CHAPTER 12

Analysis of Variance: One-Factor Repeated Measures

Summary

The design described in this chapter is the analysis-of-variance version of the paired-samples *t* test. The only difference is that a *one-factor repeated measures ANOVA* can analyze *more* than two levels of the independent variable; a *t* test can analyze *only* two levels.

Like a one-way ANOVA, a one-factor repeated measures ANOVA has *one independent variable* (factor) that has two or more levels and there is *one dependent variable*. However, with a one-factor repeated measures ANOVA, there is a reason to match up the scores in the different treatments. Reasons might be that the same person contributed a score to each of the treatments or that a sub-group of participants (equal in size to the number of treatments) was alike on some matching variable.

In a display of the data for a one-factor repeated measures ANOVA, columns represent the treatments and rows represent the matched participants. A one-factor repeated measures ANOVA partitions the total variance in the dependent variable scores among *three* identifiable sources. One source is the variability due to the independent variable (columns); degrees of freedom are $N_K - 1$. A second source is the variance that is due to participants (rows); $df = N_t - 1$. The third source is the variance that remains (the error variance) $df = (N_K - 1)(N_t - 1)$. The F test, which determines if there are any significant differences among the treatment means, is a ratio of the mean square for the treatments divided by the mean square for error.

As a comparison, a one-way ANOVA partitions the total variance into only two sources, a treatment variance and an error variance. A one-factor repeated measures ANOVA, however, removes the effect of participants from the total variance, which makes it more sensitive than a one-way ANOVA. The variance is removed because in the one-factor repeated measures ANOVA, there should be minimum variance between conditions due to participants. This is because participants are either matched on some specific, important criteria, or because they are the same participant.

Chapter 12

One advantage of one-factor repeated measures ANOVA is that it is more *efficient;* that is, it requires less time and effort to obtain a given number of scores. *second advantage* is that it is more *powerful* because the error variance is smaller. The error variance is smaller because the variance due to the participants has been removed. A *disadvantage* of a one-factor repeated measures ANOVA is that it may contain unwanted *carryover* effects.

Like other ANOVA designs in previous chapters, pairwise comparisons among the several treatments can be made with Tukey *HSD* tests.

Type I and Type II errors were explained again. Type I errors occur when you reject a true null hypothesis and a Type II error occurs when you retain a false null hypothesis.

Two of the mathematical *assumptions* of one-factor repeated measures ANOVA are that the population scores are normally distributed and that the data show covariance matrix sphericity, a concept that was not explained due to its mathematical complexity.

Multiple-Choice Questions _____

Data Set 12-1. Work carefully—one error can cause more than one question to be missed.

Participants	X_1	X_2	X_3	Σ
1	2	3	7	12
2	3	5	6	14
Σ	5	8	13	26

1. In Data Set 12-1, SS_{tot} is equal to
   (1) 19.33;
   (2) 106.00;
   (3) 127.67;
   (4) none of the above; answer is _____.

2. In Data Set 12-1, SS_{treat} is equal to
   (1) 0.67;
   (2) 16.33;
   (3) 124.67;
   (4) none of the above; answer is _____.

3. In Data Set 12-1, MS_{error} is equal to
   (1) 2.33;
   (2) 1.50;
   (3) 1.17;
   (4) none of the above; answer is _____.

4. In Data Set 12-1, the *F* value for a repeated-measures ANOVA is
   (1) 3.50;
   (2) 4.44;
   (3) 10.20;
   (4) none of the above; answer is _____.

5. A repeated-measures ANOVA removes _____ variance from further consideration in the analysis.
   (1) between treatments;
   (2) between subjects;
   (3) error;
   (4) all of the above.

6. The *F* ratio in a repeated-measures ANOVA consists of the
   (1) between-subjects variance divided by the between-treatments variance;
   (2) between-treatments variance divided by the between-subjects variance;
   (3) between-subjects variance divided by the error variance;
   (4) between-treatments variance divided by the error variance.

7. A one-factor repeated-measures ANOVA is like a one-way ANOVA with respect to
   (1) the number of pieces that the total variance is partitioned into;
   (2) its efficiency;
   (3) its power;
   (4) none of the above.

8. The number of independent variables that can be handled by a one-factor repeated-ANOVA
   (1) is 1;
   (2) is 2;
   (3) is 3;
   (4) depends on the number of levels of the independent variable.

9. A one-factor repeated-measures ANOVA partitions the total variance into _____ component(s).
   (1) 1;
   (2) 2;
   (3) 3;
   (4) 4.

10. An *F* value of 3.50 with 4 and 10 degrees of freedom is obtained from the data. You should _____ the null hypothesis, even though you might be making a _____ error.
   (1) reject; Type I;
   (2) reject; Type II;
   (3) retain; Type I;
   (4) retain; Type II;

11. Which answer first defines a Type I error and then a Type II error?
   (1) retain a false null hypothesis; reject a true null hypothesis;
   (2) retain a false null hypothesis; retain a true null hypothesis;
   (3) reject a false null hypothesis; retain a true null hypothesis;
   (4) reject a true null hypothesis; retain a false null hypothesis.

Chapter 12

12. For which of the descriptions that follow would a repeated-measures ANOVA not be appropriate? A study in which
    (1) the population variances are quite different;
    (2) there are carryover effects from one administration of one level of the independent variable to the next;
    (3) both of the above;
    (4) neither of the above.

13. The advantages listed by your text for a repeated-measures ANOVA were
    (1) accuracy and elegance;
    (2) precision and adaptability;
    (3) efficiency and power;
    (4) simplicity and congruence.

14. A disadvantage of the repeated-measures ANOVA described in your text is that you cannot
    (1) make pairwise tests after the F test;
    (2) test the significance of the between-subjects term;
    (3) test more than three levels of the independent variable;
    (4) all of the above.

15. What is the critical value for a repeated-measures ANOVA that has three subjects who provide data for four conditions? Let $\alpha = .05$.
    (1) 3.84;
    (2) 4.76;
    (3) 5.14;
    (4) none of the above.

16. Which of the following is an advantage of a repeated-measures ANOVA over one-way ANOVA?
    (1) The repeated-measures ANOVA is more efficient;
    (2) The repeated-measures ANOVA eliminates variance due to participants;
    (3) The repeated-measures ANOVA is more powerful;
    (4) All are advantages.

Chapter 12

17. With a repeated-measures ANOVA, error variance due to subjects is lower because

    (1) the subjects are matched on some variable;
    (2) the subjects are the same people in different conditions;
    (3) both (1) and (2) could be correct;
    (4) neither (1) nor (2) can be correct.

18. Theoretically, the difference between a one-way ANOVA and a repeated-measures ANOVA is that

    (1) the one-way ANOVA is more powerful;
    (2) the repeated-measures ANOVA is more powerful;
    (3) there is no difference in power;
    (4) not enough information to answer the question.

19. A psychologist finds a significant difference between two conditions. She is very happy, and decides to repeat the study. This time, she finds no significant difference. Suppose she runs the study ten additional times, and fails to find a significant difference. There is a good chance that the significant difference she found the first time was due to

    (1) Type I error;
    (2) Type II error;
    (3) either Type I or Type II error;
    (4) neither Type I nor Type II error.

20. Type II errors are made when the researcher

    (1) rejects the null hypothesis when it shouldn't be rejected;
    (2) retains the null hypothesis when it shouldn't be rejected;
    (3) rejects the null hypothesis when it should be rejected;
    (4) retains the null hypothesis when it should be rejected.

Short Answer Questions _____

1. List all the advantages you can think of for using a repeated-measures design over an independent group design. If you were to design a study using a repeated-measure design, what would be your main concern?

2. Design a repeated-measures experiment. In doing so, identify independent and dependent variables, hypotheses and statement of the problem.

Problems _____

1. A classic study describe in a previous chapter taught us that our memories vary depending on the level at which we process information. Craik and Tulving (1975) presented nouns visually to participants for 0.2 seconds and later had them recognize as many as they could. Before each noun was presented, one of three kinds of questions was posed. To get an answer these three kinds of questions required different levels of processing. Examples of these three levels were:

   "Was the word in capital letters?"—shallow processing

   "Does the word rhyme with train?"—medium processing

   "Does the word fit in this sentence, 'The girl put the _____ on the table'?"—deep processing

   The proportions of presented words that were recognized in each condition are shown in the table, which was constructed to produce mean proportions like those found by Craik and Tulving. Analyze the scores with a repeated-measures ANOVA and make all three pairwise comparisons with Tukey *HSD* tests. Write an interpretation.

	Level of Processing		
Participant	Shallow	Medium	Deep
1	5	40	90
2	30	60	80
3	10	50	85
4	8	30	85
5	22	70	60

2. T. S. Spatz (1991) conducted workshops teaching women to do breast self examination. She gave participants a 27-item true/false test of their knowledge before they were trained (pretest), after they were trained (posttest), and again three months later (follow-up). The scores below mimic her results. Analyze them with a repeated-measures ANOVA and Tukey *HSD* tests. Write an interpretation.

Participant	Pretest	Posttest	Follow-up
1	7	22	16
2	10	20	22
3	10	23	24
4	13	21	16
5	15	26	22
6	17	26	26

3. A study by O'Brien and his colleagues (O'Brien, Albrecht, Hakala, & Rizzella, 1995) found that participants were able to remember information presented earlier in a text when they were prompted to do so. The information was presented early in the text (first two sentences), the middle of the text (sentence 5-7) or at the end (sentence 9-11). They measured reaction time as an indication of whether or not the participants were thinking about those concepts at the end of the passage. The data below represent reaction time scores in milliseconds. Analyze these data with a repeated-measures ANOVA and pairwise comparisons. Write an interpretation.

Participant	Early	Middle	Late
1	514	521	512
2	525	526	505
3	601	618	609
4	499	492	533
5	537	598	544