PSYC 301: Intermediate Research Methods and Data Analysis

Assignment #2

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1.a)

The researcher set out to look at the relationship between age and verbal recall by assessing verbal recall for four specific age Groups. The age Groups are Group 1: 14-17; Group 2: 19-22; Group 3: 26-30; and Group 4: 36-40. There were 53 participants total, 15 in Group 1: 12 in Group 2: 13 in Group 3: and 13 in Group 4. This study has an unbalanced design since the number of participants in each Group is not equal. The variables being studied were age and verbal recall. Age is the independent variable, and it is a categorical variable because the ages are specific Groups. Whereas verbal recall is the dependent variable. I will assume this study is a fixed factor design since the Groups of the independent variable were chosen in advance.

Step 1:

For statistical inferences, I assert that the parent population distribution is normal. Therefore: $X_j \sim N\left(\mu_j, \sigma_\varepsilon^2\right) \forall j$

Step 2

The hypothesis for this study:

H_o: $\mu1 = \mu2 = \mu3 = \mu4 = \mu$ versus H_1: not H_o

Step 3:

For assumption checking, I will assume that the k conditional populations are normal. I will assume that the homogeneity of the variances is equal. Also, I will assume that the scores are identically and independently distributed (IID). The normality of the distribution and the homogeneity can be verified, but the IID cannot be confirmed. Therefore, I need to believe that my research design is good and IID is appropriately done.

Step 4:

If $X_j \sim N\left(\mu_j, \sigma_\varepsilon^2\right) \forall j$ and H0: $\mu1 = \mu2 = \mu3 = \mu4 = \mu$ is true then
$F\ \frac{MSbetween}{MSwithin} \sim F_{dfbetween,dfwithin} = F_{3,49} \rightarrow$ null distribution

Step 5:

I set alpha to ∝ = .05

If Pobs is less than ∝ = .05, then reject Ho; otherwise, accept Ho

Step 6:

I complete the study and data analysis and confirm my assumptions.

Data Analysis:

The population means differ based on the age Group's verbal recall scores. Group one ages, 14-17 has a mean of 16.73 and a standard error of the mean of 1.18 (Figure 1). Due to the high standard error of the mean, my estimate may not be very precise. This Group had a median of 17 and a mood of 22 (Figure 1). The distribution is negatively skewed with a g1 (skewness) of -0.401 and a standard error of 0.580, and platykurtic with a g2 (kurtosis) of -1.168 and a standard error of 1.121. The range is 13, the variance is 20.78 and the standard deviation is 4.559. There are no outliers for Group one (see figure 9).

Group two, ages 19-22 has a mean of 12.22 and a standard error of the mean of 1.003 (figure 3). Due to having a moderately high standard error of the mean, my estimate may not be very precise. The Group's median is 12.50 and the mode is 14 (figure 3). The distribution is negatively skewed with a g1 of -0.243 and a standard error of 0.637. It is also leptokurtic with a g2 of 1.402 and a standard error of 1.232 (figure 3). The range is 14, the variance is 12.061 and the standard deviation is 3.473. There are no outliers, but there is a potential outlier which is value 19 (see figure 9).

Group three, ages 26-30 has a mean of 6 and a standard error of 0.439 (figure 5). The Group's median is 6 and the mode is 4, 6 and 7. The distribution is positively skewed with a g1 of 0.299 and a standard error of 0.616. It is platykurtic with a g2 of -0.618 and a standard error of 1.191 (figure 5). The range is 5, the variance is 2.500 and the standard deviation is 1.58. There are no outliers for Group three (see figure 9).

Group four, ages 36-40 has a mean of 6.85 and a standard error of the mean of 0.639 (figure 7). The Group's median is 6 and the mode is 6 (figure 7). The distribution is positively skewed with a g1 of 1.091 and a standard error of 0.616 (figure 7). It is leptokurtic with a g2 of 0.626 and a standard error of 1.191 (figure 7). The range is 8, the variance is 5.308 and the standard deviation is 2.304. There are no outliers for Group four (see figure 9).

Assumption Checking:

Assumption checking for Normality:

The IID cannot be verified, but I will assert that it is sound based on an adequate research design. I will use the histograms and Q-Q plots to certify normality. Although my sample size is not large, it may be difficult to assume normality. The histogram for Group one looks a bit platykurtic (see figure 2). The Q-Q plots show the values deviate from the control line and form a pattern of deviation (see figure 10). Based on the histogram and Q-Q plots, I will not be able to assume normality, so I will compute 95% confidence intervals around the skewness and kurtosis statistics to observe if they cover the value of zero. The value captured zero, so I will retain the normality assumption for Group one.

The histogram for Group two looks a bit leptokurtic (see figure 4). The Q-Q plots show the majority of values deviate from the control line and that there is a bit of a pattern of deviation (see figure 11). Based on the histogram and Q-Q plots, I will not be able to assume normality, so I will compute 95% confidence intervals around the skewness and kurtosis statistics to observe if they cover the value of zero. The value captured zero, so I will retain the normality assumption for Group two.

The histogram for Group three looks platykurtic (see figure 6). The Q-Q plots show the values fall close to the control line. Based on the histogram and Q-Q plots, I will not be able to assume normality, so I will compute 95% confidence intervals around the skewness and kurtosis statistics to observe if they cover the value of zero. The value captured zero, so I will retain the normality assumption for Group three.

The histogram for Group four looks leptokurtic (see figure 8). The Q-Q plots show the values follow a pattern of deviation around the control line (see figure 13). Based on the histogram and Q-Q plots, I will not be able to assume normality, so I will compute 95% confidence intervals around the skewness and kurtosis statistics to observe if they cover the value of zero. The value captured zero, so I will retain the normality assumption for Group four.

Based on calculating all 95% intervals for all four age Groups around the sample skewness and kurtosis statistic capture zero. I will use this as evidence to support the assumption of normality for all four age Groups as sound.

<u>Group one:</u>

UCL = $g1 + Z_{0.05}(s.e.g1) = -0.401 + 1.96\ (0.580) = 0.74$

LCL = $g1 - Z_{0.05}(s.e.g1) = -0.401 - 1.96\ (0.580) = -1.54$

UCL = $g2 + Z_{0.05}(s.e.g1)$ = -1.168 + 1.96 (1.121) = 1.03

LCL = $g2 - Z_{0.05}(s.e.g1)$ = -1.168 - 1.96 (1.121) = -3.27

<u>Group two:</u>

UCL = $g1 + Z_{0.05}(s.e.g1)$ = -0.243 + 1.96 (0.637) = 1.01

LCL = $g1 - Z_{0.05}(s.e.g1)$ = -0.243 – 1.96 (0.637) = -1.49

UCL = $g2 + Z_{0.05}(s.e.g1)$ = 1.402 + 1.96 (1.232) = 3.82

LCL = $g2 - Z_{0.05}(s.e.g1)$ = 1.402 – 1.96 (1.232) = -1.01

<u>Group three:</u>

UCL = $g1 + Z_{0.05}(s.e.g1)$ = 0.299 + 1.96 (0.616) = 1.51

LCL = $g1 - Z_{0.05}(s.e.g1)$ = 0.299 – 1.96 (0.616) = -0.98

UCL = $g2 + Z_{0.05}(s.e.g1)$ = -0.618 + 1.96 (1.191) = 1.72

LCL = $g2 - Z_{0.05}(s.e.g1)$ = -0.618 - 1.96 (1.191) = -2.95

Group four:

UCL = $g1 + Z_{0.05}(s.e.g1)$ = 1.091 + 1.96 (0.616) = 2.29836

LCL = $g1 - Z_{0.05}(s.e.g1)$ = 1.091 – 1.96 (0.616) = -0.11636

UCL = $g2 + Z_{0.05}(s.e.g1)$ = 0.626 + 1.96 (1.191) = 2.96036

LCL = $g2 - Z_{0.05}(s.e.g1)$ = 0.626 – 1.96 (1.191) = -1.70836

Assumption checking for Homogeneity of Variances:

For the Levene's test the hypothesis is

$H0: \sigma_1^2 = \sigma_2^2 = \sigma_3^2 = \sigma_4^2 versus\ H1: not\ H0$

I set alpha to 0.05 for the test. My Levene statistic is 5.203. My degrees of freedom are 3 and 49. My Pobs is .003 which is smaller than my alpha of .05, therefore I reject, and my homogeneity of variances assumption is violated. Since this assumption has been violated, I will use the Welch procedure. So, Welch's F statistic is 30.745 and Pobs is 0.000. The degrees of freedom are 3 and 25.589.

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Number of Verbal Recall	Based on Mean	5.203	3	49	.003
	Based on Median	4.828	3	49	.005
	Based on Median and with adjusted df	4.828	3	38.845	.006
	Based on trimmed mean	5.092	3	49	.004

Robust Tests of Equality of Means

Number of Verbal Recall

	Statistic[a]	df1	df2	Sig.
Welch	30.754	3	25.589	.000

a. Asymptotically F distributed.

Step 7:

I will run the test and come to a conclusion.

ANOVA

Number of Verbal Recall

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1058.255	3	352.752	33.414	.000
Within Groups	517.292	49	10.557		
Total	1575.547	52			

The conditional mean for Group one M=16.73 and conditional variance is 20.781. For Group two conditional mean is M= 12.33 and the conditional variance is 12.061. For Group three the conditional mean is M= 6 and the conditional variance is 2.5. For Group four the conditional mean is M= 6.85 and conditional variance is 5.308. The MSbetween is 352.752 and the MSwithin is 10.557. F (3,49) = 33.414 and Pobs $\approx 0.000 < \alpha = .05$: therefore, reject $H0: \mu 1 = \mu 2 = \mu 3 = \mu 4 = \mu$, and conclude there is a population effect of age on verbal recall. Due to the fixed factor design, I can only generalize the findings to the age Groups that were picked for this study. Also, I can not make causal inference about the effect of age on verbal recall because there was not random assignment to the conditions, because the age of Groupings of the participants was predetermined.

To see where the differences are I can run a post-Hoc test. Since there are four comparisons, I will run Tukey's Honest Significant Difference (HSD). For this study, k=4, harmonic n = 13.16. If Pobs is smaller than alpha, I will reject.

Multiple Comparisons

Dependent Variable: Number of Verbal Recall

Tukey HSD

(I) Age Group	(J) Age Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Group 1: 14-17	Group 2: 19-22	4.400*	1.258	.005	1.05	7.75
	Group 3: 26-30	10.733*	1.231	.000	7.46	14.01
	Group 4: 36-40	9.887*	1.231	.000	6.61	13.16
Group 2: 19-22	Group 1: 14-17	-4.400*	1.258	.005	-7.75	-1.05
	Group 3: 26-30	6.333*	1.301	.000	2.87	9.79
	Group 4: 36-40	5.487*	1.301	.001	2.03	8.95

Group 3: 26-30	Group 1: 14-17	-10.733*	1.231	.000	-14.01	-7.46
	Group 2: 19-22	-6.333*	1.301	.000	-9.79	-2.87
	Group 4: 36-40	-.846	1.274	.910	-4.24	2.54
Group 4: 36-40	Group 1: 14-17	-9.887*	1.231	.000	-13.16	-6.61
	Group 2: 19-22	-5.487*	1.301	.001	-8.95	-2.03
	Group 3: 26-30	.846	1.274	.910	-2.54	4.24

*. The mean difference is significant at the 0.05 level.

The only one where Pobs is greater than alpha is when Group three is compared to Group four. Based on Tukey's HSD table Group 3 and Group 4 are considered to have equal means so they will be accepted, since Pobs of 0.910 is larger than alpha of .05. The rest of the null hypotheses have been rejected because they are statistically significant differences between the Groups. When Group one is compared to Group two the mean difference is 4.4, the standard error is 1.258 and Pobs is 0.005, so I reject. When Group one is compared to Group three the mean difference is 10.73, the standard error is 1.231 and Pobs is 0.00, so I reject. When Group one is compared to Group four the mean difference is 9.887, the standard error is 1.231 and Pobs is 0.000, so I reject. When Group two is compared to Group three the mean difference 6.33, the standard error is 1.301 and Pobs is 0.000, so I reject. When Group two is compared to Group four the mean difference is 5.487, the standard error 1.301 and Pobs is 0.001, so I reject. When Group four is compared to Group three the mean difference is 0.846, the standard error is 1.274 and the Pobs is 0.910, so I accept. For the null hypotheses are rejected, I will compute the magnitude of effect.

<u>Magnitude of Effect:</u>

This study used a fixed factor design because the participants were assigned to a particular age Group of the independent variable. Using a fixed factor design does not affect the F statistic, but it does influence how I calculate and estimate the magnitude of the effect.

$$\widehat{\omega}^2 = \frac{\hat{\sigma}_t^2}{\hat{\sigma}_t^2 + \hat{\sigma}_\epsilon^2} + \frac{SSbetweenobs - MSwithinobs\ (k-1)}{SStotal + MSwithinobs} = \frac{1058.255 - 10.557\ (3)}{1575.547 + 10.557} = 0.65$$

Thus, I estimate that the proportion of variance in the dependent variable is because of the effects of the independent variable is approximately 0.65 or 65%. This estimate can only be generalized to the particular levels of the IV used in the study.

1.b) Power Profile:

I have an unbalanced design because my sample sizes are not all equal so I will use a harmonic n. For this study k= 4 and I set alpha to .05. For this study $n_1 = 15, n_2$ = 12, n_3 = 13, n_4 = 13. My harmonic n = 13.16 which I got from:

$4 \div ((1 \div 15) + (1 \div 12) + (1 \div 13) + (1 \div 13)) = 13.16.$

To complete my power analysis, I am using Tiku's table "F1=3, A=0.05."

The $df_{between}$ $(F1)$ = k-1 = 4-1 = 3. The $df_{within}(F2)$= k (nj -1) = 4(13.16-1) = 48.64.

Effect Size (ϕ^1)	$\phi = \phi^1 \sqrt{n}$	**Power** (Obtained from table)
.10	.10 √13.16= 0.36	= ~0.11
.25	.25 √13.16= 0.91	=~0.3
.40	.40 √13.16= 1.45	= ~0.60

Figure 1: Descriptive Statistics for Group One: Ages 14-17

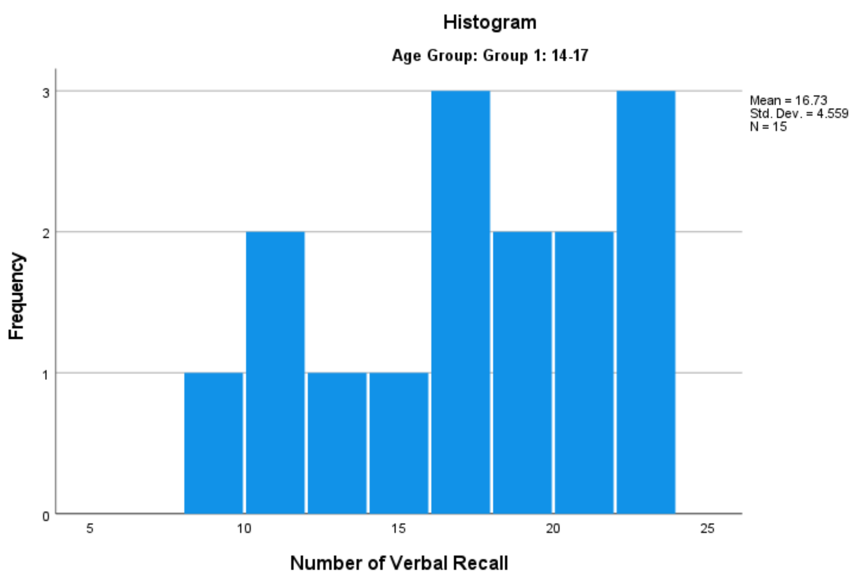
Statistics

Number of Verbal Recall

N	Valid	15
	Missing	0
Mean		16.73
Std. Error of Mean		1.177
Median		17.00
Mode		22
Std. Deviation		4.559
Variance		20.781
Skewness		-.401
Std. Error of Skewness		.580
Kurtosis		-1.168
Std. Error of Kurtosis		1.121
Range		13

a. Age Group = Group 1: 14-17

Figure 2: Histogram for Group One:



<u>Figure 3: Descriptive Statistics for Group two: Ages 19-22</u>

Statistics[a]

Number of Verbal Recall

N	Valid	12
	Missing	0
Mean		12.33
Std. Error of Mean		1.003
Median		12.50
Mode		14
Std. Deviation		3.473
Variance		12.061
Skewness		-.243
Std. Error of Skewness		.637
Kurtosis		1.402
Std. Error of Kurtosis		1.232
Range		14

a. Age Group = Group 2: 19-22

<u>Figure 4 Histogram for Group two:</u>

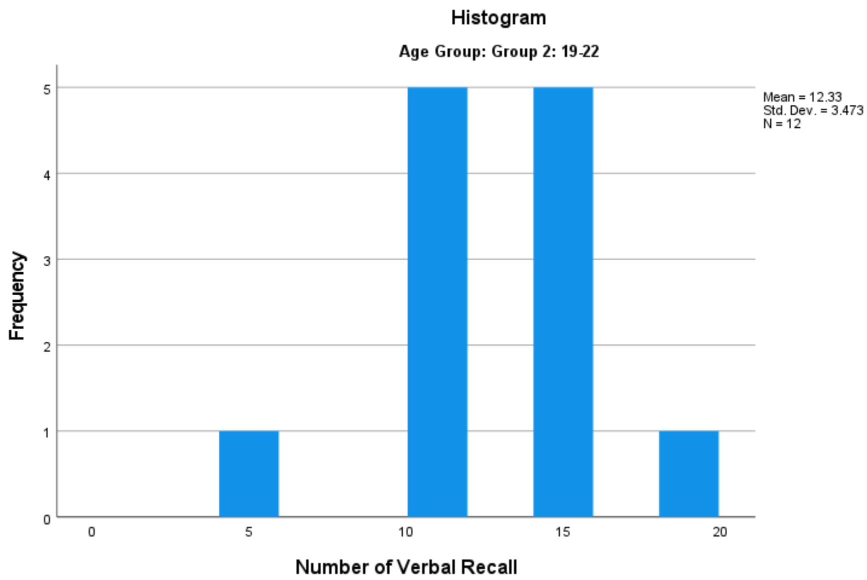


Figure 5: Descriptive Statistics for Group three: ages 26-30

Statistics[a]

Number of Verbal Recall

N	Valid	13
	Missing	0
Mean		6.00
Std. Error of Mean		.439
Median		6.00
Mode		4[b]
Std. Deviation		1.581
Variance		2.500
Skewness		.299
Std. Error of Skewness		.616
Kurtosis		-.618
Std. Error of Kurtosis		1.191
Range		5

a. Age Group = Group 3: 26-30

b. Multiple modes exist. The smallest value is shown

Figure 6: Histogram for Group three:

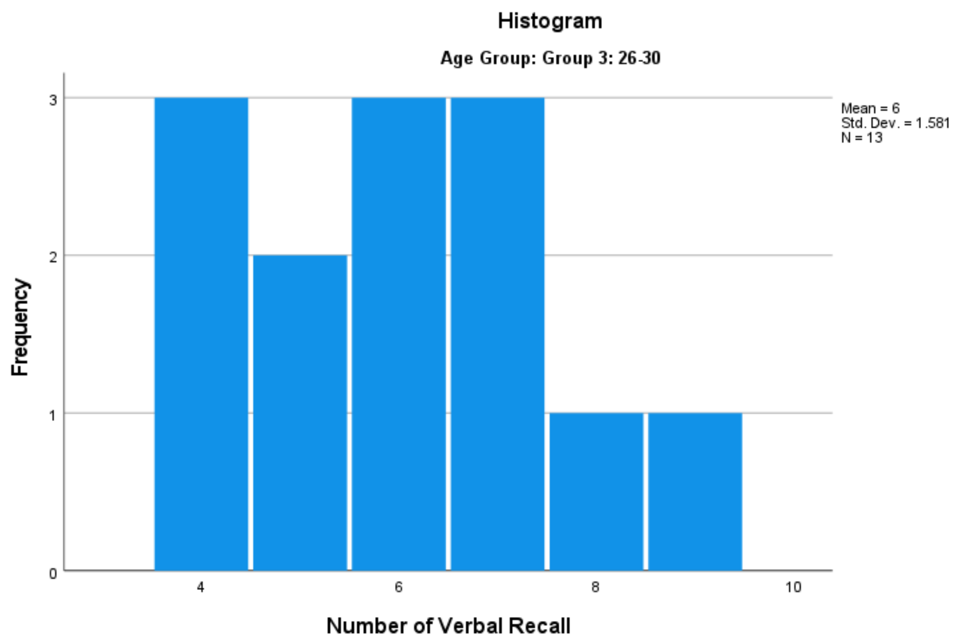


Figure 7: Descriptive Statistics for Group four: ages 36-40

Statistics[a]

Number of Verbal Recall

N	Valid	13
	Missing	0
Mean		6.85
Std. Error of Mean		.639
Median		6.00
Mode		6
Std. Deviation		2.304
Variance		5.308
Skewness		1.091
Std. Error of Skewness		.616
Kurtosis		.626
Std. Error of Kurtosis		1.191
Range		8

a. Age Group = Group 4: 36-40

Figure 8: Histogram for Group four:

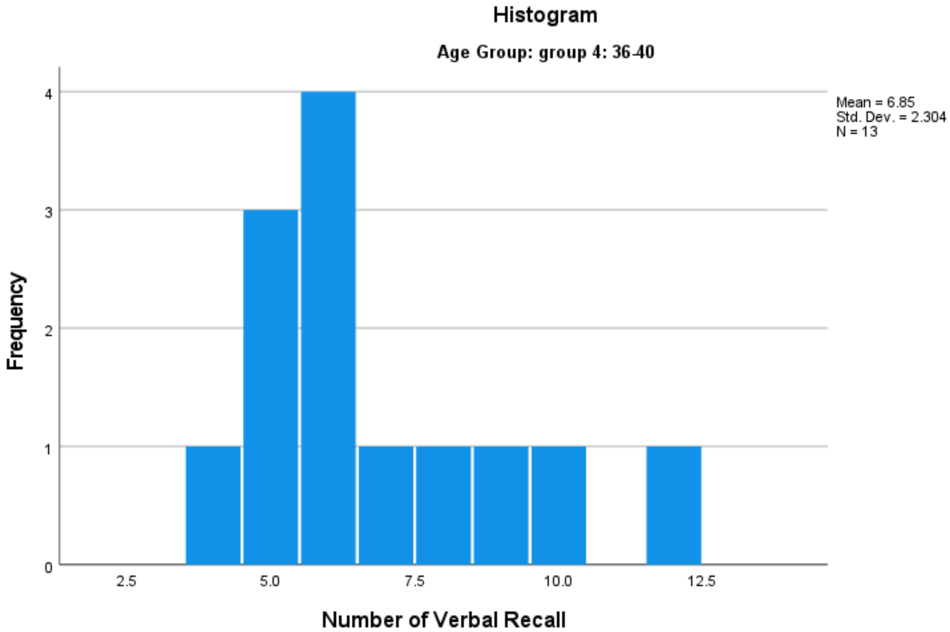


Figure 9: Boxplot of all four Groups.

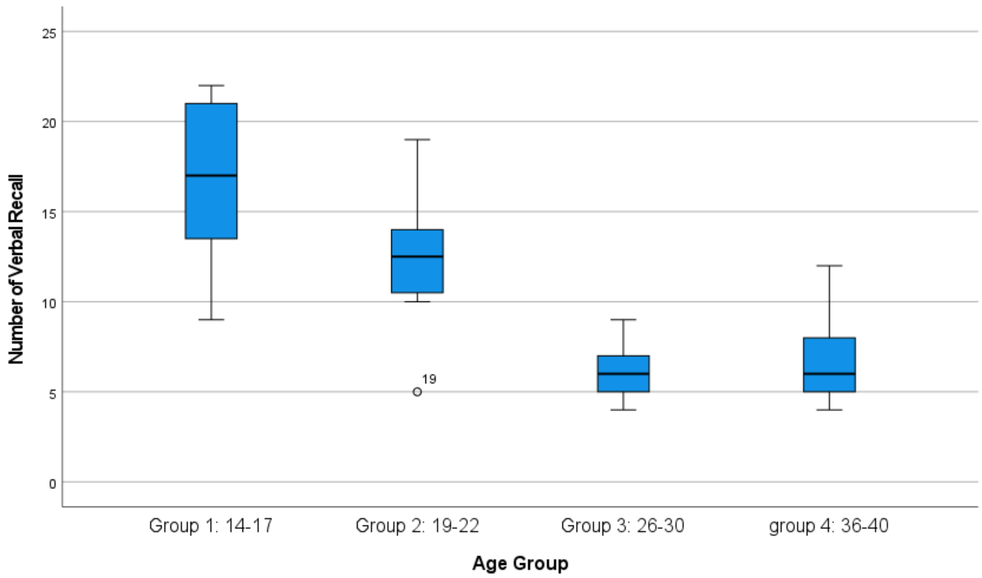


Figure 10: Q-Q Plot for Group One.

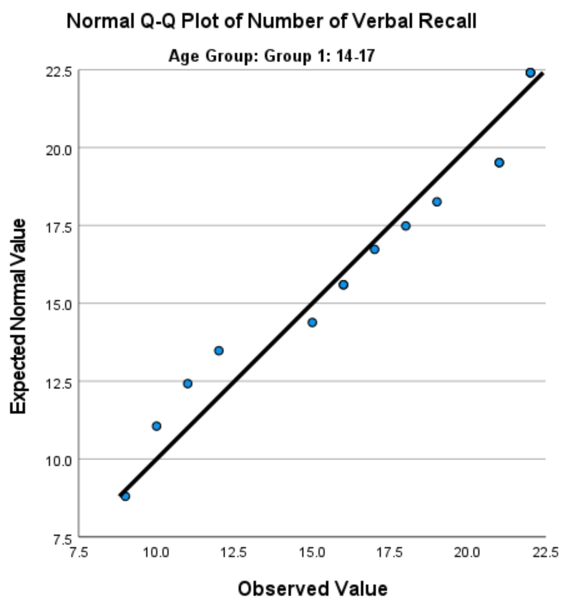


Figure 11: Q-Q Plot for Group Two.

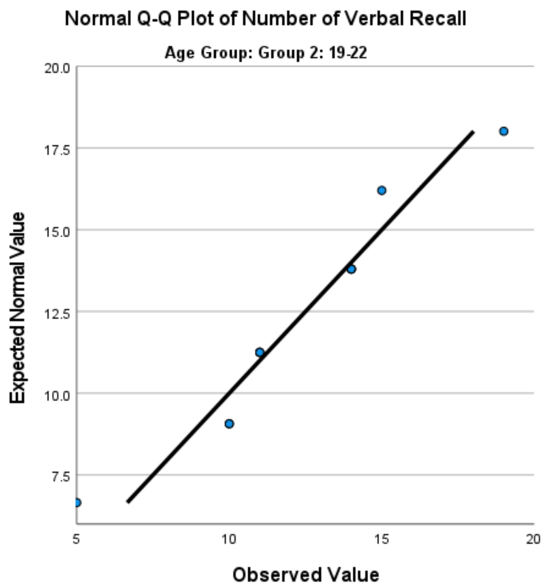


Figure 12: Q-Q Plot for Group Three

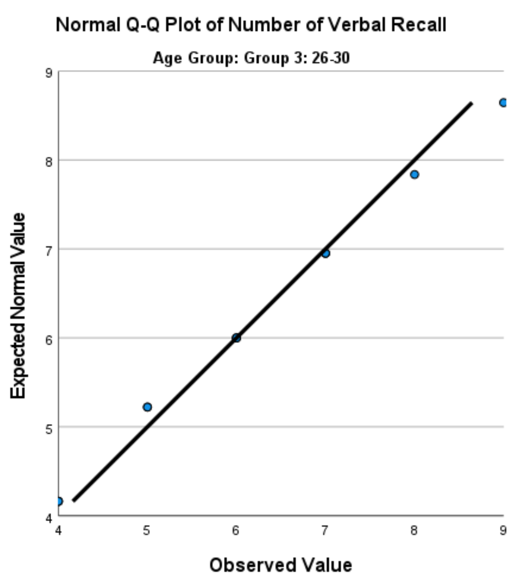
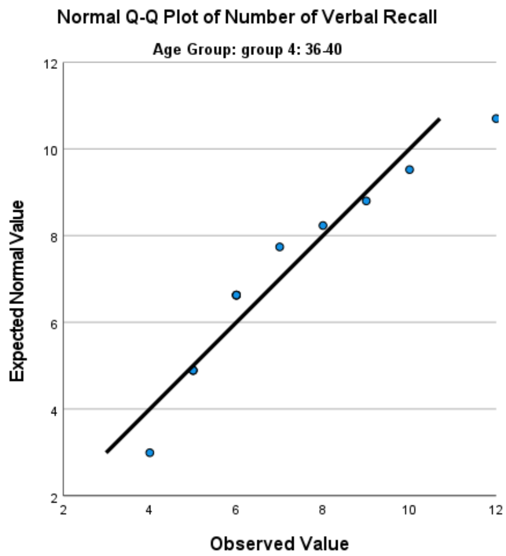


Figure 13: Q-Q Plot for Group Four



2.a) These tests are not independent. There are also not orthogonal because they have overlapping information. The tests I and II are complex comparisons, whereas III is a simple pairwise compassions. Initially, when I sum the weights of the contrasts in their row, they equal zero.

Contrast 1: 0.333 + 0.333 + 0.333 -1 = 0.

Contrast 2: 0.5 + 0.5 -0.5 -0.5 = 0.

Contrasts 3, 1 + 0 +0 -1 =0.

However, when I multiple all the contrasts the products of each contrast do not equal zero.

For 1 & 2: (.333) (0.5) + (0.333) (0.5) + (0.333) (-0.5) + (-1) (-0.5) = 0.6661.

For 1 & 3: (.333) (1) + (.333) (0) + (.333) (0) + (-1) (-1) = 1.333

For 2 & 3: (0.5) (1) + (0.5) (0) + (-0.5) (0) + (-0.5) (-1) = 1

Therefore, I conclude that these tests are not independent.

Contrast Coefficients

	Age Group			
Contrast	Group 1: 14-17	Group 2: 19-22	Group 3: 26-30	Group 4: 36-40
1	.333	.333	.333	-1
2	.5	.5	-.5	-.5
3	1	0	0	-1

2. b) For this test, c=3 since there are three comparisons. Since the tests are not independent, I can only calculate an upper bound familywise rate. I will use: $FW \leq 1(1-\alpha^1)^c$. $1(1-0.05)^3$=0.14.

The familywise rate without controlling for familywise error with an $\alpha = 0.05$ would be 0.14 or 14%.

2.c) The researcher can use the Bonferroni correction to control for familywise error. Since she has three comparisons, she has a small c. Since the comparisons are not orthogonal, the familywise error will be upper bound. For this correction, alpha will be set to 0.05 and c=3

Bonferroni correction: $\alpha' = \frac{\alpha}{c}$ so, $\alpha' = \frac{.05}{3} = 0.0166$

Therefore, the per test alpha will be 0.016. If Pobs is smaller than α'=0.016 I will reject the null hypothesis of the three comparisons. Based on the "contrast table" all the pobs are smaller than α'=0.016, so I reject all the null hypotheses. With assuming equal variances for all three tests, contrast one, the t-statistic = 4.654, degrees of freedom =49 and Pobs =< $.001$, *which is less than* $\alpha' = 0.016$, so I reject. For contrast two the t − statisitc = 9.057, standard error = 0.896, degrees of freedom = 49, and Pobs =< $.001$, *which is less than* $\alpha' = 0.016$, so I reject . For contrast three, the t-statistic =8.030, degrees of freedom =49, standard error =1.231, and Pobs =< $.001$, *which is less than* $\alpha' = 0.016$, so I reject . Since I rejected all three null hypotheses, I will compute the magnitude of effect.

Contrast Tests

		Contrast	Value of Contrast	Std. Error	t	df	Sig. (2-tailed)	95% Confidence Interval	
								Lower	Upper
Number of Verbal Recall	Assumes equal variances	1	4.83[a]	1.038	4.654	49	<.001	2.74	6.92
		2	8.11	.896	9.057	49	<.001	6.31	9.91
		3	9.89	1.231	8.030	49	<.001	7.41	12.36
	Does not assume equal variances	1	4.83[a]	.833	5.796	28.821	<.001	3.13	6.54
		2	8.11	.865	9.379	36.382	<.001	6.36	9.86
		3	9.89	1.339	7.382	21.309	<.001	7.10	12.67

a. The sum of the contrast coefficients is not zero.

Magnitude of effect estimation:

Since I rejected all three null hypotheses, I will use Cohen's d for all three. I got the MSwithin value from the ANOVA table.

Null hypothesis #1:

- $\hat{d} = \frac{\widehat{\psi_i}}{\sqrt{MSwithin}} = \frac{4.83}{\sqrt{10.557}} = \frac{4.83}{3.249}$=1.49

Null hypothesis #2:

- $\hat{d} = \frac{\widehat{\psi_i}}{\sqrt{MSwithin}} = \frac{8.11}{\sqrt{10.557}} = \frac{8.11}{3.249}\ 2.50$

Null hypothesis #3:

- $\hat{d} = \frac{\widehat{\psi_i}}{\sqrt{MSwithin}} = \frac{9.89}{\sqrt{10.557}}\frac{9.89}{3.249}\ 3.04$

3.) This study looked at animals' memory process by exposing them to a fear-producing stimulus to see if learning of the avoidance response took place. There were 45 animal participants. The dependent variable is the time it took the animals to step across the line on the test trail. The two other factors are factor A and factor B, which are categorical variables. Factor A is where the electrodes were placed in the cortex, either in a neutral site, area A or area B. Factor B which is the level of electrical stimulation the animal received, either 50, 100 or 150. Since there are three factor for both factors A and factor B, this is a 3x3 factorial design. This is a fixed factor design because the factors were not randomly selected. Also, I am assuming that the animal participants were randomly assigned to a condition for factor A and Factor B. Therefore, I can only make generalizations to the particular levels included in the study.

Step 1:

For statistical inferences, I assert that the parent population distribution is normal. Therefore: $X_{jk} \sim N\left(\mu_{jk}, \sigma^2\right), j$ =1,2,3 k =1,2,3 (j is factor A and k is factor B)

Step 2

The hypotheses for this study:

1) $H_0: \alpha_1 = \alpha_2 = \alpha_3 = 0$ vs. $H_1: \alpha_1 \neq \alpha_2 \neq \alpha_3$

2) $H_0: \beta_1 = \beta_2 = \beta_3 = 0 \; vs, H_1: not\ H_0$

3) H_0: the simple main effects of A are not a function of level of B or vice versa. Vs. $H_1: not\ H_0$

Step 3:

For assumption checking, I will assume the conditional populations are normal, conditional on the specific crossing for the levels of each factor. I will assume there is homoscedasticity within the Group populations that have equal variances regarding the dependent variable. Also, I will assume that the scores are identically and independently distributed (IID) across and within the jk Groups. The normality of the distribution can be proven by looking at the histograms, Q-Q plots and calculating confidence intervals. The homoscedasticity of the within Group population will be presumed to have equal variances regarding the dependent variable and tested through SPSS. The IID cannot be confirmed, so, I need to believe that my research design is good and IID is appropriately done.

Step 4:

For this study the link is as follows:

If $X_{jk} \sim N\left(\mu_{jk}, \sigma^2\right) \; \forall \; jk$ and $H_0: effect\ parameter \; = \; 0 \; is\ true,$ then $F \; \frac{MSeffect}{MSerror} \sim F_{dfeffect, dferror}$ → null distribution

Step 5:

For all the three omnibus tests, alpha is set to 0.05. If the Pobs is less than alpha of 0.05 then I will reject. If Pobs is greater than alpha of 0.05 then I will accept the null hypothesis.

Step 6:

I complete the study and data analysis and confirm my assumptions.

Data Analysis:

The population means differ based on who was in which condition. For factor A1 and B1, the mean was 28.60, the median was 28 and the mode was 20 (figure 1). The distribution is positively skewed with g1= 0.823 and standard error or 0.913, and leptokurtic with g2= 1.379 (s.e.=2) (figure 2). The range is 20, and the variance is 54.800, and the standard deviation is 7.403.

For factor A1 and B2, the mean was 28, the median 27 and the mode 23 (figure 1, box 2). The distribution is positively skewed with g1= 0.800 (s.e.=0.913) and platykurtic with g2=0.68 (s.e.=2) (figure3). The range is 12, and the variance is 22, and the standard deviation is 3.690.

For factor A1 and B3, the mean is 28, the median is 28 and the mode 20 (figure 1, box 3). The distribution is negatively skewed with g1= -0.354 (s.e. =0.913) and __ with g2 =0.307 (s.e.=2) (figure 4). The range is 15, and the variance is 31.5, and the standard deviation is 5.612.

For factor A2 and B1, the mean is 16.80, the median 15 and the mode is 11 (figure 1, box 4). The distribution is positively skewed with g1= 1.242 and (s.e.=0.913) and leptokurtic with g2=1.784 (s.e.=2) (figure 5). The range is 15, and the variance is 32.7, and the standard deviation is 5.718.

For factor A2 and B2, the mean is 23, the median is 22 and the mode is 19 (figure 1, box5). The distribution is positively skewed with g1=1.640 and (s.e.=0.913) and leptokurtic with g2=2.948 (s.e.=2) (figure 6). The range is 12, and the variance is 22.5, and the standard deviation is 4.743.

For factor A2 and B3, the mean is 26.80, the median is 27, and the mode is 21 (figure 1, box 6). The distribution is positively skewed with g1=0.8 (s.e.=0.913) and leptokurtic with g2=0.596 (s.e.=2) (figure 7). The range is 14, and the variance is 29.2, and the standard deviation is 5.404.

For factor A3 and B1, the mean is 24.40, the median is 23, and the mode is 23 (figure 1, box 7). The distribution is negatively skewed with g1= -0.179 (s.e.=0.913) and leptokurtic with g2=-0.869 (s.e.=2) (figure 8). The range is 12, and the variance is 22.3, and the standard deviation is 4.722.

For factor A3 and B2, the mean is 16, the median is 16 and the mode is 9 (figure 1, box 8). The distribution is positively skewed with g1=0.354 (s.e.=0.913), mesokurtic with g2=0.307 (s.e.=2) (figure 9). The range is 15, and the variance is 31.5, and the standard deviation is 5.612.

For factor A3 and B3, the mean is 26.40, the median is 28 and the mode is 30 (figure 1, box 9). The distribution is negatively skewed with g1= -0.575 (s.e.=0.913) and leptokurtic g2= -2.460 (s.e.=2) (figure 10). The range is 9, and the variance is 17.3, and the standard deviation is 4.159.

Assumption checking:

The IID cannot be verified, but I will assert that it is sound based on an adequate research design. I will use the histograms and Q-Q plots to certify normality. Although my sample size is not large, it may be difficult to assume normality.

The histogram looks a bit leptokurtic for electrode implant condition one and electrical stimulation condition 1 (see figure 2). The Q-Q plots show some of the values deviate from the control line (figure 11).

The histogram is platykurtic for electrode implant condition one and electrical stimulation condition 2 (see figure 3). The Q-Q plots show that all the values deviate from the control line, and it looks like there is a pattern of deviation (figure 12).

The histogram looks a bit leptokurtic for electrode implant condition one and electrical stimulation condition 3 (see figure 2). The Q-Q plots show that some of the values are on the control line, but some deviate (figure 13).

The histogram looks leptokurtic for electrode implant condition two and electrical stimulation condition 2 (see figure 4). The Q-Q plots show that all the values deviate (figure 15).

The histogram looks platykurtic for electrode implant condition two and electrical stimulation condition 3 (see figure 5). The Q-Q plots show that only one value is on the control line: the rest deviate from the control line (figure 16).

The histogram looks leptokurtic for electrode implant condition three and electrical stimulation condition 1 (see figure 6). The Q-Q plots show that only two values touch the control line, and the rest deviate (figure 17).

The histogram looks mesokurtic for electrode implant condition three and electrical stimulation condition 2 (see figure 7). The Q-Q plots show only two values are on the control line. The rest deviate slightly (figure 18).

The histogram looks mesokurtic for electrode implant condition three and electrical stimulation condition 3 (see figure 9). The Q-Q plots show that all the values deviate (figure 19).

The histogram looks leptokurtic for electrode implant condition two and electrical stimulation condition 1 (see figure 10). The Q-Q plots show all the values deviate from the control line (figure 14).

The Q-Q plots I am most concerned about are the ones for A2, B3 & A3, B3. Therefore, I will be calculating confidence intervals for them.

<u>A2 & B3</u>

UCL = $g1 + Z_{0.05}(s.e.g1) =$ 0.800 + 1.96 (0.913) = 2.589

LCL = $g1 - Z_{0.05}(s.e.g1)$ = 0.800 - 1.96 (0.913) = -0.989

UCL = $g2 + Z_{0.05}(s.e.g1)$ = 0.596 + 1.96 (2.00) =4.516

LCL = $g2 - Z_{0.05}(s.e.g1)$ = 0.596 - 1.96 (2.00) = -3.92

A3 & B3

UCL = $g1 + Z_{0.05}(s.e.g1)$ = -0.575 + 1.96 (0.913) = 2.36

LCL = $g1 - Z_{0.05}(s.e.g1)$ = -0.575 - 1.96 (0.913) = -1.214

UCL = $g2 + Z_{0.05}(s.e.g1)$ = -2.460 + 1.96 (2.00) = 1.46

LCL = $g2 - Z_{0.05}(s.e.g1)$ = -2.460 - 1.96 (2.00) = -6.38

Based on the confidence interval calculations covering 0, I can validate the normality assumption

Assumption checking homogeneity of variances:

Based on the Levene's test, alpha is 0.05, F (8,36) = 0.148, and Pobs is 0.996. Since Pobs is larger than alpha, I accept that the assumption has been validated.

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

		Levene Statistic	df1	df2	Sig.
Time to Cross line	Based on Mean	.148	8	36	.996
	Based on Median	.136	8	36	.997
	Based on Median and with adjusted df	.136	8	31.498	.997
	Based on trimmed mean	.146	8	36	.996

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

a. Dependent variable: Time to Cross line

b. Design: Intercept + CortexArea + ElectricalLevel + CortexArea * ElectricalLevel

Step 7:

The results of the three omnibus two-way ANOVA. The test interaction is between factor A and B (Cortex area x electrical level). $\alpha = 0.05$, F $(4,36) = 3.172, Pobs = 0.02$. Since Pobs =0.025 $< \alpha = 0.05, reject\ H_0$. Therefore, I determine there is a simple main effect of A that differs across the three levels of B. So, there is an interaction effect on the population average on time to cross the test line between where the electrode was implanted and the level of electrical stimulation. Since the null hypothesis was rejected, I will calculate the magnitude of effect.

Tests of Between-Subjects Effects

Dependent Variable: Time to Cross line

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	916.578[a]	8	114.572	3.909	.002
Intercept	26402.222	1	26402.222	900.758	.000
CortexArea	356.044	2	178.022	6.074	.005
ElectricalLevel	188.578	2	94.289	3.217	.052
CortexArea * ElectricalLevel	371.956	4	92.989	3.172	.025
Error	1055.200	36	29.311		
Total	28374.000	45			
Corrected Total	1971.778	44			

a. R Squared = .465 (Adjusted R Squared = .346)

<u>Magnitude of Effect and Simultaneous Inference for AB Interaction Effect</u>

<u>Magnitude of the population interaction effect:</u>

To get $\hat{\omega}^2_{aB}$, I need to calculate the variance for every component. For the "nab" part, n=5, a=3, b=3. Because it is a fixed design with pre-chosen conditions and randomly assigned participants, with a sound assumption of homogeneity of variance, I will calculate variance:

$\hat{\sigma}^2 = MS_{within} = 29.311$

$$\hat{\sigma}_a{}^2 = \frac{MSaobs - Mswithinobs)(a-1)}{nab} = \frac{178.022-29.311(2)}{(5)(3)(3)} = 297.422$$

$$\hat{\sigma}_\beta{}^2 = \frac{(MSbobs - MSwithinobs)(b-1)}{nAb} = \frac{94.289-29.311(2)}{(5)(3)(3)} = 2.89$$

$$\hat{\sigma}^2_{aB} = \frac{MSABobs - MSwithinobs)(a-1)(b-1)}{nab} = \frac{92.989-29.311(2)(2)}{(5)(3)(3)} = 5.66$$

Therefore, the estimate of MOE ($\hat{\omega}^2_{aB)}$ is:

$$\hat{\omega}^2{}_a\beta \frac{\widehat{\omega 2}aB}{\hat{\sigma}^2+\hat{\sigma}^2a+\hat{\sigma}^2\beta+\hat{\sigma}^2a\beta} = \frac{5.66}{29.311+2.97.422+2.89+5.66} = 0.01688$$

Therefore, it is estimated that the proportion of the variance in the dependent variable is explained by the interaction effect between where the electrode was implanted, and the level of electrical stimulation is 0.0168 or about 1.7%. The estimate of the partial omega-squared is

$$\hat{\omega}^2{}_a\beta._a\beta \frac{\hat{\sigma}2aB}{\hat{\sigma}2+\hat{\sigma}2aB} = \frac{5.66}{29.311+5.66} = 0.1618$$

This provides the estimate of the proportion of the variability in the dependent variable (time to cross the test line) which is due to the interaction effect between where the electrode was implanted, and the level of electrical stimulation without the consideration of either of the animals effects on conditions.

Test of Effect of Factor A (Electrode placement):

$X_j.\sim N\left(\mu_j.,\sigma^2\right),\ j = 1,2,3$

)$H_0: \alpha_1 = \alpha_2 = \alpha_3 = 0$ vs. $H_1: \alpha_1 \neq \alpha_2 \neq \alpha_3$

$\alpha = 0.05, F(2,36) = 6.074$, Pobs = 0.005

Since Pobs =0.005 $< \alpha - 0.05, reject\ H_0: \alpha_1 = \alpha_2 = \alpha_3 = 0$ and conclude there is a main effect of electrode placement, particularly, there is a population difference between the average number of errors on electrode placement versus electrical stimulation. The magnitude of this effect is estimated by both the full and partial omega-squared estimates, and are, respectively,

$\widehat{\omega}^2{}_{a}\frac{\widehat{\sigma}2a}{\widehat{\sigma}^2+\widehat{\sigma}^2\alpha+\widehat{\sigma}^2\beta+\widehat{\sigma}^2\alpha\beta} = \frac{297.422}{29.311+297.422+2.89+5.66}$ =0.887 and,

$\widehat{\omega}^2{}_{a\cdot a}\beta\ \frac{\widehat{\sigma}2a}{\widehat{\sigma}2+\widehat{\sigma}2a} = \frac{297.422}{29.311+297.422} = 0.910$

Therefore, it is estimated that the proportion of the variance in the time to cross the test line is approximately 0.88 and approximately 0.91 when not considering either the effect of the electrical stimulation condition or the interaction between electrode placement and electrical stimulation.

Test of Effect of Factor B (Electrical stimulation condition):

)$X_k.\sim N\left(\mu_k.,\sigma^2\right),\ k = 1,2,3$
) $H_0: \beta_1 = \beta_2 = \beta_3 = 0\ vs, H_1: not\ H_0$
)$\alpha = 0.05, F(2,36) = 3.217, Pobs = 0.052$
Since Pobs =0.052> $\alpha = 0.05, I\ accept\ H_0: \beta_1 = \beta_2 = \beta_3 = 0$ and conclude there is no main effect of factor B.

To conclude, the results above indicate that there is a population interaction effect between factor A and factor B (Cortex area x electrical level). So, it appears that the effect is due to the interaction effect between where the electrode was implanted, and the level of electrical stimulation. However, no significant effect was found for the effect of factor B. But there was a significant effect found for factor A.

Figure 1: Descriptive Statistics

Statistics

Time to Cross line

1	1	N	Valid	5
			Missing	0
		Mean		28.60
		Std. Error of Mean		3.311
		Median		28.00

		Mode		20[a]
		Std. Deviation		7.403
		Variance		54.800
		Skewness		.823
		Std. Error of Skewness		.913
		Kurtosis		1.379
		Std. Error of Kurtosis		2.000
		Range		20
		Minimum		20
		Maximum		40
	2	N	Valid	5
			Missing	0
		Mean		28.00
		Std. Error of Mean		2.098
		Median		27.00
		Mode		23[a]
		Std. Deviation		4.690
		Variance		22.000
		Skewness		.800
		Std. Error of Skewness		.913
		Kurtosis		.068
		Std. Error of Kurtosis		2.000
		Range		12
		Minimum		23
		Maximum		35
	3	N	Valid	5
			Missing	0
		Mean		28.00
		Std. Error of Mean		2.510
		Median		28.00
		Mode		20[a]
		Std. Deviation		5.612
		Variance		31.500
		Skewness		-.354
		Std. Error of Skewness		.913

		Kurtosis		.307
		Std. Error of Kurtosis		2.000
		Range		15
		Minimum		20
		Maximum		35
2	1	N	Valid	5
			Missing	0
		Mean		16.80
		Std. Error of Mean		2.557
		Median		15.00
		Mode		11[a]
		Std. Deviation		5.718
		Variance		32.700
		Skewness		1.242
		Std. Error of Skewness		.913
		Kurtosis		1.784
		Std. Error of Kurtosis		2.000
		Range		15
		Minimum		11
		Maximum		26
	2	N	Valid	5
			Missing	0
		Mean		23.00
		Std. Error of Mean		2.121
		Median		22.00
		Mode		19[a]
		Std. Deviation		4.743
		Variance		22.500
		Skewness		1.640
		Std. Error of Skewness		.913
		Kurtosis		2.948
		Std. Error of Kurtosis		2.000
		Range		12
		Minimum		19
		Maximum		31
	3	N	Valid	5

			Missing	0
		Mean		26.80
		Std. Error of Mean		2.417
		Median		27.00
		Mode		21[a]
		Std. Deviation		5.404
		Variance		29.200
		Skewness		.800
		Std. Error of Skewness		.913
		Kurtosis		.596
		Std. Error of Kurtosis		2.000
		Range		14
		Minimum		21
		Maximum		35
3	1	N	Valid	5
			Missing	0
		Mean		24.40
		Std. Error of Mean		2.112
		Median		23.00
		Mode		23
		Std. Deviation		4.722
		Variance		22.300
		Skewness		-.179
		Std. Error of Skewness		.913
		Kurtosis		-.869
		Std. Error of Kurtosis		2.000
		Range		12
		Minimum		18
		Maximum		30
	2	N	Valid	5
			Missing	0
		Mean		16.00
		Std. Error of Mean		2.510
		Median		16.00
		Mode		9[a]
		Std. Deviation		5.612

		Variance		31.500
		Skewness		.354
		Std. Error of Skewness		.913
		Kurtosis		.307
		Std. Error of Kurtosis		2.000
		Range		15
		Minimum		9
		Maximum		24
	3	N	Valid	5
			Missing	0
		Mean		26.40
		Std. Error of Mean		1.860
		Median		28.00
		Mode		30
		Std. Deviation		4.159
		Variance		17.300
		Skewness		-.575
		Std. Error of Skewness		.913
		Kurtosis		-2.460
		Std. Error of Kurtosis		2.000
		Range		9
		Minimum		21
		Maximum		30

a. Multiple modes exist. The smallest value is shown

Figure 2: Histogram of Factor A1 and Factor B1

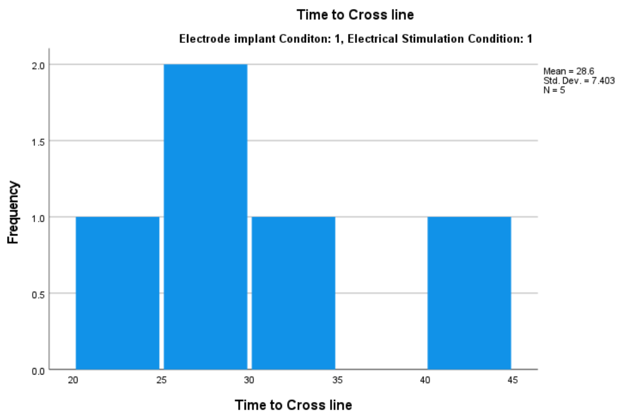


Figure 3: Histogram of Factor A1 and Factor B2

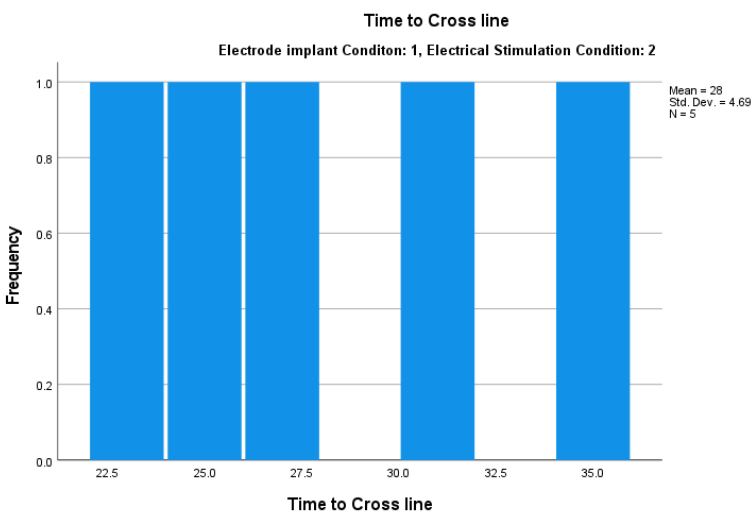


Figure 4: Histogram of Factor A1 and Factor B3

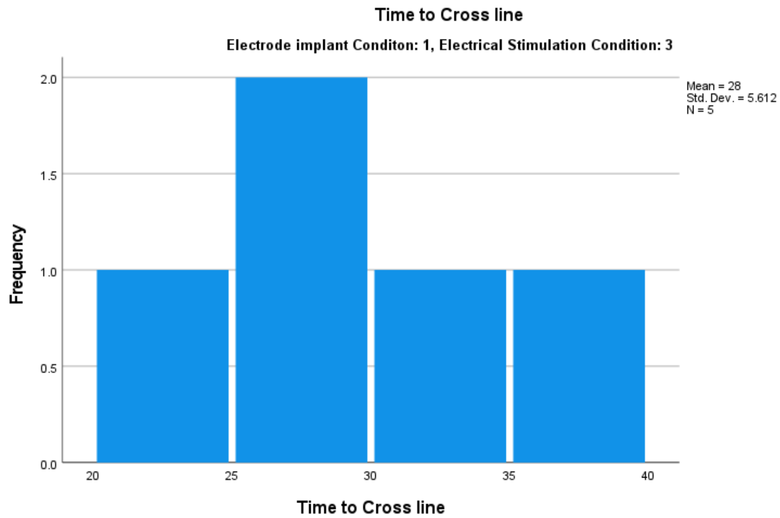


Figure 5: Histogram of Factor A2 and Factor B2

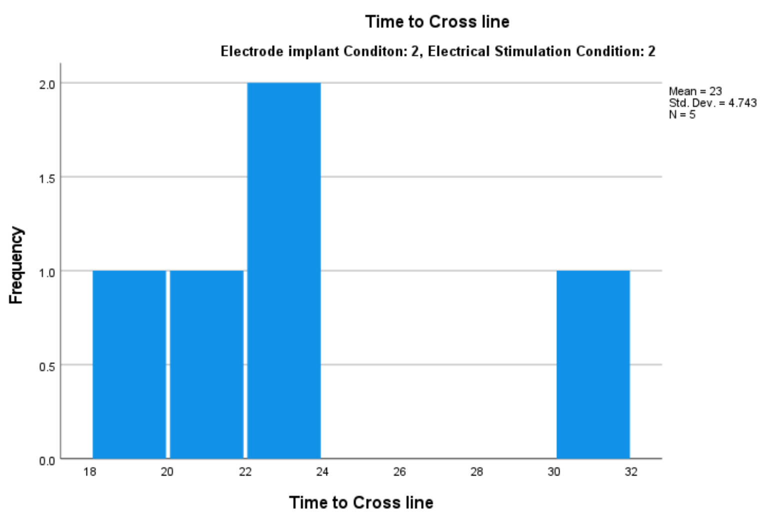


Figure 6: Histogram of Factor A2 and Factor B3

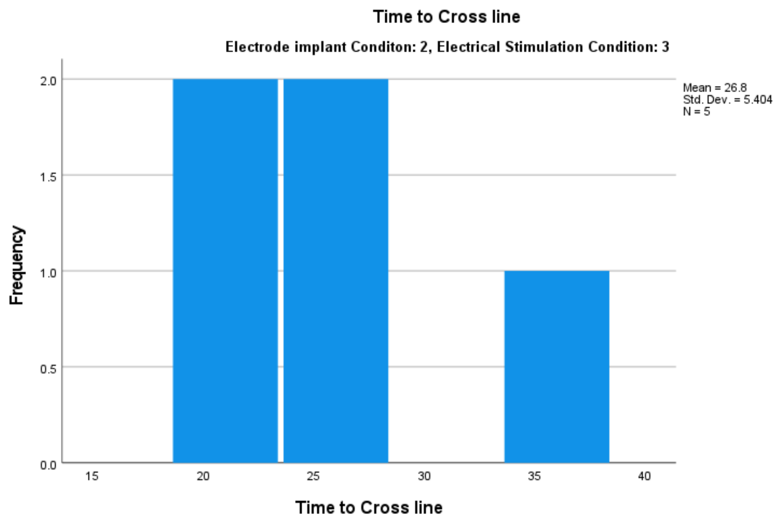


Figure 7: Histogram of Factor A3 and Factor B1

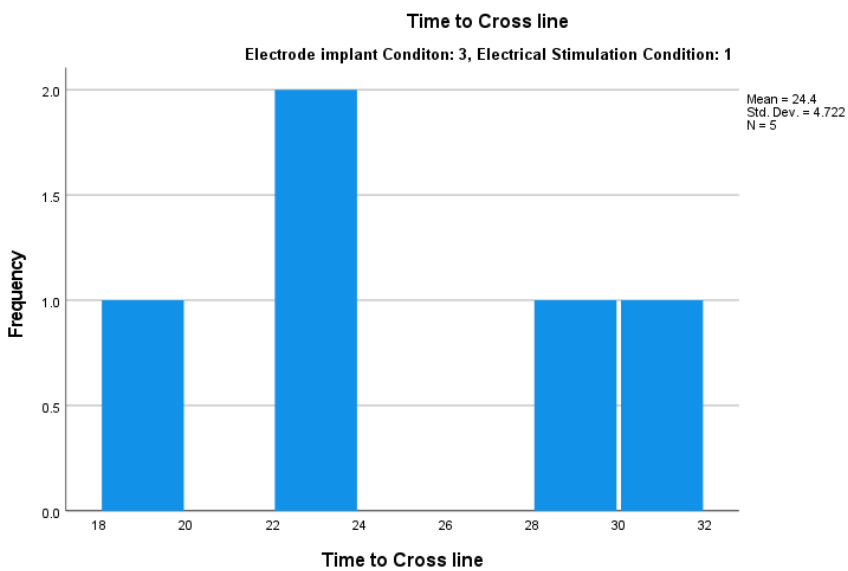


Figure 8: Histogram of Factor A3 and Factor B2

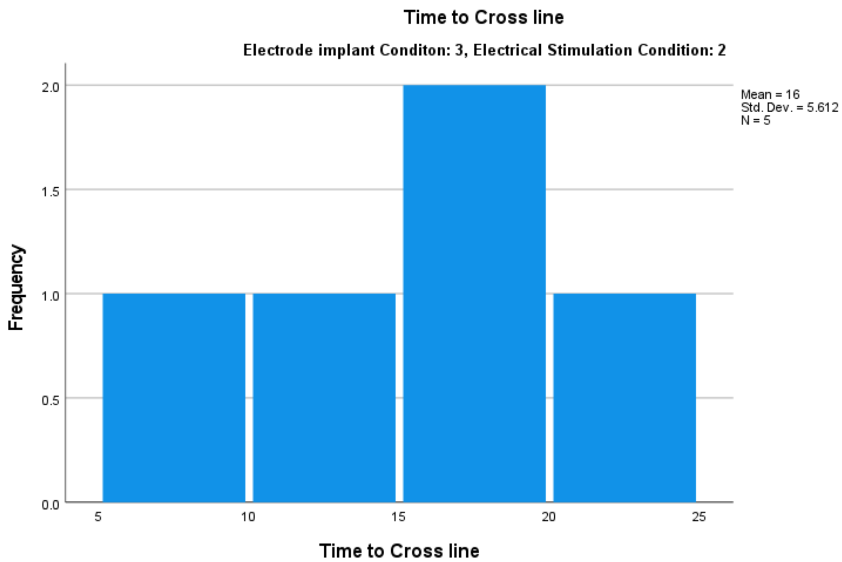


Figure 9: Histogram of Factor A3 and Factor B3

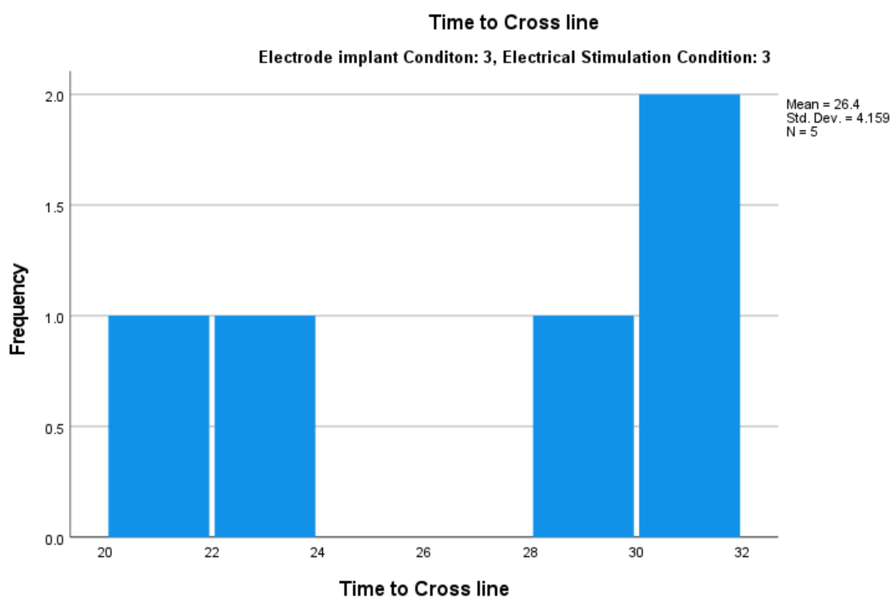


Figure 10: Histogram of Factor A2 and Factor B1

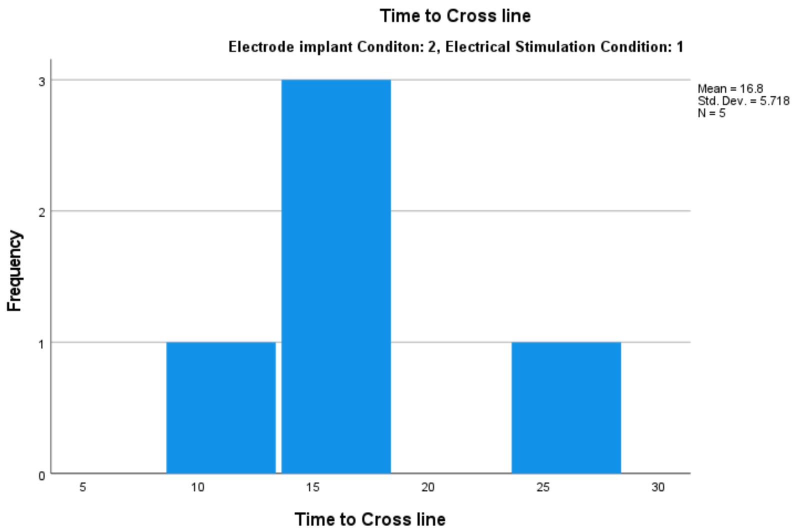


Figure 11: A1, B1 Q-Q plot

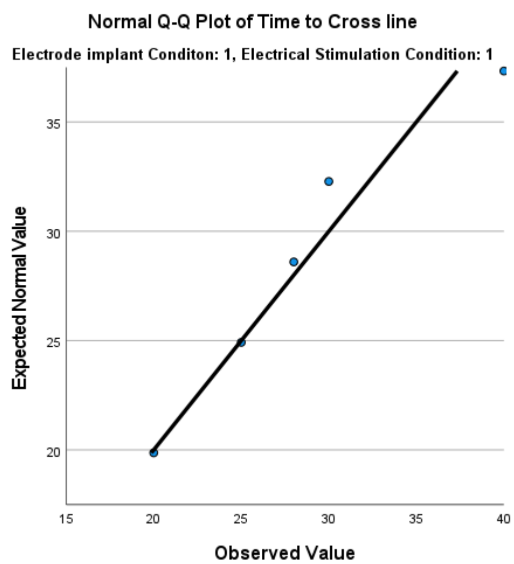


Figure 12: A1, B2 Q-Q plot

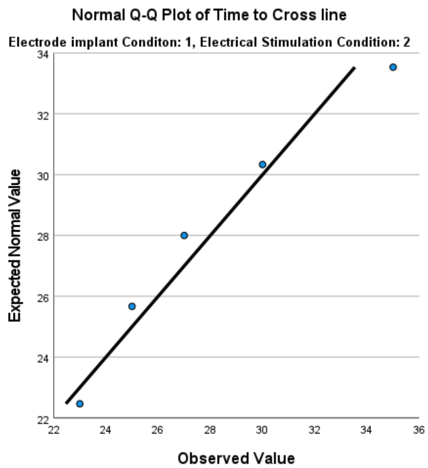


Figure 13: A1, B3 Q-Q plot

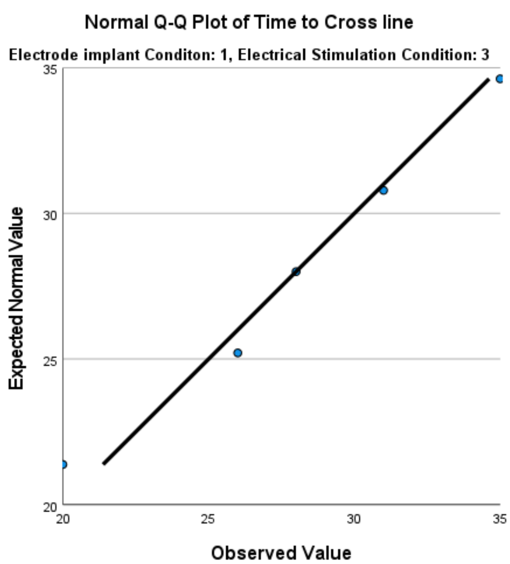


Figure 14: A2, B1 Q-Q plot

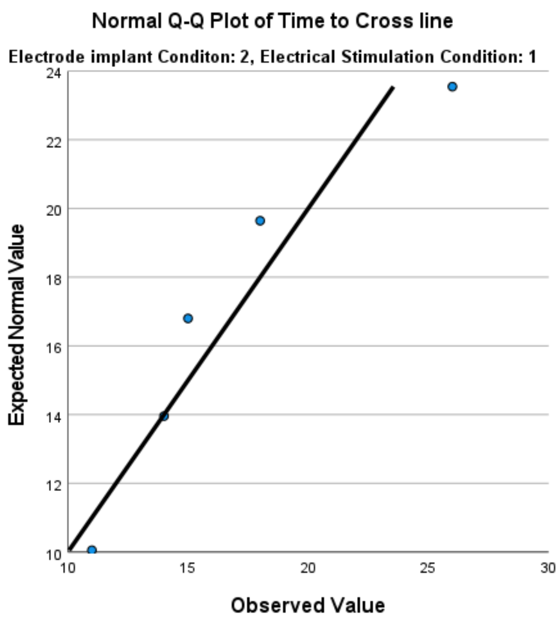


Figure 15: A2, B2 Q-Q plot

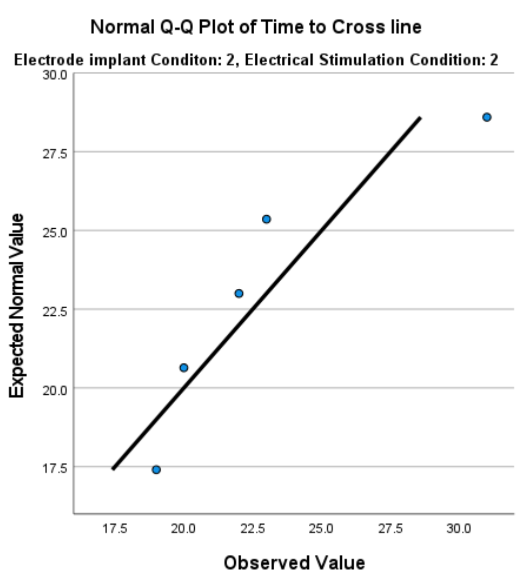


Figure 16: A2, B3 Q-Q plot

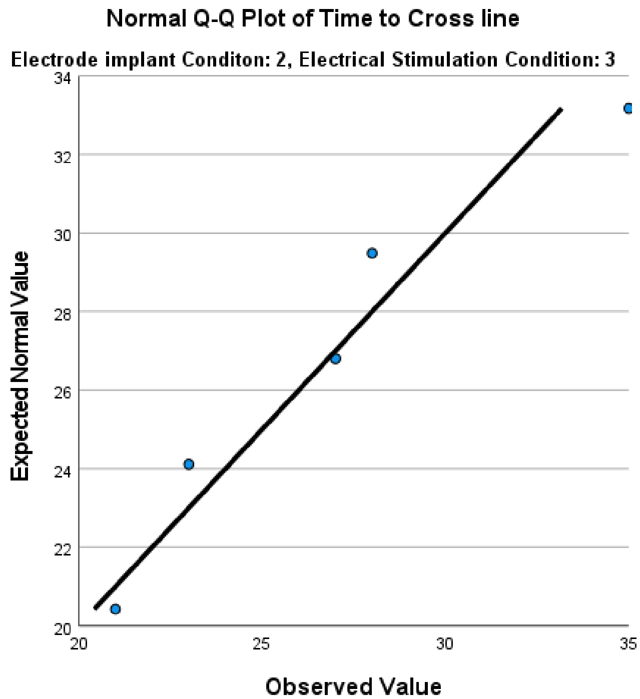


Figure 17: A3, B1 Q-Q plot

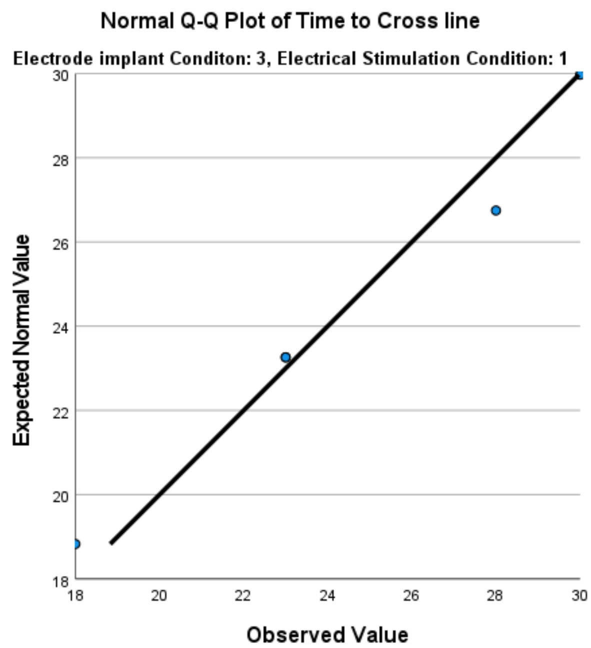


Figure 18: A3, B2 Q-Q plot

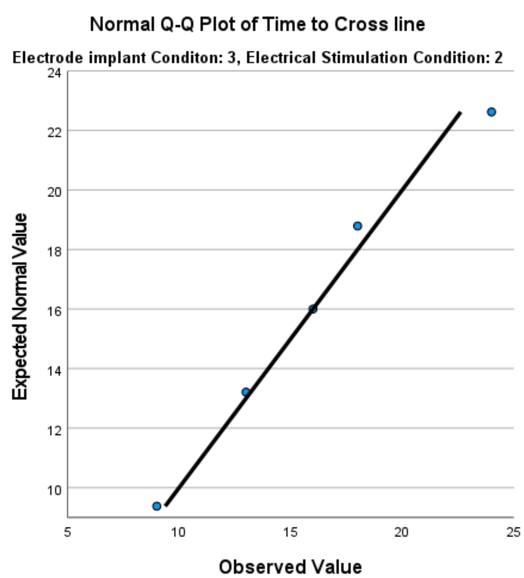
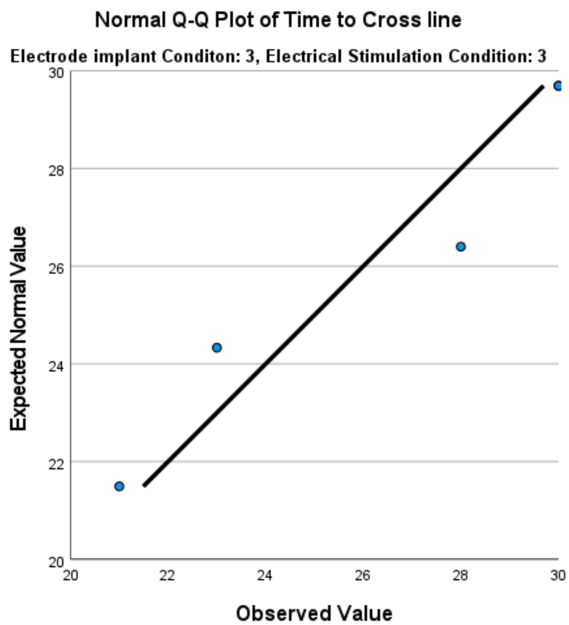


Figure 19: A3, B3 Q-Q plot


Normal Q-Q Plot of Time to Cross line
Electrode implant Conditon: 3, Electrical Stimulation Condition: 3
Expected Normal Value
Observed Value
30
28
26
24
22
20
20
22
24
26
28
30