need a cup of flour or some other ingredient but do not have a one-cup measuring cup so instead you use three 1/3 cups? In most recipes, the difference is probably not too serious, but this experiment will explore the variability in these two measuring strategies. The weights of one cupful of items measured with a one-cup measuring cup will be compared to the weights of one cupful of items measured by three 1/3 cup measuring cups.

MATERIALS

- One 1 cup measuring cup
- One 1/3 cup measuring cup
- A small bowl
- A scale that measures to the nearest gram
- A set of small items such as beads or dried beans that can be measured in cups

GROUP SIZE

Two to four students per group.

METHODS

A total of ten weights will be recorded for both the one cup measuring strategy and the three 1/3 cup measuring strategy. The order of the measurements will be randomized to reduce the effect of the order. (Perhaps the last measurements will be conducted with more fatigue or sloppiness, for example.) Summary statistics and graphical displays will be used to compare the measuring instruments.

1. Table 3.1 shows an example of how to randomize the order. Let **One** represent one 1 cup measurements and **Thirds** represent three 1/3 cup measurements. As shown in Table 3.1, begin by listing the variable name **One** ten times and **Thirds** ten times on paper or in a spreadsheet. Use a random number generator or a random digit table to assign a random number to each listing of the variable name. Then sort the list of variable names by the random number. The sorted list of variable names is the sequence that will be used to take the measurements. All groups should generate random numbers independently so that each group has a unique randomized sequence. Use Table 3.2 to record the randomized sequence for your group.
2. Place a bowl on the scale. Set the scale to measure in grams and calibrate the scale to zero with the bowl on the scale. Following the sequence in Table 3.2, begin measuring weights for the variables **One** and **Thirds**.
   - For the variable **One**, use the one cup measuring cup to scoop out a cupful of the items and put them in the bowl. Record the weight in Table 3.3. Return the items to the original set of items.
   - For the variable **Thirds**, use the 1/3 cup measuring cup to scoop out three 1/3 cups of the items and put them in the bowl. Record the weight in Table 3.3. Return the items to the original set items.

3. Complete Figure 3-1 by constructing side-by-side boxplots of the variables **One** and **Thirds**.
4. Find the mean, median, and standard deviation for **One** and **Thirds** and record them in Table 3.6. Use Tables 3.4 and 3.5 to aid with the calculation of standard deviation. Recall the formula for standard deviation:

$$s = \sqrt{\frac{\Sigma(x - \bar{x})^2}{n - 1}}$$

5. Use statistical software to find the mean, median and standard deviation for **One** and **Thirds**. Use these results to check table 3.6.

Table 3.1: *Example sequence of measurements sorted by random number*

Non-randomized order	Random Number	Randomized Sequence	Random Number Sorted
One	3	One	3
One	78	Thirds	8
One	93	One	15
One	83	One	17
One	90	One	24
One	36	Thirds	30
One	24	One	36
One	17	Thirds	48
One	50	One	50
One	15	Thirds	53
Thirds	96	Thirds	62
Thirds	48	Thirds	73
Thirds	8	One	78
Thirds	73	Thirds	80
Thirds	81	Thirds	81
Thirds	62	One	83
Thirds	80	Thirds	89
Thirds	30	One	90
Thirds	89	One	93
Thirds	53	Thirds	96

Reality Check

Measurement plays an important role in most disciplines. In medicine, the effect of the measuring instrument can have severe health implications. A study at a pediatric urban hospital (Wu Chang, 2010) compared dosing instruments for children's liquid medication including oral syringes, droppers, dosing spoons, and dosing cups. Parents were instructed to measure a teaspoon or 5 ml of Children's Tylenol using different instruments. Results showed that measurement errors were smaller overall for syringes and droppers. The largest measurement errors were made with dosing cups and almost all of these errors were overdoses. At least one trial resulted in an overdose of 300%.