

## 12.10: Pairwise (Correlated)

### Learning Objectives

- Compute the Bonferroni correction
- Calculate pairwise comparisons using the Bonferroni correction

In the section on all pairwise comparisons among independent groups, the Tukey HSD test was the recommended procedure. However, when you have one group with several scores from the same subjects, the Tukey test makes an assumption that is unlikely to hold: The variance of difference scores is the same for all pairwise differences between means.

The standard practice for pairwise comparisons with correlated observations is to compare each pair of means using the method outlined in the section "Difference Between Two Means (Correlated Pairs)" with the addition of the Bonferroni correction described in the section "Specific Comparisons." For example, suppose you were going to do all pairwise comparisons among four means and hold the familywise error rate at 0.05. Since there are six possible pairwise comparisons among four means, you would use  $0.05/6 = 0.0083$  for the per-comparison error rate.

As an example, consider the case study "Stroop Interference." There were three tasks, each performed by 47 subjects. In the "words" task, subjects read the names of 60 color words written in black ink; in the "color" task, subjects named the colors of 60 rectangles; in the "interference" task, subjects named the ink color of 60 conflicting color words. The times to read the stimuli were recorded. In order to compute all pairwise comparisons, the difference in times for each pair of conditions for each subject is calculated. Table 12.10.1 shows these scores for five of the 47 subjects.

Table 12.10.1: Pairwise Differences

| W-C | W-I | C-I |
|-----|-----|-----|
| -3  | -24 | -21 |
| 2   | -41 | -43 |
| -1  | -18 | -17 |
| -4  | -23 | -19 |
| -2  | -17 | -15 |

Table 12.10.2 shows data for all 47 subjects.

**Table 12.10.2: Pairwise Differences for 47 subjects**

| W-C | W-I | C-I |
|-----|-----|-----|
| -3  | -24 | -21 |
| 2   | -41 | -43 |
| -1  | -18 | -17 |
| -4  | -23 | -19 |
| -2  | -17 | -15 |
| -3  | -15 | -12 |
| -3  | -28 | -25 |
| -3  | -36 | -33 |

|     |     |     |
|-----|-----|-----|
| -3  | -17 | -14 |
| -2  | -10 | -8  |
| -1  | -11 | -10 |
| -1  | -10 | -9  |
| -3  | -26 | -23 |
| 0   | -4  | -4  |
| -4  | -28 | -24 |
| -5  | -19 | -14 |
| -5  | -18 | -13 |
| -8  | -23 | -15 |
| -7  | -22 | -15 |
| -3  | -28 | -25 |
| -9  | -30 | -21 |
| -5  | -21 | -16 |
| -7  | -23 | -16 |
| -9  | -21 | -12 |
| -7  | -35 | -28 |
| -4  | -27 | -23 |
| -4  | -25 | -21 |
| -2  | -16 | -14 |
| -3  | -14 | -11 |
| -5  | -14 | -9  |
| -3  | -14 | -11 |
| -5  | -15 | -10 |
| -12 | -25 | -13 |
| -1  | -9  | -8  |
| -2  | -13 | -11 |
| -8  | -17 | -9  |

|    |     |     |
|----|-----|-----|
| 3  | -13 | -16 |
| -6 | -33 | -27 |
| -3 | -12 | -9  |
| -7 | -19 | -12 |
| -8 | -19 | -11 |
| -6 | -31 | -25 |
| -1 | -19 | -18 |
| -5 | -13 | -8  |
| -3 | -18 | -15 |
| -9 | -28 | -19 |
| -5 | -22 | -17 |

The means, standard deviations ( $Sd$ ), and standard error of the mean ( $Sem$ ),  $t$ , and  $p$  for all 47 subjects are shown in Table 12.10.3 The  $t$ 's are computed by dividing the means by the standard errors of the mean. Since there are 47 subjects, the degrees of freedom is 46. Notice how different the standard deviations are. For the Tukey test to be valid, all population values of the standard deviation would have to be the same.

Table 12.10.3: Pairwise Comparisons

| Comparison | Mean   | Sd   | Sem  | t      | p      |
|------------|--------|------|------|--------|--------|
| W-C        | -4.15  | 2.99 | 0.44 | -9.53  | <0.001 |
| W-I        | -20.51 | 7.84 | 1.14 | -17.93 | <0.001 |
| C-I        | -16.36 | 7.47 | 1.09 | -15.02 | <0.001 |

Using the **Bonferroni correction** for three comparisons, the  $p$  value has to be below  $0.05/3 = 0.0167$  for an effect to be significant at the 0.05 level. For these data, all  $p$  values are far below that, and therefore all pairwise differences are significant.

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