how we Can explain or interpret F-values in a Two-Way ANOVA?

Authored by

stats writer

November 21, 2025

RECOMMENDED CITATION

stats writer (2025). *how we Can explain or interpret F-values in a Two-Way ANOVA?*. PSYCHOLOGICAL SCALES. Retrieved from https://scales.arabpsychology.com/?p=99224

The interpretation of F-values is central to conducting a Two-Way ANOVA. These statistical metrics are designed to assess whether the main effects of two independent variables, and crucially, their combined interaction effect, are statistically significant in influencing a dependent variable. The core computation involves calculating the ratio of systematic variance to error variance.

Specifically, the F-value is derived by dividing the variance explained by a factor (Mean Square Between groups, or MSB) by the unexplained variance (Mean Square Within groups, or MSW). A high F-value suggests that the variation explained by the independent variable is much larger than the error variation. If the calculated F-value exceeds the critical value determined by the F-distribution for the given degrees of freedom, we then reject the null hypothesis, confirming a statistically significant effect. Consequently, a larger F-value serves as evidence for a greater discrepancy between the group means.

Understanding the Purpose of a Two-Way ANOVA

A Two-Way ANOVA is a powerful inferential statistical technique utilized when researchers wish to simultaneously evaluate the impact of two categorical independent variables (often referred to as factors) on a continuous dependent variable. This method is essential for determining if there is a statistically meaningful difference among the means of multiple independent groups, where those groups are defined by the levels of the two factors.

Unlike a one-way ANOVA, which assesses only a single factor, the two-way approach provides three distinct tests of significance. These tests examine the main effect of Factor 1, the main effect of Factor 2, and the combined influence, or interaction effect, between the two factors. By analyzing these components simultaneously, we gain a comprehensive understanding of how experimental variables affect the outcome, ensuring that we account for potential synergistic or antagonistic effects.

Deconstructing the ANOVA Summary Table

Whenever you execute a Two-Way ANOVA using statistical software, the resulting output is summarized in a table. This table contains crucial metrics necessary for interpreting the results, specifically the variance components for each source of variation: Factor 1, Factor 2, their Interaction, and the Residuals (error term).

This summary structure organizes the results by calculation type, detailing the Sum of Squares (SS), Degrees of Freedom (df), Mean Squares (MS), the calculated F-statistic, and the corresponding P-value. Each row represents a specific source of variation that contributes to the total variability in the dependent measure.

Source	Sum of Squares (SS)	df	Mean Squares (MS)	F	P-value
Factor 1	15.8	1	15.8	11.205	0.0015
Factor 2	505.6	2	252.78	179.087	0.0000
Interaction	13.0	2	6.5	4.609	0.0141
Residuals	76.2	54	1.41		

The Calculation of the F-Statistic

The F-value is the test statistic used to evaluate the null hypothesis for each effect in the ANOVA table. For the main effects and the interaction effect, the calculation follows a standardized ratio. This ratio compares the variance attributed to the specific effect (the Mean Square for the Factor or Interaction) against the variance attributed to random error (the Mean Square Residuals).

This comparison allows us to gauge whether the differences observed among the group means are larger than what would be expected due to random chance alone. Essentially, we are comparing the variance explained by our experimental manipulation versus the unexplained variance inherent in the data.

Each of the **F-values** presented in the summary table are calculated according to this formula:

F-value = Mean Squares (Effect or Factor) / Mean Squares (Residuals)

Interpreting Statistical Significance via P-Values

Crucially, every calculated F-value has a corresponding p-value. The p-value represents the probability of obtaining the observed data (or data more extreme) assuming that the null hypothesis (i.e., that there is no effect) is true. This probability is the primary statistical tool for deciding whether to accept or reject the null hypothesis for a given factor.

The decision rule hinges on comparing the p-value against a predetermined significance threshold, denoted as alpha ($alpha$). Typically, researchers set $alpha$ at 0.05. If the calculated p-value is less than this critical threshold (e.g., $p < 0.05$), we conclude that the factor or interaction term has a statistically significant effect on the outcome being measured, warranting the rejection of the null hypothesis for that specific effect.

Practical Example: Analyzing Weight Loss Factors

To illustrate the interpretation of F-values in a Two-Way ANOVA, consider a practical research scenario. Suppose a study aims to determine how two independent factors--exercise intensity (Factor 1) and gender (Factor 2)--influence the dependent variable of weight loss over a one-month period.

The experiment involves recruiting 60 participants: 30 men and 30 women. Within each gender group, 10 participants are randomly assigned to follow a program of either no exercise, light exercise, or intense exercise for one month. We then perform a Two-Way ANOVA analysis on the weight loss data using statistical software, yielding the following summary output that demonstrates the results:

Source	Sum of Squares (SS)	df	Mean Squares (MS)	F	P-value
Gender	15.8	1	15.8	11.205	0.0015
Exercise	505.6	2	252.78	179.087	0.0000
Gender * Exercise	13.0	2	6.5	4.609	0.0141
Residuals	76.2	54	1.41		

Interpretation of Main Effect: Gender

We begin the interpretation by focusing on the primary effect of the Gender factor. The calculated F-value is derived by comparing the Mean Square for Gender against the Mean Square for Residuals, serving as a ratio of the variance explained by gender versus the variance unexplained by the model.

The calculation is performed as follows: MS Gender / MS Residuals = 15.8 / 1.41, resulting in an F-statistic of **11.197**. The corresponding p-value is **0.0015**. Since 0.0015 is substantially less than the standard alpha level of 0.05, we confidently conclude that **gender** has a statistically significant effect on weight loss. This means the average weight loss differs significantly between men and women, irrespective of the exercise intensity levels.

The F-value is calculated as MS Gender / MS Residuals = 15.8 / 1.41 = **11.197**.
The corresponding p-value is **.0015**.
Since this p-value is less than .05, we conclude that gender has a **statistically significant** effect on weight loss.

Interpretation of Main Effect: Exercise Intensity

Next, we examine the influence of the second independent variable, Exercise Intensity, on weight loss. The F-value for Exercise Intensity is calculated as MS Exercise / MS Residuals = 252.78 / 1.41, yielding a result of **179.087**. This exceptionally large F-statistic indicates that variance due to exercise is overwhelmingly greater than the random error.

This high F-statistic is accompanied by a very low p-value (**<.0000**). Given that the p-value is virtually zero and far below the 0.05 significance level, we strongly reject the null hypothesis and conclude that **exercise intensity** has a highly statistically significant effect on the amount of weight lost.

The F-value is calculated as MS Exercise / MS Residuals = 252.78 / 1.41 = **179.087**.
The corresponding p-value is **<.0000**.
Since this p-value is less than .05, we conclude that exercise has a **statistically significant** effect on weight loss.

Interpretation of the Interaction Effect

The analysis of the interaction effect (Gender * Exercise) reveals whether the impact of exercise intensity on weight loss differs significantly depending on the gender of the participant. This test is crucial for a nuanced interpretation of the findings.

The F-value for the interaction is calculated as MS Gender * Exercise / MS Residuals = 6.5 / 1.41, resulting in **4.609**. This F-statistic is paired with a p-value of **0.0141**. Since 0.0141 is less than 0.05, we determine that the interaction effect between gender and exercise intensity is statistically significant. This suggests that the relationship between exercise and weight loss is not additive; instead, the effect of exercise is moderated by gender.

The F-value is calculated as MS Gender * Exercise / MS Residuals = 6.5 / 1.41 = **4.609**.
The corresponding p-value is **.0141**.
Since this p-value is less than .05, we conclude that the **interaction between gender and exercise** has a statistically significant effect on weight loss.

Concluding the Analysis and Next Steps

In this particular research example, our comprehensive analysis showed that both main factors (gender and exercise) had a statistically significant impact on the response variable (weight loss). Furthermore, the critical finding was that the interaction effect between the two factors was also statistically significant. This outcome confirms that the specific weight loss achieved at a certain exercise intensity depends on whether the participant is male or female.

Note: When the interaction effect is statistically significant, relying solely on the main effects can lead to incomplete or misleading conclusions. Therefore, the next crucial analytical step involves creating an interaction plot to better understand the nature of the interaction and visualize exactly how the two factors affect the response variable across their respective levels.

The following tutorials explain how to perform a Two-Way ANOVA using various specialized statistical software packages: