

What are the Four Assumptions Made in a T-Test?

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The t-test is one of the most widely utilized inferential statistical tests, designed specifically to determine if there is a statistically significant difference between the means of two groups. However, the reliability and validity of the results derived from a t-test depend entirely upon meeting a specific set of requirements known as assumptions. Ignoring these prerequisites can lead to flawed conclusions and incorrect interpretations of the data.

There are four fundamental assumptions underpinning the proper execution of a standard two-sample independent t-test: the data must exhibit independence of observations, approximate normal distribution, homogeneity of variances (or homoscedasticity), and finally, samples must be obtained through a method of random sampling. These conditions ensure that the statistical model is appropriate for the collected data, allowing for robust hypothesis testing.

In essence, these assumptions stipulate that the data should be distributed in a bell-curve shape, possess roughly equal variation between the groups being compared, consist of observations that do not influence each other, and accurately represent the underlying population from which they were drawn. These assumptions must be rigorously tested and met in order for the results of the t-test to be reliable and valid.

The Four Critical Assumptions of the T-Test

When applying the t-test to compare the means of two groups, we rely on the following four core statistical assumptions regarding the nature of the samples:

Independence of Observations: The data points within one sample must not be related to or influenced by the data points in the other sample.

Normality: The distributions of the scores in both comparison groups should approximate a normal distribution.

Homogeneity of Variances: The variance (or spread) of the scores must be roughly equal across the two samples (a condition also known as homoscedasticity).

Random Sampling: Both samples must be derived from the broader population using a robust random sampling technique.

If one or more of these foundational assumptions are violated, the resulting statistical inferences from the two-sample t-test may be unreliable or even misleading. In this tutorial we provide an explanation of each assumption, how to determine if the assumption is met, and what to do if the assumption is violated.

Assumption 1: Independence of Observations

A two-sample t-test requires the assumption that the observations in one sample are statistically independent of the observations in the other sample. This means that the score of a participant in Group A must not be linked to or influenced by the score of a participant in Group B. If the observations are dependent (e.g., if the same individuals appear in both samples, which would necessitate a paired t-test), it is not valid to draw conclusions about the differences between two distinct populations.

This independence is a crucial aspect of the study design. Violation of this assumption fundamentally invalidates the standard error calculation used by the test, leading to inaccurate confidence intervals and p-values. Researchers must ensure that data points are collected independently to maintain the integrity of the statistical comparison.

How to Check this Assumption

The easiest and most reliable way to check this assumption is to verify the study's design and data collection procedures. Specifically, you must confirm that each observation only appears once across the two samples and that the collection method used for both samples was based on proper random sampling techniques, ensuring no systematic relationship between the groups.

What to Do if this Assumption is Violated

If this assumption is violated, the results of the two-sample t-test are completely invalid. In this severe scenario, the recommended course of action is to collect two entirely new samples. These new samples must be acquired using a strict random sampling method, ensuring definitively that each individual included in one sample does not belong to the other sample.

Assumption 2: Approximate Normal Distribution (Normality)

A two-sample t-test operates on the assumption that the underlying distributions of the populations from which both samples were drawn are approximately normally distributed. While the t-test is generally robust against minor deviations from normality, particularly with large sample sizes ($N > 50$), adherence to this assumption is critical when dealing with small datasets.

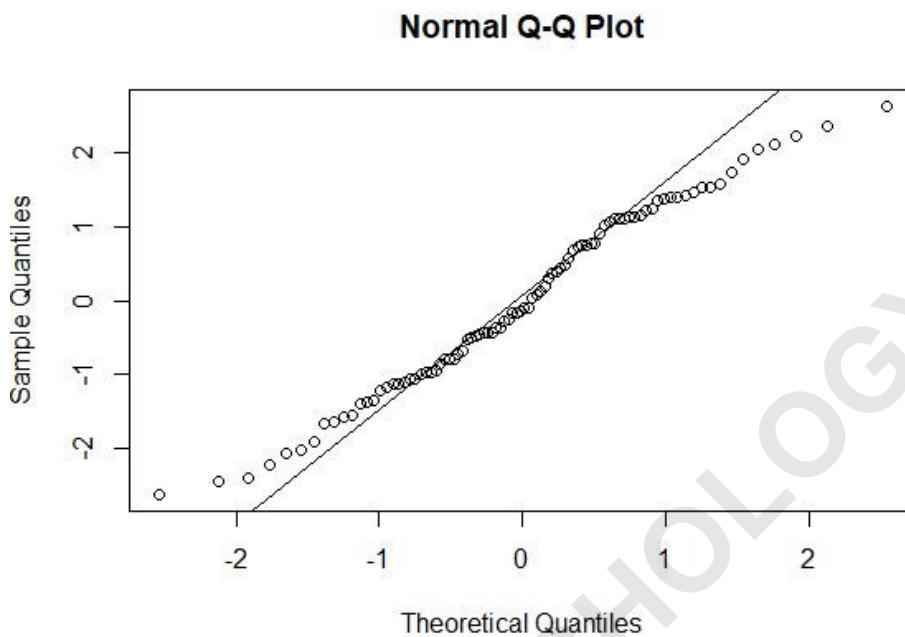
How to Check this Assumption

The methodology for checking normality should be adapted based on the sample size.

Small Samples ($n < 50$): If the sample sizes are small, we can use a formal statistical test, such as the Shapiro-Wilk test, to determine if each sample is normally distributed. If the p-value of the

Shapiro-Wilk test is less than a predefined significance level (e.g., 0.05), then we conclude that the data is significantly non-normally distributed.

Large Samples ($n \geq 50$): If the sample sizes are large, visual inspection is often more reliable than formal tests. It is better to use a Q-Q plot to visually check if the data is normally distributed, as the Central Limit Theorem helps ensure the sampling distribution of the mean is normal.



If the data points roughly fall along a straight diagonal line in a Q-Q plot, then the dataset likely follows a normal distribution.

What to Do if this Assumption is Violated

If the normality assumption is severely violated, especially with small samples, then we should perform the Mann-Whitney U test. This test is the non-parametric equivalent to the two-sample t-test and does not make the strict assumption that the two samples are normally distributed. Non-parametric tests analyze ranks rather than the raw data values.

Assumption 3: Homogeneity of Variances

The standard two-sample t-test assumes that the two samples have roughly equal variances, a condition known as homogeneity of variances. If the variances are unequal (heteroscedastic), the pooled estimate of the standard deviation used in the standard t-test formula becomes biased, potentially affecting the accuracy of the Type I error rate.

How to Check this Assumption

While formal statistical tests (like Levene's test) are available, a helpful rule of thumb is often employed to quickly assess if the variances between the two samples are equal: If the ratio of the larger variance to the smaller variance is less than 4, then we can generally assume the variances are approximately equal and proceed with the standard two-sample t-test.

For example, suppose Sample 1 has a variance of 24.5 and Sample 2 has a variance of 15.2. The ratio of the larger sample variance to the smaller sample variance would be calculated as:

Ratio Calculation:

$$24.5 / 15.2 = 1.61$$

Since this ratio (1.61) is less than the threshold of 4, we would assume that the variances between the two groups are approximately equal, satisfying the condition of homogeneity of variances.

What to Do if this Assumption is Violated

If the assumption of homogeneity of variances is violated, we should perform Welch's t-test instead of the standard t-test. Welch's t-test is an adaptation of the t-test that does not assume equal variances. It adjusts the degrees of freedom calculation to robustly compare the means even when the spreads of the two groups are substantially different.

Assumption 4: Random Sampling

The two-sample t-test assumes that both samples were obtained using a rigorous random sampling method. This procedural requirement ensures that the collected data accurately reflects the characteristics of the larger population of interest, which is fundamental for generalizing the findings beyond the sample itself.

How to Check this Assumption

There is no formal statistical test available to check this assumption; compliance rests entirely on the quality of the experimental design. Instead, researchers must verify that both samples were obtained using a formal random sampling strategy such that every individual in the target population had an equal probability of being included in either sample.

What to Do if this Assumption is Violated

If the random sampling assumption is violated (e.g., if convenience sampling was used), then it is

unlikely that our two samples are truly representative of the population of interest. In this case, we cannot generalize the findings from the two-sample t-test to the overall population with statistical reliability. In this scenario, the most responsible action is to redesign the sampling procedure and collect two new samples using a proper random sampling method.

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