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ABSTRACT

Analysis of variance (ANOVA) designs typically use what is referred to as crossed design to test for differences between means of groups. In a balanced, or crossed, one-way ANOVA, each student (unit of analysis) would have a score in each of the experimental conditions. In a two-way design, the analysis is considered crossed if each level from one way is contained in each level of the other way. In this design, every person (unit of analysis) has a score in every cell. Many experimental designs in the behavioral sciences do not qualify as a crossed design. Units of measurement are rather "nested" inside other factors. A crossed experimental design would neglect the hierarchical structure of the data and produce incorrect interpretations of results. Neglecting a nested design when one actually exists will make the researcher: (1) wrongly attribute a main effect to an interaction effect when, in fact, no interaction exists; (2) divide by the wrong degrees of freedom when determining the mean square and F-value (and the statistical significance of the F-value); and (3) assume that a main effect has a smaller effect size (eta-squared) because the sum of squares for that effect is being partly attributed to the interaction effect. (SLD)

Nested ANOVA vs. crossed ANOVA: When and how to use which

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Nested ANOVA vs. crossed ANOVA: When and how to use which

"Crossed" One-Way ANOVA

ANOVA designs typically use what is referred to as a "crossed design" to test for differences between means of groups. In a crossed (or balanced) one-way ANOVA design, a researcher would expect each subject to have a score in each cell. For example, a teacher may want to test the differences in results obtained from three reading strategies. The teacher would record scores for each of his or her students in each of the experimental (reading strategies) conditions. The analysis would be a balanced, or crossed, one-way ANOVA design because each student would have a score in each of the experimental conditions.

"Crossed" Two-Way ANOVA

In a two-way design, the analysis is considered crossed if each level from one way is contained in each level of the other way. In this design, every person (assuming persons are the unit of analysis) has a score in every cell. For example, suppose a researcher was interested in the effects of three different dosages of vitamins administered in two different forms (oral and injection) to children. In this example, the first way would have three levels (dosages) and the second way would contain two levels (oral or injection). This would yield a 3 X 2 ANOVA with six (3 * 2 = 6) cells in the design. For this experiment, each child would have 6 scores, one in each cell. This type of design, illustrated by the crosstabulation in Table 1, is referred to as a crossed design because each person has a score in every cell.

Insert Table 1 about here

Nested ANOVA Designs

Many experimental designs in the behavioral sciences do not qualify as a crossed design. Units of measurement are, rather, "nested" inside other factors. Consider the following examples of nested designs: students nested within classrooms; students nested within schools; and students nested within classrooms nested within schools. In each of the occasions listed above, a crossed experimental design would neglect the hierarchical structure of the data and would produce incorrect interpretations of results.

To illustrate the effects of neglecting nested structure, a hypothetical data set of student reading scores has been created. In this example, student scores are obtained in five teachers' classrooms within each of four different schools. If the data from this experiment were not correctly treated as a nested design, the analysis would entail a crossed 4 X 5 ANOVA. Table 2 shows what the data structure would look like if this crossed analysis were performed. Table 3 illustrates the results of the crossed data ANOVA.

Insert Tables 2 and 3 about here

Although not previously stated, a nested structure is implicit in this design. It stands to reason that each of the five teachers does not teach in each of the four schools, but that they only tech in one school only. Recognizing this hierarchical structure, we treat each teacher as a unique factor within each school. Therefore, instead of a 4 X 5 ANOVA, we have a 4 X 20 ANOVA with four schools in the first way and twenty teachers in the second way. Table 4 illustrates the revised structure of this data. It should be noted, before the ANOVA is run, that there is no interaction effect in this data set since each teacher is in one and only one school and each student is in one and only one classroom.

Insert Tables 4 and 5 about here

Table 5 shows the results from the 4 X 20 ANOVA of the data in Table 4. Notice that the sum of squares (SS) for the teacher main effect in Table 5 is exactly equal to the combined SS of the teacher main effect and school*teacher interaction effect from Table 3. This illustrates how a researcher could fail to reject a null hypothesis simply because the data were incorrectly structured.

What Happens When I Use a Crossed Design and Should Have Used a Nested Design?

Although recognizing the structure of the data will help to yield accurate results, one price that is paid for performing a nested design is that of confounded results (Lindman, 1992). In this example, the teacher main effect and school*teacher interaction effect are considered confounded. The issue of confounded effects plays a larger role in interpretation of results than in the actual statistical test (Lindman, 1992). In this example, the large eta squared for the schools main effect is likely to be interpreted as differences between factors that are independent of teachers (e.g., administration and ethnic make-up of students). This would lead the researcher to assume that the teacher main effect is testing the difference between the mean scores of students between classrooms, independent of schools. In a nested design, however, the teacher main effect is somewhat dependant on the school main effect because not all teachers were randomly assigned to all schools. Thus, the results are confounded and the large eta squared for the teacher main effect could be due, in part, to the differences between children within schools.

For example, it could be that teacher 5 in school 1 (mean of 2.5) is actually a better teacher than teacher 6 in school 2 (mean of 4) and the difference in mean score is simply due to the type of school that the teachers are in. The teacher main effect would not detect this difference, but would test only for the differences between the means of the 2 students within each classroom unique to that level of the school way. In other words, the results from the ANOVA in Table 5 tells us that we should reject the null hypothesis that the means of the students' scores in teachers' classrooms within each level of the school way are equal. For a more detailed description of interpreting results from nested ANOVA designs see Hicks (1973) and Lindman (1992).

<u>Summary of Findings: Neglecting a nested design when one exists will make the researcher . . .</u>

1. . . . wrongly attribute a main effect to an interaction effect when in fact no interaction exists.
2. . . . divide by the wrong degrees of freedom when determining the mean square and F-value (also the statistical significance of the F-value).
3. . . . assume that a main effect has a smaller effect size (eta-squared) because the sum of squares for that effect (in this case the teacher main effect) is being partly attributed to the interaction effect (in this case the school*teacher interaction effect).

References

Hicks, C. R. (1973). Fundamental concepts in the design of experiments. New York: Holt, Rinehart and Winston.

Lindman, H. R. (1992). Analysis of variance in experimental design. New York: Springer-Verlag.

Table 1

Hypothetical crosstabulation of a completely crossed 3X2 design with 4 subjects

	Dosage 1	Dosage 2	Dosage 3
Oral	Subject 1 score Subject 2 score Subject 3 score Subject 4 score	Subject 1 score Subject 2 score Subject 3 score Subject 4 score	Subject 1 score Subject 2 score Subject 3 score Subject 4 score
Injection	Subject 1 score Subject 2 score Subject 3 score Subject 4 score	Subject 1 score Subject 2 score Subject 3 score Subject 4 score	Subject 1 score Subject 2 score Subject 3 score Subject 4 score

Table 2

Data for a crossed design of the reading data

	School			
Teacher	1	2	3	4
1	8	4	10	8
	7	4	10	8
2	7	4	10	8
	6	5	8	8
3	6	5	9	10
	5	5	8	10
4	5	6	6	10
	5	7	7	10
5	3	8	7	11
	2	8	6	12

Table 3

ANOVA for crossed data

Source	SS	df	MS	F	Sig.	Eta Squared
School	118.900	3	39.633	113.238	.000	.558
Teacher	.850	4	.212	.607	.662	.004
School*Teacher	86.350	12	7.196	20.560	.000	.405
Error	7.000	20	.350			
Total	213.100	39				

Table 4

Data for a nested design of the reading data

	School			
Teacher	1	2	3	4
1	8 7			
2	7 6			
3	6 5			
4	5 5			
5	3 2			
6		4 4		
7		4 5		
8		5 5		
9		6 7		
10		8 8		
11			10 10	
12			10 8	
13			9 8	
14			6 7	
15			7 6	
16				8 8
17				8 8
18				10 10
19				10 10
20				11 12

Table 5

ANOVA for nested data

Source	SS	df	MS	F	Sig.	Eta Squared
School	118.900	3	39.633	113.238	.000	.558
Teacher	87.200	16	5.450	15.571	.000	.409
School*Teacher						
Error	7.000	20	.350			
Total	213.100	39				

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