

How to Easily Perform a One-Way ANOVA in SAS

Authored by
stats writer

December 1, 2025

RECOMMENDED CITATION

stats writer (2025). *How to Easily Perform a One-Way ANOVA in SAS*. PSYCHOLOGICAL SCALES. Retrieved from <https://scales.arabpsychology.com/?p=103437>

The One-Way Analysis of Variance (ANOVA) is a powerful statistical technique utilized to determine if there are statistically significant differences between the means of three or more independent groups. In statistical software packages like SAS (Statistical Analysis System), performing this analysis is streamlined through specialized procedures.

SAS offers two primary procedures for conducting ANOVA: the generalized PROC GLM (General Linear Models) and the more specialized PROC ANOVA. While PROC GLM is capable of handling complex experimental designs, for balanced designs like a simple one-way ANOVA, PROC ANOVA is often the preferred choice due to its efficiency and clarity. Both procedures require precise specification of the experimental model, including identifying the response (dependent) variable and the classification (independent) variable.

This comprehensive tutorial serves as an expert guide, providing a step-by-step example on how to effectively structure your data, execute the analysis using the PROC ANOVA procedure in SAS, and meticulously interpret the resulting output tables, including the critical F statistic, p-value, and necessary post-hoc tests.

Understanding SAS Procedures for ANOVA

While the original instruction mentioned PROC GLM, PROC ANOVA is generally used for balanced designs (equal sample sizes per group), which is often the case in pedagogical examples. It is essential to understand the difference. The General Linear Model (GLM) procedure is comprehensive and handles both balanced and unbalanced designs, making it universally applicable. However, PROC ANOVA is specifically designed to be computationally efficient when all groups have the same number of observations, as seen in the example data.

For a basic one-way analysis, both procedures function similarly, but PROC ANOVA is often favored for its speed when balance is confirmed. The syntax requires a **CLASS** statement to define the grouping variable (the independent factor) and a **MODEL** statement to define the relationship between the response variable (dependent) and the factor variable. This clarity in syntax ensures the statistical model is correctly specified for testing the null hypothesis.

Crucially, the ultimate goal of the procedure is to decompose the total variation in the dependent variable into variation attributable to the different group means (Between Groups variation) and variation due to random error (Within Groups variation). The ratio of these variances provides the F statistic, which determines the statistical significance of the overall test. This foundational understanding is vital before diving into the coding implementation.

Step 1: Defining the Research Question and Preparing the Dataset

Before any statistical analysis can commence, the research objective must be clearly defined, and

the data must be properly formatted within the SAS environment. For a one-way ANOVA, we typically investigate whether an independent categorical variable (the factor) has a significant effect on a continuous dependent variable (the response). Consider a scenario where a researcher is testing the efficacy of three distinct study methods (A, B, and C) on student performance, measured by exam scores.

In this example, 24 students were recruited, 8 assigned to each of the three methods. The independent variable is **Method** (A, B, or C), which is categorical, and the dependent variable is the **Score**, which is continuous. This structure is ideal for One-Way ANOVA. The crucial step is translating this experimental data into a clean, ready-to-use SAS dataset, typically using the **DATA** step and **DATALINES** statement.

The exam results for each participant, categorized by their assigned study method, are visualized in the table below. Note how the dataset is structured vertically, with one row per observation, adhering to the requirements for most statistical software. This format ensures that data creation in SAS is straightforward and reliable.

Method A	Method B	Method C
78	81	84
81	83	88
82	83	88
82	85	89
85	86	90
88	88	93
88	90	95
90	91	98

To implement this dataset in SAS, we use the following code block. The input statement specifies that the variable **Method** is a character variable (indicated by the \$ sign) and **Score** is numeric. The **RUN** statement executes the data step, creating a temporary dataset named `my_data` in the current session.

```
/*create dataset*/  
data my_data;  
input Method $ Score;  
datalines;  
A 78  
A 81
```

```
A 82  
A 82  
A 85  
A 88  
A 88  
A 90  
B 81  
B 83  
B 83  
B 85  
B 86  
B 88  
B 90  
B 91  
C 84  
C 88  
C 88  
C 89  
C 90  
C 93  
C 95  
C 98  
;  
run;
```

Step 2: Executing the Analysis using PROC ANOVA

With the data successfully loaded into the `my_data` temporary dataset, the next action is to invoke the statistical procedure required for the analysis. We utilize `PROC ANOVA`, specifying the dataset we created. This procedure is efficient for balanced designs, ensuring timely execution of the variance analysis. The code structure is precise and declarative, defining the roles of the variables in the statistical model.

The core of the analysis rests on three critical statements: the **CLASS** statement, the **MODEL** statement, and the **MEANS** statement. The **CLASS Method;** statement identifies `Method` as the categorical independent variable (the factor whose levels define the groups). The **MODEL Score = Method;** statement formally defines the model, indicating that the response variable, `Score`, is modeled by the factor `Method`. This is where SAS understands the nature of the comparison.

A crucial addition to this code is the **MEANS** statement, which is essential for conducting post-hoc tests. If the overall ANOVA test indicates a significant difference among the means (i.e., we reject the null hypothesis), the post-hoc test helps pinpoint exactly which pairs of means differ. We request the **Tukey's Honestly Significant Difference (HSD)** test using the `/ tukey` option. We also add the `cldiff` option to request the 95% confidence intervals for the differences between means, providing valuable context regarding the magnitude of the effect.

The following syntax encapsulates the entire analytical process, initiating the ANOVA calculation and requesting the necessary multiple comparison procedures upon execution of the **RUN** statement.

```
/*perform one-way ANOVA*/  
proc ANOVA data=my_data;  
class Method;  
model Score = Method;  
means Method / tukey cldiff;  
run;
```

Step 3: Analyzing the Overall ANOVA Summary Table

Upon successful execution of the PROC ANOVA step, SAS generates a series of output tables. The most critical initial output is the ANOVA summary table, which details the partitioning of variance and provides the fundamental test of the null hypothesis. This table is essential for determining if the independent variable (Method) has any statistically significant effect on the dependent variable (Score).

The table displays the Sums of Squares, Degrees of Freedom (DF), Mean Squares, the calculated **F Value**, and the corresponding p-value ($Pr > F$). The F Value is calculated as the ratio of the Mean Square for the model (Between Groups variance) to the Mean Square for the Error (Within Groups variance). A larger F statistic suggests that the differences among the group means are substantial relative to the inherent variability within the groups.

For this specific study, we establish the formal hypotheses for the statistical test:

H0 (Null Hypothesis): The mean exam scores are equal across all three study methods ($\mu_A = \mu_B = \mu_C$).

HA (Alternative Hypothesis): At least one study method mean is significantly different from the others.

Examining the generated output summary table below, we focus on the row corresponding to the `Method` factor:

The ANOVA Procedure

Dependent Variable: Score

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	175.5833333	87.7916667	5.26	0.0140
Error	21	350.2500000	16.6785714		
Corrected Total	23	525.8333333			

R-Square	Coeff Var	Root MSE	Score Mean
0.333914	4.698685	4.083941	86.91667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Method	2	175.5833333	87.7916667	5.26	0.0140

Key findings extracted from the ANOVA table include:

The Degrees of Freedom for the Method (Model) is **2** ($k-1$, where k is the number of groups).

The F Value is calculated as **5.26**.

The corresponding p-value ($Pr > F$) is **0.0140**.

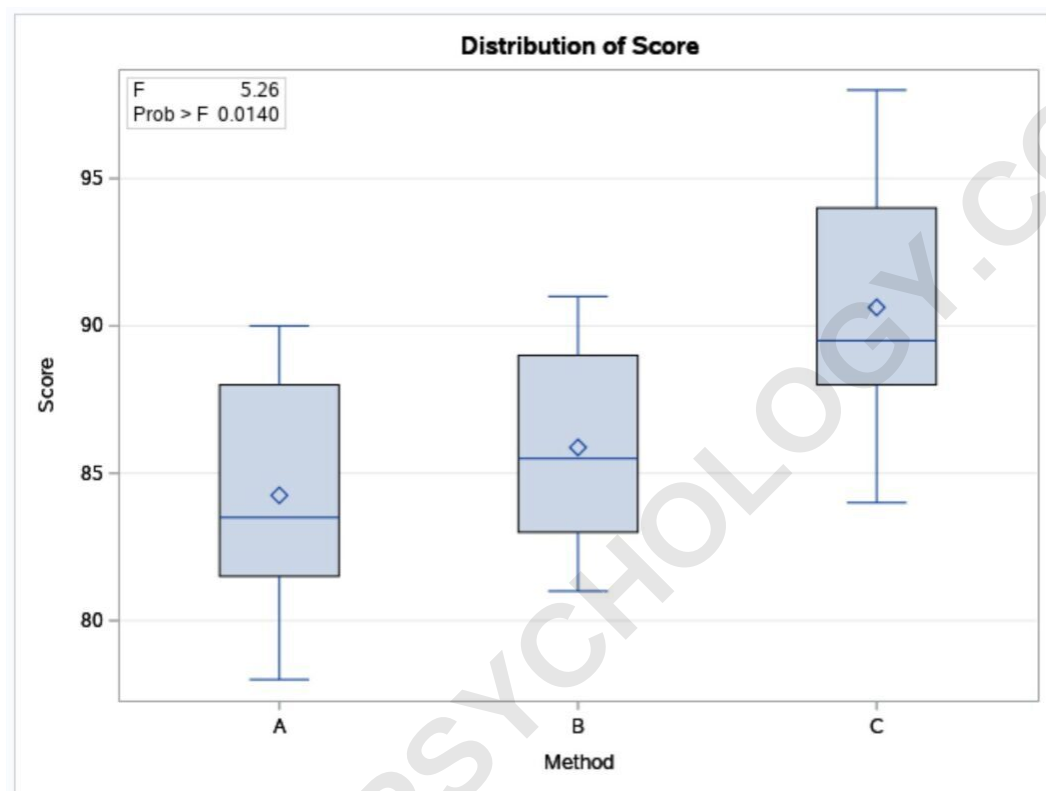
Using the standard significance level of $\alpha = 0.05$, since the calculated p-value (0.0140) is less than 0.05, we conclude that there is sufficient evidence to **reject the null hypothesis** (H_0). This crucial finding indicates that the mean exam score is not statistically equal across all three studying methods. In practical terms, the choice of study method has a significant impact on student performance, necessitating further investigation into which specific methods are driving this difference.

Step 4: Using Visualizations to Confirm Distribution and Trends

While the numerical output from the ANOVA table is definitive regarding statistical significance, it is always beneficial to examine the data distribution graphically. SAS often provides visual aids, such as boxplots, alongside the formal statistical tests, especially when using interactive environments or specific options in the procedure. These visualizations help confirm assumptions and provide intuitive insight into where the differences lie.

The boxplot visualization clearly depicts the spread, central tendency (median), and presence of potential outliers for the exam scores within each of the three treatment groups (Methods A, B, and C). By visually comparing the notches and the boxes themselves, we can gain an early understanding of group separation, which should align with the ANOVA results.

Observing the boxplots generated by SAS, which are displayed below, several trends become apparent. Method C exhibits a box that is generally shifted upwards compared to Methods A and B. This visual difference suggests that students using Method C generally achieved higher exam scores. Furthermore, the spread (interquartile range, represented by the box length) appears comparable across the groups, which is a good sign related to the homogeneity of variance assumption necessary for ANOVA.



Specifically, the median line for Method C is clearly above the medians for Methods A and B. Although Method A and Method B appear similar, Method C visually stands out as the highest-performing group. This visualization reinforces the rejection of the null hypothesis established in Step 3 and sets the stage for the definitive post-hoc analysis that follows.

Step 5: Identifying Specific Mean Differences with Tukey's HSD

Rejecting the null hypothesis in the overall ANOVA only confirms that at least one group mean is different; it does not specify which groups differ from one another. To isolate these specific differences while controlling the Type I error rate across multiple comparisons, a post-hoc test is required. Since we specified `/ tukey` in the PROC ANOVA statement, SAS provides the results for Tukey's Honestly Significant Difference (HSD) test.

Tukey's HSD performs all possible pairwise comparisons (A vs. B, A vs. C, and B vs. C) and

provides adjusted p-values for each comparison. The output table, often labeled as "Tukey's Studentized Range (HSD) Test," is presented below. The table systematically compares the mean differences, confidence limits, and the crucial adjusted probability values (P-Value, often noted as $Pr > |T|$ or similar).

A simple method for interpreting this output, often highlighted by SAS with asterisks, is to look for comparisons marked as statistically significant. In the output shown, the presence of stars (***) or a p-value below our alpha level (0.05) next to a comparison indicates a statistically significant mean difference. We must examine each pairwise comparison carefully.

The ANOVA Procedure

Tukey's Studentized Range (HSD) Test for Score

Note: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	21
Error Mean Square	16.67857
Critical Value of Studentized Range	3.56462
Minimum Significant Difference	5.1469

Comparisons significant at the 0.05 level are indicated by ***.

Method Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
C - B	4.750	-0.397	9.897	
C - A	6.375	1.228	11.522	***
B - C	-4.750	-9.897	0.397	
B - A	1.625	-3.522	6.772	
A - C	-6.375	-11.522	-1.228	***
A - B	-1.625	-6.772	3.522	

From the results table, we draw the following conclusions regarding the impact of the different study methods:

Method A vs. Method C: This comparison shows a significant difference, indicated by the associated statistics. This means that Method C leads to significantly different exam scores compared to Method A. The confidence interval for this difference, , further confirms the finding, as the interval does not contain zero, suggesting a true difference in population means.

Method A vs. Method B: The difference between these two methods is not statistically significant.

Method B vs. Method C: The difference between these two methods is also not statistically significant.

Therefore, based on the Tukey HSD results, the only statistically significant difference in mean exam scores exists between **Study Method A and Study Method C**. Method C proved superior to Method A, while Method B's performance did not significantly diverge from either A or C under these experimental conditions.

Step 6: Formal Reporting of the One-Way ANOVA Findings

The final and crucial stage of any statistical analysis is clearly and concisely reporting the results, typically following established scientific formats, such as APA Style. Reporting should summarize the test performed, the primary outcome, the specific statistical values, and the results of any follow-up tests conducted. Accuracy in reporting the degrees of freedom, the F-ratio, and the p-value is paramount.

When reporting the overall ANOVA, the degrees of freedom for the effect (Between Groups, $DF = 2$) and the degrees of freedom for the error (Within Groups, $DF = 21$, calculated as $N - k = 24 - 3$) must be cited alongside the F-statistic and its corresponding p-value. This provides the reader with sufficient information to evaluate the overall statistical test of the null hypothesis. The interpretation must explicitly link the statistical results back to the original research question concerning the impact of the studying methods.

Since the overall ANOVA was significant, the report must immediately transition to describing the Tukey's HSD results. This section details which specific groups generated the observed difference. We must report the confidence interval for the significant difference, as this communicates the practical effect size--how much higher, on average, the scores were in the significant comparison.

The formal summary of the analysis conducted in SAS is structured as follows:

A One-Way Analysis of Variance was executed to assess the potential effect of three different studying methods (A, B, and C) on student exam scores. The results indicated that there was a statistically significant difference in mean exam scores across the three methods, $F(2, 21) = 5.26$, $p = 0.014$. This required follow-up analysis to localize the specific differences.

Post-hoc analysis using Tukey's Honestly Significant Difference (HSD) test was performed to control for Type I error across the multiple pairwise comparisons. The results revealed that the mean exam score for Method C was significantly higher than the mean exam score for Method A. The 95% confidence interval for this difference in means was calculated as , confirming a robust difference.

No other pairwise comparisons yielded statistically significant results. Specifically, there was no

significant difference observed between Method A and Method B, nor between Method B and Method C. Therefore, the researcher can conclude that Method C is statistically superior to Method A in improving exam performance.

ARABPSYCHOLOGY.COM