# 11.2: Variables, Data, and Hypotheses that Fit a Repeated-Measures ANOVA

## Variables

The repeated-measures ANOVA requires the use of one qualitative factor or treatment variable. Each of these terms simply refers to the fact that different conditions of one variable are being experienced by the sample. This type of factor variable is the independent variable (IV) when a true experiment is being performed. However, repeated-measures ANOVA can also be used with non-experimental designs in which case this variable is more appropriately referred to as a factor or grouping variable rather than a true IV.

The other variable is quantitative and is measured the same way under each of the conditions; this variable is the dependent variable (DV) when a true experiment is performed. This quantitative variable is the thing being compared under each of the conditions. For example, a group of individuals could be given four meals, each prepared using different versions of a recipe, and asked to rate how much they enjoyed each meal on a scale of 0 to 10. In this example, the individuals make up the sample and would report their enjoyment four times each, once for each of the meals. The different versions of the meal make up the different conditions or factors. The ratings of enjoyment make up the focal outcome variable (DV). When ANOVA is used with a non experimental design, the DV is sometimes referred to as a "test variable" to clarify that it is not a true DV.

## 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 repeated-measures ANOVA is used. Most of these are the same that must be true for dependent samples *t*-tests. First, the data for the same continuous, quantitative variable must have been measured multiple times on the same interval or ratio scale. Second, the scores from all of the waves of measurement must be matched. This means that the same participants have scores for each condition that can be identified together such that the researcher knows which score at each wave belongs to each person. A researcher needs to be able to identify the scores for each person so they can see how much that participant's score changed from one wave of testing to another. Third, data for the quantitative variable should be fairly normally distributed in each group without notable impact due to outliers (such as problematic skew). Finally, there is homogeneity of variances but extended to comparisons between more than just two waves of data.

## Hypotheses

Hypotheses for the repeated-measures ANOVA must include both the qualitative factor variable (which may also be referred to as the treatment, grouping, or independent variable) and a quantitative variable (which may also be referred to as the test, outcome, or dependent variable). ANOVA uses a one-tailed test which is often referred to as a right-tailed test (referring to the right side of a distribution). Therefore, we will review the different constructions of hypotheses which are appropriate for ANOVA but those will not be used to differentiate between using a one-tailed or a two-tailed test.

Just like for a one-way ANOVA, repeated-measures ANOVA is broken down into two tests: an omnibus test and a post-hoc test. The omnibus test is used to test whether the mean measured at any one time is significantly different from the mean measured at another time. However, the omnibus test cannot tell you which means were different from which other means. This is why a post-hoc test is needed when an omnibus test result is significant. The post-hoc test is used to check each group mean against the others to determine which ones were significantly different than each other, two means at a time. Comparisons done two at a time are often referred to as "pairwise comparisons." Thus, we can think of the omnibus portion of the ANOVA as useful in assessing a non-directional hypothesis by testing whether any means were different and the post-hoc portion as useful in assessing any directional aspects of the hypothesis. Keep these aspects of the repeated-measures ANOVA in mind as we review the hypotheses.

For the repeated-measures ANOVA, the non-directional research hypothesis is that the means are not the same under each condition or wave of testing. This would mean that at least one mean would be different than at least one other mean, breaking a pattern of equality across all means. The corresponding null hypothesis is that the means are the same under each condition or wave of testing. Note that because there can be more than three conditions 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 just those three. The non-directional research and corresponding null hypotheses can be summarized as follows:

Non-Directional Hypothesis for a Repeated-Measures ANOVA

| | | |
|---|---|---|
| **Research hypothesis** | The means for each condition or wave of testing are not all equal to each other. | $H_A: \mu_1 \neq \mu_2 \neq \mu_{3...}$ |

| | | |
|---|---|---|
| **Null hypothesis** | The means for each condition or wave of testing are all equal to each other. | $H_0 : \mu_1 = \mu_2 = \mu_3 \ldots$ |

There are many different directional hypotheses possible for the repeated-measures 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 Condition 1 will be *greater than* the mean for Condition 2 and that the mean for Condition 2 will be *greater than* the mean for Condition 3. The corresponding null hypothesis is that the means for Conditions 1 through 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 Repeated-Measures ANOVA

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

Note that testing a non-directional hypothesis (which will be the focus of this chapter) only requires the use of the omnibus test but that a directional hypothesis would require the use of both the omnibus test and post-hoc analyses. A non-directional hypothesis is supported when the repeated-measures ANOVA omnibus result is significant. A directional hypothesis is supported when the both the omnibus result is significant and the post-hoc results are in the direction hypothesized and also significant.

## Experimental Design and Cause-Effect.

The repeated-measures ANOVA is sometimes used to analyze data from an experiment when multiple conditions are being tested and compared. However, it can also be used to test data collected using non-experimental research methods. When an experimental design is used and other features are present, it may be appropriate to use causal language when interpreting and/or reporting results. For example, the grouping variable can be referred to as a true independent variable (IV) or as an experimental variable when an experiment is performed. It can also be appropriate to report whether different conditions of the IV caused changes in the dependent variable. However, when non-experimental methods are used causal language is not appropriate. In these cases, it is more accurate to use terms like grouping variable, factor, or condition rather than IV or causal 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 (see Chapter 8 for a review of experimental designs and causal language).

### What is a Factor?

In a repeated-measures design, the qualitative variable refers to the conditions, factors, treatments, or waves the same participants experienced. This variable is often called a factor variable in non-experimental research and an independent variable in experimental research. The quantitative variable is measured under each condition using the same participants. This is often referred to as the test variable or focal variable in non-experimental research and the dependent variable in experimental research.

## Reading Review 11.1

1. What assumptions must be met before using a repeated-measures ANOVA?
2. What is a non-directional hypothesis that could be tested using a repeated-measures ANOVA?
3. Which terms may be used to refer to the qualitative variable when using repeated measures ANOVA?
4. Which terms may be used to refer to the quantitative variable when using repeated measures ANOVA?