Simple Tricks for Using SPSS for Windows

Chapter 14. Follow-up Tests for the Two-Way Factorial ANOVA

The Interaction is Not Significant

If you have performed a two-way ANOVA using the "General Linear Model, Univariate…" choice from the Analyze menu, and the interaction is not statistically significant, but one of the main effects is significant and has more than two levels, it is easy to perform pairwise comparisons among the marginal means of the significant main effect. Just return to the "Univariate" dialog box, and click on Post Hoc … When the "Post Hoc" box opens, you will see your two factors listed on the left; move the factor you want to test further (or, if applicable, both of them) to the right. Next, choose the post hoc procedure that you prefer (you will have the same choices that are available from the Post Hoc box of Compare Means … One-Way ANOVA, including methods – like Games-Howell -- that are based on separate-variance tests), and perform the analysis. You will get the output for the two-way ANOVA again, but this time Post Hoc tests on your selected factor(s) will appear.

If the interaction is significant, it may still make sense (e.g., the interaction is ordinal) to follow up on significant main effects. However, you may also want to test the simple main effects (i.e., one-way ANOVAs for one of the factors conducted separately at each level of the other factor). This is also easy to do in SPSS for Windows, but that fact is certainly not obvious from the menu selections or the Help topics. [I would not have known about the syntax shortcut I describe below, had I not seen it in the helpful data analysis guide by Weinberg and Abramowitz (2002).] Bear in mind that even if the interaction falls a bit short of significance at the conventional .05 level, it may be reasonable to analyze the simple main effects anyway, especially if your pattern of cell means is consistent with your hypotheses and expectations.

Testing Simple Main Effects

There are actually several methods for testing simple main effects in SPSS for Windows, but I will begin with the simplest and proceed to more complex methods only when necessary. To make this method as concrete as possible, I will use an exercise from my text as an example. Exercise #5 in section B of Chapter 14 (p. 420 in the 2nd edition) provides data for a 2 X 3 ANOVA, in which there are two TYPES of students (average and gifted) crossed with three teaching METHODS (traditional, videotape, and computer). In this particular example, the interaction falls short of significance ($p = .12$), but the simple main effects are easily interpretable, so I will continue with this example.

Separate Error Terms. As with any two-way ANOVA, there are two sets of simple effects to test; for this example, we can compare the three methods for each type of student, and/or compare the two types of student for each method. The simple effects of Method represent the more interesting problem, because a significant simple effect then calls for pairwise comparisons among the three different methods. The simplest way to conduct these tests does not even require the General Linear Model (GLM) menu that you used for the two-way ANOVA. You can select Split File … from the Data menu, click on Organize Output by Groups and move the TYPE factor to the space labeled "Groups Based On." Then, to perform the simple main effects for METHOD, you need only open the dialog box for One-Way ANOVA from the Analyze/Compare Means menu and move METHOD to the "Factor" space (of course, whatever name you are using for the DV – e.g., finexam – should be moved to the "Dependent List"). Your output will consist of two separate one-way ANOVAs of Method on your DV: one for the average students, and another for the gifted students. If either or both of these ANOVAs is significant, you can return to the One-Way ANOVA dialog box and select Post Hoc in order to generate pairwise (i.e., cell-to-cell) comparisons.

The only drawback to the procedure described above is that it uses a different error term for each simple effect. For example, the denominator for the F ratio testing the simple effect of Method for the gifted students is based on the average variance for just the three groups of gifted students; unlike the error term for the entire (i.e., omnibus) two-way ANOVA, it is not based on all six groups of students in the study. Having separate error terms only becomes a drawback, however, if homogeneity of variance (HOV) across all cells of the two-way ANOVA is a reasonable assumption. Given HOV, some power can be gained by using the common error term (for all three F ratios) of the two-way ANOVA as the error term for each of the simple main effects. The extra power comes from the larger number of degrees of freedom associated with the omnibus error term, just as in the case of using MS_W for protected t tests, instead of pooling only the variances for the two conditions being compared.

Assuming HOV. How do you know if HOV is reasonable for a two-way ANOVA? You can request a homogeneity test as an Option from the GLM/Univariate box. But if your ANOVA is balanced (i.e., all cells have the same n), and no cell standard deviation is more than about four times any other, you can feel quite safe using the omnibus error term for all of your follow-up tests. On the other hand, the more that your cell sizes and SD's both diverge, the more it is recommended that you use separate error terms, as in the Split File method described above -- perhaps even using separate-variance ANOVA's (e.g., the Welch method) to test the simple main effects. Of course, as always, you would first need to investigate why your SD's differ so much. If you are comfortable assuming HOV, and you want to use the same, omnibus error term for testing each simple main effect, you will have to use the Syntax window of SPSS, but fortunately very little needs to be typed in. In fact, all you really need in order to analyze the Type by Method example are the two lines below.

```
UNIANOVA  finexam  BY type method
  /EMMEANS = TABLES (type*method) comp (method).
```

[Note that this is all one long command so it is important that the first line <u>not</u> end with a period, and that the second line does.] The first line runs the ordinary two-way ANOVA. The second line produces three additional boxes of results. [Note: EMMEANS stands for Estimated Marginal Means.] The first is a table of the cell means, with 95% CI's for the population mean for each cell; this table is generated, not surprisingly, by specifying: "TABLES (type*method)". [If you want the usual descriptive statistics -- with SD's for each cell, for instance -- just insert /PRINT = DESCRIPTIVE between the two lines above.]

The second and third of the additional boxes are produced by adding "comp (method)" to the EMMEAN subcommand ("comp" is short for compare, and you can write the whole word out, if you prefer). The second box contains all of the possible pairwise comparisons among the Methods, separately for each Type of student. These are the cell-to-cell comparisons you would want to see to follow-up on any significant simple main effect – so it is odd that this box is displayed <u>before</u> the box that contains the tests of the simple main effects. Before looking at the second box, look in the third box to see the usual one-way ANOVA summary table for each of your simple main effects (gifted and average, for the current example).

For any significant simple main effect, it then becomes appropriate to look in the second box to see which pairs of levels differ significantly. The default choice for these pairwise tests is "LSD", which in this context means that the p values are not adjusted for the fact that you are making multiple post hoc comparisons. If you want to make a Bonferroni adjustment to the p values for the pairwise comparisons, add: ADJ (BONFERRONI), just before the period on the second line. In this example, the Bonferroni adjustment causes all of the p values to be multiplied by 3, because there are three possible pairs of methods for each simple main effect. A less drastic form of the Bonferroni correction can be obtained by inserting ADJ (SIDAK), instead.

Pasting the Syntax. If you want to add just an Option or two to your analysis, you can add a few words, or perhaps a line or two, to the two syntax lines printed above (e.g., /PRINT = DESCRIPTIVE). However, if you would like to add several options, plots, post hoc and homogeneity tests, etc., it will probably be easier, and certainly less error-prone, to make your selections from the GLM/Univariate dialog box, and then click on Paste, rather than OK. This action will produce a syntax file with a number of subcommands, many of which you don't need because they represent default conditions [e.g., /CRITERIA = ALPHA(.05)]. However, if you want the EMMEANS subcommand to be included (in a form that will test your simple main effects), you need to make the following selection before clicking on Paste. After opening the Option box, you will see both of your factors and their interaction listed in the upper-left corner; highlight and then move the interaction (which will look like this: type*method) over to the space on the upper right. Because you have made this selection, when you click on Paste the following subcommand will be included in your Syntax window:

```
/EMMEANS = TABLES (type*method).
```

You still have to insert "comp (method)" at the end of that line if you want SPSS to test the simple main effects of Method at each level of Type (you will get the pairwise comparisons for each simple effect automatically, whether you want them or not). Now, suppose that Type actually has four levels, and you want to test the simple effects of this factor, as well; this will require a second /EMMEANS subcommand. Also suppose that, because Type has four levels, you want to use a Bonferroni correction to adjust the p values from the pairwise (cell-to-cell) comparisons for that factor. Your Syntax file would need to contain something like this command:

```
UNIANOVA  finexam  BY type method
  /EMMEANS = TABLES (type*method) comp (method)
  /EMMEANS = TABLES (type*method) comp (type) adj (Bonferroni).
```

Testing Interaction Contrasts

In the Type X Method example, looking at the simple effect of Method for each Type provided one way to understand why the interaction was nearly significant: There was very little difference among the Method means for the gifted students, but there was a considerable difference for the average students. Another way to analyze the interaction into smaller, and therefore more easily interpretable, pieces is to look at interaction contrasts – that is, the amounts of interaction contained in the various possible 2 X 2 (one df) subsets of the total factorial design. If you look at a plot of the cell means for the current example, you will see that there is a good deal of interaction remaining if you delete either the video or computer conditions, but very little interaction if you delete the traditional method. You can use Select Cases from the Data menu to eliminate any one of the methods from a particular analysis and then perform a two-way ANOVA involving the remaining two methods, but the error term for the interaction will change each time you eliminate a different condition. If you want to use the error term from the omnibus two-way ANOVA for all of your interaction contrasts, you can specify your contrasts with the LMATRIX subcommand.

The order in which you place your contrast coefficients on the LMATRIX line is determined by the order in which your factors are expressed in the UNIANOVA command. In the UNIANOVA commands above, Type is listed before Method, making it the "slower-moving" factor. That means you should imagine your cell means laid along one line like this: average/traditional; average/video; average/computer; gifted/traditional; gifted/video; gifted/computer. The coefficients for the 2 X 2 contrast that eliminates the middle of the three methods (i.e., videotape in this example) would appear in your syntax file like this:

```
UNIANOVA  finexam  BY Type Method
  /LMATRIX type*method 1 0 -1 -1 0 1 .
```

Note that if Method were listed *before* Type, then Method would be the slower-moving factor, and the same contrast indicated above would require the following order of contrast coefficients:

```
UNIANOVA  finexam  BY Method Type
  /LMATRIX type*method 1 -1 0  0  -1 1 .
```

Note that now the first two coefficients represent the two Types for the traditional method, and the last two stand for the two Types for the computer method (the two zeroes in the middle eliminate the video condition). Also note that the order of the factors that specifies the interaction on the LMATRIX line does not matter (i.e., no distinction is made between type*method and method*type). Of course, you can also perform simple cell-to-cell comparisons by using 1 and -1 for the two cells to be compared, and 0's in the rest of the places. However, if you want to conduct more than one or two such comparisons, you will probably find it much more convenient to use the appropriate specifications on an EMMEANS subcommand.

The output you will get from the preceding two-line command begins with the usual two-way ANOVA summary table generated by the first line. The LMATRIX subcommand produces two additional boxes of results under the heading Custom Hypothesis Tests. The first of these, "contrast results", contains the estimated value and standard error (along with the sig. value and CI) for the specified contrast, which is labeled L1 (more than one contrast could be specified in the same command, in which case you would also see values for L2, L3, etc.). In this case, the SPSS notation agrees with the notation I use in my text, in that L refers to the single "difference" score that you get by applying the coefficients of a *L*inear contrast to a set of cell means. The second additional box contains the usual summary table for the one-way ANOVA that tests the significance of the contrast (if more than one contrast has been specified, this one-way ANOVA tests all of these contrasts simultaneously).

Complex Contrasts. The LMATRIX subcommand gives you the flexibility to specify any linear contrast, including complex contrasts. If you want to compare the two Types of students learning by the traditional method to the two types averaged across the video and computer methods, you could use the following command:

```
UNIANOVA  finexam  BY Type Method
  /LMATRIX type*method 1 1 -2 -1 -1 2 .
```

Note that I reverted to my previous practice of listing Type before Method. Also note that you would get the same results from using fractional coefficients (i.e., .5 .5 -1 -.5 -.5 1), but it is easy in this to double all the coefficients and to not have to work with fractions.

If one of your factors is quantitative (e.g., dosage), and the other is qualitative (e.g., type of drug), an interaction involving linear trends may be appropriate. Given two different drugs, each at four different dosages, the following complex contrast can be a very powerful way to test the drug by dosage interaction.

```
UNIANOVA  response  BY Drug Dosage
  /LMATRIX drug*dosage -3 -1  1  3  3  1 -1 -3 .
```

In later chapters, I will demonstrate even more complex uses for the LMATRIX subcommand.

Reference

Weinberg, S. L., & Abramowitz, S. K. (2002). Data Analysis for the Behavioral Sciences Using SPSS. New York: Cambridge University Press.