Assignment 6

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Exercise 1 (breakers and gaugers)

It is important to check if certain assumptions are met before performing ANOVA. Those include

- Measurements are independent.
  Based on the information of the exercise we can conclude that all measurements are independent (gauger and breaker)
- Measurements are normally distributed.
  Testing for normality results in all data being normally distributed (without outliers).

  Breaker - 1, Gauger - 1,2,3:

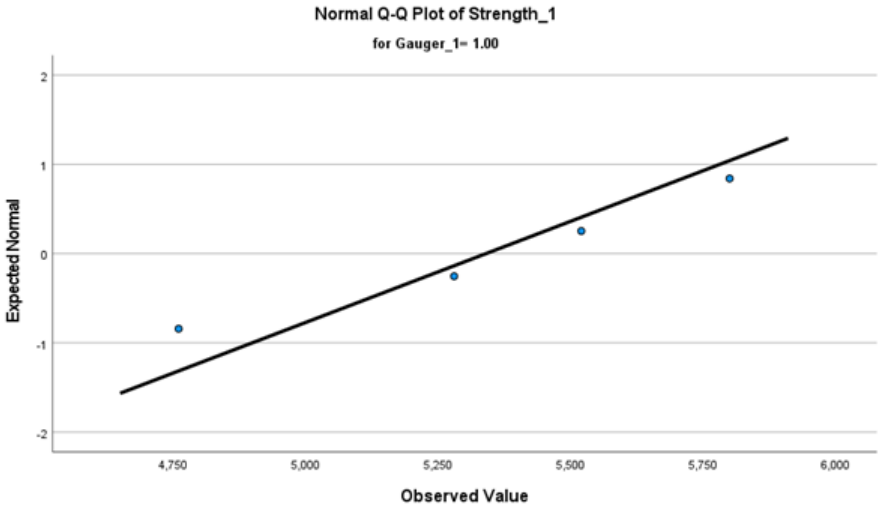
Descriptives

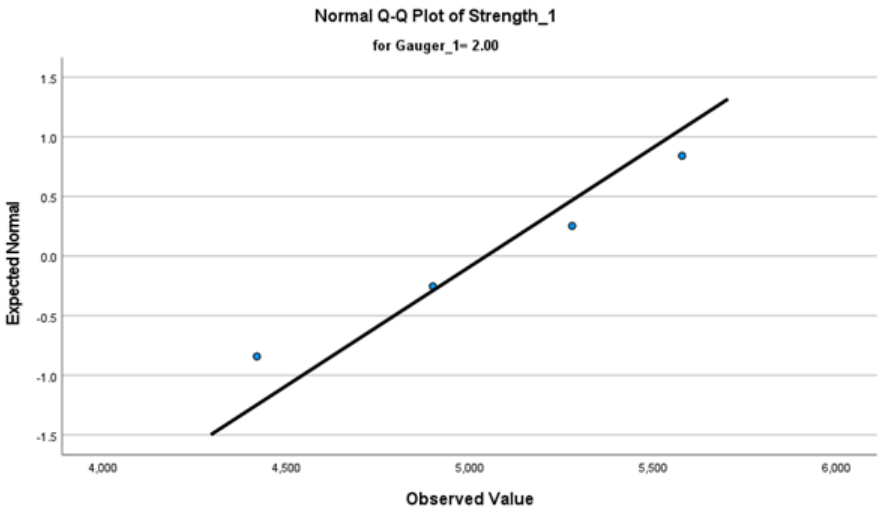
	Gauger_1			Statistic	Std. Error
Strength_1	1.00	Mean		5340.0000	220.60523
		95% Confidence Interval for Mean	Lower Bound	4637.9357	
			Upper Bound	6042.0643	
		5% Trimmed Mean		5346.6667	
		Median		5400.0000	
		Variance		194666.667	
		Std. Deviation		441.21046	
		Minimum		4760.00	
		Maximum		5800.00	
		Range		1040.00	
		Interquartile Range		840.00	
		Skewness		-.715	1.014
		Kurtosis		.486	2.619
	2.00	Mean		5045.0000	250.51613
		95% Confidence Interval for Mean	Lower Bound	4247.7459	
			Upper Bound	5842.2541	
		5% Trimmed Mean		5050.0000	
		Median		5090.0000	
		Variance		251033.333	
		Std. Deviation		501.03227	
		Minimum		4420.00	
		Maximum		5580.00	
		Range		1160.00	
		Interquartile Range		965.00	
		Skewness		-.430	1.014
		Kurtosis		-.911	2.619
	3.00	Mean		5675.0000	174.42764
		95% Confidence Interval for Mean	Lower Bound	5119.8934	
			Upper Bound	6230.1066	
		5% Trimmed Mean		5665.5556	
		Median		5590.0000	
		Variance		121700.000	
		Std. Deviation		348.85527	
		Minimum		5360.00	
		Maximum		6160.00	
		Range		800.00	
		Interquartile Range		645.00	
		Skewness		1.216	1.014
		Kurtosis		1.380	2.619

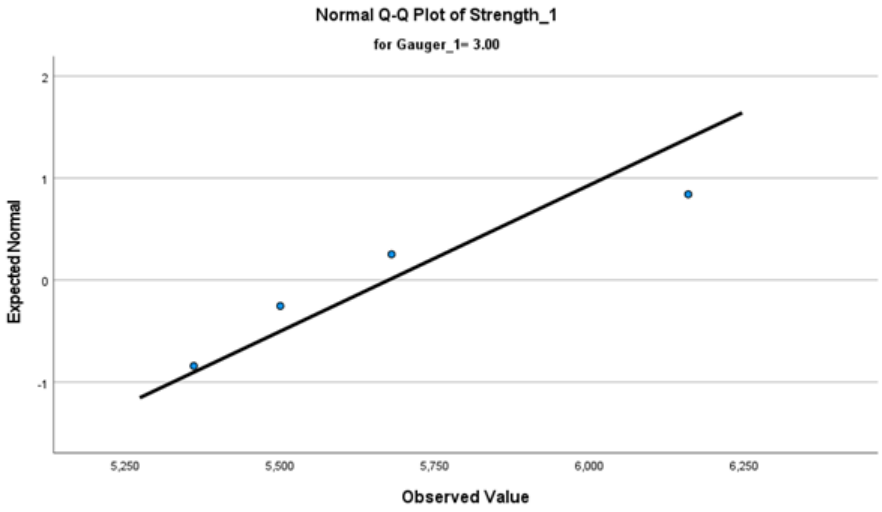
Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Gauger_1	Statistic	df	Sig.	Statistic	df	Sig.
Strength_1	1.00	.196	4	.	.975	4	.874
	2.00	.180	4	.	.983	4	.920
	3.00	.244	4	.	.921	4	.540

a. Lilliefors Significance Correction







Breaker - 2, Gauger - 1,2,3:

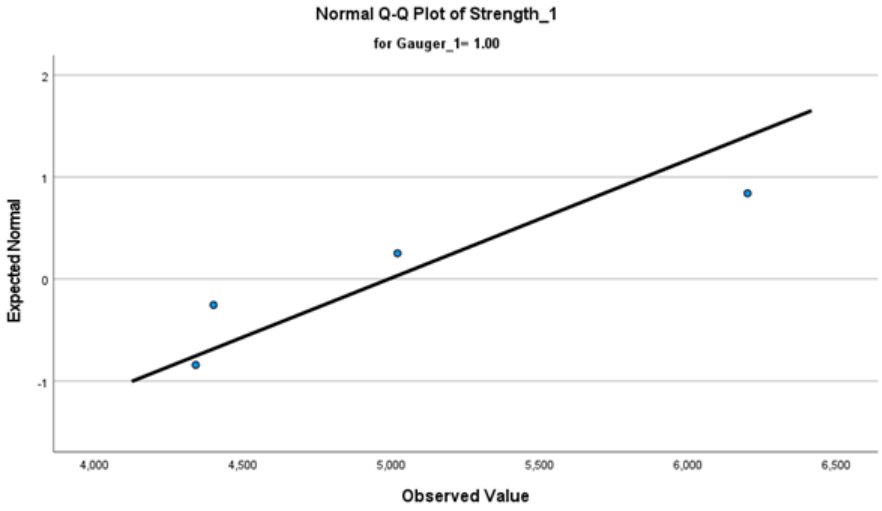
Descriptives

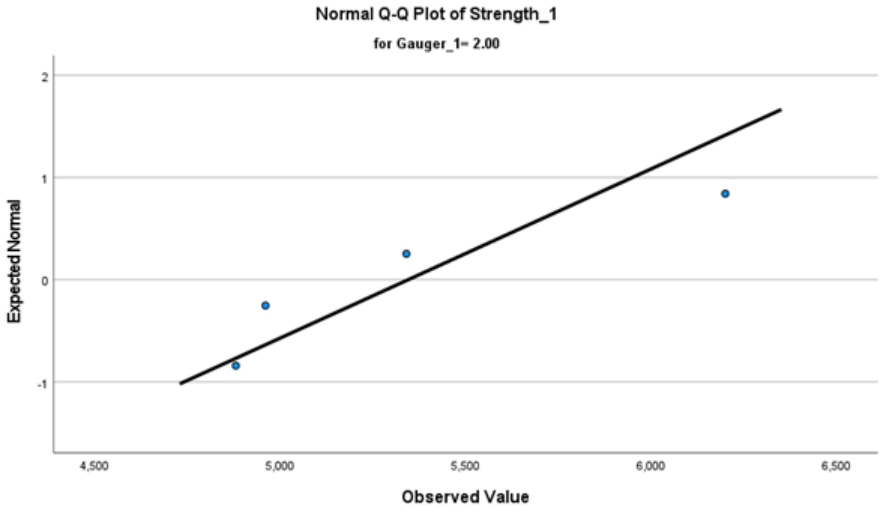
	Gauger_1			Statistic	Std. Error
Strength_1	1.00	Mean		4990.0000	431.62484
		95% Confidence Interval for Mean	Lower Bound	3616.3771	
			Upper Bound	6363.6229	
		5% Trimmed Mean		4958.8889	
		Median		4710.0000	
		Variance		745200.000	
		Std. Deviation		863.24967	
		Minimum		4340.00	
		Maximum		6200.00	
		Range		1860.00	
		Interquartile Range		1550.00	
		Skewness		1.339	1.014
		Kurtosis		1.166	2.619
	2.00	Mean		5345.0000	302.14511
		95% Confidence Interval for Mean	Lower Bound	4383.4394	
			Upper Bound	6306.5606	
		5% Trimmed Mean		5323.3333	
		Median		5150.0000	
		Variance		365166.667	
		Std. Deviation		604.29022	
		Minimum		4880.00	
		Maximum		6200.00	
		Range		1320.00	
		Interquartile Range		1085.00	
		Skewness		1.412	1.014
		Kurtosis		1.577	2.619
	3.00	Mean		5415.0000	220.81289
		95% Confidence Interval for Mean	Lower Bound	4712.2748	
			Upper Bound	6117.7252	
		5% Trimmed Mean		5434.4444	
		Median		5590.0000	
		Variance		195033.333	
		Std. Deviation		441.62578	
		Minimum		4760.00	
		Maximum		5720.00	
		Range		960.00	
		Interquartile Range		735.00	
		Skewness		-1.865	1.014
		Kurtosis		3.582	2.619

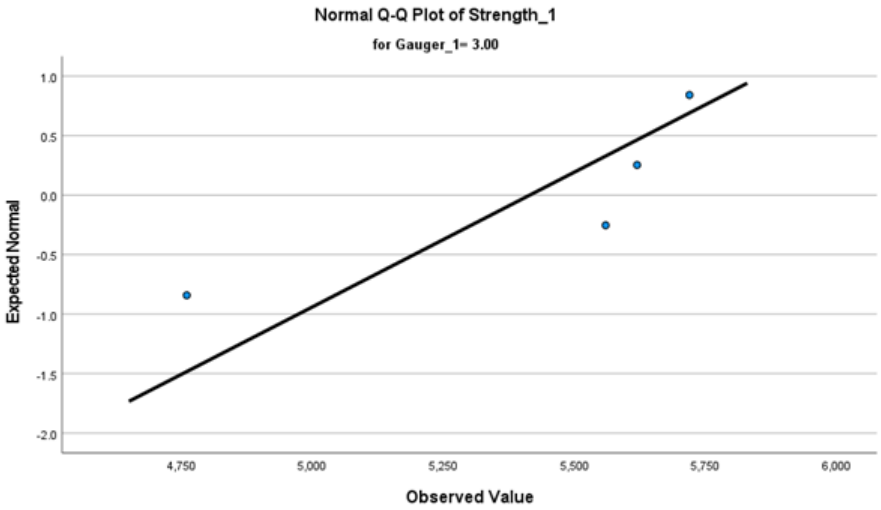
Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Gauger_1	Statistic	df	Sig.	Statistic	df	Sig.
Strength_1	1.00	.253	4	.	.854	4	.238
	2.00	.253	4	.	.860	4	.259
	3.00	.379	4	.	.767	4	.055

a. Lilliefors Significance Correction







Breaker - 3, Gauger - 1,2,3:

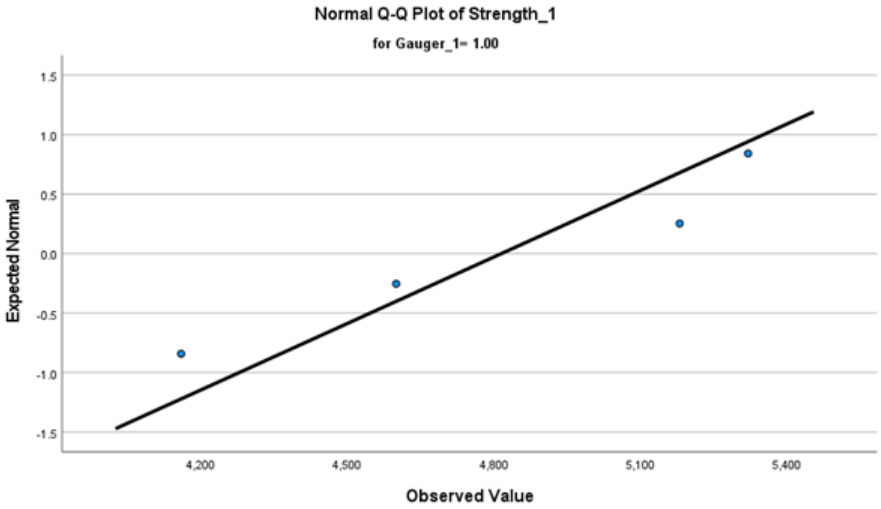
Descriptives

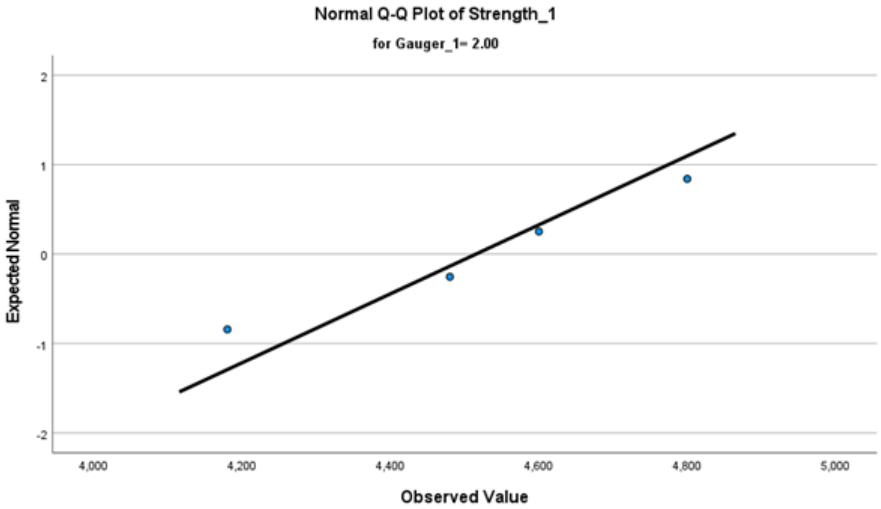
	Gauger_1			Statistic	Std. Error
Strength_1	1.00	Mean		4815.0000	268.25050
		95% Confidence Interval for Mean	Lower Bound	3961.3072	
			Upper Bound	5668.6928	
		5% Trimmed Mean		4823.3333	
		Median		4890.0000	
		Variance		287833.333	
		Std. Deviation		536.50101	
		Minimum		4160.00	
		Maximum		5320.00	
		Range		1160.00	
		Interquartile Range		1015.00	
		Skewness		-.490	1.014
		Kurtosis		-2.678	2.619
	2.00	Mean		4515.0000	129.71122
		95% Confidence Interval for Mean	Lower Bound	4102.2010	
			Upper Bound	4927.7990	
		5% Trimmed Mean		4517.7778	
		Median		4540.0000	
		Variance		67300.000	
		Std. Deviation		259.42244	
		Minimum		4180.00	
		Maximum		4800.00	
		Range		620.00	
		Interquartile Range		495.00	
		Skewness		-.530	1.014
		Kurtosis		.664	2.619
	3.00	Mean		4917.5000	246.92695
		95% Confidence Interval for Mean	Lower Bound	4131.6683	
			Upper Bound	5703.3317	
		5% Trimmed Mean		4905.0000	
		Median		4805.0000	
		Variance		243891.667	
		Std. Deviation		493.85389	
		Minimum		4460.00	
		Maximum		5600.00	
		Range		1140.00	
		Interquartile Range		917.50	
		Skewness		1.155	1.014
		Kurtosis		1.292	2.619

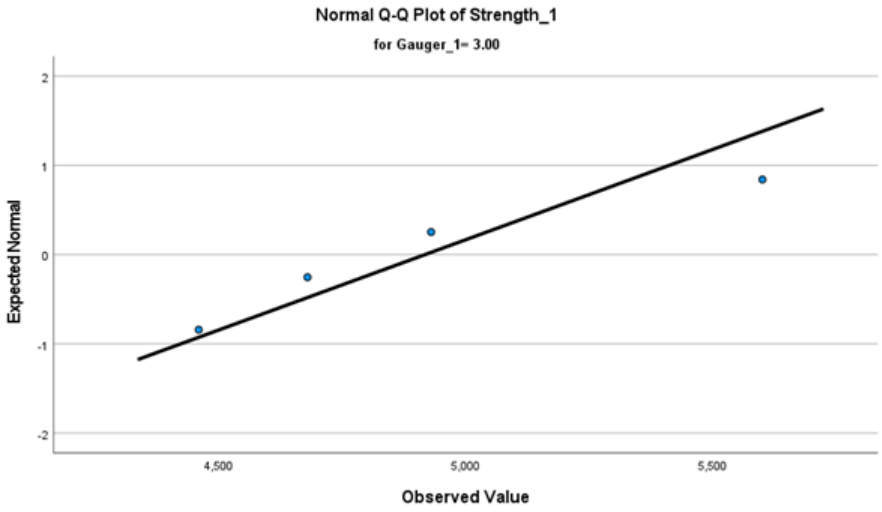
Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Gauger_1	Statistic	df	Sig.	Statistic	df	Sig.
Strength_1	1.00	.252	4	.	.925	4	.565
	2.00	.196	4	.	.986	4	.933
	3.00	.240	4	.	.930	4	.597

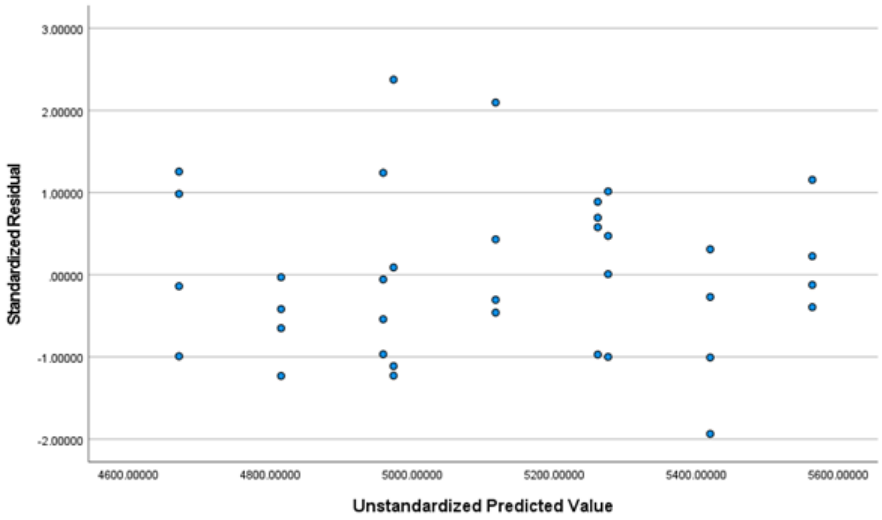
a. Lilliefors Significance Correction







- There is a common variance for all samples.
  There is a common variance observed in the plot below. It appears to be a random scatter plot with equal vertical spread along the horizontal axis.



As all the three assumptions have been satisfied, we proceed with the **ANOVA** test.
We can see here that gauger has three levels, and breaker has three levels and that each level has a number of 12 measurements.

Between-Subjects Factors

		N
Gauger	1.00	12
	2.00	12
	3.00	12
Breaker	1.00	12
	2.00	12
	3.00	12

The mean, standard deviation and the number of samples in each combination is described in detail.

Descriptive Statistics

Dependent Variable: Strength

Gauger	Breaker	Mean	Std. Deviation	N
1.00	1.00	5340.00	441.210	4
	2.00	4990.00	863.250	4
	3.00	4815.00	536.501	4
	Total	5048.33	621.930	12
2.00	1.00	5045.00	501.032	4
	2.00	5345.00	604.290	4
	3.00	4515.00	259.422	4
	Total	4968.33	561.133	12
3.00	1.00	5675.00	348.855	4
	2.00	5415.00	441.626	4
	3.00	4917.50	493.854	4
	Total	5335.83	510.534	12
Total	1.00	5353.33	476.452	12
	2.00	5250.00	627.520	12
	3.00	4749.17	441.803	12
	Total	5117.50	572.760	36

From the results of the Levene's test, all the null hypothesis is accepted. This is because the error variance across all the dependent variables is equal and also the value of p is greater than 0.05 in all the cases.

Levene's Test of Equality of Error Variances[a,b]

		Levene Statistic	df1	df2	Sig.
Strength	Based on Mean	.803	8	27	.606
	Based on Median	.608	8	27	.763
	Based on Median and with adjusted df	.608	8	15.809	.759
	Based on trimmed mean	.790	8	27	.616

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: Strength

b. Design: Intercept + Gauger + Breaker + Gauger * Breaker

The parameters describe that there are eight estimators involved in this case.

Parameter Estimates

Dependent Variable: Strength

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Partial Eta Squared
Intercept	4917.500	262.034	18.767	.000	4379.851	5455.149	.929
[Gauger=1.00]	-102.500	370.572	-.277	.784	-862.851	657.851	.003
[Gauger=2.00]	-402.500	370.572	-1.086	.287	-1162.851	357.851	.042
[Gauger=3.00]	0[a]	.	.	.	.	.	.
[Breaker=1.00]	757.500	370.572	2.044	.051	-2.851	1517.851	.134
[Breaker=2.00]	497.500	370.572	1.343	.191	-262.851	1257.851	.063
[Breaker=3.00]	0[a]	.	.	.	.	.	.
[Gauger=1.00] * [Breaker=1.00]	-232.500	524.068	-.444	.661	-1307.799	842.799	.007
[Gauger=1.00] * [Breaker=2.00]	-322.500	524.068	-.615	.543	-1397.799	752.799	.014
[Gauger=1.00] * [Breaker=3.00]	0[a]	.	.	.	.	.	.
[Gauger=2.00] * [Breaker=1.00]	-227.500	524.068	-.434	.668	-1302.799	847.799	.007
[Gauger=2.00] * [Breaker=2.00]	332.500	524.068	.634	.531	-742.799	1407.799	.015
[Gauger=2.00] * [Breaker=3.00]	0[a]	.	.	.	.	.	.
[Gauger=3.00] * [Breaker=1.00]	0[a]	.	.	.	.	.	.
[Gauger=3.00] * [Breaker=2.00]	0[a]	.	.	.	.	.	.
[Gauger=3.00] * [Breaker=3.00]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

The critical value was found to be 2.73 from the F distribution table. We reject the null hypothesis (H_0) if F $\geq$ c = 2.73 (F_{27}^4 & $\alpha = 5\%$). From the table of test between the subjects with interaction effects provided below, the value of F statistic for interaction (gauger*breaker) is 0.604. Therefore, we accept the null hypothesis that the combined effect of gauger and breaker is zero. The acceptance of null hypothesis can also be proved by the p value (0.663) in the table.

Tests of Between-Subjects Effects

Dependent Variable: Strength

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4066400.00[a]	8	508300.000	1.851	.111	.354
Intercept	942797025.0	1	942797025.0	3432.756	.000	.992
Gauger	896450.000	2	448225.000	1.632	.214	.108
Breaker	2506116.667	2	1253058.333	4.562	.020	.253
Gauger * Breaker	663833.333	4	165958.333	.604	.663	.082
Error	7415475.000	27	274647.222			
Total	954278900.0	36				
Corrected Total	11481875.00	35				

a. R Squared = .354 (Adjusted R Squared = .163)

To investigate the best conditions for achieving the highest expected value of the strength we need to verify which variable describe strength. This can be done by analyzing the ANOVA without interaction.

Tests of Between-Subjects Effects

Dependent Variable: Strength

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3402566.67[a]	4	850641.667	3.264	.024	.296
Intercept	942797025.0	1	942797025.0	3617.476	.000	.992
Gauger	896450.000	2	448225.000	1.720	.196	.100
Breaker	2506116.667	2	1253058.333	4.808	.015	.237
Error	8079308.333	31	260622.849			
Total	954278900.0	36				
Corrected Total	11481875.00	35				

a. R Squared = .296 (Adjusted R Squared = .206)

Gauger: The critical value was found to be between 3.32 and 3.23 from the F distribution table. We reject the null hypothesis (H_0) if F $\geq$ c = [3.23,3.32] (F^2_{31} & $\alpha = 5\%$). From the table of test between the subjects without interaction effects provided above, the value of F statistic for gauger is 1.720. Therefore, we **accept** the null hypothesis that the gauger has no effect on describing the strength. The acceptance of null hypothesis can also be proved by the p value (0.196) in the table.

Breaker: The critical value was found to be between 3.32 and 3.23 from the F distribution table. We reject the null hypothesis (H_0) if F $\geq$ c = [3.23,3.32] (F^2_{31} & $\alpha = 5\%$). From the table of test between the subjects without interaction effects provided above, the value of F statistic for breaker is 4.808. Therefore, we **reject** the null hypothesis that the breaker has no effect on describing the strength. The rejection of null hypothesis can also be proved by the p value (0.015) in the table. Furthermore, the partial eta squared indicates a 0.237 for breaker, meaning that the dependent variable (strength) consists of 23.7% out of breaker influence.

Multiple Comparisons

Dependent Variable: Strength

	(I) Breaker	(J) Breaker	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	1.00	2.00	103.33	213.950	.880	-427.14	633.80
		3.00	604.17*	213.950	.023	73.70	1134.64
	2.00	1.00	-103.33	213.950	.880	-633.80	427.14
		3.00	500.83	213.950	.067	-29.64	1031.30
	3.00	1.00	-604.17*	213.950	.023	-1134.64	-73.70
		2.00	-500.83	213.950	.067	-1031.30	29.64
Scheffe	1.00	2.00	103.33	213.950	.890	-450.80	657.47
		3.00	604.17*	213.950	.030	50.03	1158.30
	2.00	1.00	-103.33	213.950	.890	-657.47	450.80
		3.00	500.83	213.950	.083	-53.30	1054.97
	3.00	1.00	-604.17*	213.950	.030	-1158.30	-50.03
		2.00	-500.83	213.950	.083	-1054.97	53.30
Bonferroni	1.00	2.00	103.33	213.950	1.000	-442.76	649.43
		3.00	604.17*	213.950	.026	58.07	1150.26
	2.00	1.00	-103.33	213.950	1.000	-649.43	442.76
		3.00	500.83	213.950	.081	-45.26	1046.93
	3.00	1.00	-604.17*	213.950	.026	-1150.26	-58.07
		2.00	-500.83	213.950	.081	-1046.93	45.26

Based on observed means.
The error term is Mean Square(Error) = 274647.222.

*. The mean difference is significant at the .05 level.

We can see here that based on the significant value breaker 1 vs breaker 3 always has a significant difference (for all three tests). In other words, the p value of breaker 1 vs breaker 3 is always less than 0.05 for all the three tests performed. This means that both variables differ in outcome and thus

influence the strength accordingly. Based on the mean difference (I-J), we can see that breaker 1 is higher than breaker 3, meaning that breaker 1 gives the cement a higher strength. This then provides the answer for which is the best condition for achieving the best strength: **breaker 1 or 2 with any gauger**.

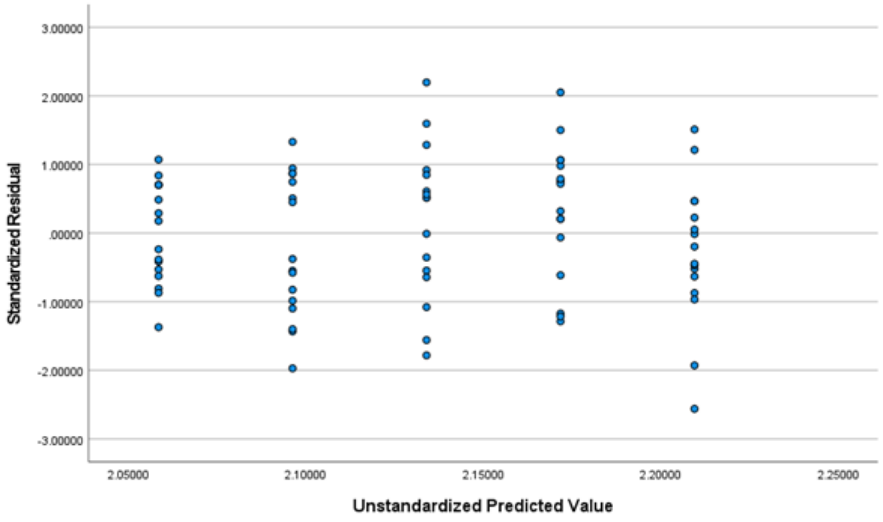
Exercise 2 (Skin resistance)

It is important to check if certain assumptions are met before performing ANOVA. Those include

- Measurements are independent.
  Based on the information of the exercise we can conclude that all measurements are independent (resistance).

- Measurements are normally distributed.
  Testing for normality results in four out of five data not being normally distributed. So, the log transform of the resistance value was calculated to make the measurements distribute normally. An outlier was found in the box plot of electrode 1 but as it was in the nearest point, I decided to include that value. The results of these normality tests are given in the next page.

- There is a common variance for all samples.
  There is a common variance observed in the plot below. It appears to be a random scatter plot with equal vertical spread along the horizontal axis.



Normlaity Test Results:

Resistance, Electrodes - 1,2,3,4,5:

Descriptives

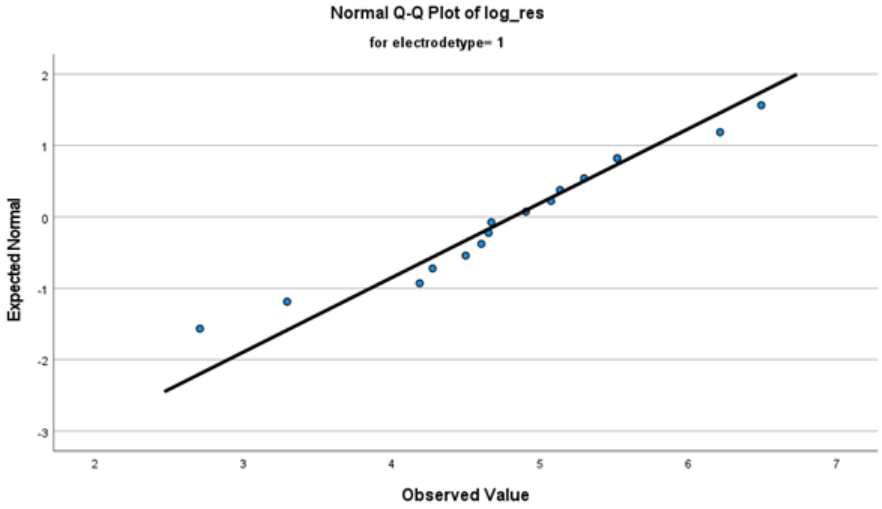
	electrodetype			Statistic	Std. Error
log_res	1	Mean		4.8166	.23979
		95% Confidence Interval for Mean	Lower Bound	4.3055	
			Upper Bound	5.3277	
		5% Trimmed Mean		4.8407	
		Median		4.7891	
		Variance		.920	
		Std. Deviation		.95917	
		Minimum		2.71	
		Maximum		6.49	
		Range		3.78	
		Interquartile Range		1.13	
		Skewness		-.436	.564
		Kurtosis		.721	1.091
	2	Mean		5.3099	.23017
		95% Confidence Interval for Mean	Lower Bound	4.8193	
			Upper Bound	5.8005	
		5% Trimmed Mean		5.3046	
		Median		5.4841	
		Variance		.848	
		Std. Deviation		.92067	
		Minimum		3.81	
		Maximum		6.91	
		Range		3.10	
		Interquartile Range		1.41	
		Skewness		-.335	.564
		Kurtosis		-.606	1.091
	3	Mean		5.0932	.26029
		95% Confidence Interval for Mean	Lower Bound	4.5384	
			Upper Bound	5.6480	
		5% Trimmed Mean		5.0916	
		Median		5.3936	
		Variance		1.084	
		Std. Deviation		1.04116	
		Minimum		3.26	
		Maximum		6.96	
		Range		3.70	
		Interquartile Range		1.41	
		Skewness		-.178	.564
		Kurtosis		-.541	1.091
	4	Mean		4.6242	.23959
		95% Confidence Interval for Mean	Lower Bound	4.1135	
			Upper Bound	5.1349	
		5% Trimmed Mean		4.6347	
		Median		4.3974	
		Variance		.918	
		Std. Deviation		.95837	
		Minimum		3.00	
		Maximum		6.06	
		Range		3.07	
		Interquartile Range		1.77	
		Skewness		-.057	.564
		Kurtosis		-1.385	1.091
	5	Mean		4.7251	.16993
		95% Confidence Interval for Mean	Lower Bound	4.3629	
			Upper Bound	5.0873	
		5% Trimmed Mean		4.7389	
		Median		4.7135	
		Variance		.462	
		Std. Deviation		.67973	
		Minimum		3.47	
		Maximum		5.74	
		Range		2.27	
		Interquartile Range		1.21	
		Skewness		-.174	.564
		Kurtosis		-1.143	1.091

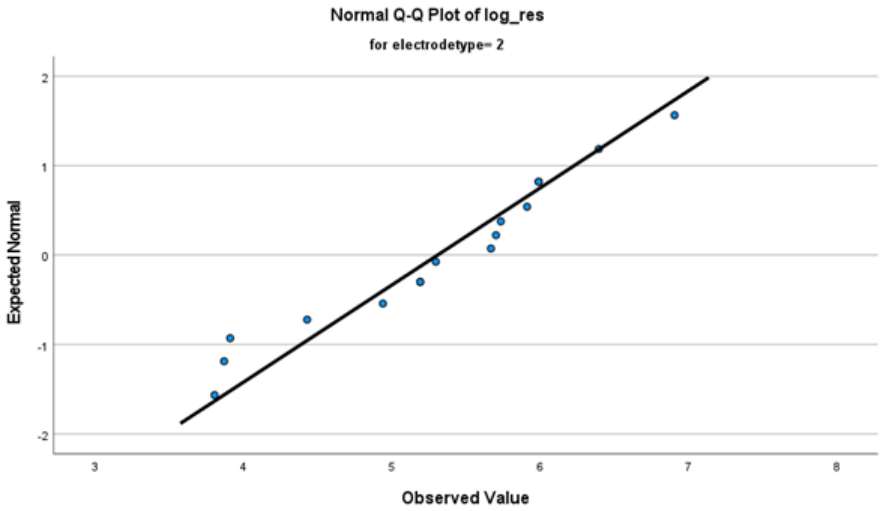
Tests of Normality

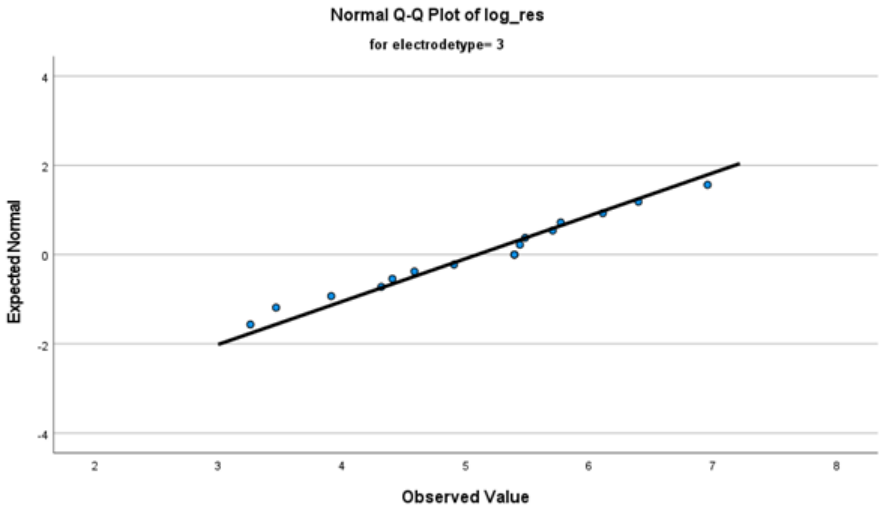
		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	electrodetype	Statistic	df	Sig.	Statistic	df	Sig.
log_res	1	.132	16	.200*	.965	16	.757
	2	.152	16	.200*	.941	16	.359
	3	.176	16	.200	.974	16	.894
	4	.180	16	.177	.931	16	.249
	5	.150	16	.200*	.945	16	.416

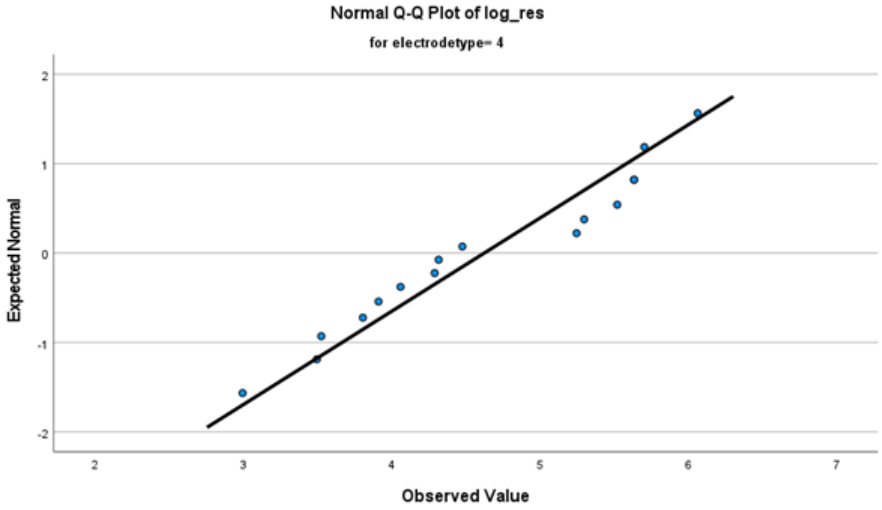
*. This is a lower bound of the true significance.

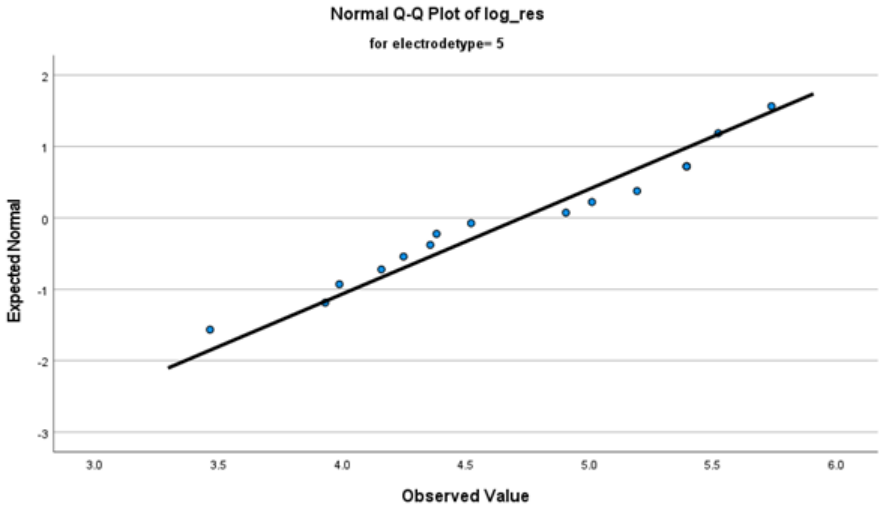
a. Lilliefors Significance Correction

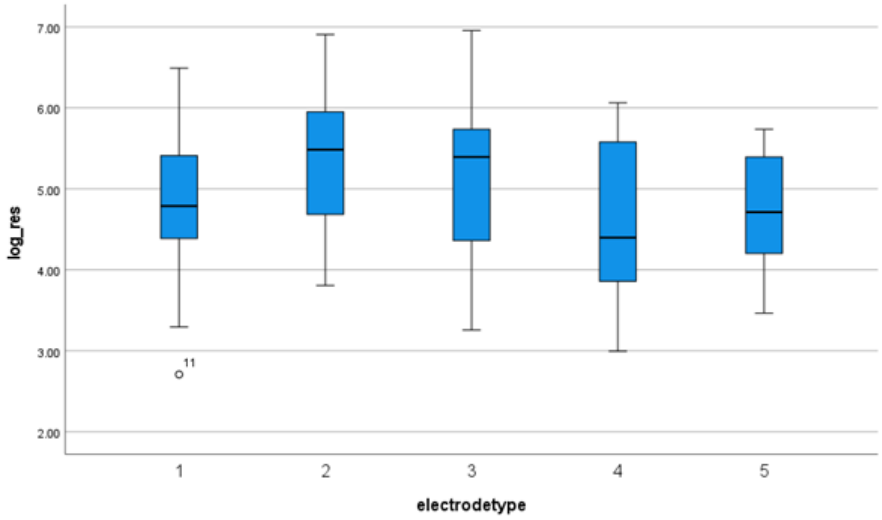





Normal Q-Q Plot of log_res
for electrodetype= 3
Expected Normal
Observed Value
4
2
0
-2
-4
2
3
4
5
6
7
8


Normal Q-Q Plot of log_res
for electrodetype= 4
Expected Normal
Observed Value
2
1
0
-1
-2
2
3
4
5
6
7


Normal Q-Q Plot of log_res
for electrodetype= 5
Expected Normal
Observed Value
2
1
0
-1
-2
-3
3.0
3.5
4.0
4.5
5.0
5.5
6.0



As all the three assumptions have been satisfied, we proceed with the **ANOVA** test.

ANOVA test: with two extreme data points (1000 and 1050) of subject 15

We can see here that there are 16 subjects with each 5 electrodes.

Between-Subjects Factors

		N
subject	1	5
	2	5
	3	5
	4	5
	5	5
	6	5
	7	5
	8	5
	9	5
	10	5
	11	5
	12	5
	13	5
	14	5
	15	5
	16	5
electrodetype	1	16
	2	16
	3	16
	4	16
	5	16

The mean, standard deviation and the number of samples in each combination is described in detail.

Descriptive Statistics

Dependent Variable: log_res

subject	electrodetype	Mean	Std. Deviation	N
1	1	6.2146	.	1
	2	5.9915	.	1
	3	4.5850	.	1
	4	5.2983	.	1
	5	5.5215	.	1
	Total	5.5222	.63800	5
2	1	6.4922	.	1
	2	6.3969	.	1
	3	6.3969	.	1
	4	4.3175	.	1
	5	5.7366	.	1
	Total	5.8680	.91796	5
3	1	5.5215	.	1
	2	5.9135	.	1
	3	5.3936	.	1
	4	5.5215	.	1
	5	5.3936	.	1
	Total	5.5487	.21369	5
4	1	4.2767	.	1
	2	4.9416	.	1
	3	5.4806	.	1
	4	3.4965	.	1
	5	3.9890	.	1
	Total	4.4369	.78339	5
5	1	4.9053	.	1
	2	5.7038	.	1
	3	6.1092	.	1
	4	6.0638	.	1
	5	4.2485	.	1
	Total	5.4061	.80723	5
6	1	3.2958	.	1
	2	4.4308	.	1
	3	4.9053	.	1
	4	5.2470	.	1
	5	5.1930	.	1
	Total	4.6144	.80496	5
7	1	4.6052	.	1
	2	3.9120	.	1
	3	4.4067	.	1
	4	4.2905	.	1
	5	4.3567	.	1
	Total	4.3142	.25364	5
8	1	4.6540	.	1
	2	5.1930	.	1
	3	3.4657	.	1
	4	4.0604	.	1
	5	3.4657	.	1
	Total	4.1678	.75575	5
9	1	4.4998	.	1
	2	5.1930	.	1
	3	5.3936	.	1
	4	3.5264	.	1
	5	4.1589	.	1
	Total	4.5543	.76294	5

10	1	5.2983	.	1
	2	5.6699	.	1
	3	5.7683	.	1
	4	5.6348	.	1
	5	4.9053	.	1
	Total	5.4553	.35476	5
11	1	2.7081	.	1
	2	3.8067	.	1
	3	4.3175	.	1
	4	4.4773	.	1
	5	4.3820	.	1
	Total	3.9383	.73520	5
12	1	5.0752	.	1
	2	5.2983	.	1
	3	5.7038	.	1
	4	5.7038	.	1
	5	5.3936	.	1
	Total	5.4349	.27127	5
13	1	5.5215	.	1
	2	5.9915	.	1
	3	3.9120	.	1
	4	3.9120	.	1
	5	4.5218	.	1
	Total	4.7718	.94743	5
14	1	5.1358	.	1
	2	5.7366	.	1
	3	5.4381	.	1
	4	2.9957	.	1
	5	5.0106	.	1
	Total	4.8634	1.08129	5
15	1	4.1897	.	1
	2	6.9078	.	1
	3	6.9565	.	1
	4	5.6348	.	1
	5	5.3936	.	1
	Total	5.8165	1.15640	5
16	1	4.6728	.	1
	2	3.8712	.	1
	3	3.2581	.	1
	4	3.8067	.	1
	5	3.9318	.	1
	Total	3.9081	.50486	5
Total	1	4.8166	.95917	16
	2	5.3099	.92067	16
	3	5.0932	1.04116	16
	4	4.6242	.95837	16
	5	4.7251	.67973	16
	Total	4.9138	.93165	80

The parameters describe that there are 19 estimators involved in this case.

Parameter Estimates

Dependent Variable: log_res

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	3.719	.355	10.483	.000	3.010	4.429	.647
[subject=1]	1.614	.449	3.596	.001	.716	2.512	.177
[subject=2]	1.960	.449	4.367	.000	1.062	2.858	.241
[subject=3]	1.641	.449	3.656	.001	.743	2.538	.182
[subject=4]	.529	.449	1.178	.243	-.369	1.426	.023
[subject=5]	1.498	.449	3.338	.001	.600	2.396	.157
[subject=6]	.706	.449	1.574	.121	-.191	1.604	.040
[subject=7]	.406	.449	.905	.369	-.492	1.304	.013
[subject=8]	.260	.449	.579	.565	-.638	1.157	.006
[subject=9]	.646	.449	1.440	.155	-.252	1.544	.033
[subject=10]	1.547	.449	3.447	.001	.649	2.445	.165
[subject=11]	.030	.449	.067	.947	-.868	.928	.000
[subject=12]	1.527	.449	3.402	.001	.629	2.425	.162
[subject=13]	.864	.449	1.924	.059	-.034	1.761	.058
[subject=14]	.955	.449	2.128	.037	.058	1.853	.070
[subject=15]	1.908	.449	4.252	.000	1.011	2.806	.232
[subject=16]	0[a]	.	.	.	.	.	.
[electrodetype=1]	.092	.251	.365	.717	-.410	.593	.002
[electrodetype=2]	.585	.251	2.331	.023	.083	1.087	.083
[electrodetype=3]	.368	.251	1.467	.148	-.134	.870	.035
[electrodetype=4]	-.101	.251	-.402	.689	-.603	.401	.003
[electrodetype=5]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Tests of Between-Subjects Effects

Dependent Variable: log_res

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	38.357[a]	19	2.019	4.009	.000	.559
Intercept	1931.640	1	1931.640	3836.038	.000	.985
subject	33.269	15	2.218	4.405	.000	.524
electrodetype	5.087	4	1.272	2.526	.050	.144
Error	30.213	60	.504			
Total	2000.210	80				
Corrected Total	68.570	79				

a. R Squared = .559 (Adjusted R Squared = .420)

Electrode Type: The critical value was found to be between 2.53 and 2.61 from the F distribution table. We reject the null hypothesis (H_0) if F $\geq$ c = [2.53,2.61] (F^4_{60} & $\alpha = 5\%$). From the table of test between the subjects provided above, the value of F statistic for electrode type is 2.526 (appx. 2.53) . Therefore, we **reject** the null hypothesis that the electrode type has no effect on describing the resistance. The rejection of null hypothesis can also be proved by the p value (0.05) in the table.

Subject: The rejection of null hypothesis can be proved by the p value (0.000) in the table. The value of sig is less than 0.05 and so we **reject** the null hypothesis that the subject has no effect on describing the strength.
Furthermore, the partial eta squared indicates a 0.524 for subject, meaning that the dependent variable (resistance) consists of 52.4% out of subject influence.
In conclusion, both the subject and electrode type has an effect on the resistance.

Multiple Comparisons

Dependent Variable: log_res

	(I) electrodetype	(J) electrodetype	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	-.4932	.25089	.295	-1.1988	.2124
		3	-.2765	.25089	.805	-.9822	.4291
		4	.1925	.25089	.939	-.5131	.8981
		5	.0915	.25089	.996	-.6141	.7971
	2	1	.4932	.25089	.295	-.2124	1.1988
		3	.2167	.25089	.909	-.4889	.9223
		4	.6857	.25089	.061	-.0199	1.3913
		5	.5847	.25089	.150	-.1209	1.2903
	3	1	.2765	.25089	.805	-.4291	.9822
		2	-.2167	.25089	.909	-.9223	.4889
		4	.4690	.25089	.345	-.2366	1.1746
		5	.3681	.25089	.588	-.3376	1.0737
	4	1	-.1925	.25089	.939	-.8981	.5131
		2	-.6857	.25089	.061	-1.3913	.0199
		3	-.4690	.25089	.345	-1.1746	.2366
		5	-.1010	.25089	.994	-.8066	.6047
	5	1	-.0915	.25089	.996	-.7971	.6141
		2	-.5847	.25089	.150	-1.2903	.1209
		3	-.3681	.25089	.588	-1.0737	.3376
		4	.1010	.25089	.994	-.6047	.8066
Scheffe	1	2	-.4932	.25089	.433	-1.2906	.3041
		3	-.2765	.25089	.874	-1.0739	.5208
		4	.1925	.25089	.964	-.6049	.9898
		5	.0915	.25089	.998	-.7059	.8889
	2	1	.4932	.25089	.433	-.3041	1.2906
		3	.2167	.25089	.945	-.5807	1.0140
		4	.6857	.25089	.128	-.1117	1.4830
		5	.5847	.25089	.259	-.2126	1.3821
	3	1	.2765	.25089	.874	-.5208	1.0739
		2	-.2167	.25089	.945	-1.0140	.5807
		4	.4690	.25089	.485	-.3284	1.2664
		5	.3681	.25089	.708	-.4293	1.1654
	4	1	-.1925	.25089	.964	-.9898	.6049
		2	-.6857	.25089	.128	-1.4830	.1117
		3	-.4690	.25089	.485	-1.2664	.3284
		5	-.1010	.25089	.997	-.8983	.6964
	5	1	-.0915	.25089	.998	-.8889	.7059
		2	-.5847	.25089	.259	-1.3821	.2126
		3	-.3681	.25089	.708	-1.1654	.4293
		4	.1010	.25089	.997	-.6964	.8983
Bonferroni	1	2	-.4932	.25089	.539	-1.2244	.2380
		3	-.2765	.25089	1.000	-1.0078	.4547
		4	.1925	.25089	1.000	-.5388	.9237
		5	.0915	.25089	1.000	-.6397	.8227
	2	1	.4932	.25089	.539	-.2380	1.2244
		3	.2167	.25089	1.000	-.5145	.9479
		4	.6857	.25089	.082	-.0455	1.4169
		5	.5847	.25089	.232	-.1465	1.3160
	3	1	.2765	.25089	1.000	-.4547	1.0078
		2	-.2167	.25089	1.000	-.9479	.5145
		4	.4690	.25089	.664	-.2622	1.2002
		5	.3681	.25089	1.000	-.3632	1.0993
	4	1	-.1925	.25089	1.000	-.9237	.5388
		2	-.6857	.25089	.082	-1.4169	.0455
		3	-.4690	.25089	.664	-1.2002	.2622
		5	-.1010	.25089	1.000	-.8322	.6303
	5	1	-.0915	.25089	1.000	-.8227	.6397
		2	-.5847	.25089	.232	-1.3160	.1465
		3	-.3681	.25089	1.000	-1.0993	.3632
		4	.1010	.25089	1.000	-.6303	.8322

Based on observed means.
The error term is Mean Square(Error) = .504.

We can see that there are no significant differences between the electrodes for every post-hoc test. Meaning that all electrodes describe the same outcomes and **perform similarly**. This can also be verified with the table below. This describes that the means fall within the same subset, thus no difference between means.

log_res

	electrodetype	N	Subset 1	Subset 2
Tukey HSD[a,b]	4	16	4.6242	
	5	16	4.7251	
	1	16	4.8166	
	3	16	5.0932	
	2	16	5.3099	
	Sig.		.061	
Scheffe[a,b]	4	16	4.6242	
	5	16	4.7251	
	1	16	4.8166	
	3	16	5.0932	
	2	16	5.3099	
	Sig.		.128	
Ryan-Einot-Gabriel-Welsch F[b]	4	16	4.6242	
	5	16	4.7251	4.7251
	1	16	4.8166	4.8166
	3	16	5.0932	5.0932
	2	16		5.3099
	Sig.		.286	.091

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .504.

a. Uses Harmonic Mean Sample Size = 16.000.

b. Alpha = .05.

ANOVA test: without two extreme data points (1000 and 1050) of subject 15

We can see here that there are 15 subjects with each 5 electrodes and 1 subject with 3 electrodes.

Between-Subjects Factors

		N
subject	1	5
	2	5
	3	5
	4	5
	5	5
	6	5
	7	5
	8	5
	9	5
	10	5
	11	5
	12	5
	13	5
	14	5
	15	3
	16	5
electrodetype	1	16
	2	15
	3	15
	4	16
	5	16

The mean, standard deviation and the number of samples in each combination is described in detail.

Descriptive Statistics

Dependent Variable: log_res

subject	electrodetype	Mean	Std. Deviation	N
1	1	6.2146	.	1
	2	5.9915	.	1
	3	4.5850	.	1
	4	5.2983	.	1
	5	5.5215	.	1
	Total	5.5222	.63800	5
2	1	6.4922	.	1
	2	6.3969	.	1
	3	6.3969	.	1
	4	4.3175	.	1
	5	5.7366	.	1
	Total	5.8680	.91796	5
3	1	5.5215	.	1
	2	5.9135	.	1
	3	5.3936	.	1
	4	5.5215	.	1
	5	5.3936	.	1
	Total	5.5487	.21369	5
4	1	4.2767	.	1
	2	4.9416	.	1
	3	5.4806	.	1
	4	3.4965	.	1
	5	3.9890	.	1
	Total	4.4369	.78339	5
5	1	4.9053	.	1
	2	5.7038	.	1
	3	6.1092	.	1
	4	6.0638	.	1
	5	4.2485	.	1
	Total	5.4061	.80723	5
6	1	3.2958	.	1
	2	4.4308	.	1
	3	4.9053	.	1
	4	5.2470	.	1
	5	5.1930	.	1
	Total	4.6144	.80496	5
7	1	4.6052	.	1
	2	3.9120	.	1
	3	4.4067	.	1
	4	4.2905	.	1
	5	4.3567	.	1
	Total	4.3142	.25364	5
8	1	4.6540	.	1
	2	5.1930	.	1
	3	3.4657	.	1
	4	4.0604	.	1
	5	3.4657	.	1
	Total	4.1678	.75575	5
9	1	4.4998	.	1
	2	5.1930	.	1
	3	5.3936	.	1
	4	3.5264	.	1
	5	4.1589	.	1
	Total	4.5543	.76294	5

10	1	5.2983	.	1
	2	5.6699	.	1
	3	5.7683	.	1
	4	5.6348	.	1
	5	4.9053	.	1
	Total	5.4553	.35476	5
11	1	2.7081	.	1
	2	3.8067	.	1
	3	4.3175	.	1
	4	4.4773	.	1
	5	4.3820	.	1
	Total	3.9383	.73520	5
12	1	5.0752	.	1
	2	5.2983	.	1
	3	5.7038	.	1
	4	5.7038	.	1
	5	5.3936	.	1
	Total	5.4349	.27127	5
13	1	5.5215	.	1
	2	5.9915	.	1
	3	3.9120	.	1
	4	3.9120	.	1
	5	4.5218	.	1
	Total	4.7718	.94743	5
14	1	5.1358	.	1
	2	5.7366	.	1
	3	5.4381	.	1
	4	2.9957	.	1
	5	5.0106	.	1
	Total	4.8634	1.08129	5
15	1	4.1897	.	1
	4	5.6348	.	1
	5	5.3936	.	1
	Total	5.0727	.77418	3
16	1	4.6728	.	1
	2	3.8712	.	1
	3	3.2581	.	1
	4	3.8067	.	1
	5	3.9318	.	1
	Total	3.9081	.50486	5
Total	1	4.8166	.95917	16
	2	5.2033	.84477	15
	3	4.9690	.94705	15
	4	4.6242	.95837	16
	5	4.7251	.67973	16
	Total	4.8621	.88430	78

The parameters describe that there are 19 estimators involved in this case.

Parameter Estimates

Dependent Variable: log_res

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	3.756	.346	10.851	.000	3.063	4.449	.670
[subject=1]	1.614	.437	3.690	.000	.739	2.490	.190
[subject=2]	1.960	.437	4.481	.000	1.084	2.835	.257
[subject=3]	1.641	.437	3.751	.000	.765	2.516	.195
[subject=4]	.529	.437	1.209	.232	-.347	1.404	.025
[subject=5]	1.498	.437	3.425	.001	.622	2.373	.168
[subject=6]	.706	.437	1.615	.112	-.169	1.582	.043
[subject=7]	.406	.437	.928	.357	-.469	1.282	.015
[subject=8]	.260	.437	.594	.555	-.616	1.135	.006
[subject=9]	.646	.437	1.477	.145	-.229	1.522	.036
[subject=10]	1.547	.437	3.537	.001	.672	2.423	.177
[subject=11]	.030	.437	.069	.945	-.845	.906	.000
[subject=12]	1.527	.437	3.491	.001	.651	2.402	.174
[subject=13]	.864	.437	1.975	.053	-.012	1.739	.063
[subject=14]	.955	.437	2.184	.033	.080	1.831	.076
[subject=15]	1.320	.509	2.591	.012	.300	2.339	.104
[subject=16]	0[a]	.	.	.	.	.	.
[electrodetype=1]	.092	.245	.374	.710	-.398	.581	.002
[electrodetype=2]	.502	.250	2.007	.049	.001	1.002	.065
[electrodetype=3]	.267	.250	1.069	.289	-.233	.767	.019
[electrodetype=4]	-.101	.245	-.413	.681	-.590	.388	.003
[electrodetype=5]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Tests of Between-Subjects Effects

Dependent Variable: log_res

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	32.474[a]	19	1.709	3.574	.000	.539
Intercept	1821.846	1	1821.846	3809.454	.000	.985
subject	29.317	15	1.954	4.087	.000	.514
electrodetype	3.412	4	.853	1.784	.144	.110
Error	27.738	58	.478			
Total	1904.099	78				
Corrected Total	60.212	77				

a. R Squared = .539 (Adjusted R Squared = .388)

Electrode Type: The critical value was found to be between 2.53 and 2.61 from the F distribution table. We reject the null hypothesis (H_0) if F $\geq$ c = [2.53,2.61] (F^4_{58} & $\alpha = 5\%$). From the table of test between the subjects provided above, the value of F statistic for electrode type is 1.784. Therefore, we **accept** the null hypothesis that the electrode type has no effect on describing the resistance. The acceptance of null hypothesis can also be proved by the p value (0.144) in the table.

Subject: The rejection of null hypothesis can be proved by the p value (0.000) in the table. The value of sig is less than 0.05 and so we **reject** the null hypothesis that the subject has no effect on describing the strength.
Furthermore, the partial eta squared indicates a 0.514 for subject, meaning that the dependent variable (resistance) consists of 51.4% out of subject influence.
In conclusion, the resistance does not depend on the electrode type but is dependent on the subject.

Multiple Comparisons

Dependent Variable: log_res

	(I) electrodetype	(J) electrodetype	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	-.3867	.24854	.531	-1.0865	.3131
		3	-.1523	.24854	.972	-.8521	.5474
		4	.1925	.24450	.933	-.4959	.8808
		5	.0915	.24450	.996	-.5969	.7799
	2	1	.3867	.24854	.531	-.3131	1.0865
		3	.2344	.25252	.885	-.4766	.9453
		4	.5792	.24854	.150	-.1206	1.2789
		5	.4782	.24854	.316	-.2215	1.1780
	3	1	.1523	.24854	.972	-.5474	.8521
		2	-.2344	.25252	.885	-.9453	.4766
		4	.3448	.24854	.638	-.3550	1.0445
		5	.2438	.24854	.863	-.4559	.9436
	4	1	-.1925	.24450	.933	-.8808	.4959
		2	-.5792	.24854	.150	-1.2789	.1206
		3	-.3448	.24854	.638	-1.0445	.3550
		5	-.1010	.24450	.994	-.7893	.5874
	5	1	-.0915	.24450	.996	-.7799	.5969
		2	-.4782	.24854	.316	-1.1780	.2215
		3	-.2438	.24854	.863	-.9436	.4559
		4	.1010	.24450	.994	-.5874	.7893
Scheffe	1	2	-.3867	.24854	.660	-1.1775	.4041
		3	-.1523	.24854	.984	-.9431	.6384
		4	.1925	.24450	.960	-.5855	.9704
		5	.0915	.24450	.998	-.6864	.8694
	2	1	.3867	.24854	.660	-.4041	1.1775
		3	.2344	.25252	.929	-.5690	1.0378
		4	.5792	.24854	.260	-.2116	1.3699
		5	.4782	.24854	.455	-.3126	1.2690
	3	1	.1523	.24854	.984	-.6384	.9431
		2	-.2344	.25252	.929	-1.0378	.5690
		4	.3448	.24854	.749	-.4460	1.1356
		5	.2438	.24854	.914	-.5469	1.0346
	4	1	-.1925	.24450	.960	-.9704	.5855
		2	-.5792	.24854	.260	-1.3699	.2116
		3	-.3448	.24854	.749	-1.1356	.4460
		5	-.1010	.24450	.996	-.8789	.6770
	5	1	-.0915	.24450	.998	-.8694	.6864
		2	-.4782	.24854	.455	-1.2690	.3126
		3	-.2438	.24854	.914	-1.0346	.5469
		4	.1010	.24450	.996	-.6770	.8789
Bonferroni	1	2	-.3867	.24854	1.000	-1.1120	.3386
		3	-.1523	.24854	1.000	-.8777	.5730
		4	.1925	.24450	1.000	-.5211	.9060
		5	.0915	.24450	1.000	-.6220	.8051
	2	1	.3867	.24854	1.000	-.3386	1.1120
		3	.2344	.25252	1.000	-.5026	.9713
		4	.5792	.24854	.233	-.1462	1.3045
		5	.4782	.24854	.593	-.2471	1.2035
	3	1	.1523	.24854	1.000	-.5730	.8777
		2	-.2344	.25252	1.000	-.9713	.5026
		4	.3448	.24854	1.000	-.3806	1.0701
		5	.2438	.24854	1.000	-.4815	.9692
	4	1	-.1925	.24450	1.000	-.9060	.5211
		2	-.5792	.24854	.233	-1.3045	.1462
		3	-.3448	.24854	1.000	-1.0701	.3806
		5	-.1010	.24450	1.000	-.8145	.6126
	5	1	-.0915	.24450	1.000	-.8051	.6220
		2	-.4782	.24854	.593	-1.2035	.2471
		3	-.2438	.24854	1.000	-.9692	.4815
		4	.1010	.24450	1.000	-.6126	.8145

Based on observed means.
The error term is Mean Square(Error) = .478.

We can see that there are no significant differences between the electrodes for every post-hoc test. Meaning that all electrodes describe the same outcomes and **perform similarly**. This can also be verified with the table below. This describes that the means fall within the same subset, thus no difference between means.

log_res

	electrodetype	N	Subset 1
Tukey HSD[a,b,c]	4	16	4.6242
	5	16	4.7251
	1	16	4.8166
	3	15	4.9690
	2	15	5.2033
	Sig.		.148
Scheffe[a,b,c]	4	16	4.6242
	5	16	4.7251
	1	16	4.8166
	3	15	4.9690
	2	15	5.2033
	Sig.		.257
Ryan-Einot-Gabriel-Welsch F[c]	4	16	4.6242
	5	16	4.7251
	1	16	4.8166
	3	15	4.9690
	2	15	5.2033
	Sig.		.174

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .478.

a. Uses Harmonic Mean Sample Size = 15.584.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.