# Two-Way ANOVA Theoretical and Practical Calculations: In-Class Exercise

Psychology 311
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The e-book *[R] Companion for Experimental Design and Analysis for Psychology* by Williams, Krishnan, and Abdi contains the following example.

> Consider a replication of an experiment by Tulving & Pearlstone (1966), in which 60 subjects were asked to learn lists of 12, 24 or 48 words (factor A with 3 levels). These words can be put in pairs by categories (for example, apple and orange can be grouped as "fruits"). Subjects were asked to learn these words, and the category name was shown at the same time as the words were presented. Subjects were told that they did not have to learn the category names. After a very short time, subjects were asked to recall the words. At that time half of the subjects were given the list of the category names, and the other half had to recall the words without the list of categories (factor B with 2 levels). The dependent variable is the number of words recalled by each subject. Note that both factors are fixed. (p. 192)

The data are presented in the following table:

| Factor $\mathcal{B}$ | Factor $\mathcal{A}$ | | | | | |
|---|---|---|---|---|---|---|
| | $a_1$: 12 words | | $a_2$: 24 words | | $a_3$: 48 words | |
| $b_1$ Free Recall | 11 | 07 | 13 | 15 | 17 | 16 |
| | 09 | 12 | 18 | 13 | 20 | 23 |
| | 13 | 11 | 19 | 09 | 22 | 19 |
| | 09 | 10 | 13 | 08 | 13 | 20 |
| | 08 | 10 | 08 | 14 | 21 | 19 |
| $b_2$ Cued Recall | 12 | 10 | 13 | 14 | 32 | 30 |
| | 12 | 12 | 21 | 13 | 31 | 33 |
| | 07 | 10 | 20 | 14 | 27 | 25 |
| | 09 | 07 | 15 | 16 | 30 | 25 |
| | 09 | 12 | 17 | 07 | 29 | 28 |

1. Our first step is to get the data into R in a form suitable for analysis. Create a data file containing the 60 scores, with appropriate factor levels. There are many ways you could do this. One way is to first enter the dependent variable scores directly into R, then add the group labels as `factor` variables. We need to be sure to keep track of the order in which we entered the data. One way is to subdivide the data according to the "slowest moving" factor in the data set. To add the factor variables, you should take a close look at the help file for the `gl` function.

2. Let's look at the interaction plot. Imagine for a moment that the plot displayed population cell means. Which main effects, simple main effects, and interactions are *zero*?

3. Next, perform the two-way ANOVA using the `aov` function.

4. Use the quick calculation method for main effects to calculate the $F$ test for the main effect of `list_length`.

5. Test the significance of the simple main effect of `list_length` under "Free Recall."

6. Construct a confidence interval for $\omega^2$ for the main effect of `list_length`.

7. We can, of course, "go the other way" to compute the power to detect an effect corresponding to a particular value of $\omega^2$ by using the above equation to convert $\omega^2$ to $\lambda$. In this case, suppose that $n = 10$ per cell in a $2 \times 3$ 2-way ANOVA, and that $\omega^2 = .60$. What would be the power?

8. After observing a particular value of $F$, is it possible to construct a confidence interval on what the value of power was in the experiment just performed?