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Understanding P-values | Definition and Examples

Published on July 16, 2020 by Rebecca Bevans. Revised on June 22, 2023.

The **p value** is a number, calculated from a statistical test, that describes how likely you are to have found a particular set of observations if the null hypothesis were true.

P values are used in hypothesis testing to help decide whether to reject the null hypothesis. The smaller the *p* value, the more likely you are to reject the null hypothesis.

What is a null hypothesis?

All statistical tests have a null hypothesis. For most tests, the null hypothesis is that there is no relationship between your variables of interest or that there is no difference among groups.

For example, in a two-tailed *t* test, the null hypothesis is that the difference between two groups is zero.

You want to know whether there is a difference in longevity

and diet B. You can statistically test the difference between
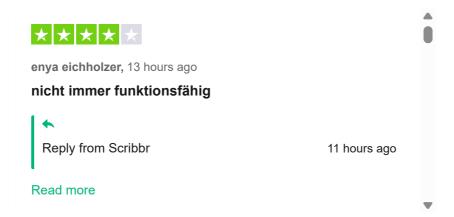these two diets using a two-tailed t test.

- **Null hypothesis (H_0):** there is no difference in longevity
  between the two groups.
- **Alternative hypothesis (H_A or H_1):** there is a difference
  in longevity between the two groups.

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What exactly is a *p* value?

The ***p* value**, or probability value, tells you how likely it is that your

The p value tells you how often you would expect to see a test

your statistical test if the null hypothesis of that test was true. The p value gets smaller as the test statistic calculated from your data gets further away from the range of test statistics predicted by the null hypothesis.

The p value is a proportion: if your p value is 0.05, that means that 5% of the time you would see a test statistic at least as extreme as the one you found if the null hypothesis was true.

> **Example: Test statistic and p value**
>
> If the mice live equally long on either diet, then the test statistic from your t test will closely match the test statistic from the null hypothesis (that there is no difference between groups), and the resulting p value will be close to 1. It likely won't reach exactly 1, because in real life the groups will probably not be perfectly equal.
>
> If, however, there is an average difference in longevity between the two groups, then your test statistic will move further away from the values predicted by the null hypothesis, and the p value will get smaller. The p value will never reach zero, because there's always a possibility, even if extremely unlikely, that the patterns in your data occurred by chance.

How do you calculate the p value?

P values are usually automatically calculated by your statistical program (R, SPSS, etc.).

You can also find tables for estimating the p value of your test statistic online. These tables show, based on the test statistic and

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The calculation of the *p* value depends on the statistical test you

- Different statistical tests have different assumptions and generate different test statistics. You should choose the statistical test that best fits your data and matches the effect or relationship you want to test.
- The number of independent variables you include in your test changes how large or small the test statistic needs to be to generate the same *p* value.

Example: Choosing a statistical test

If you are comparing only two different diets, then a two-sample *t* test is a good way to compare the groups. To compare three different diets, use an ANOVA instead – doing multiple pairwise comparisons will result in artificially low *p* values and lets you overestimate the significance of the difference between groups.

No matter what test you use, the *p* value always describes the same thing: how often you can expect to see a test statistic as extreme or more extreme than the one calculated from your test.

P values and statistical significance

P values are most often used by researchers to say whether a certain pattern they have measured is statistically significant.

Statistical significance is another way of saying that the *p* value of a statistical test is small enough to reject the null hypothesis of the test.

How small is small enough? The most common threshold is $p < 0.05$; that is, when you would expect to find a test statistic as
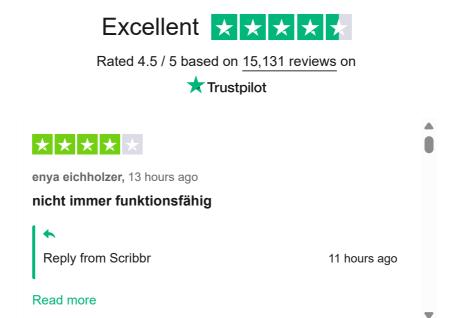
The threshold value for determining statistical significance is also

Example: Statistical significance

Your comparison of the two mouse diets results in a *p* value of less than 0.01, below your alpha value of 0.05; therefore you determine that there is a statistically significant difference between the two diets.

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Reporting *p* values

P values of statistical tests are usually reported in the results section of a research paper along with the key information needed

coefficient in a linear regression, or the average difference

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Example: Reporting the results

In our comparison of mouse diet A and mouse diet B, we found that the lifespan on diet A (M = 2.1 years; SD = 0.12) was significantly shorter than the lifespan on diet B (M = 2.6 years; SD = 0.1), with an average difference of 6 months (t(80) = -12.75; $p < 0.01$).

Caution when using p values

P values are often interpreted as your risk of rejecting the null hypothesis of your test when the null hypothesis is actually true.

In reality, the risk of rejecting the null hypothesis is often higher than the p value, especially when looking at a single study or when using small sample sizes. This is because the smaller your frame of reference, the greater the chance that you stumble across a statistically significant pattern completely by accident.

P values are also often interpreted as supporting or refuting the alternative hypothesis. This is not the case. **The p value can only tell you whether or not the null hypothesis is supported.** It cannot tell you whether your alternative hypothesis is true, or why.

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Frequently asked questions about p-values

What is a p-value?   ⌄

A *p-value*, or probability value, is a number describing how likely

hypothesis of your statistical test.

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Rebecca Bevans

Rebecca is working on her PhD in soil ecology and spends her free

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An Easy Introduction to Statistical Significance (With Examples)

If a result is statistically significant, that means it's unlikely to be explained solely by random factors or chance.

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Test statistics | Definition, Interpretation, and Examples

The test statistic is a number, calculated from a statistical test, used to find if your data could have occurred under the null hypothesis.

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