**WHICH WITHIN-SUBJECT OR MIXED-MODEL ANALYSES SHOULD I USE?**

**by Simon Moss**

Within-subject analyses—as well as mixed-model analyses—are utilized in two circumstances. First, these analyses are often used to compare the same group of people, animals, objects, specimens, and so forth, on some measure or measures, over time. For example, as the table below shows, you might want to compare the intelligence of people at three times: before they begin university, during university, and after they complete university. Or, you might want to explore whether the yield of various crops is better after, compared to before, some chemical treatment.

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| --- | --- | --- | --- |
| Person\_ID | IQ before uni | IQ during uni | IQ after uni |
| 1 | 97 | 99 | 91 |
| 2 | 103 | 109 | 108 |
| 3 | 99 | 102 | 107 |
| 4 | 109 | 114 | 108 |
| 1 | 125 | 122 | 129 |
| 2 | 119 | 124 | 131 |
| 3 | 105 | 101 | 108 |
| 4 | 89 | 82 | 84 |
| 1 | 92 | 91 | 97 |
| 2 | 98 | 102 | 108 |
| 3 | 104 | 111 | 121 |
| 4 | 102 | 105 | 101 |

Second, these analyses are sometimes utilized to compare matched groups of people, animals, objects, specimens, and so forth, on some measure or measures. For example, to assess whether studying statistics enhances IQ, you could recruit 10 pairs of twins. One twin in each pair is instructed to study statistics and then complete an IQ test. The second twin in each pair is instructed to refrain from studying statistics—a challenging task—and also complete an IQ test. The two groups are thus matched: Each member in one group is matched to one member in the second group, as the following table highlights.

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| --- | --- | --- | --- |
| Family\_ID | IQ of twin who studied stats | IQ of twin who did not study stats | Household income |
| 1 | 97 | 99 | $91, 000 |
| 2 | 103 | 109 | $108, 000 |
| 3 | 99 | 102 | $107, 000 |
| 4 | 109 | 114 | $108, 000 |
| 1 | 125 | 122 | $129, 000 |
| 2 | 119 | 124 | $131, 000 |
| 3 | 105 | 101 | $108, 000 |
| 4 | 89 | 82 | $84, 000 |
| 1 | 92 | 91 | $97, 000 |
| 2 | 98 | 102 | $108, 000 |
| 3 | 104 | 111 | $121, 000 |
| 4 | 102 | 105 | $101, 000 |

A variety of alternatives are available, including dependent or paired samples t-tests, ANOVAs, trend analyses, and profile analyses. Other more complex techniques might also be applicable. To decide which variants to utilize, you need to answer several questions

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| **Number of times scales** |

First, many studies are designed to explore whether some measure—such as the IQ of people or the yield of some crop—varies over time. Yet, in some instances, the researcher examines more than one time scale at a time. To illustrate,

* Imagine you want to assess the confidence of individuals—as measured on a scale from 1 to 10—at four times: summer, autumn, winter, and spring. In this instance, the design obviously comprises one time scale, perhaps called *season*.
* Now imagine you want to assess the confidence of individuals at eight times—twice in each season. Specifically, you might want to assess confidence in the morning and in the afternoon during each season. In this instance, the design most likely comprises two time scales, perhaps called *season* and *time of day*. That is, your analyses would generate information about whether season affects confidence and whether time of day affects confidence. Furthermore, the analyses could generate information about whether the effect of season depends on time of day.

Therefore, decide whether your design comprises 0, 1, 2, or more time scales. The majority of studies in this cluster will comprise 1 time scale.

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| **Number of matched grouping variables** |

Occasionally, your design will include matched groups. Usually, these studies will comprise only one matched grouping variable. But occasionally these studies will comprise two or more matched group variables. To illustrate, suppose you want to examine which of two teaching approaches—such as online videos versus hypnosis—helps students learn statistics. In addition, you want to explore whether the effect of each approach depends on gender. Hence, you want to explore two independent variables: teaching approach and gender. In this example

* Teaching approach could be matched. For example, the researcher could recruit pairs of individuals, in which the members of each pair work in the same field. One member of each pair could be asked to watch online videos and the member of each pair could be asked to be hypnotized. The benefit is that students who watch online videos are from the same fields as the students who are hypnotized: Any differences in learning between these approaches cannot be ascribed to the field in which they work.
* Gender could be matched too. For example, the researcher could recruit siblings. The brother would be assigned to the male group, and the sister would be assigned to the female group. The benefit is that differences between the genders in learning could not be ascribed to characteristics that vary across families—such as family income. That is, these characteristics could be the same in the male and female group.

Therefore, in this example, the number of matched grouping variables could be 0, 1, or 2, depending on how the researcher recruits participants and assigns these participants to groups.

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| **Calculate the number of within-subject variables** |

The number of within-subject variables is simply the number time scales plus the number of matched groups. Typically, for this cluster of techniques, the number of within-subject variables is one or two.

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| **Number of measures** |

This cluster of techniques is typically designed to explore whether some measure or measures—such as confidence or crop yield—varies across time or across matched groups. You now need to ascertain the number of measures in your analysis. To achieve this goal, you need to consider several principles:

* Often, your analysis will include only one measure, such as confidence, weight, crop yield, and so forth
* Sometimes, your analysis will include more than one measure.
* However, if none of your measures belong to the same category, examine each measure separately—and therefore examine one measure at a time.
* For example, suppose the measures include five personality traits, such as the degree to which individuals are extraverted, conscientious, and agreeable. In this instance, you would probably examine each measure in the same analysis
* In contrast, suppose the measures include income, weight, extraversion, and eye color. These measures are unrelated to each other—and will usually be examined in separate analyses. And each analysis might examine only measure at a time.

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| **Numerical versus categorical measures** |

To decide which of these techniques to conduct, you need to appreciate the distinction between numerical measures and categorical measures. For example

* Imagine you want to assess whether the confidence of individuals—as measured on a scale from 1 to 10—changes over time. In this instance, confidence is a numeric variable: Each person is assigned a number
* In contrast, imagine you want to assess whether eye color varies over time. In this instance, eye color is a categorical variable: Each person is assigned a category, such as blue, green, or brown.

Even if we coded blue eyes as 0 and brown eyes as 1, eye color would still be a categorical variable. The numbers 0 and 1 are merely symbols to represent categories. They are not true numbers. For example, brown eyes, or 1, are not actually higher than blue eyes, or 0.

In most studies, the measures will be numerical. In some studies, the measures will be categorical. However

* In some instances, the design comprises both numerical and categorical variables
* In these circumstances, unless your statistical skills are advanced, do not explore numerical measures and categorical measures in the same analysis
* That is, conduct one analysis to explore the numerical measures. Conduct a second analysis to explore the categorical measures

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| **Number of between-subject variables and covariates** |

Sometimes, when you conduct this cluster of techniques, you want to ascertain whether the effect of time or matched grouping variables depends on other variables, such as the hair color or age of individuals. These variables, if not matched, are called between-subject variables if categorical and covariates if numerical. To illustrate

* Imagine you want to assess whether the change of confidence over time—as measured on a scale from 1 to 10—depends on the hair color of people. Assume the people with brown hair and the people with blonde hair are not matched in any way. This design comprises on between-subject variable: hair color.
* Imagine you want to assess whether the change of confidence over time—as measured on a scale from 1 to 10—depends on the age of people: this design comprises one covariate: age.

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| **Pattern of trends** |

In many studies, researchers want to assess whether some measure—such as confidence or crop yield—varies across several times. They might, for instance, want to explore crop yield over 5 times.

In these circumstances, rather than merely explore whether the measure varies across time, the researcher might also want to characterize the pattern of change over time. Does crop yield increase in a linear fashion? Or does crop yield increase in a quadratic fashion—more like a U shape or upside down U? Once you answer these questions, use the table below to decide which technique to conduct.

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| Techniques to examine whether some measure varies over time | | | | | |
| Number of within-subject variables | Number of measures | Numerical versus categorical measures | Number of between-subject variables or covariates | Other aims | Technique to use |
| 1 – with two time periods or two matched groups | 1 | Numerical | 0 | NA | Dependent or paired samples t-test |
| 1 – with more than two time periods or matched groups | 1 | Numerical | 0 | NA | Within-subject or repeated measures one-way ANOVA |
| 1 – with more than two time periods or matched groups | 1 | Numerical | 0 | To examine patterns over time | Trend analysis |
| 1 – with two time periods or two matched groups | 1 | Categorical | 0 | NA | McNemar test |
| 1 – with more than two time periods or matched groups | 1 | Categorical—but with one two possible categories | 0 | NA | Cochran Q test |
| 2 | 1 | Numerical | 0 | NA | Two-way within-subject ANOVA |
| 1 or more | 1 | Numerical | 1 or more between-subject variable | NA | Mixed model ANOVA |
| 1 or more | 1 | Numerical | 1 or more covariates |  | Within-subject ANCOVA |
| 1 or more | 1 | Numerical | 1 or more between-subject variables and 1 or more covariates |  | Mixed model ANCOVA |
| 1 or more | More than 1 | Numerical | 0 | NA | Within-subject MANOVA |
| 1 or more | More than 1 | Numerical | 1 or more between-subject variable | NA | Mixed-model MANOVA—or profile analysis |
| 1 or more | More than 1 | Numerical | 1 or more covariates | NA | Within-subject MANCOVA |
| 1 or more | More than 1 | Numerical | 1 or more between-subject variable and 1 or more covariates | NA | Mixed-model MANCOVA |

If this table does not describe your design—such as because the analysis comprises more than one categorical measure

* Perhaps simplify the design: For example, consider each categorical measure separately
* Consider a slightly more complex technique, called generalized estimating equations—a technique that is discussed in Learnline
* Consult a statistics expert