10.2: Variables, Data, and Hypotheses that Fit a One-way ANOVA

Variables

The one-way ANOVA requires the use of one qualitative grouping variable with two or more independent groups (though ANOVA is only recommended when there are at least three independent groups) and a quantitative variable which was measured the same way in each group. An example of a qualitative grouping variable with four groups would be class standing where participants are grouped as "Freshmen," "Sophomores," "Juniors," and "Seniors." The grouping variable is used to distinguish the independent groups which are going to be compared. The thing being compared between the groups is the quantitative variable. This is sometimes considered an outcome variable. An example of a quantitative variable would be hours of sleep. In this example, all participants would have their hours of sleep measured and used in the analysis. For example, if a researcher wanted to test whether those with different class standings had different mean hours of sleep per night, the qualitative grouping variable would be class standing and the quantitative variable being compared between the four groups would be sleep hours.

Data

Each statistical test has some assumptions which must be met in order for the formula to function properly. In keeping, there are a few assumptions about the data which must be met before a one-way ANOVA is used. First, the data for the quantitative variable should have been measured the same way for all cases in each of the groups. Second, the data for the quantitative variable must be measured on the interval or ratio scales of measurement. Third the members of the groups must be non-overlapping (i.e. independent of one another). This means that no participant can be in more than one group. Fourth, data for the quantitative variable should be fairly normally distributed in each group. Finally, there should be homogeneity of variances. **Homogeneity of variances** is when the variances for the quantitative variable of each group are similar. When variances are not homogeneous it means that the groups have different amounts of error (as measured using variance) so their distribution curves have different widths and heights. When variances are not homogenous, adjustments to the formula are required. An alternative option to consider when variances are significantly different is reviewed later in this chapter. It is also helpful, though not always required, that the sample sizes of the groups be similar. When variances are similar among groups, unequal sample sizes of groups may not need to be considered. For now, if all five of these assumptions are met, the one-way ANOVA can be used.

Hypotheses

Before we can review the hypotheses which are appropriate for ANOVA, we need to review a distinguishing characteristics of ANOVA. ANOVA is often performed with a companion test. To distinguish these the ANOVA is often referred to as an omnibus test and its companion is known as a post-hoc test. The omnibus test is used to test whether there is at least one group mean that is significantly different from another. This is what the ANOVA, itself, is able to determine. However, the ANOVA cannot tell us which group(s) were different from which other group(s). Therefore, the ANOVA alone is not sufficient for testing directional hypotheses. This is why a second analysis known as post-hoc testing is sometimes needed alongside an ANOVA. Post-hoc tests are used to check each group mean against the others to determine which ones were significantly different from each other. Thus, this chapter includes both how to perform the ANOVA (omnibus test) and post-hoc tests to provide you with the skills necessary for testing directional and non-directional hypotheses. We will cover how to perform both the omnibus tests and post-hoc tests, as needed, in our computation sections later in this chapter.

Hypotheses for the one-way ANOVA must include both a qualitative grouping variable and a quantitative test variable. The non-directional hypothesis is the default as it is the only kind of hypothesis that can be tested using the ANOVA formula alone. However, directional hypotheses can also be tested provided post-hoc analyses are performed following the one-way ANOVA. For the one-way ANOVA, the non-directional research hypothesis is that the sample means will be different from each other. The corresponding null hypothesis is that the sample means will not be different from each other. Note: Because there can be more than three groups in an ANOVA, only three will be shown and ellipses will be used to indicate that the hypothesis could be expanded to include more than three groups. The non-directional research and corresponding null hypotheses can be summarized as follows:

Non-Directional Hypothesis for a One-Way ANOVA

Research hypothesis	The means of the groups are not all equal to each other.	$H_A: \mu_1 \neq \mu_2 \neq \mu_3$
Null hypothesis	The means of the groups are all equal to each other.	$H_0: \mu_1 = \mu_2 = \mu_{3\ldots}$

To test a non-directional hypothesis such as this, only the omnibus part of ANOVA is required.

There are many different directional hypotheses possible for the one-way ANOVA. We will review just one of them as an example presuming there are three groups being compared. One possible directional research hypothesis is that the mean for Group 1 will be *greater than* the mean for Group 2 and that the mean for Group 2 will be *greater than* the mean for Group 3. The corresponding null hypothesis is that the means for Group 1 through Group 3 will be less than or equal to each other, respectively. This version of the research and corresponding null hypotheses can be summarized as follows:

Example of a Directional Hypothesis for a One-Way ANOVA

Research hypothesis	The mean of Group 1 will be greater than the mean of Group 2 and the mean for Group 2 will be greater than the mean for Group 3.	$H_A : \mu_1 > \mu_2 > \mu_3$
Null hypothesis	The mean of Group 1 will not be greater than the mean of Group 2 and/or the mean for Group 2 will not be greater than the mean for Group 3.	$H_0 : \mu_1 \leq \mu_2 \leq \mu_{3\ldots}$

To test a directional hypothesis such as this, both the ANOVA and post-hoc tests are required. The omnibus can only tell us whether any of the means are different and the post-hoc adds to this by specifying which means were different and in which ways (i.e. which group means were significantly higher than others, which were significantly lower, and which were not significantly different).

It is important to note that the ANOVA omnibus formula is broad and uses a one-tailed test which is often referred to as a right-tailed test regardless of whether the hypothesis is directional or not. This is distinct from how the direction of hypotheses are used to determine whether a one-tailed or two-tailed test of the hypothesis is needed when using *t*-tests. In ANOVA, the directional aspects of a hypothesis, when present, require a secondary analysis known as post-hoc testing.

Experimental Design and Cause-Effect.

The one-way ANOVA is sometimes used to analyze data from an experiment when multiple conditions are being tested and compared. When a true experimental design is used (and other relevant conditions such as temporal precedence are met) it can be appropriate to use causal language in hypotheses and when interpreting results (see Chapter 8 for a review of experimental designs and deducing cause-effect). When ANOVA is used to test cause-effect patterns, the qualitative grouping variable is the *independent variable* and the quantitative test variable is the *dependent variable* (see Chapter 1 for a review of these two categorizations of variables). However, one-way ANOVA is flexible and can also be used to compare the means of different groups when data were not acquired using an experimental design. Thus, it is not always appropriate to use causal language with ANOVA. The grouping variable in ANOVA is, therefore, often referred to as a *factor* rather than an independent variable. It is best to use non-causal language as a default and to only switch to using causal language when it is known that an experimental design was used and that causal language is appropriate.

Reading Review 10.1

1. How many independent groups can be compared using one-way ANOVA?
2. What assumptions must be met before using a one-way ANOVA?
3. For what two reasons is one-way ANOVA preferred over using independent sample *t*-tests to compare the means of three or more independent groups?
4. When ANOVA is used to test data from an experiment, which variable generally serves as the independent variable and which generally serves as the dependent variable?
5. What is the grouping variable referred to in ANOVA when data are being tested from non experimental designs?
6. What kind of hypothesis can be fully tested using the ANOVA omnibus test?
7. What kinds of hypothesis require post-hoc testing be performed in addition to the ANOVA omnibus test?