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Type I & Type II Errors | Differences, Examples, Visualizations

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In statistics, a **Type I error** is a false positive conclusion, while a **Type II error** is a false negative conclusion.

Making a statistical decision always involves uncertainties, so the risks of making these errors are unavoidable in hypothesis testing.

The probability of making a Type I error is the significance level, or alpha (α), while the probability of making a Type II error is beta (β). These risks can be minimized through careful planning in your study design.

Example: Type I vs Type II error

You decide to get tested for COVID-19 based on mild symptoms. There are two errors that could potentially occur:

- **Type I error (false positive):** the test result says you have coronavirus, but you actually don't.
- **Type II error (false negative):** the test result says you don't have coronavirus, but you actually do.

Error in statistical decision-making

Using hypothesis testing, you can make decisions about whether your data support or refute your research predictions with null and alternative hypotheses.

Hypothesis testing starts with the assumption of no difference between groups or no relationship between variables in the population—this is the **null hypothesis**. It's always paired with an **alternative hypothesis**, which is your research prediction of an actual difference between groups or a true relationship between variables.

> **Example: Null and alternative hypothesis**
>
> You test whether a new drug intervention can alleviate symptoms of an autoimmune disease.
>
> In this case:
>
> - The null hypothesis (H_0) is that the new drug has no effect on symptoms of the disease.
> - The alternative hypothesis (H_1) is that the drug is effective for alleviating symptoms of the disease.

Then, you decide whether the null hypothesis can be rejected based on your data and the results of a statistical test. Since these decisions are based on probabilities, there is always a risk of making the wrong conclusion.

- If your results show statistical significance, that means they are very unlikely to occur if the null hypothesis is true. In this

- If your findinas do not show statistical sianificance. thev have

Therefore, you fail to reject your null hypothesis. But sometimes, this may be a Type II error.

Example: Type I and Type II errors

A Type I error happens when you get false positive results: you conclude that the drug intervention improved symptoms when it actually didn't. These improvements could have arisen from other random factors or measurement errors.

A Type II error happens when you get false negative results: you conclude that the drug intervention didn't improve symptoms when it actually did. Your study may have missed key indicators of improvements or attributed any improvements to other factors instead.

Type I and Type II Error

Null hypothesis is ...	True	False
Rejected	Type I error False positive Probability = α	Correct decision True positive Probability = 1 – β
Not rejected	Correct decision True negative Probability = 1 – α	Type II error False negative Probability = β

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Type I error

A Type I error means rejecting the null hypothesis when it's actually true. It means concluding that results are **statistically significant** when, in reality, they came about purely by chance or because of unrelated factors.

The risk of committing this error is the significance level (alpha or α) you choose. That's a value that you set at the beginning of your study to assess the statistical probability of obtaining your results (p value).

The significance level is usually set at 0.05 or 5%. This means that your results only have a 5% chance of occurring, or less, if the null hypothesis is actually true.

If the p value of your test is lower than the significance level, it means your results are statistically significant and consistent with the alternative hypothesis. If your p value is higher than the significance level, then your results are considered statistically non-significant.

Example: Statistical significance and Type I error

In your clinical study, you compare the symptoms of patients who received the new drug intervention or a control treatment. Using a t test, you obtain a p value of .035. This p value is lower than your alpha of .05, so you consider your results statistically significant and reject the null hypothesis.

However, the *p* value means that there is a 3.5% chance of

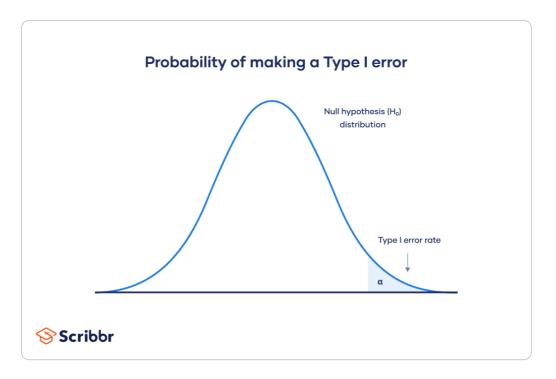Therefore, there is still a risk of making a Type I error.

To reduce the Type I error probability, you can simply set a lower significance level.

Type I error rate

The null hypothesis distribution curve below shows the probabilities of obtaining all possible results if the study were repeated with new samples and the null hypothesis were true in the population.

At the tail end, the shaded area represents alpha. It's also called a **critical region** in statistics.

If your results fall in the critical region of this curve, they are considered statistically significant and the null hypothesis is rejected. However, this is a false positive conclusion, because the null hypothesis is actually true in this case!

Probability of making a Type I error

Null hypothesis (H_0) distribution

Type I error rate

α

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Type II error

actually false. This is not quite the same as "accepting" the null hypothesis, because hypothesis testing can only tell you whether to reject the null hypothesis.

Instead, a Type II error means failing to conclude there was an effect when there actually was. In reality, your study may not have had enough **statistical power** to detect an effect of a certain size.

Power is the extent to which a test can correctly detect a real effect when there is one. A power level of 80% or higher is usually considered acceptable.

The risk of a Type II error is inversely related to the statistical power of a study. The higher the statistical power, the lower the probability of making a Type II error.

Example: Statistical power and Type II error

When preparing your clinical study, you complete a power analysis and determine that with your sample size, you have an 80% chance of detecting an effect size of 20% or greater. An effect size of 20% means that the drug intervention reduces symptoms by 20% more than the control treatment.

However, a Type II may occur if an effect that's smaller than this size. A smaller effect size is unlikely to be detected in your study due to inadequate statistical power.

Statistical power is determined by:

- **Size of the effect**: Larger effects are more easily detected.
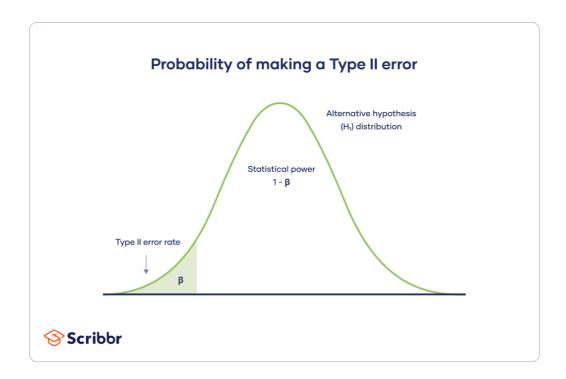- **Measurement error**: Systematic and random errors in recorded data reduce power.

To (indirectly) reduce the risk of a Type II error, you can increase the sample size or the significance level.

Type II error rate

The alternative hypothesis distribution curve below shows the probabilities of obtaining all possible results if the study were repeated with new samples and the alternative hypothesis were true in the population.

The Type II error rate is beta (β), represented by the shaded area on the left side. The remaining area under the curve represents statistical power, which is $1 - \beta$.

Increasing the statistical power of your test directly decreases the risk of making a Type II error.

Probability of making a Type II error

Alternative hypothesis
(H_1) distribution

Statistical power
$1 - \beta$

Type II error rate

β

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Trade-off between Type I and Type II errors

The Type I and Type II error rates influence each other. That's

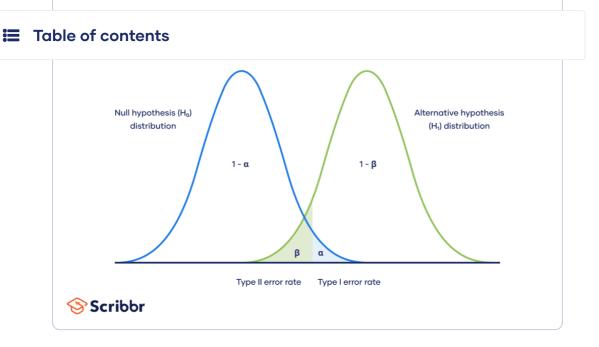This means there's an important tradeoff between Type I and Type

- Setting a lower significance level decreases a Type I error risk, but increases a Type II error risk.
- Increasing the power of a test decreases a Type II error risk, but increases a Type I error risk.

This trade-off is visualized in the graph below. It shows two curves:

- The **null hypothesis distribution** shows all possible results you'd obtain if the null hypothesis is true. The correct conclusion for any point on this distribution means not rejecting the null hypothesis.
- The **alternative hypothesis distribution** shows all possible results you'd obtain if the alternative hypothesis is true. The correct conclusion for any point on this distribution means rejecting the null hypothesis.

Type I and Type II errors occur where these two distributions overlap. The blue shaded area represents alpha, the Type I error rate, and the green shaded area represents beta, the Type II error rate.

By setting the Type I error rate, you indirectly influence the size of the Type II error rate as well.

It's important to strike a balance between the risks of making Type I and Type II errors. Reducing the alpha always comes at the cost of increasing beta, and vice versa.

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Is a Type I or Type II error worse?

For statisticians, a Type I error is usually worse. In practical terms, however, either type of error could be worse depending on your research context.

A Type I error means mistakenly going against the main statistical

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Based on the incorrect conclusion that the new drug intervention is effective, over a million patients are prescribed the medication, despite risks of severe side effects and inadequate research on the outcomes. The consequences of this Type I error also mean that other treatment options are rejected in favor of this intervention.

In contrast, a Type II error means failing to reject a null hypothesis. It may only result in missed opportunities to innovate, but these can also have important practical consequences.

Example: Consequences of a Type II error

If a Type II error is made, the drug intervention is considered ineffective when it can actually improve symptoms of the disease. This means that a medication with important clinical significance doesn't reach a large number of patients who could tangibly benefit from it.

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Frequently asked questions about Type I and II errors

What are Type I and Type II errors? ❯

How do you reduce the risk of making a Type I error? ❯

How do you reduce the risk of making a Type II error? ❯

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Pritha has an academic background in English, psychology and
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If a result is statistically significant, that means it's unlikely to be explained solely

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Understanding P values | Definition and Examples

The p-value shows the likelihood of your data occurring under the null hypothesis. P-values help determine statistical significance.

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Statistical Power and Why It Matters | A Simple Introduction

Statistical power, or sensitivity, is the likelihood of a significance test detecting an effect when there actually is one.

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