Choosing the Right Statistical Test | Types & Examples

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Statistical tests are used in hypothesis testing. They can be used to:

- determine whether a predictor variable has a statistically significant relationship with an outcome variable.
- estimate the difference between two or more groups.

Statistical tests assume a null hypothesis of no relationship or no difference between groups. Then they determine whether the observed data fall outside of the range of values predicted by the null hypothesis.

If you already know what types of variables you're dealing with, you can use the flowchart to choose the right statistical test for your data.

Statistical tests flowchart

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What does a statistical test do?

Statistical tests work by calculating a **test statistic** – a number that describes how much the relationship between variables in your test differs from the null hypothesis of no relationship.

It then calculates a **_p_ value** (probability value). The *p*-value estimates how likely it is that you would see the difference described by the test statistic if the null hypothesis of no relationship were true.

If the value of the test statistic is more extreme than the statistic calculated from the null hypothesis, then you can infer a **statistically significant relationship** between the predictor and outcome variables.

If the value of the test statistic is less extreme than the one calculated from the null hypothesis, then you can infer **no statistically significant relationship** between the predictor and outcome variables.

When to perform a statistical test

You can perform statistical tests on data that have been collected in a statistically valid manner – either through an <u>experiment</u>, or through observations made using <u>probability sampling methods</u>.

For a statistical test to be <u>valid</u>, your sample size needs to be large enough to approximate the true distribution of the population being studied.

To determine which statistical test to use, you need to know:

- whether your data meets certain assumptions.
- the <u>types of variables</u> that you're dealing with.

Statistical assumptions

Statistical tests make some common assumptions about the data they are testing:

1. **Independence of observations** (a.k.a. no autocorrelation): The observations/variables you include in your test are not related (for example, multiple measurements of a single test subject are not independent, while measurements of multiple different test subjects are independent).

2. **Homogeneity of variance**: the <u>variance</u> within each group being compared is similar among all groups. If one group has much more variation than others, it will limit the test's effectiveness.

3. **Normality of data**: the data follows a <u>normal distribution</u> (a.k.a. a bell curve). This assumption applies only to <u>quantitative data</u>.

If your data do not meet the assumptions of normality or homogeneity of variance, you may be able to perform a **nonparametric statistical test**, which allows you to make comparisons without any assumptions about the data distribution.

If your data do not meet the assumption of independence of observations, you may be able to use a test that accounts for structure in your data (repeated-measures tests or tests that include blocking variables).

Types of variables

The <u>types of variables</u> you have usually determine what type of statistical test you can use.

Quantitative variables represent amounts of things (e.g. the number of trees in a forest). Types of quantitative variables include:

- **Continuous** (aka <u>ratio</u> variables): represent measures and can usually be divided into units smaller than one (e.g. 0.75 grams).
- **Discrete** (aka integer variables): represent counts and usually can't be divided into units smaller than one (e.g. 1 tree).

Categorical variables represent groupings of things (e.g. the different tree species in a forest). Types of categorical variables include:

- **Ordinal**: represent data with an order (e.g. rankings).
- **Nominal**: represent group names (e.g. brands or species names).
- **Binary**: represent data with a yes/no or 1/0 outcome (e.g. win or lose).

Choose the test that fits the types of predictor and outcome variables you have collected (if you are doing an <u>experiment</u>, these are the <u>independent and dependent variables</u>). Consult the tables below to see which test best matches your variables.

Choosing a parametric test: regression, comparison, or correlation

Parametric tests usually have stricter requirements than nonparametric tests, and are able to make stronger inferences from the data. They can only be conducted with data that adheres to the common assumptions of statistical tests.

The most common types of parametric test include regression tests, comparison tests, and correlation tests.

Regression tests

Regression tests look for **cause-and-effect relationships**. They can be used to estimate the effect of one or more continuous variables on another variable.

	Predictor variable	Outcome variable	Research question example
Simple linear regression	- Continuous - 1 predictor	- Continuous - 1 outcome	What is the effect of income on longevity?
Multiple linear regression	- Continuous - 2 or more predictors	- Continuous - 1 outcome	What is the effect of income and minutes of exercise per day on longevity?
Logistic regression	Continuous	Binary	What is the effect of drug dosage on the survival of a test subject?

Comparison tests

Comparison tests look for **differences among group means**. They can be used to test the effect of a categorical variable on the <u>mean value</u> of some other characteristic.

<u>T-tests</u> are used when comparing the means of precisely two groups (e.g., the average heights of men and women). <u>ANOVA</u> and MANOVA tests are used when comparing the <u>means</u> of more than two groups (e.g., the average heights of children, teenagers, and adults).

	Predictor variable	Outcome variable	Research question example
Paired t-test	• Categorical • 1 predictor	• Quantitative • groups come from the same population	What is the effect of two different test prep programs on the average exam scores for students from the same class?
Independent t-test	• Categorical • 1 predictor	• Quantitative • groups come from different populations	What is the difference in average exam scores for students from two different schools?
ANOVA	• Categorical • 1 or more predictor	• Quantitative • 1 outcome	What is the difference in average pain levels among post-surgical patients given three different painkillers?
MANOVA	• Categorical • 1 or more predictor	• Quantitative • 2 or more outcome	What is the effect of flower species on petal length, petal width, and stem length?

Correlation tests

<u>Correlation tests</u> **check whether variables are related** without hypothesizing a cause-and-effect relationship.

These can be used to test whether two variables you want to use in (for example) a multiple regression test are autocorrelated.

	Variables	Research question example
Pearson's _r_	2 continuous variables	How are latitude and temperature related?

Choosing a nonparametric test

Non-parametric tests don't make as many assumptions about the data, and are useful when one or more of the common statistical assumptions are violated. However, the inferences they make aren't as strong as with parametric tests.
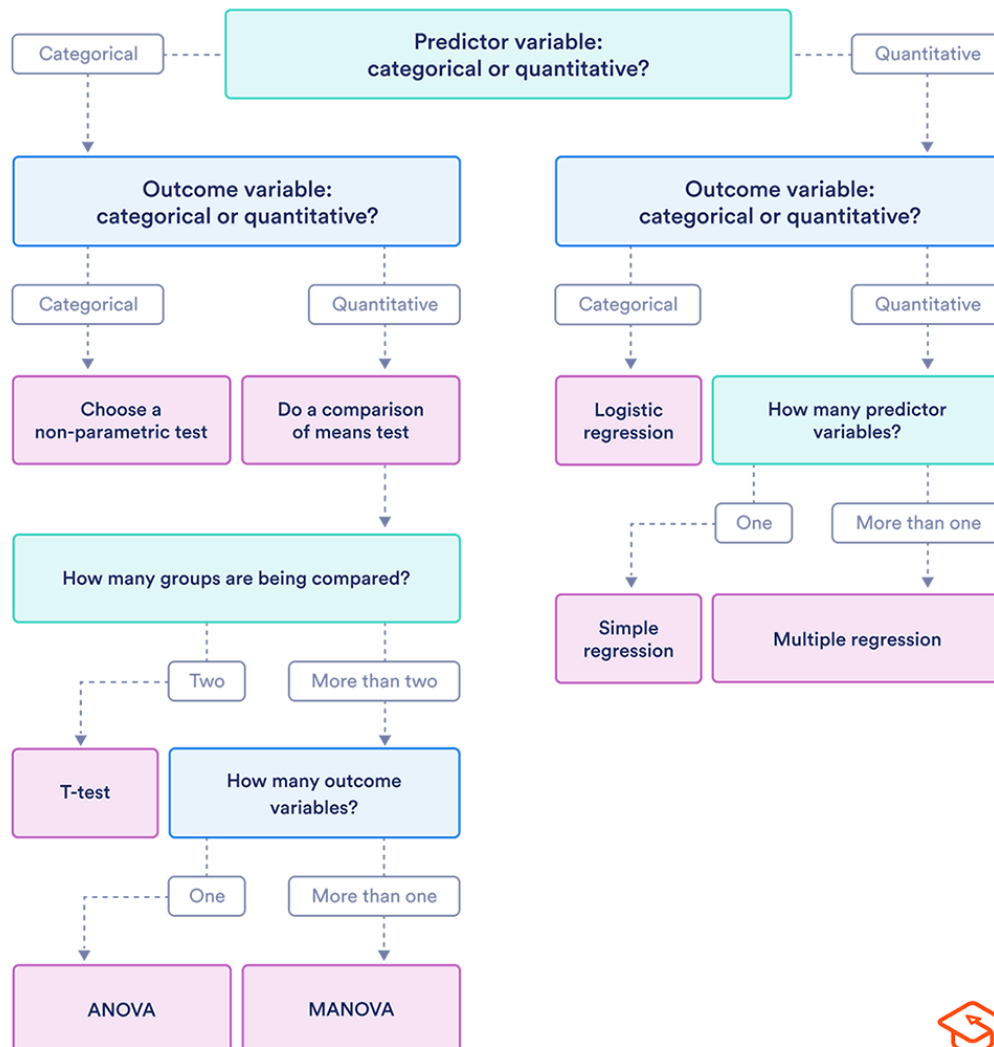
	Predictor variable	Outcome variable	Use in place of…
Spearman's _r_	Quantitative	Quantitative	<u>Pearson's _r_</u>
<u>**Chi square test of independence**</u>	Categorical	Categorical	Pearson's _r_
Sign test	Categorical	Quantitative	One-sample _t_-test
Kruskal–Wallis _H_	• Categorical • 3 or more groups	Quantitative	ANOVA
ANOSIM	• Categorical • 3 or more groups	• Quantitative • 2 or more outcome variables	MANOVA
Wilcoxon Rank-Sum test	• Categorical • 2 groups	• Quantitative • groups come from different populations	Independent t-test
Wilcoxon Signed-rank test	• Categorical • 2 groups	• Quantitative • groups come from the same population	Paired t-test

Flowchart: choosing a statistical test

This flowchart helps you choose among parametric tests. For nonparametric alternatives, check the table above.

Choosing a statistical test

This flowchart helps you choose among parametric tests

Predictor variable: categorical or quantitative?

- Categorical
  - Outcome variable: categorical or quantitative?
    - Categorical → Choose a non-parametric test
    - Quantitative → Do a comparison of means test
      - How many groups are being compared?
        - Two → T-test
        - More than two → How many outcome variables?
          - One → ANOVA
          - More than one → MANOVA
- Quantitative
  - Outcome variable: categorical or quantitative?
    - Categorical → Logistic regression
    - Quantitative → How many predictor variables?
      - One → Simple regression
      - More than one → Multiple regression

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Frequently asked questions about statistical tests

What are the main assumptions of statistical tests?

Statistical tests commonly assume that:

1. the data are normally distributed
2. the groups that are being compared have similar variance
3. the data are independent

If your data does not meet these assumptions you might still be able to use a nonparametric statistical test, which have fewer requirements but also make weaker inferences.

What is a test statistic?

A test statistic is a number calculated by a statistical test. It describes how far your observed data is from the null hypothesis of no relationship between variables or no difference among sample groups.

The test statistic tells you how different two or more groups are from the overall population mean, or how different a linear slope is from the slope predicted by a null hypothesis. Different test statistics are used in different statistical tests.

What is statistical significance?

Statistical significance is a term used by researchers to state that it is unlikely their observations could have occurred under the null hypothesis of a statistical test. Significance is usually denoted by a *p-value*, or probability value.

Statistical significance is arbitrary – it depends on the threshold, or alpha value, chosen by the researcher. The most common threshold is $p < 0.05$, which means that the data is likely to occur less than 5% of the time under the null hypothesis.

When the *p*-value falls below the chosen alpha value, then we say the result of the test is statistically significant.

What is the difference between quantitative and categorical variables?

Quantitative variables are any variables where the data represent amounts (e.g. height, weight, or age).

Categorical variables are any variables where the data represent groups. This includes rankings (e.g. finishing places in a race), classifications (e.g. brands of cereal), and binary outcomes (e.g. coin flips).

You need to know what type of variables you are working with to choose the right statistical test for your data and interpret your results.

What is the difference between discrete and continuous variables?

Discrete and continuous variables are two types of quantitative variables:

- **Discrete variables** represent counts (e.g. the number of objects in a collection).
- **Continuous variables** represent measurable amounts (e.g. water volume or weight).

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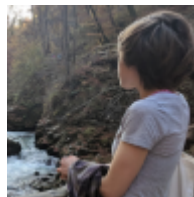
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Rebecca is working on her PhD in soil ecology and spends her free time writing. She's very happy to be able to nerd out about statistics with all of you.