

Two Way ANOVA Calculator

Factorial ANOVA - Balanced design

Fixed effects, Mixed effects, Random effects and Mixed repeated measures

[Video](#) [Information](#) [One way ANOVA](#) [Levene's test](#)

Model:

Fixed effect (A-Fixed, B-Fixed) - no repeats

Significance level (α):

0.05

Effect:

Medium

Effect Size:

0.25

Interaction

With interaction

Outliers:

Included

Effect type:

f²

Digits:

4

Step by step

- Enter raw data directly

Enter raw data from excel

Enter sample data directly

Balanced two Factor ANOVA with Replication - several values per cell. The data should be separated by Enter or , (comma).
ANOVA without Replication - one value per cell.
The tool ignores empty cells or non-numeric cells.

Var A \ Var B	Conventional	Assertiveness-based
Novice	11 11 11 13 13 13 17 17 1	19 19 19 18 18 18 20 20 1
Expert	20 20 20 16 7 16 17 18 18	20 20 20 20 13 20 18 20 2

Calculate

Insert column

Delete column

Insert row

Delete row

Clear

Load example

Enter sample data from excel


Calculate

Clear

Validate

Load example

Load last run

ou may copy the data from Excel, Google sheets or any tool that separate the data with **Tab** and **Line Feed**. Copy the data, **one block of consecutive columns includes the header**, and [paste](#). Click to see example: 
empty cells or non-numeric cells will be ignored

[How to do with R?](#)

ANOVA table

Hover over the cells for formulas and calculation.

Source	DF	Sum of Square (SS)	Mean Square (MS)	F Statistic (df ₁ ,df ₂)	P-value
Factor A - rows (A)	1	1474.3122	1474.3122	99.7094 (1,308)	0
Factor B - columns (B)	1	136.0128	136.0128	9.1987 (1,308)	0.002628
Interaction AB	1	6.9427	6.9427	0.4695 (1,308)	0.4937
Error	308	4554.1169	14.7861		
Total	311	6171.3846	19.8437		

Two sample ANOVA - fixed test, using F distribution (right-tailed)

Factor - A

1. H₀ hypothesis

https://www.statskingdom.com/two-way-anova-calculator.html

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Since the p-value < α , H_0 is rejected.
Some of the groups' averages consider to be not equal.
In other words, the difference between the averages of some groups is big enough to be statistically significant.

2. P-value

The p-value equals 0, ($P(x \leq 99.7094) = 1$). It means that the chance of type I error (rejecting a correct H_0) is small: 0 (0%). The smaller the p-value the more it supports H_1 .

3. Test statistic

The test statistic F_A equals 99.7094, which is not in the 95% region of acceptance: $[-\infty : 3.8718]$.

4. Effect size

The observed effect size η^2 is **large, 0.24**. This indicates that the magnitude of the difference between the average is large.

Factor - B

1. H_0 hypothesis

Since the p-value < α , H_0 is rejected.
Some of the groups' averages consider to be not equal.
In other words, the difference between the averages of some groups is big enough to be statistically significant.

2. P-value

The p-value equals 0.002628, ($P(x \leq 9.1987) = 0.9974$). It means that the chance of type I error (rejecting a correct H_0) is small: 0.002628 (0.26%). The smaller the p-value the more it supports H_1 .

3. Test statistic

The test statistic F_A equals 9.1987, which is not in the 95% region of acceptance: $[-\infty : 3.8718]$.

4. Effect size

The observed effect size η^2 is **small, 0.029**. This indicates that the magnitude of the difference between the average is small.

Interaction AB

1. H_0 hypothesis

Since the p-value > α , H_0 can not be rejected.
The averages of all groups assume to be equal.
In other words, the difference between the averages of all groups is not big enough to be statistically significant.
A non-significance result can not prove that H_0 is correct, only that the null assumption can not be rejected.

2. P-value

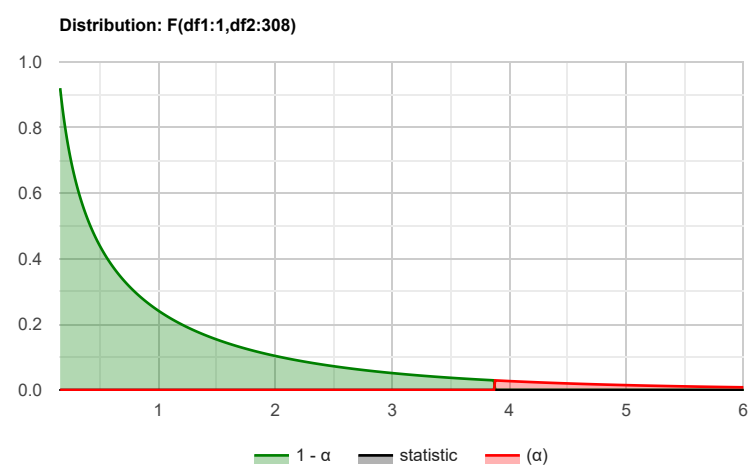
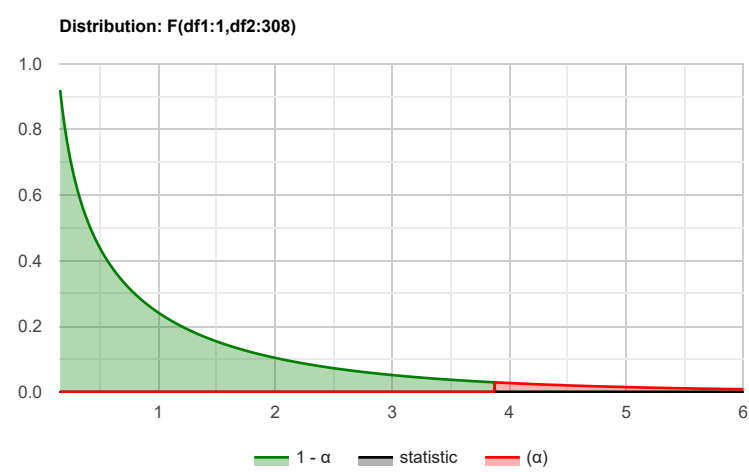
The p-value equals 0.4937, ($P(x \leq 0.4695) = 0.5063$). It means that the chance of type I error, rejecting a correct H_0 , is too high: 0.4937 (49.37%). The larger the p-value the more it supports H_0 .

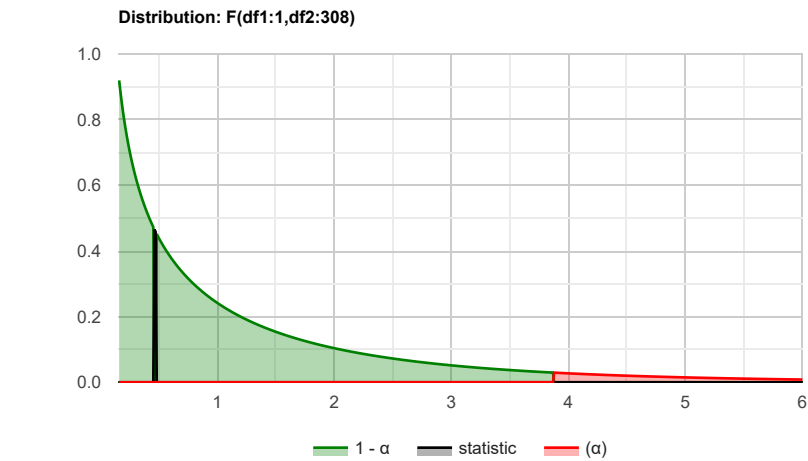
3. Test statistic

The test statistic F_A equals 0.4695, which is in the 95% region of acceptance: $[-\infty : 3.8718]$.

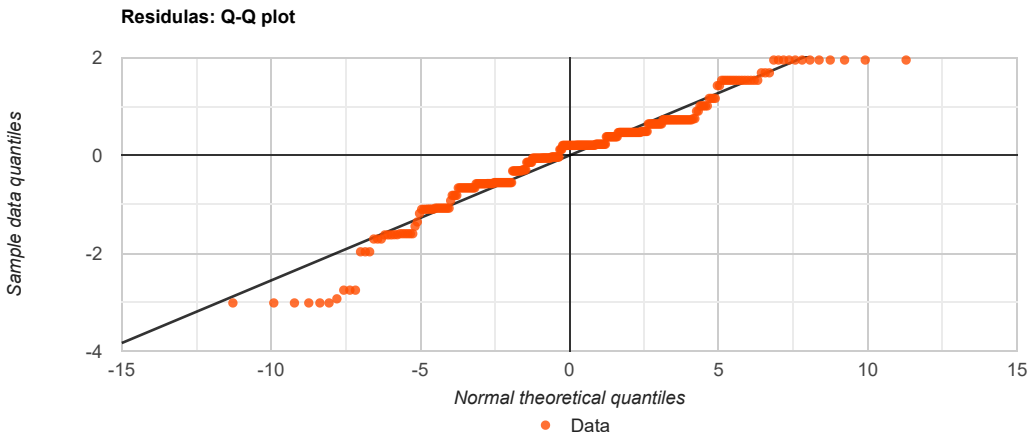
4. Effect size

The observed effect size η^2 is **very small, 0.0015**. This indicates that the magnitude of the difference between the average is very small.

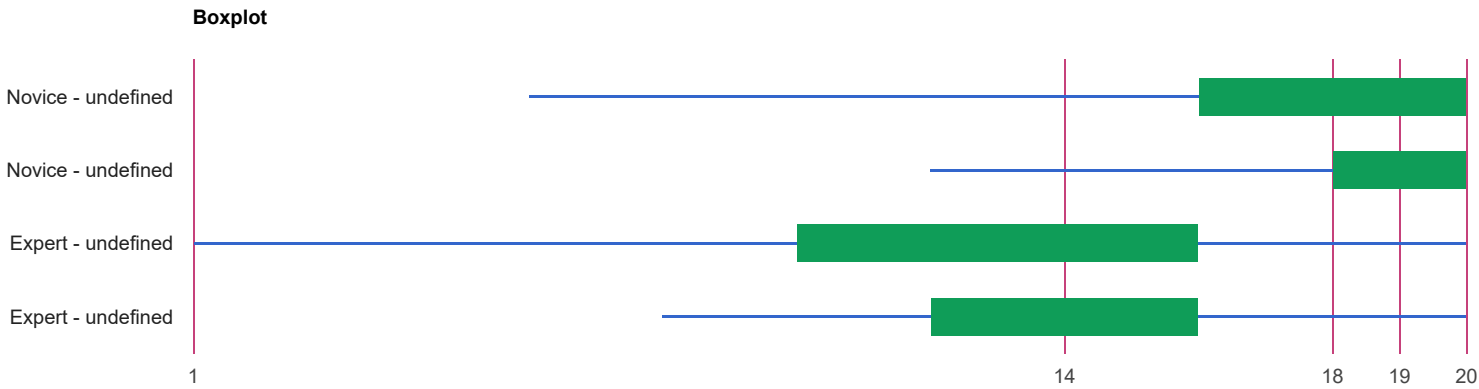




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Right click on: [Save image](#), (please use 'save link as...' or 'open link in new tab').



Right click on: [Save image](#), (please use 'save link as...' or 'open link in new tab').

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Outliers Outliers' detection method: Tukey Fence, k=1.5. Residuals doesn't contain outliers. The two way ANOVA test is robust to the presence of outliers.			
Normality The assumption was checked based on the Shapiro-Wilk Test . (α=0.05) It is assumed that the residuals does not follow a normal distribution (p-value is 3.328e-8). The test is considered robust for moderate violation of the normality assumption.			
Test power: Factor - A The test priori power is strong 1			
Test power: Factor - B The test priori power is strong 1			
Test power: Interaction The test priori power is strong 1			
Balanced design undefined			

Tukey HSD / Tukey Kramer

Count			
Var A \ Var B	undefined	undefined	Total
Novice	69	69	138

Expert	87	87	174
Total	156	156	312

Average

Var A \ Var B	undefined	undefined	Total
Novice	17.2174	18.2029	17.7101
Expert	12.5402	14.1264	13.3333
Total	14.609	15.9295	15.2692

Variance

Var A \ Var B	undefined	undefined	Total
Novice	7.702	4.2818	6.1927
Expert	30.6466	12.8327	22.2466
Total	25.8139	13.124	19.8437

Mean confidence interval (CL:0.95)

Var A \ Var B	undefined	undefined	Total
Novice	[11.8175,22.6172]	[14.1768,22.229]	[12.8504,22.5699]
Expert	[1.7525,23.3279]	[7.1458,21.1071]	[4.1155,22.5512]
Total	[4.6829,24.5351]	[8.8519,23.0071]	[6.5523,23.9861]

Differential effects

Var A \ Var B	undefined	undefined	Total
Novice	0.1675	-0.1675	2.4409
Expert	-0.1328	0.1328	-1.9359
Total	-0.6603	0.6603	0

Cells - the differential effects of the interactions.
For example, the effect of the interactions of the categories **undefined** and **Novice** is **0.1675**.
Totals - the differential effects of factor A (right column) and factor B (bottom row).
For example, the effect of factor B category **undefined** is **-0.6603**.

Residuals

A	B	Y _{ij,k}	Formula: Y _{ij,k} - \bar{Y}_{ij}	Residual
Novice	undefined	11	11 - 17.217	-6.2174
Novice	undefined	11	11 - 17.217	-6.2174
Novice	undefined	11	11 - 17.217	-6.2174
Novice	undefined	13	13 - 17.217	-4.2174
Novice	undefined	13	13 - 17.217	-4.2174
Novice	undefined	13	13 - 17.217	-4.2174
Novice	undefined	17	17 - 17.217	-0.2174
Novice	undefined	17	17 - 17.217	-0.2174
Novice	undefined	17	17 - 17.217	-0.2174
Novice	undefined	16	16 - 17.217	-1.2174
Novice	undefined	16	16 - 17.217	-1.2174
Novice	undefined	16	16 - 17.217	-1.2174
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	19	19 - 17.217	1.7826
Novice	undefined	6	6 - 17.217	-11.2174
Novice	undefined	17	17 - 17.217	-0.2174
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	15	15 - 17.217	-2.2174

Novice	undefined	15	15 - 17.217	-2.2174
Novice	undefined	15	15 - 17.217	-2.2174
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	15	15 - 17.217	-2.2174
Novice	undefined	15	15 - 17.217	-2.2174
Novice	undefined	15	15 - 17.217	-2.2174
Novice	undefined	16	16 - 17.217	-1.2174
Novice	undefined	16	16 - 17.217	-1.2174
Novice	undefined	16	16 - 17.217	-1.2174
Novice	undefined	17	17 - 17.217	-0.2174
Novice	undefined	17	17 - 17.217	-0.2174
Novice	undefined	17	17 - 17.217	-0.2174
Novice	undefined	15	15 - 17.217	-2.2174
Novice	undefined	15	15 - 17.217	-2.2174
Novice	undefined	15	15 - 17.217	-2.2174
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	20	20 - 17.217	2.7826
Novice	undefined	17	17 - 17.217	-0.2174
Novice	undefined	17	17 - 17.217	-0.2174
Novice	undefined	17	17 - 17.217	-0.2174
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	18	18 - 17.217	0.7826
Novice	undefined	18	18 - 17.217	0.7826
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Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	18	18 - 18.203	-0.2029
Novice	undefined	18	18 - 18.203	-0.2029
Novice	undefined	18	18 - 18.203	-0.2029
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	18	18 - 18.203	-0.2029
Novice	undefined	13	13 - 18.203	-5.2029
Novice	undefined	12	12 - 18.203	-6.2029
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	16	16 - 18.203	-2.2029
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	18	18 - 18.203	-0.2029
Novice	undefined	16	16 - 18.203	-2.2029
Novice	undefined	12	12 - 18.203	-6.2029
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	17	17 - 18.203	-1.2029
Novice	undefined	18	18 - 18.203	-0.2029
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	16	16 - 18.203	-2.2029
Novice	undefined	17	17 - 18.203	-1.2029
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	17	17 - 18.203	-1.2029
Novice	undefined	20	20 - 18.203	1.7971

Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	18	18 - 18.203	-0.2029
Novice	undefined	16	16 - 18.203	-2.2029
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	18	18 - 18.203	-0.2029
Novice	undefined	17	17 - 18.203	-1.2029
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	14	14 - 18.203	-4.2029
Novice	undefined	14	14 - 18.203	-4.2029
Novice	undefined	14	14 - 18.203	-4.2029
Novice	undefined	16	16 - 18.203	-2.2029
Novice	undefined	16	16 - 18.203	-2.2029
Novice	undefined	14	14 - 18.203	-4.2029
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	18	18 - 18.203	-0.2029
Novice	undefined	18	18 - 18.203	-0.2029
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	19	19 - 18.203	0.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Expert	undefined	20	20 - 12.54	7.4598
Expert	undefined	20	20 - 12.54	7.4598
Expert	undefined	20	20 - 12.54	7.4598
Expert	undefined	16	16 - 12.54	3.4598
Expert	undefined	7	7 - 12.54	-5.5402
Expert	undefined	16	16 - 12.54	3.4598
Expert	undefined	17	17 - 12.54	4.4598
Expert	undefined	18	18 - 12.54	5.4598
Expert	undefined	18	18 - 12.54	5.4598
Expert	undefined	14	14 - 12.54	1.4598
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Expert	undefined	14	14 - 12.54	1.4598
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Expert	undefined	20	20 - 12.54	7.4598
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Expert	undefined	15	15 - 12.54	2.4598
Expert	undefined	15	15 - 12.54	2.4598
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Expert	undefined	15	15 - 12.54	2.4598
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Expert	undefined	19	19 - 12.54	6.4598
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Expert	undefined	20	20 - 12.54	7.4598

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Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	15	15 - 12.54	2.4598
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Expert	undefined	10	10 - 12.54	-2.5402
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Expert	undefined	12	12 - 12.54	-0.5402
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Expert	undefined	14	14 - 12.54	1.4598
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Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	13	13 - 14.126	-1.1264
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	18	18 - 14.126	3.8736
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Expert	undefined	18	18 - 14.126	3.8736
Expert	undefined	17	17 - 14.126	2.8736
Expert	undefined	11	11 - 14.126	-3.1264
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	15	15 - 14.126	0.8736
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	17	17 - 14.126	2.8736
Expert	undefined	15	15 - 14.126	0.8736
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	14	14 - 14.126	-0.1264

Expert	undefined	14	14 - 14.126	-0.1264
Expert	undefined	14	14 - 14.126	-0.1264
Expert	undefined	15	15 - 14.126	0.8736
Expert	undefined	15	15 - 14.126	0.8736
Expert	undefined	15	15 - 14.126	0.8736
Expert	undefined	13	13 - 14.126	-1.1264
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Expert	undefined	16	16 - 14.126	1.8736
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Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	15	15 - 14.126	0.8736
Expert	undefined	15	15 - 14.126	0.8736
Expert	undefined	15	15 - 14.126	0.8736
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	16	16 - 14.126	1.8736
Expert	undefined	16	16 - 14.126	1.8736
Expert	undefined	16	16 - 14.126	1.8736
Expert	undefined	18	18 - 14.126	3.8736
Expert	undefined	18	18 - 14.126	3.8736
Expert	undefined	18	18 - 14.126	3.8736
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Expert	undefined	10	10 - 14.126	-4.1264
Expert	undefined	10	10 - 14.126	-4.1264
Expert	undefined	15	15 - 14.126	0.8736
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Expert	undefined	8	8 - 14.126	-6.1264
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	11	11 - 14.126	-3.1264
Expert	undefined	11	11 - 14.126	-3.1264
Expert	undefined	11	11 - 14.126	-3.1264
Expert	undefined	8	8 - 14.126	-6.1264
Expert	undefined	8	8 - 14.126	-6.1264
Expert	undefined	8	8 - 14.126	-6.1264
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	14	14 - 14.126	-0.1264
Expert	undefined	14	14 - 14.126	-0.1264
Expert	undefined	14	14 - 14.126	-0.1264
Expert	undefined	10	10 - 14.126	-4.1264
Expert	undefined	10	10 - 14.126	-4.1264
Expert	undefined	10	10 - 14.126	-4.1264
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	12	12 - 14.126	-2.1264
Expert	undefined	12	12 - 14.126	-2.1264

Information

Models

There are many possible models, this calculator deal currently only with the following balanced models:

- **Fixed effect model (A-Fixed, B-Fixed), no repeats** - both factors are fixed.
- **Mixed effect model (A-Random, B-Fixed), no repeats** - factor A is random, factor B is fixed, each subject is measured only once.
- **Mixed effect model (A-Fixed, B-Random), no repeats** - factor A is fixed, factor B is random, each subject is measured only once.
- **Random effect model (A-Random, B-Random), no repeats**
- **Mixed repeated measures (A-Fixed, B-Repeated)** - factor A is fixed, factor B uses the same subject for all the categories.

You may use data with replications, or data without replications.

What is balanced model?

The balanced design has the same number of observations in each cell - each combination of factor.

Currently this calculator supports only the balanced design.

When the model is **unbalanced**, it causes correlation between the factors and the interaction if it is proportional, and also between the factors if it is unbalance but not proportional.

hence you don't know how to divide the shared sum of squares between the two factors.

There are several methods how to deal with the shared sum of squares.

Type I - sequenceial, the first some of squares (SS) you calculate get the shared some of squares, in this case the order is matter!

Type II - conservative, it assumes there is no interaction between the factors, it ignores the shared SS between the factors. Type III - it assumes there is interaction between the factors, it ignores all the shared SS between the factors and between the factors and the intercation.

Targets

The two way ANOVA test checks the following targets using sample data.

- Checks if the difference between **Factor A** averages of two or more categories is significant
- Checks if the difference between **Factor B** averages of two or more categories is significant
- Checks if there is an interaction between **Factor A** and **Factor B**

When performing ANOVA test, we try to determine if the difference between the averages reflects a real difference between the groups, or is due to the random noise inside each group.

The F statistic represents the ratio of the variance between the groups and the variance inside the groups. Unlike many other statistic tests, the smaller the F statistic the more likely the averages are equal.

Right-tailed F test, for ANOVA test you can use only the right tail. [Why?](#)

Hypotheses

Factor A: $H_0: \mu_1 = .. = \mu_a$

There is no difference in the means of variable A categories.

Factor B: $H_0: \mu_1 = .. = \mu_b$

There is no difference in the means of variable B categories.

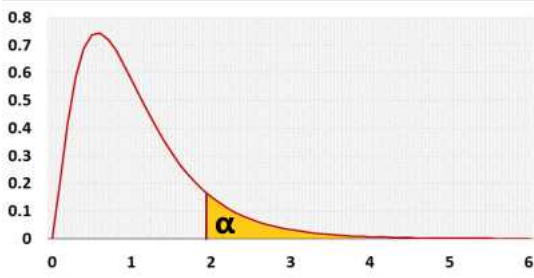
H_0 : Interaction(A_iB_j) = 0 ($\forall i = 1$ to $a, j = 1$ to b)

There is no interaction between variable A and variable B, i.e., for all the cells, the effect of variable A on the cells' means is not depend on the effect of variable B, and vice versa.

Test statistic

Fixed Model	Mixed Model	Random Model	Mixed Repeated
$F_A = \frac{MS_A}{MS_E}$	$F_A = \frac{MS_A}{MS_{AB}}$	$F_A = \frac{MS_A}{MS_{AB}}$	$F_A = \frac{MS_A}{MS_{SWA}}$
$F_B = \frac{MS_B}{MS_E}$	$F_B = \frac{MS_B}{MS_E}$	$F_B = \frac{MS_B}{MS_{AB}}$	$F_B = \frac{MS_B}{MS_{BSWA}}$
$F_{AB} = \frac{MS_{AB}}{MS_E}$	$F_{AB} = \frac{MS_{AB}}{MS_E}$	$F_{AB} = \frac{MS_{AB}}{MS_E}$	$F_{AB} = \frac{MS_{AB}}{MS_{BSWA}}$


F distribution



Assumptions

- The dependent variable is continuous (ratio or interval)
- Two categorical independent variables
- Independent observations (no repeated measure)
- The residuals distribution is normal
- Homogeneity of variances, a similar variance for each cell

Required Sample Data

 Sample data from all compared groups

Parameters

- a** - the number of categories in variable A, number of rows.
- b** - the number of categories in variable B, number of columns.
- n_i** - sample side of category i of variable A (row i).
- n_j** - sample side of category j of variable B (column j).
- n_{ij}** - sample side of cell ij (row i, column j). In the balance $n_{ij}=n/(a*b)$
- n** - overall sample side, includes all the groups ($\sum n_{ij}, i=1$ to $a, j=1$ to b).
- \bar{Y}_i** - average of all the observations of category i of variable A (row i).
- \bar{Y}_j** - average of all the observations of category j of variable B (column j).
- \bar{Y}** - overall average ($\sum Y_{ij,k} / n, i=1$ to $a, j=1$ to $b, k=1$ to n_{ij}).

Repeated measures ANOVA

- s** - represent the order of subject in category i (subject 1 in category 1 is different than subject 1 in category 2)
- sub** - number of subjects per cell, cell is one combination of variable A and variable B. For the balance design: $N=a*b*sub$.
- $\bar{Y}_{i,s}$** - subject's average, $\sum Y_{ij,s}$ for subject i,s ,the average of all the observations of subject s of category j of variable B (column j).
- \bar{Y}** - overall average ($\sum Y_{ij,s} / n$)

Results calculations

Sum of squares

The sum of squares accumulates the squared differences related to the effect we try to estimate.

SS_A - the squared differences related to the effect of variable A. You compare the average of every category to the total average. The same value as the sum of squares between groups in one way ANOVA.

SS_B - the same as SS_A , for variable B.

SS_{AB} - the squared differences related to the effect of the combination of variable A and variable B in each cell, Since we try to understand the influence of the interaction AB, the interaction of the specific value of variable A and the specific value of variable B, we take the average of each cell, remove the influence of variable A and variable B, and compare to the total average.

A effect = $\bar{Y}_i - \bar{Y}$

B effect = $\bar{Y}_j - \bar{Y}$

AB effect = Cell average - A effect - B effect - Total average.

= $\bar{Y}_{ij} - (\bar{Y}_i - \bar{Y}) - (\bar{Y}_j - \bar{Y}) - \bar{Y}$.

= $\bar{Y}_{ij} - \bar{Y}_i - \bar{Y}_j + \bar{Y}$.

Take the square of each difference

$\bar{Y}_{ij} - \bar{Y}_i - \bar{Y}_j + \bar{Y})^2$.

Count the square differences of each value in the cell, hence multiply by the sample size of each cell (n_{ij}).

