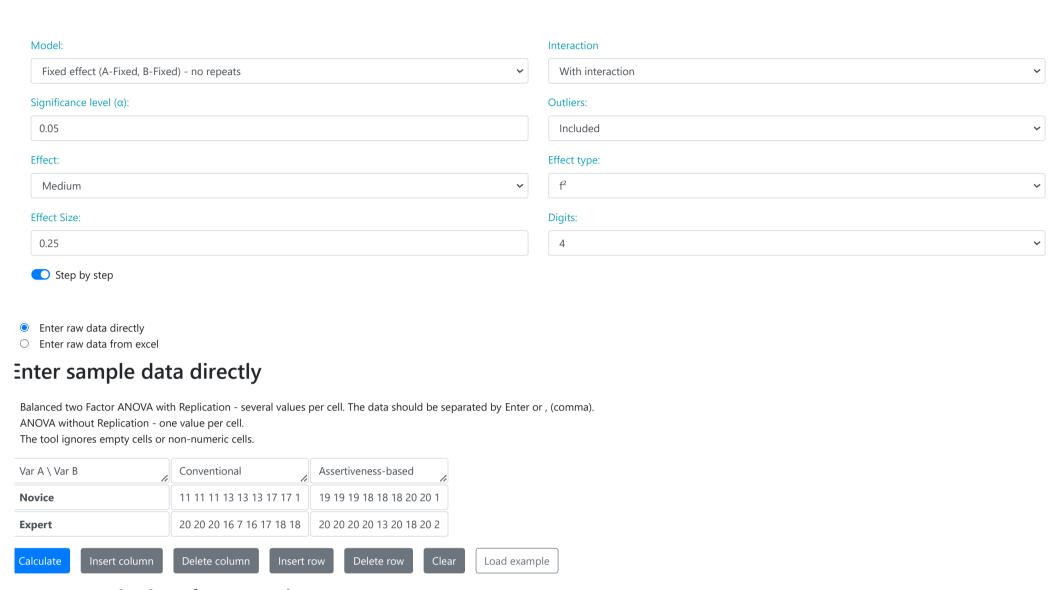
8/4/22, 2:31 PM

Two Way ANOVA Calculator

Factorial ANOVA - Balanced design

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

<u>Video</u> <u>Information</u> <u>One way ANOVA</u> <u>Levene's test</u>



Enter sample data from excel



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: impty 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

Since the p-value $< \alpha$, 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, ($P(x \le 99.7094) = 1$). 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 $\mathbf{F_A}$ equals 99.7094, which is not in the 95% region of acceptance: [- ∞ : 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. H₀ hypothesis

Since the p-value $< \alpha$, 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, ($P(x \le 9.1987) = 0.9974$). It means that the chance of type I error (rejecting a correct H₀) is small: 0.002628 (0.26%). The smaller the p-value the more it supports H₁.

3. Test statistic

The test statistic $\mathbf{F_A}$ equals 9.1987, which is not in the 95% region of acceptance: [- ∞ : 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. H₀ hypothesis

Since the p-value > α , H₀ 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 H₀ is correct, only that the null assumption can not be rejected.

2. P-value

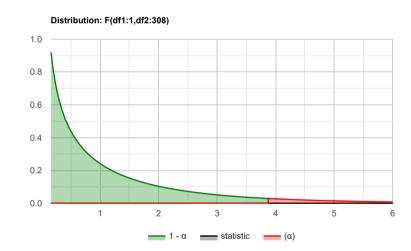
The p-value equals 0.4937, ($P(x \le 0.4695) = 0.5063$). It means that the chance of type I error, rejecting a correct H_0 , is too high: 0.4937 (49.37%). The larger the p-value the more it supports H_0 .

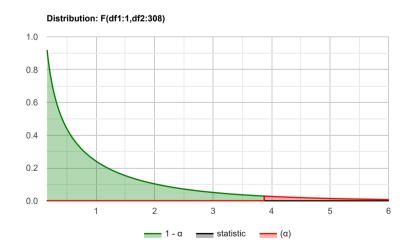
3. Test statistic

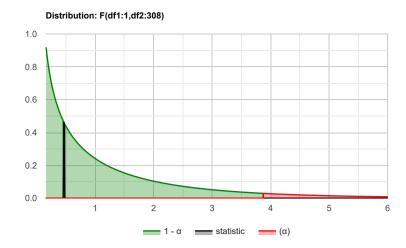
The test statistic $\mathbf{F_A}$ equals 0.4695, which is in the 95% region of acceptance: [- ∞ : 3.8718].

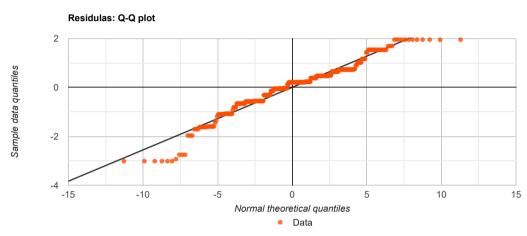
4. Effect size

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.









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



Right click on: <u>Save image</u>, (please use 'save link as...' or 'open link in new tab').

/alidation

Outliers

Outliers' detection method: Tukey Fence, k=1.5.

Residuals doesn't contain outliers. The ${\color{blue}two~way~ANOVA}$ 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 ${\bf 1}$

Test power: Interaction

The test priori power is strong 1

Balanced design

undefined

Tukey HSD / Tukey Kramer

Co	u	r	١t

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

Expert	87	87	174
Total	156	156	312

<u>Average</u>

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

<u>Variance</u>

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]

<u>Differential effects</u>

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**.

B 11 1

Note eddfried 14	Residuals				
Noticeundefined1111-722742-774Noticeundefined1313-722742-774Noticeundefined1313-722742-774Noticeundefined1313-722742-774Noticeundefined177-722742-774Noticeundefined177-722702-774Noticeundefined1717-722702-774Noticeundefined1616-722712-77412-774Noticeundefined1616-722712-77412-774Noticeundefined1616-722712-77412-774Noticeundefined1616-722712-77412-774Noticeundefined1616-722712-77412-774Noticeundefined1616-722712-77412-774Noticeundefined1616-722712-77412-774Noticeundefined1616-722712-77412-782Noticeundefined1616-722712-72417-724Noticeundefined1616-722717-72417-724Noticeundefined1616-722717-72417-724Noticeundefined1016-722717-72417-724Noticeundefined1016-722717-72417-724Noticeundefined1016-722717-72417-724Noticeundefined1616-7227 <t< th=""><th>A</th><th>В</th><th>$Y_{i,j,k}$</th><th>Formula: $Y_{i,j,k}$ - $\bar{Y}_{i,j}$</th><th>Residual</th></t<>	A	В	$Y_{i,j,k}$	Formula: $Y_{i,j,k}$ - $\bar{Y}_{i,j}$	Residual
Noviceundefined1111.12174.21744.2174Noticeundefined1313.172374.2174Noticeundefined1313.172374.2174Noticeundefined1313.172374.2174Noticeundefined1717.172370.2174Noticeundefined1717.172370.2174Noticeundefined1616.172371.2174Noticeundefined1616.172371.2174Noticeundefined1616.172371.2174Noticeundefined2016.172371.2174Noticeundefined2016.172371.2726Noticeundefined2010.172372.726Noticeundefined2010.172372.726Noticeundefined2010.172372.726Noticeundefined1818.172370.726Noticeundefined2010.172372.726Noticeundefined2010.172372.726Noticeundefined2010.172372.726Noticeundefined2010.172372.726Noticeundefined2010.172372.726Noticeundefined2010.172372.726Noticeundefined2010.172372.726Noticeundefined1911.172472.726Noticeundefined1211.172472.726 </td <td>Novice</td> <td>undefined</td> <td>11</td> <td>11 - 17.217</td> <td>-6.2174</td>	Novice	undefined	11	11 - 17.217	-6.2174
Novice undefined 13 13-17217 42174 Novice undefined 13 13-17217 42174 Novice undefined 13 13-17217 42174 Novice undefined 17 17-17217 62174 Novice undefined 17 7-17217 62174 Novice undefined 16 16-17217 1-12174 Novice undefined 16 16-17217 1-12174 Novice undefined 26 16-17217 1-2174 Novice undefined 20 20-172217 27826 Novice undefined 20	Novice	undefined	11	11 - 17.217	-6.2174
Novice undefined 3 13-17217 42174 Novice undefined 13 1-17217 42174 Novice undefined 17 17-17217 42174 Novice undefined 17 17-17217 42174 Novice undefined 16 16-17217 12174 Novice undefined 16 16-17217 12174 Novice undefined 26 16-17217 2724 Novice undefined 20 20-17217 27826 Novice undefined 20 20-17217<	Novice	undefined	11	11 - 17.217	-6.2174
Notice undefined 13 3-7.217 4-2174 2-174 Notice undefined 17 17-217 2-174 2-174 2-174 Notice undefined 17 2-172 2-172 2-174 2-174 Notice undefined 16 1-172 2-172 2-174 2-174 Notice undefined 16 1-172 2-172 2-174 2-174 Notice undefined 20 2-172 2-172 2-174 2-174 Notice undefined 20 2-172	Novice	undefined	13	13 - 17.217	-4.2174
Novice undefined 17 17-1217 -0.2174 Novice undefined 17 17-1217 -0.2174 Novice undefined 17 17-1217 -0.2174 Novice undefined 16 16-17217 -1.2174 -1.2174 Novice undefined 16 16-17217 -1.2174 -1.2174 Novice undefined 16 16-17217 -1.2174 -1.2174 Novice undefined 20 20-17217 -2.2286 -1.2274 Novice undefined 20 20-17217 -2.2286 -2.2286 Novice undefined 20 20-17217 -2.2286 -2.2286 Novice undefined 18 18-17237 -2.2274 -2.2286 Novice undefined 20 20-17237 -2.2286 -2.2286 Novice undefined 20 20-17237 -2.2286 -2.2286 Novice undefined 20 20-17237 -2.2286	Novice	undefined	13	13 - 17.217	-4.2174
Navice undefined 17 17-17217 0-2174 Novice undefined 17 17-17217 0-2174 Novice undefined 16 16-17217 1-2174 1-2174 Novice undefined 16 16-17217 1-2174 1-2174 Novice undefined 26 16-17217 2-286 1-2174 Novice undefined 20 20-17217 2-286 Novice undefined 20 20-17217 2-286 Novice undefined 20 20-17217 2-286 Novice undefined 18 18-17217 0-286 Novice undefined 18 18-17217 0-286 Novice undefined 20 20-17217 2-286 N	Novice	undefined	13	13 - 17.217	-4.2174
Novice Undefined 17 7 - 7 - 7 2 17 - 2 174 Novice undefined 16 16 - 17 2 17 - 1 2 174 Novice undefined 16 16 - 17 2 17 - 1 2 174 Novice undefined 20 20 - 17 2 17 - 2 7826 Novice undefined 20 20 - 17 2 17 2 7826 Novice undefined 20 20 - 17 2 17 2 7826 Novice undefined 20 20 - 17 2 17 2 7826 Novice undefined 18 18 - 17 2 17 2 7826 Novice undefined 18 18 - 17 2 17 2 7826 Novice undefined 18 18 - 17 2 17 2 7826 Novice undefined 20 20 - 17 2 17 2 7826 Novice undefined 20 20 - 17 2 17 2 7826 Novice undefined 20 20 - 17 2 17 2 7826 Novice undefined 19 19 - 17 2 17 2 7826	Novice	undefined	17	17 - 17.217	-0.2174
Novice undefined 16 16 - 17.217 2.174 2.174 Novice undefined 16 16 - 17.217 2.174 2.174 Novice undefined 16 16 - 17.217 2.174 2.174 Novice undefined 20 20 - 17.217 2.7826 2.7826 Novice undefined 20 20 - 17.217 2.7826 2.7826 Novice undefined 18 18 - 17.217 2.7826 2.7826 Novice undefined 18 18 - 17.217 2.7826 2.7826 Novice undefined 18 18 - 17.217 2.7826 2.7826 Novice undefined 20 20 - 17.217 2.7826 2.7826 Novice u	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 20 20-17.217 27826 Novice undefined 20 20-17.217 27826 Novice undefined 20 20-17.217 27826 Novice undefined 18 18-17.217 0.7826 Novice undefined 18 18-17.217 0.7826 Novice undefined 20 20-17.217 27826 Novice undefined 17 17-17.217 27826 Novice undefined 18	Novice	undefined	17	17 - 17.217	-0.2174
Novice undefined 16 16-17.217 17-124 2.174 Novice undefined 20 20-17.217 27826 Novice undefined 20 20-17.217 27826 Novice undefined 20 20-17.217 27826 Novice undefined 18 18-17.217 0.7826 Novice undefined 20 20-17.217 27826 Novice undefined 19 19-17.217 27826 Novice undefined 19 19-17.217 27826 Novice undefined </td <td>Novice</td> <td>undefined</td> <td>16</td> <td>16 - 17.217</td> <td>-1.2174</td>	Novice	undefined	16	16 - 17.217	-1.2174
Novice undefined 20 20-17217 2.7826 Novice undefined 20 20-17217 2.7826 Novice undefined 20 20-17217 2.7826 Novice undefined 18 18-17217 0.7826 Novice undefined 18 18-17217 0.7826 Novice undefined 20 20-17217 2.7826 Novice undefined 20 20-17217 1.7217 1.7217 Novice undefined 19 19-17217 1.717217 1.717214 1.71724 Novice undefined 18 18-17217 1.717217 0.7	Novice	undefined	16	16 - 17.217	-1.2174
Novice undefined 20 20 - 17 217 27 826 Novice undefined 20 20 - 17 217 27 826 Novice undefined 18 18 - 17 217 07826 Novice undefined 18 18 - 17 217 07826 Novice undefined 18 18 - 17 217 07826 Novice undefined 20 20 - 17 217 27826 Novice undefined 19 19 - 17 217 27 217 27 2826 Novice undefined 18 18 - 17 217 27 217 27 226	Novice	undefined	16	16 - 17.217	-1.2174
Novice undefined 20 20-17:217 27826 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 19 19-17:217 2.7826 Novice undefined 19 19-17:217 2.7826 Novice undefined 17 17-17:217 0.2174 0.2174 Novice undefined 18 18-17:217 0.7826 0.7826 No	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 9 19-17.217 2.7826 Novice undefined 19 19-17.217 2.7826 Novice undefined 18 18-17.217 2.714 2.714 Novice undefined 18 18-17.217 2.7826 2.7826 Novi	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 20 20 - 17.217 2.7826 Novice undefined 9 20 - 17.217 2.7826 Novice undefined 19 9 - 17.217 1.7826 1.7826 Novice undefined 17 17 - 17.217 0.7826 1.7826 Novice undefined 18 18 - 17.217 0.7826 0.7826 Novice undefined 18 18 - 17.217	Novice	undefined	20	20 - 17.217	2.7826
Novice undefined 18 18 - 17.217 07826 Novice undefined 20 20 - 17.217 27826 Novice undefined 19 19 - 17.217 27826 Novice undefined 19 19 - 17.217 17826 Novice undefined 17 - 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 27826 Novice undefined 20 20-17.217 17826 Novice undefined 19 19-17.217 17826 Novice undefined 17 17-17.217 2174 20-174 Novice undefined 18 18-17.217 07826 07826 Novice undefined 18 18-17.217 07826 07826 Novice undefined 18 18-17.217 07826 07826 Novice undefined 18 18-17.217 07826	Novice	undefined	18	18 - 17.217	0.7826
Novice undefined 20 20-17.217 27826 Novice undefined 19 19-17.217 17826 Novice undefined 6 6-17.217 11.2174 Novice undefined 7 17-17.217 27826 Novice undefined 18 18-17.217 07826 Novice undefined 20	Novice	undefined	18	18 - 17.217	0.7826
Novice undefined 20 20 - 17,217 27826 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 1,7826 Novice undefined 17 7 - 17,217 1,71214 Novice undefined 17 7 - 17,217 - 11,2174 Novice undefined 18 18 - 17,217 0,7826 Novice <t< td=""><td>Novice</td><td>undefined</td><td>20</td><td>20 - 17.217</td><td>2.7826</td></t<>	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 2 0 - 17.217 2,7826 Novice	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 20 20 - 17.217 2.7826 Novice undefined 20 20 - 17.217 2.7826 Novice undefined 20 20 - 17.217 2.7826 Novice	Novice	undefined	20	20 - 17.217	2.7826
Novice undefined 20 20 - 17,217 2,7217 2,7226 Novice undefined 19 19 - 17,217 1,7227 1,7217 Novice undefined 6 6 - 17,217 - 0,2174 - 0,2174 Novice undefined 18 18 - 17,217 0,7826 - 0,7826 Novice undefined 18 18 - 17,217 0,7826 - 0,7826 Novice undefined 18 18 - 17,217 0,7826 - 0,7826 Novice undefined 18 18 - 17,217 0,7826 - 0,7826 Novice undefined 18 18 - 17,217 0,7826 - 0,7826 Novice undefined 18 18 - 17,217 0,7826 - 0,7826 Novice undefined 18 18 - 17,217 0,7826 - 0,7826 Novice undefined 20 20 - 17,217 2,7826 - 0,7826 Novice undefined 20 20 - 17,217 2,7826 - 0,7826 <td< td=""><td>Novice</td><td>undefined</td><td>20</td><td>20 - 17.217</td><td>2.7826</td></td<>	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 20 20 - 17.217 2.7826 Novice	Novice	undefined	20	20 - 17.217	2.7826
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 20 20 - 17.217 2.7826 Novice	Novice	undefined	20	20 - 17.217	2.7826
Novice undefined 17 17 - 17.217 -0.2174 Novice undefined 18 18 - 17.217 0.7826 Novice undefined 20 20 - 17.217 2.7826 Novice	Novice	undefined	19	19 - 17.217	1.7826
Novice undefined 18 18 - 17.217 0.7826 Novice undefined 20 20 - 17.217 2.7826 Novice <	Novice	undefined	6	6 - 17.217	-11.2174
Novice undefined 18 18 - 17.217 0.7826 Novice undefined 20 20 - 17.217 2.7826	Novice	undefined	17	17 - 17.217	-0.2174
Novice undefined 18 18 - 17.217 0.7826 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 18 18 - 17.217 0.7826 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	18	18 - 17.217	0.7826
Novice undefined 18 18 - 17.217 0.7826 Novice undefined 20 20 - 17.217 2.7826	Novice	undefined	18	18 - 17.217	0.7826
Novice undefined 20 20 - 17.217 2.7826	Novice	undefined	18	18 - 17.217	0.7826
Novice undefined 20 20 - 17.217 2.7826	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 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	20	20 - 17.217	2.7826
	Novice	undefined	15	15 - 17.217	-2.2174

5/4/22, 2.31 FW			TWO Way ANOVA calculator	
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
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	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	16	16 - 18.203	-2.2029
Novice	undefined	20	20 - 18.203	1.7971
Novice	undefined	20	20 - 18.203	1.7971
Novice Novice	undefined undefined	20 18 16	20 - 18.203 18 - 18.203	1.7971 -0.2029
Novice Novice Novice	undefined undefined undefined undefined	20 18 16 12	20 - 18.203 18 - 18.203 16 - 18.203 12 - 18.203	1.7971 -0.2029 -2.2029 -6.2029
Novice Novice Novice Novice	undefined undefined undefined undefined undefined	20 18 16 12 20	20 - 18.203 18 - 18.203 16 - 18.203 12 - 18.203 20 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971
Novice Novice Novice	undefined undefined undefined undefined undefined undefined undefined	20 18 16 12 20 20	20 - 18.203 18 - 18.203 16 - 18.203 12 - 18.203 20 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971 1.7971
Novice Novice Novice Novice	undefined undefined undefined undefined undefined	20 18 16 12 20	20 - 18.203 18 - 18.203 16 - 18.203 12 - 18.203 20 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971
Novice Novice Novice Novice Novice Novice	undefined undefined undefined undefined undefined undefined undefined	20 18 16 12 20 20	20 - 18.203 18 - 18.203 16 - 18.203 12 - 18.203 20 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971 1.7971
Novice Novice Novice Novice Novice Novice Novice Novice Novice	undefined undefined undefined undefined undefined undefined undefined undefined undefined	20 18 16 12 20 20 20	20 - 18.203 18 - 18.203 16 - 18.203 12 - 18.203 20 - 18.203 20 - 18.203 19 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971 1.7971 1.7971 0.7971
Novice	undefined	20 18 16 12 20 20 20 19	20 - 18.203 18 - 18.203 16 - 18.203 12 - 18.203 20 - 18.203 20 - 18.203 20 - 18.203 19 - 18.203 17 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971 1.7971 1.7971 0.7971 -1.2029
Novice	undefined	20 18 16 12 20 20 20 19 17 18	20 - 18.203 18 - 18.203 16 - 18.203 12 - 18.203 20 - 18.203 20 - 18.203 19 - 18.203 17 - 18.203 18 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971 1.7971 1.7971 0.7971 -1.2029 -0.2029
Novice	undefined	20 18 16 12 20 20 20 19	20 - 18.203 18 - 18.203 16 - 18.203 12 - 18.203 20 - 18.203 20 - 18.203 20 - 18.203 19 - 18.203 17 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971 1.7971 1.7971 0.7971 -1.2029
Novice	undefined	20 18 16 12 20 20 20 19 17 18	20 - 18.203 18 - 18.203 16 - 18.203 12 - 18.203 20 - 18.203 20 - 18.203 19 - 18.203 17 - 18.203 18 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971 1.7971 1.7971 0.7971 -1.2029 -0.2029
Novice	undefined	20 18 16 12 20 20 20 19 17 18 19 16	20 - 18.203 18 - 18.203 16 - 18.203 20 - 18.203 20 - 18.203 20 - 18.203 19 - 18.203 17 - 18.203 18 - 18.203 19 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971 1.7971 1.7971 0.7971 -1.2029 -0.2029 0.7971 -2.2029
Novice	undefined	20 18 16 12 20 20 20 19 17 18 19 16 17	20 - 18.203 18 - 18.203 16 - 18.203 20 - 18.203 20 - 18.203 20 - 18.203 19 - 18.203 17 - 18.203 18 - 18.203 17 - 18.203 17 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971 1.7971 1.7971 0.7971 -1.2029 -0.2029 0.7971 -2.2029 -1.2029
Novice	undefined	20 18 16 12 20 20 20 19 17 18 19 16 17 19	20 - 18.203 18 - 18.203 16 - 18.203 20 - 18.203 20 - 18.203 20 - 18.203 19 - 18.203 17 - 18.203 18 - 18.203 19 - 18.203 19 - 18.203 10 - 18.203 11 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971 1.7971 1.7971 1.7971 -1.2029 -0.2029 0.7971 -2.2029 -1.2029 0.7971
Novice	undefined	20 18 16 12 20 20 20 19 17 18 19 16 17 19	20 - 18.203 18 - 18.203 16 - 18.203 20 - 18.203 20 - 18.203 20 - 18.203 19 - 18.203 17 - 18.203 18 - 18.203 19 - 18.203 17 - 18.203 17 - 18.203 17 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971 1.7971 1.7971 1.7971 0.7971 -1.2029 -0.2029 0.7971 -2.2029 -1.2029 0.7971 -1.2029
Novice	undefined	20 18 16 12 20 20 20 19 17 18 19 16 17 19	20 - 18.203 18 - 18.203 16 - 18.203 20 - 18.203 20 - 18.203 20 - 18.203 19 - 18.203 17 - 18.203 18 - 18.203 19 - 18.203 19 - 18.203 10 - 18.203 11 - 18.203	1.7971 -0.2029 -2.2029 -6.2029 1.7971 1.7971 1.7971 1.7971 -1.2029 -0.2029 0.7971 -2.2029 -1.2029 0.7971

/4/22, 2:31 PM			Two Way ANOVA calculator	
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
	undefined		20 - 18.203	1.7971
Novice		20		
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
Expert	undefined	14	14 - 12.54	1.4598
Expert	undefined	14	14 - 12.54	1.4598
Expert	undefined	2	2 - 12.54	-10.5402
Expert	undefined	2	2 - 12.54	-10.5402
Expert	undefined	2	2 - 12.54	-10.5402
Expert	undefined	9	9 - 12.54	-3.5402
Expert	undefined	8	8 - 12.54	-4.5402
Expert	undefined	10	10 - 12.54	-2.5402
	undefined	20	20 - 12.54	7.4598
Expert				
Expert	undefined	20	20 - 12.54	7.4598
Expert	undefined	20	20 - 12.54	7.4598
Expert	undefined	15	15 - 12.54	2.4598
Expert	undefined	15	15 - 12.54	2.4598
Expert	undefined	15	15 - 12.54	2.4598
Expert	undefined	15	15 - 12.54	2.4598
Expert	undefined	15	15 - 12.54	2.4598
Expert	undefined	15	15 - 12.54	2.4598
Expert	undefined	12	12 - 12.54	-0.5402
Expert	undefined	12	12 - 12.54	-0.5402
Expert	undefined	12	12 - 12.54	-0.5402
Expert	undefined	6	6 - 12.54	-6.5402
Expert	undefined	6	6 - 12.54	-6.5402
Expert	undefined	6	6 - 12.54	-6.5402
Expert	undefined	19	19 - 12.54	6.4598
Expert	undefined	19	19 - 12.54	6.4598
Expert	undefined	19	19 - 12.54	6.4598
LANCIL	unuenneu	13		
		20		
Expert	undefined	20	20 - 12.54	7.4598
	undefined undefined	20	20 - 12.54 20 - 12.54	7.4598 7.4598

5/4/22, 2.31 FW			Two way Anova calculator	
Expert	undefined	20	20 - 12.54	7.4598
Expert	undefined	13	13 - 12.54	0.4598
Expert	undefined	13	13 - 12.54	0.4598
Expert	undefined	13	13 - 12.54	0.4598
Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	15	15 - 12.54	2.4598
Expert	undefined	15	15 - 12.54	2.4598
Expert	undefined	15	15 - 12.54	2.4598
Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	17	17 - 12.54	4.4598
Expert	undefined	17	17 - 12.54	4.4598
Expert	undefined	17	17 - 12.54	4.4598
Expert	undefined	5	5 - 12.54	-7.5402
Expert	undefined	5	5 - 12.54	-7.5402
Expert	undefined	5	5 - 12.54	-7.5402
Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	12	12 - 12.54	-0.5402
Expert	undefined	12	12 - 12.54	-0.5402
Expert	undefined	12	12 - 12.54	-0.5402
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	14	14 - 12.54	1.4598
Expert	undefined	14	14 - 12.54	1.4598
Expert	undefined	14	14 - 12.54	1.4598
Expert	undefined	14	14 - 12.54	1.4598
Expert	undefined	14	14 - 12.54	1.4598
Expert	undefined	14	14 - 12.54	1.4598
Expert	undefined	1	1 - 12.54	-11.5402
Expert	undefined	1	1 - 12.54	-11.5402
Expert	undefined	1	1 - 12.54	-11.5402
Expert	undefined	1	1 - 12.54	-11.5402
Expert	undefined	1	1 - 12.54	-11.5402
Expert	undefined	1	1 - 12.54	-11.5402
Expert	undefined	15	15 - 12.54	2.4598
Expert	undefined	15	15 - 12.54	2.4598
	undefined	15	15 - 12.54	2.4598
Expert				
Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	10	10 - 12.54	-2.5402
Expert	undefined	14	14 - 12.54	1.4598
Expert	undefined	14	14 - 12.54	1.4598
Expert	undefined	14	14 - 12.54	1.4598
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	20	20 - 14.126	5.8736
	undefined	20		5.8736
Expert			20 - 14.126	
Expert	undefined	13	13 - 14.126	-1.1264
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	18	18 - 14.126	3.8736
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	20	20 - 14.126	5.8736
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
	undefined	15	15 - 14.126	0.8736
Expert				
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
	undefined	14	14 - 14.126	-0.1264
Expert	dideffiled			

			Two way ANOVA calculator	
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
	undefined	13	13 - 14.126	-1.1264
Expert				
Expert	undefined	13	13 - 14.126	-1.1264
Expert	undefined	13	13 - 14.126	-1.1264
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	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
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	20	20 - 14.126	5.8736
Expert	undefined	20	20 - 14.126	5.8736
	undefined	15	15 - 14.126	0.8736
Expert				
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
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	15	15 - 14.126	0.8736
Expert	undefined	15	15 - 14.126	0.8736
Expert	undefined	15	15 - 14.126	0.8736
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	8	8 - 14.126	-6.1264
Expert	undefined	8	8 - 14.126	
Expert	undefined			-6.1264
	undenned	8	8 - 14.126	-6.1264 -6.1264
Expert			8 - 14.126	-6.1264
Expert	undefined	12	8 - 14.126 12 - 14.126	-6.1264 -2.1264
Expert	undefined undefined	12 12	8 - 14.126 12 - 14.126 12 - 14.126	-6.1264 -2.1264 -2.1264
	undefined	12	8 - 14.126 12 - 14.126	-6.1264 -2.1264
Expert	undefined undefined	12 12	8 - 14.126 12 - 14.126 12 - 14.126	-6.1264 -2.1264 -2.1264
Expert Expert	undefined undefined undefined	12 12 12 11	8 - 14.126 12 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264
Expert Expert Expert Expert	undefined undefined undefined undefined undefined	12 12 12 11 11	8 - 14.126 12 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264
Expert Expert Expert Expert Expert	undefined undefined undefined undefined undefined undefined	12 12 12 11 11 11	8 - 14.126 12 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264
Expert Expert Expert Expert	undefined undefined undefined undefined undefined	12 12 12 11 11	8 - 14.126 12 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264
Expert Expert Expert Expert Expert	undefined undefined undefined undefined undefined undefined	12 12 12 11 11 11	8 - 14.126 12 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264
Expert Expert Expert Expert Expert Expert Expert Expert	undefined undefined undefined undefined undefined undefined undefined undefined undefined	12 12 12 11 11 11 8 8	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -3.1264 -6.1264
Expert Expert Expert Expert Expert Expert Expert Expert Expert	undefined	12 12 12 11 11 11 8 8	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -3.1264 -6.1264 -6.1264
Expert	undefined	12 12 12 11 11 11 8 8 8	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264
Expert Expert Expert Expert Expert Expert Expert Expert Expert	undefined	12 12 12 11 11 11 8 8	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -3.1264 -6.1264 -6.1264
Expert	undefined	12 12 12 11 11 11 8 8 8	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264
Expert	undefined	12 12 12 11 11 11 8 8 8 8 12 12	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126 12 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264 -2.1264
Expert	undefined	12 12 12 11 11 11 8 8 8 12 12 12	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126 12 - 14.126 12 - 14.126 14 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264 -2.1264 -2.1264 -0.1264
Expert	undefined	12 12 12 11 11 11 8 8 8 12 12 12 12 14	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126 12 - 14.126 14 - 14.126 14 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264 -2.1264 -2.1264 -0.1264
Expert	undefined	12 12 12 11 11 11 8 8 8 12 12 12	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126 12 - 14.126 12 - 14.126 14 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264 -2.1264 -2.1264 -0.1264
Expert	undefined	12 12 12 11 11 11 8 8 8 12 12 12 12 14	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126 12 - 14.126 14 - 14.126 14 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264 -2.1264 -2.1264 -0.1264
Expert	undefined	12 12 11 11 11 11 8 8 8 8 12 12 12 12 14 14 14	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126 12 - 14.126 14 - 14.126 14 - 14.126 14 - 14.126 14 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264 -2.1264 -0.1264 -0.1264 -0.1264 -0.1264 -0.1264
Expert	undefined	12 12 12 11 11 11 8 8 8 8 12 12 12 12 14 14 14	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126 12 - 14.126 14 - 14.126 14 - 14.126 14 - 14.126 10 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264 -2.1264 -2.1264 -0.1264 -0.1264 -0.1264 -4.1264
Expert	undefined	12 12 11 11 11 11 8 8 8 12 12 12 12 14 14 14 10	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126 14 - 14.126 14 - 14.126 14 - 14.126 10 - 14.126 10 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264 -2.1264 -0.1264 -0.1264 -0.1264 -4.1264 -4.1264 -4.1264
Expert	undefined	12 12 12 11 11 11 8 8 8 8 12 12 12 12 14 14 14	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126 12 - 14.126 14 - 14.126 14 - 14.126 14 - 14.126 10 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264 -2.1264 -2.1264 -0.1264 -0.1264 -0.1264 -4.1264
Expert	undefined	12 12 11 11 11 11 8 8 8 12 12 12 12 14 14 14 10	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126 14 - 14.126 14 - 14.126 14 - 14.126 10 - 14.126 10 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264 -2.1264 -0.1264 -0.1264 -0.1264 -4.1264 -4.1264 -4.1264
Expert	undefined	12 12 12 11 11 11 11 8 8 8 12 12 12 14 14 14 10 10 10 10 11	8 - 14.126 12 - 14.126 12 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 8 - 14.126 8 - 14.126 8 - 14.126 12 - 14.126 12 - 14.126 12 - 14.126 10 - 14.126 10 - 14.126 10 - 14.126 10 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126 11 - 14.126	-6.1264 -2.1264 -2.1264 -2.1264 -3.1264 -3.1264 -3.1264 -6.1264 -6.1264 -6.1264 -2.1264 -2.1264 -0.1264 -0.1264 -0.1264 -4.1264 -4.1264 -4.1264 -2.1264

Information

Models

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

- Fixed effect model (A-<u>Fixed</u>, B-<u>Fixed</u>), 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_i) = 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.

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**_i sample side of category j of variable B (column j).
- $\mathbf{n_{i,j}}$ sample side of cell i,j (row i, column j). In the balance $\mathbf{n_{i,i}}$ =n/(a*b)
- ${\bf n}$ overall sample side, includes all the groups ($\Sigma n_{i,j}$, i=1 to a, j=1 to b).
- $\bar{\mathbf{Y}}_{i}$ average of all the observations of category i of variable A (row i).
- $\bar{\mathbf{Y}}_{i}$ average of all the observations of category j of variable B (column j).
- $\bar{\mathbf{Y}}$ overall average ($\Sigma Y_{i,j,k}$ / n, i=1 to a, j=1 to b, k=1 to $n_{i,j}$).

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.
- $\tilde{\mathbf{Y}}_{i,s}$ subject's average, $\Sigma \mathbf{Y}_{i,i,s}$ for subject i,s ,the average of all the observations of subject s of category j of variable B (column j).
- $\mathbf{\bar{Y}}$ overall average ($\Sigma Y_{i,j,s}$ / 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.

SSAB - 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 = $\bar{Y}_i - \bar{Y}$

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

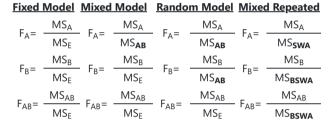
- $= \bar{Y}_{i,j} (\bar{Y}_i \bar{Y}) (\bar{Y}_j \bar{Y}) \bar{Y}.$
- $= \bar{Y}_{i,j} \bar{Y}_i \bar{Y}_j + \bar{Y}.$

Take the square of each difference

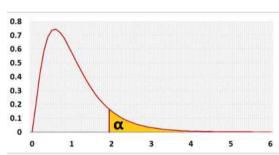
 $\bar{Y}_{i,j} - \bar{Y}_i - \bar{Y}_j + \bar{Y})^2$.

Count the square differences of each value in the cell, hence multiply by the sample size of each cell (ni,i).

Test statistic



F distribution



 $SS_{AB} = \Sigma_i^a \Sigma_j^b n_{i,j} (\bar{Y}_{i,j} - \bar{Y}_i - \bar{Y}_j + \bar{Y})^2$

Fixed and Random Effects

The fixed and random effects are related to the independent variables ().

Fixed Effect

The effect is constant across individuals.

- The categories of the variable contains the entire categories' list
- The effect of this variable is interesting. The difference between the categories is important
- There is no know pattern on the difference between the categories

Random Effect

The effect vary across individuals, the individuals may be people, products.

- The categories' list is only a sample from the entire categories' list
- The effect of this variable is not interesting by itself. The difference between the categories is not important.
- There is no know pattern on the difference between the categories

Example: collecting data from several schools.

A sample from the entire groups' population.

There is no pattern about the difference between the schools, and if there will be a pattern, it will be another factor, like school's size.

Each school is not important by itself.

When you change the interaction field or the model, the following ANOVA table and diagram will be adjusted!

ANOVA table - with interaction

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	F statistic	p-value
Factor A (rows) Between the categories of factor A	DF _A = a - 1	$SS_A = \Sigma_i^a n_i (\bar{Y}_{i^-} \bar{Y})^2$	$MS_A = SS_A / DF_A$	$F_A = MS_A / MS_E$	$P(x > F_A)$
Factor B (Columns) Between the categories of factor B	DF _B = b - 1	$SS_B = \Sigma_j^{\ b} n_j (\bar{Y}_j \text{-} \bar{Y})^2$	$MS_B = SS_B / DF_B$	$F_B = MS_B / MS_E$	$P(x > F_B)$
Interaction AB Between the cells after reducing factor A and factor B effects	$DF_{AB} = (a - 1)(b - 1)$	$SS_{AB} \! = \! \Sigma_{i}^{a} \Sigma_{j}^{b} n_{i,j} (\bar{Y}_{i,j} - \bar{Y}_{i} - \bar{Y}_{j} + \bar{Y})^{2}$	$MS_{AB} = SS_{AB} / DF_{AB}$	$F_{AB} = MS_{AB} / MS_{E}$	$P(x > F_{AB})$
Error Within the cells	DF _E = n - a*b	$SS_{E} \!\!=\!\! \Sigma_{i}{}^{a} \! \Sigma_{j}{}^{b} \! \Sigma_{k}{}^{n_{i,j}} (Y_{i,j,k} - \bar{Y}_{i,j})^{2}$	$MS_E = SS_E / DF_E$		
Total All the deviations from the average	DF _T = n - 1	$\begin{aligned} &SS_{T} = \Sigma_i{}^{a} \Sigma_j{}^{b} \Sigma_k{}^{n_{i,j}} (Y_{i,j,k} - \bar{Y})^2 \\ &SS_{T} = Sample \ Variance*(n-1) \\ &SS_{T} = SS_{A} + SS_{B} + SS_{AB} + SS_{E} \end{aligned}$	$MS_E = S^2 = SS_T / (n - 1)$		

Sum of squares diagram - with interaction

In the following diagram you may see the differences per each observation $Y_{i,j,k}$ that used to calculate the sum of squares.

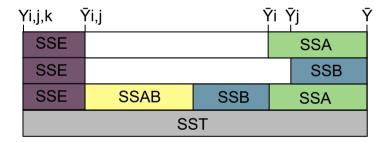
A effect: $\bar{Y}_i - \bar{Y}$.

B effect: \bar{Y}_j - \bar{Y} .

Interaction effect (AB): $Y_{i,j} - \bar{Y}_i - \bar{Y}_j + \bar{Y}$.

Error: Y_{i,j,k} - $\bar{Y}_{i,j}$.

Total effect: $Y_{i,j,k}$ - \bar{Y} .



R Code

The following R code should produce the same results

A0 :

c("Novice","

A = c(A0,A1)

B0 =

c("undefined","und

B = c(B0,B1)

DV0 :

 $\mathsf{DV} = \mathsf{c}(\mathsf{DV0}, \mathsf{DV1})$

ID0 =

c(0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,10,11,12,13,14,14,14,14,149,150,151,152,153,154,155)

ID = c(ID0,ID1)

 $df1 <- \ data.frame(A,B,DV,ID)$

Model1 <- aov(DV \sim A + B + A:B, data=df1)

summary(Model1)

res=residuals(object = Model1)