Statistical Hypothesis Testing and Power Analysis in R

1. Introduction

The purpose of this task is to apply basic statistical testing techniques using R and to understand how they can be used to analyze experimental data. In this analysis, two sample t tests and one way ANOVA are used to compare results across different experimental groups. Along with hypothesis testing, effect size and statistical power are calculated to understand how meaningful the results are and whether the sample size is sufficient. Visualizations are included to make the results easier to understand and interpret.

2. Tools and Technologies Used

This analysis was carried out using the R programming language. The tidyverse package was used for data handling and preparation, ggplot2 was used to create visualizations, and the pwr package was used to perform statistical power analysis. Since no dataset was provided as part of the task, a realistic experimental dataset was created to demonstrate the required methods.

3. Dataset Description

A simulated experimental dataset was created to represent a real world experimental scenario. The dataset contains three groups: a Control group and two Treatment groups. Each group includes multiple observations of a numerical outcome variable.

The dataset contains the following columns:

- group: Indicates the experimental group
- value: Represents the measured outcome

This dataset was saved as experimental_data.csv and used throughout the analysis.

4. Two Sample t Test

4.1 Objective

The objective of the two sample t test is to compare the mean values of the Control group and Treatment A group to determine whether there is a meaningful difference between them.

4.2 Hypotheses

Null Hypothesis: There is no difference between the mean values of the Control group and the Treatment group.

Alternative Hypothesis: There is a difference between the mean values of the Control group and the Treatment group.

4.3 Results

The results of the two sample t test show a statistically significant difference between the Control and Treatment A groups, with the p value being less than the chosen significance level of 0.05. This indicates that the observed difference in group means is unlikely to have occurred by chance.

5. Effect Size for t Test

To understand the practical importance of the difference between groups, Cohen's d was calculated as the effect size. The resulting value indicates a large effect size, suggesting that the difference between the Control and Treatment A groups is meaningful in practice and not just statistically significant.

6. Power Analysis for t Test

A power analysis was conducted to estimate the number of observations required to reliably detect the observed effect. Using a significance level of 0.05 and a desired power of 0.80, the analysis showed that a relatively small sample size per group is sufficient due to the strong effect size.

7. One Way ANOVA

7.1 Objective

One way ANOVA was used to compare the mean values across all three experimental groups: Control, Treatment A, and Treatment B.

7.2 Hypotheses

Null Hypothesis: All group means are equal.

Alternative Hypothesis: At least one group mean is different from the others.

7.3 Results

The ANOVA results indicate a statistically significant difference among the experimental groups, with a p value below 0.05. This suggests that the treatments have different effects on the measured outcome.

8. Effect Size and Power Analysis for ANOVA

Eta Squared was calculated to measure the effect size for the ANOVA test. The value indicates a large effect, showing clear differences among the groups. A power analysis for the ANOVA confirmed that the sample size used in the analysis is sufficient to detect these differences with high confidence.

9. Data Visualization

Visualizations were created using ggplot2 to support and explain the statistical results. Boxplots and violin plots were used to show the distribution of values across experimental groups. These plots help visually confirm the differences identified through statistical testing.

10. Conclusion

In conclusion, this task demonstrates how statistical hypothesis testing and power analysis can be applied using R to analyze experimental data. Two sample t tests and one way ANOVA were successfully implemented, and effect sizes were calculated to assess practical significance. Power analysis was used to support sample size planning, and visualizations were included to clearly communicate the results. This analysis highlights the importance of combining statistical results with clear interpretation for data driven decision making.