Studying the Levels of Social Anxiety

A Project For Linear Models Course by:

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1 Introduction

Social Anxiety is a term that has become more and more popular throughout the recent years. Our understanding of it has increased, where now we don't refer to it as mere shyness anymore, but a type of social phobia that affects children and adults alike, as it is the most common anxiety disorder (Stein and Stein 2008).

This project will deal with the data of Social Anxiety across Gender (Male and Female) and also Group (there are 4 groups: Healthy controls, Social Anxiety Without Depression, Social Anxiety With Depression, and Depression). The following table describes the variables involved in detail:

Name of the variable	Type	Description
Social Anxiety	Numerical	Total score of people on Social Anxiety
Sex	Categorical(2 levels)	Female and Male
Group	Categorical(4 levels)	Healthy Controls, Social Anxiety Without-Depression, Social Anxiety With Depression, and Depression

Table 1: The Structure of The Dataset Used

Using the data provided from 140 observations, this research aims to observe if there is any difference in the average level of Social Anxiety between the Groups, between the Gender and also to see if these two factors interact. A thorough analysis is conducted, and the data is fitted into models facilitating the hypothesis testing and the condition of the data itself which is unbalanced. To begin with, observation 58th was removed due to the fact that it has a missing value of Gender. Next, since the dataset was analyzed using R Studio so for the ease of analysis, the variable Group (a character variable) was changed into Group1 as a factor variable in R.

2 Exploratory Analysis

The discussion will begin with an explanatory analysis of the dataset in order to gather an initial understanding of it. Figure 1 below shows a boxplot of the Social Anxiety based on the Group. It can be seen that all groups shows different level of Social Anxiety. The highest median of Social Anxiety occurs in the Social Anxiety With Depression Group, even its level is higher compared to the Depressed Group, which surprisingly has a lower median of Social Anxiety score. At the same time, the lowest level of Social Anxiety happens in the Healthy Controls Group, which is quite logical. The boxplot also shows that the Social Anxiety Without Depression Group is known to have the lowest variability among all. However, in that group there seems to be a sign of outlier which will be analyzed further later on.

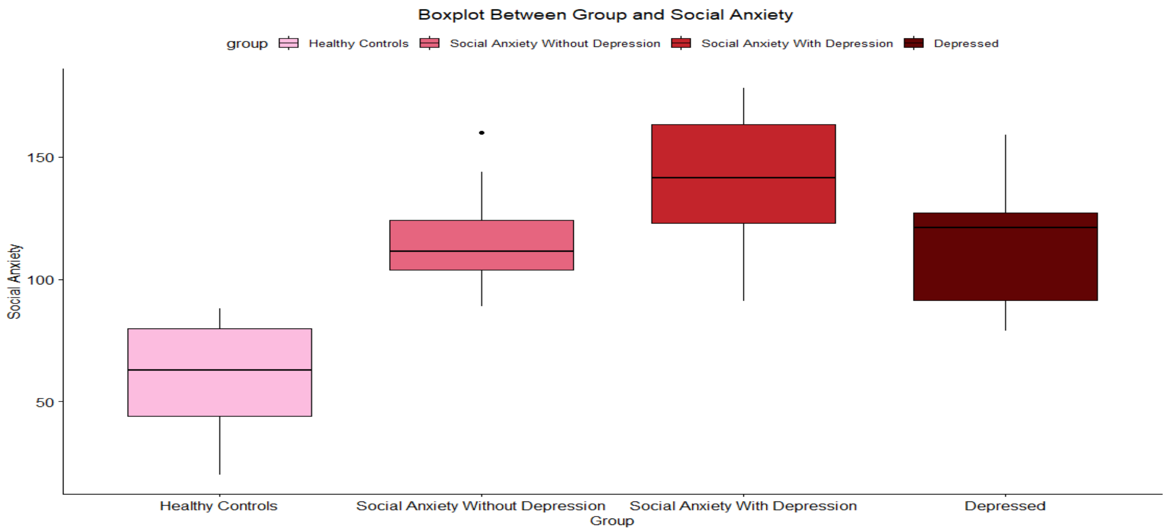

Figure 1: Boxplot between Group and Social Anxiety

To also get the idea about the level of Social Anxiety across gender, the figure 2 will be used. It shows that the level of Social Anxiety between Male and Female only differ slightly. The median of Social Anxiety in Male seems only a bit higher than in Female. The data variability of both gender looks similar and also there is no outlier seen.

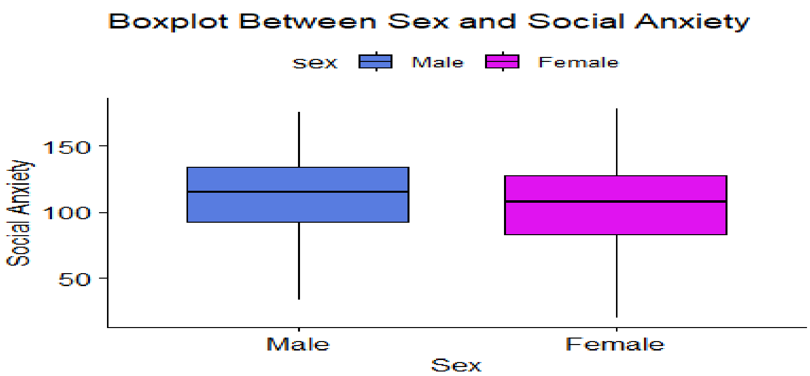

Figure 2: Boxplot between Sex and Social Anxiety

The next figure will provide a visual representation of Social Anxiety across Group and Gender. It's already known that the highest median of Social Anxiety happens in the Group of Social Anxiety With Depression. However, the Male's median of Social Anxiety in that group seems to be higher than the Female's. The Female in that group also shows the highest variability of Social Anxiety among all others.

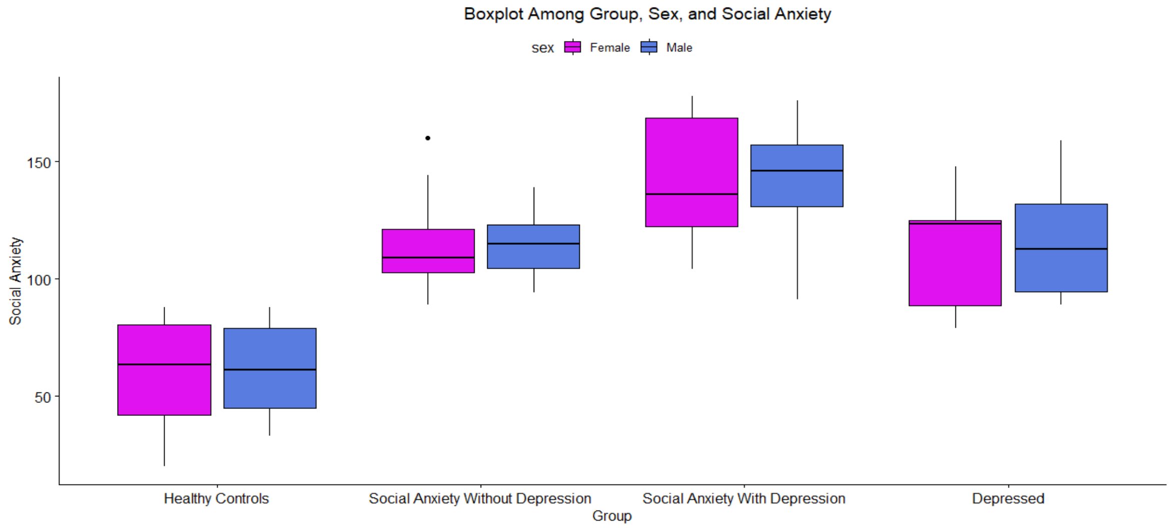

Figure 3: Boxplot Among Group, Sex and Social Anxiety

Based on the Figure 3 above, another Group that also display difference of Social Anxiety acrross Gender is the Depressed one. In the Depressed Group, Female presents higher median of Social Anxiety than Male. At the same time, the other two group which are Social Anxiety Without Depression and Healthy Controls do not show a large difference in median of Social Anxiety between the Male and Female. The boxplot once again indicates the presence of an outlier which belongs to the Social Anxiety Without Depression Group, especially for the Male. That group also seems to have the least variability compared to the others.

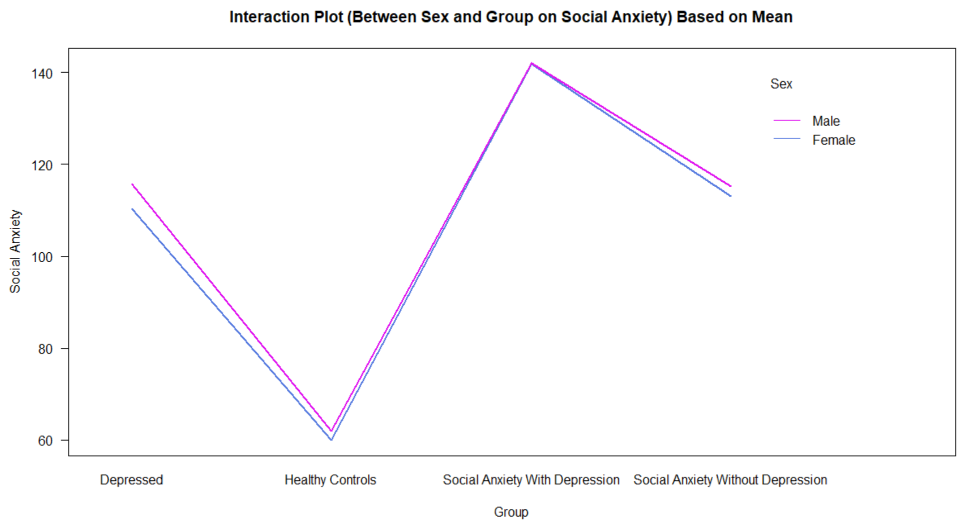

Figure 4: Interaction Plot (Between Sex and Group on Social Anxiety) Based on Mean

Figure 4 above depicts the interaction between Groups and Gender on the mean score of Social Anxiety. Based on the plot, the lines for Males and Females across the Group are not clearly parallel to each other which implies a possibility of interaction between the Gender and the Group on the Social Anxiety.

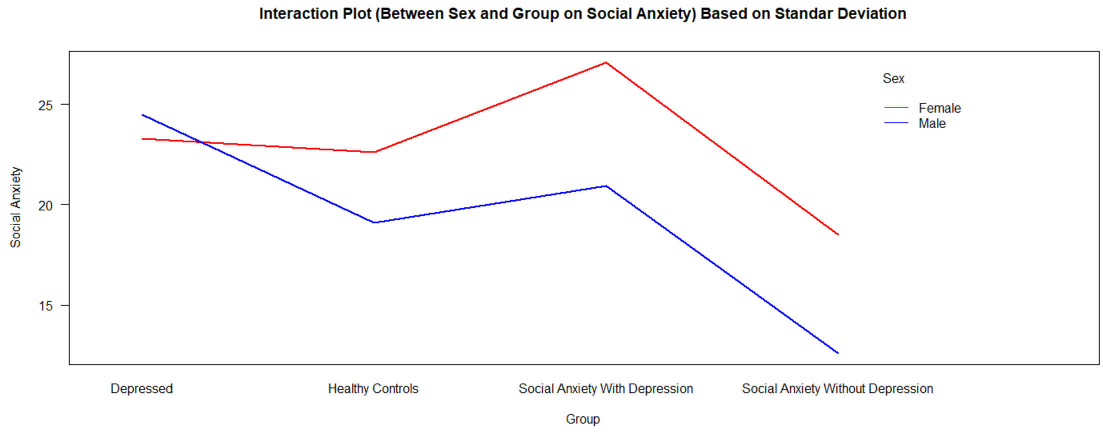

Figure 5: Interaction Plot (Between Sex and Group on Social Anxiety) Based on Standard Deviation

Figure 5 above depicts the interaction between Groups and Gender on the standard deviation score of Social Anxiety. Every combination of Gender and Group creates different level of variability in Social Anxiety. Also, the lines that show variability in Male and Female across Group are not parallel too. So, in the next step, a formal hyphotesis testing need to be conducted to test the significance of interaction between Gender and Group on Social Anxiety.

Furthermore, all the value of Frequency, Mean, and Standard Deviation of Social Anxiety in every combination between Gender & Group are then analysed to check if those values quantitatively agree with the graphical explorations that have been conducted. The values can be seen in Table 2 below.

Group	Sex	Frequency	Mean of Social Anxiety	Standar Deviation of Social Anxiety
Depressed	Female	14	110.4	23.3
Healthy Controls	Female	20	59.9	22.6
Social Anxiety With Depression	Female	22	141.9	27.1
Social Anxiety Without Depression	Female	23	113.1	18.5
Depressed	Male	8	115.8	24.5
Healthy Controls	Male	13	62.0	19.1
Social Anxiety With Depression	Male	16	141.9	20.9
Social Anxiety Without Depression	Male	23	115.3	12.6

Table 2: The Frequency and The Mean, and The Standard Deviation of Social Anxiety

Preliminary observations in the frequency combinations shows lesser number of Males than Female in all Groups, except in the Social Anxiety Without Depression Group where the frequency is the same. This indeed indicates an unbalance dataset. Meanwhile for the mean value, it can be seen that the Female in all Groups has slightly lower Social Anxiety mean score than the Male, except in the Social Anxiety With Depression Group where the mean is almost the same. However, the standard deviation of Social Anxiety score shows that Female has a little bit higher variability than Male in all Group except in the Depressed Group. All these values from the combination of Gender and Group indicates a possibility of interaction effect as suggested in the previous interaction plot.

3 Two way ANOVA

Based on the previous exploratory analysis, it is clear that there is a necessity to check the difference level of Social Anxiety between Gender and Group as well as to check whether there is a significance interaction effects between Groups and Gender on Social Anxiety. In this case, the independent variables (Groups and Gender) are all categorical and the dependent variable (Social Anxiety) is numerical so to test the idea of how the mean of Social Anxiety changes according to the levels of Gender, Groups, and their interaction a Two-way ANOVA method will be used. The model can be formulated as follows:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ijk}$$

where

- α_i is the main effect of the factor Group at level i, $(i = 1, 2, 3, 4)$
- β_j is the main effect of the factor Gender at level j, $(j = 1, 2)$
- $(\alpha\beta)_{ij}$ is the interaction effect between factors Group and Gender for level combination
- Y_{ijk} is the level of Social Anxiety of k-th observation from the ij-th combination.

3.1 Hypotheses and Assumptions

The Two-way ANOVA with interaction and unbalance sample in this study used to tests these hypotheses:

1. The mean of Social Anxiety for the four different Groups are equal. It can be denoted as: $H_0 = \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$

2. The mean of Social Anxiety for Gender (Females and Males) are equal. It can be denoted as: $H_0 = \beta_1 = \beta_2 = 0$

3. There is no interaction between Groups and Gender on the mean of Social Anxiety. It can be denoted as: $H_0 = (\alpha\beta)_{ij} = 0$, for $i = 1, 2, 3, 4$ and $j = 1, 2$

This model needs some assumptions such as the normality and the independence of error terms, as well as homoscedasticity which can be denoted as $\epsilon_{ijk} \sim N(0, \sigma^2)$. The ϵ_{ijk} denotes error of observation k-th from the ij-th combination. Furthermore, as mentioned above that there's a possibility of interaction effects noticed, then this study will use both the Type 1 and Type 3 Sum of Squares for the Two Way ANOVA so that the interaction effects are taken into consideration in a sequential and non-sequential manner.

3.2 Two-way ANOVA: Type 1 Sum of Squares

	Df	SS	MSE	F value	Pr(>F)
Group1	3	119567	39856	89.537	<2e-16 ***
Sex	1	139	139	0.312	0.578
Group1:Sex	3	92	31	0.069	0.976
Residuals	131	58313	445		

Table 3: Result from the Two Way ANOVA using Type 1 Sum of Square

The table above shows the summary of Two Way ANOVA with interaction using the Type 1 Sum of Squares which has BIC value of 1278.31. Based on the summary, it can be observed that it is only the Group which produce a significant p-value (at 5 percent level of significance). Thus, the null hypothesis that say there is no difference on the average level of Social Anxiety between the four Groups should be rejected. Then, it can be concluded that there is indeed a difference in the average level of Social Anxiety between the Group. On the contrary, for Sex (Gender) as well as for the interaction term, they both do not have significant p-value (their p-values are both greater than 5 percent level of significance). It implies that there is no significant main effect of Gender on the average level of Social Anxiety. Additionally, the interaction effect between Groups and Gender on the average level of Social Anxiety is not significant as well.

3.2.1 Model Checking

To see the validity of the model, it is important to check whether the model assumptions hold for the data or not.

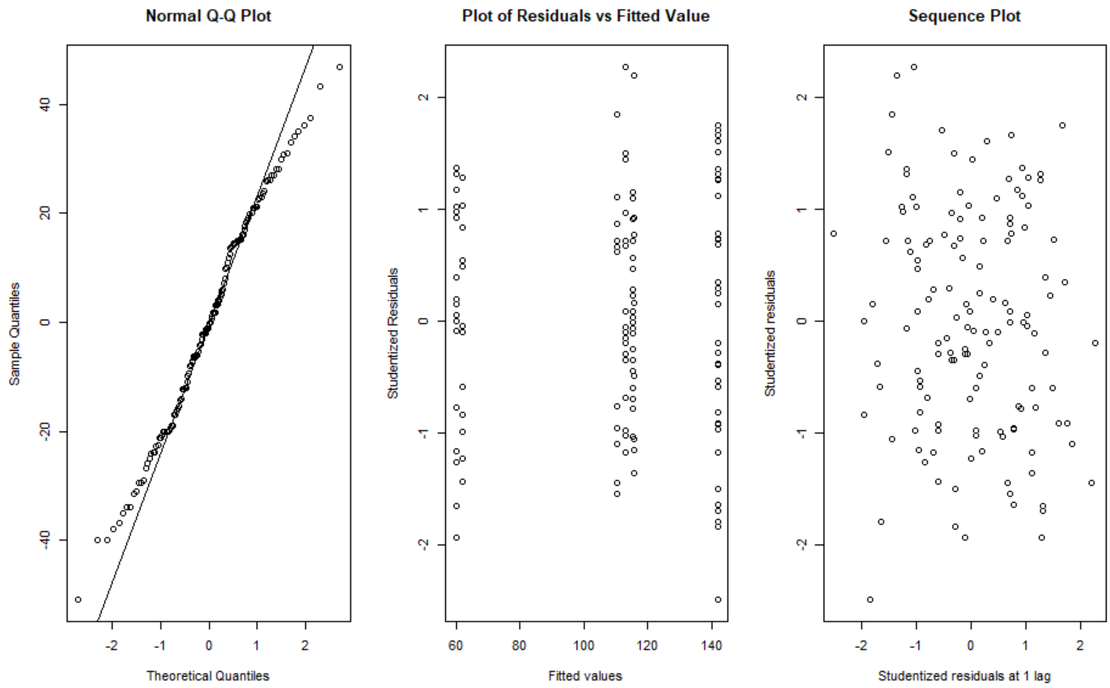

Figure 6: Plots Used for Checking The Model Assumptions (Normal Q-Q plot for Normality, Residuals vs Fitted Value Plot for Homoscedasticity and Sequence Plot for Independence)

The first assumption to be checked is Normality of the error term. To check it graphically, the Normal Q-Q Plot is used, while to check it formally, the Shapiro-Wilk test is conducted. According to pattern in the the Q-Q plot, most of the residuals follow normal distribution. The Shapiro-Wilk test also supports the result from Q-Q Plot since the test shows a p-value larger than 5 percent level of significance. So, it can be concluded that the normality assumption to use this model is fulfilled.

The second assumption to check is homoscedasticity. Graphically, it can be checked using the plot of studentized residuals against their fitted values while to test formally Levene test can be conducted. Based on the plot, the residuals are clustered in certain areas, thus indicating the presence of heteroscedasticity. Levene test also confirms the indication from the plot. The null hypothesis for Levene test states that homoscedasticity presents. However, the result of the test shows a p-value of 0.027. So, the null hypothesis should be rejected at 5% level of significance and it can be concluded that homoscedasticity assumption is violated. So,using this model can be inappropriate.

The final assumption to be checked is the independence of error terms. To test it, sequence plot is used and Durbin-Watson test is performed. In the sequence plot, studentized residuals are plotted against studentized residuals at 1 lag (as spatial variable. It results in a random pattern of residuals found that suggests the indication of independence. Then by using the Durbin-Watson test, result shows that p-value is larger than 5 percent level of significance. So, it is failed to reject the null hyphothesis of there is no first order autocorrelation (or the samples are independent). In conclusion, the independence assumption is fulfilled.

3.3 Two-way ANOVA: Type 3 Sum of Squares

	Df	Sum of Sq	RSS	AIC	F value	Pr(>F)
<none>		58313	855.43			
Group1	3	114502	172814	1000.44	85.7433	<2e-16 ***
sex	1	177	58490	853.86	0.3978	0.5293
Group1:sex	3	92	58405	849.65	0.0692	0.9762

Table 4: Result from the Two Way ANOVA using Type 3 Sum of Square

The table above shows the output from the Two Way ANOVA model using Type 3 Sum of Squares for testing the main and interaction effects and their corresponding p-values. This mode also has the same BIC value as the previous one which is 1278.31. Based on the p-values from this model, it can be noticed that the main effect of Group to the average level of Social Anxiety is significant highly, meanwhile the effect of Gender and their interaction are insignificant (at 5 percent level of significance). This means that the level of Social Anxiety is indeed significantly different between different Groups, but it doesn't differ significantly between Gender. Furthermore, the model also suggests that there is no interaction between the Groups and the Genders on the level of Social Anxiety. It implies that, despite the possibility of interaction as suggested by the interaction plot in figure 4, the interaction effect is not statistically significant. Strictly speaking, this means that if the Group is changed while keeping the Gender constant (and vice versa), the change in expected value of Social Anxiety level remains unchanged.

3.3.1 Model Checking

The validity of this TWo Way The validity of the model is again checked by testing if the underlying assumptions of the model holds. Normality assumptions are checked using Normal Q-Q plot and the plot suggests that most of the residuals follow normal distribution. Wilk-Shapiro test is also performed where the p-value obtained is 0.246 and the normality assumption here also is fulfilled. model using the Type 3 Sum of Squares is also checked to test whether the underlying assumptions of the model holds or not. The Normality assumption are checked using both Normal Q-Q plot and Shapiro-Wilk test. The Q-Q plot suggests that most of the residuals follow normal distribution while the Wilk-Shapiro test result in a p-value of 0.246 which leads to accepting the null hyphothesis. In conclusion, the normality assumption for this model is fulfilled.

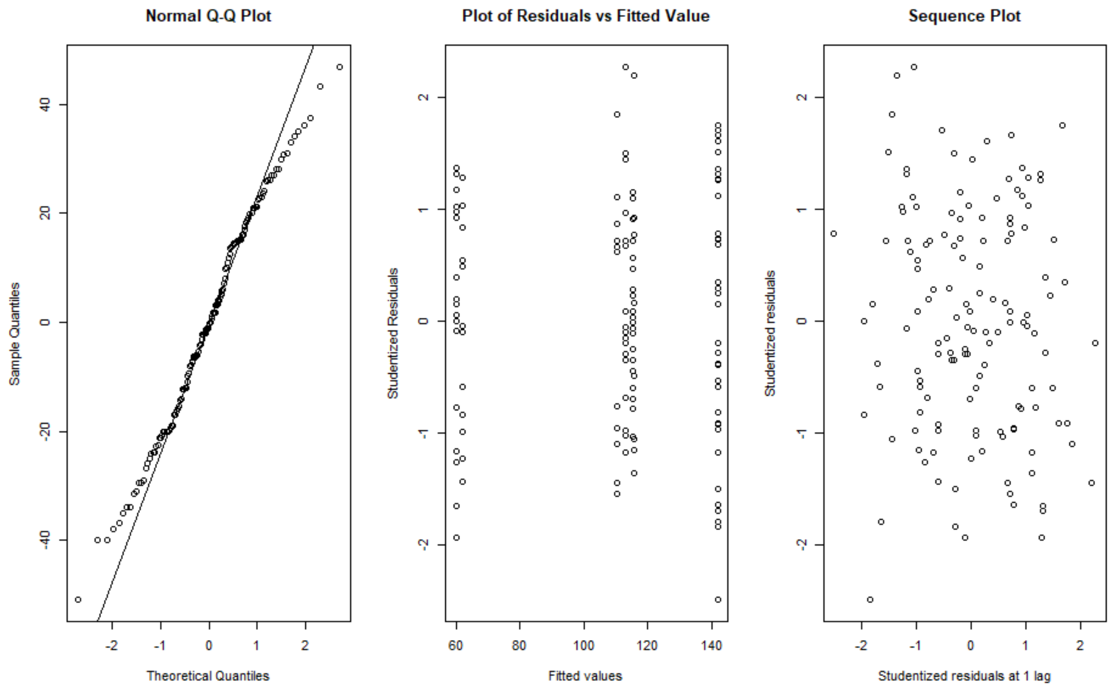

Figure 7: Plots used for checking the model assumptions. Normal Q-Q plot for normality, Residuals v/s fitted values for homosedasticity and sequence plot for independence

The two other assumptions (homoscedasticity and independence of error terms) are also checked. By using Residual vs Fitted Value Plot and the Levene Test, they suggest that there is a lack of homoscedasticity. So, this model suffers from an asummption violation. Meanwhile, testing the independence assumption by using the Sequence Plot and the Durbin-Watson test lead to the result that the plot has a random pattern and the p-value from the Durbin Watson test is greater than 5 percent level of significance. So, independence assumption is fulfilled for this model.

3.4 Conclusions Regarding The Model Fitting

Based on the summaries of both Two Way Anova model using Type 1 and Type 3 Sum of Square, it is clear that the main effect of Gender and the interaction effect between Group and Gender on the Social Anxiety are not significant according to their p-value. The only significant effect is that of different Groups on Social Anxiety.

Both the models satisfy the normality and independence assumptions. However, the assumption of homoscedasticity is violated, as evidently suggested by the Residual Plot and Levene Test. Normally, it is important for the model to satisfy this homoscedasticity condition because the lack of it (and therefore the presence of heteroscedasticity) would make the estimates less precise and this can increase the likelihood of estimates being further from the current population value.

It was also observed that using both the Type 1 and Type 3 sum of squares in the Two Way ANOVA model give the same BIC values. However, the Two-way ANOVA type 3 Sum of squares is preferred for further analysis because in Type 3 Sum of Square, every term in the model is tested in light of every other term, thus keeping less restrictions on estimation.

Using Bonferroni correction method, no outliers were found. One outlier is found when Bonferroni correction is not used. However, it is not removed, as there does not seem to be a specific reason why it occurs, other than a natural variation.

A few techniques mentioned below are tried out, in order to improve the homoscedasticity condition and the outlier issue.

3.4.1 Bonferroni correction

The Bonferroni correction is one of the methods used when the intention is to test whether a Group of parameters is significant. It is usually preferred when the number of hypotheses being tested is limited (as is this case-3). In this case, this method is recommended compared to the Sheffe method, since the number of contrasts of interest is about the same as the number of factor levels. This procedure can be applied when the family of interest is a set of pairwise comparisons, contrasts and/or linear combinations of factor levels means. $H_0^k : L_k = 0$ where $k = 1, ..., M_e$ and M_e = the total number of partial hypotheses that one wants to test in the experiment. The procedure has an approximate confidence level of $1 - \alpha$ whether the factor levels sample sizes are equal or not.

After dividing the alpha rate by the number of analyses performed, the corrected p-value = 0.017. It is noticed that again, for both Type 1 and Type 3 sum of squares, the p value for the Group is the only one that is statistically significant. However, it is to be noted that this method is quite conservative, as sometimes the correction that is applied is too severe. Nonetheless, the results match those above.

3.4.2 Box-Cox transformation

A slight deviation from normality is observed in the figures 6 and 7, which suggests the necessity for the transformation of the variable Social Anxiety. The Box-Cox transformation belongs to the family of power transformation, which may be able to give better residual fits. The response variable Y is transformed as:

$$Y_{ij} = Y_{ij}^{(\lambda)}$$

The value of λ is chosen in such a way that it maximizes the value of log-likelihood of Y with homoscedastic error, when Y is regressed by the predictor variables. The value of λ was found to be 0.955, which is in the proximity of one. However, using this Box-Cox transformation still hasn't brought any improvement in the homoscedasticity.

3.4.3 Weighted Least Squares

Transformations in Y, such as the Box-Cox transformation, might be helpful to reduce unequal error variances, but they have the disadvantage of changing the relation between the response and the independent variables. Theoretically, Weighted Least Squares (WLS) will help in curing heteroscedasticity by giving the weights to the observations. The observations with a large variance get a small weight, otherwise those with a small variance wil get a large weight to even out.

Unfortunately, even after applying WLS to the dataset in this study, the problem of heteroscedasticity has not been solved. The result of WLS is not so different from the ANOVA result, the only change is that the sum of squares value has been reduced in WLS for the variable Group.

3.4.4 Parametric Bootstrap

Based on the results of the Levene Test, it is known that at the 5% significance level, there is a violation of the homoscedasticity assumption in the ANOVA Two Way model using the data in this study. To solve this problem, WLS and Box-Cox Transformation have been carried out but still, the heteroscedasticity can not be overcome. In order to achieve the purpose of this study, which is to test the hypothesis of whether there is a difference between Groups and Gender and their interaction in the average level of Social Anxiety, then it is necessary to look for the other alternative methods. One method that is very suitable to answer the research objectives while is also able to accommodate conditions of the data is the Parametric Bootstrap Approach for Two Way ANOVA in the presence of possible interaction (based on indications on the previous interaction plot) in case of heteroscedasticity and unbalanced sample. The use of this method refers to the journal Xu, Yang, Abula and Qin (2013).

To conduct the method, the algorithm used is:

1. Based on the observed values in our data, then the mean and variance of the ij-th treatment (for $i = 1, 2, 3, 4$ and $j = 1, 2$) is calculated. The means is calculated as $\bar{y} = \frac{1}{n_{ij}} \sum_{k=1}^{n_{ij}} y_{ijk}$ and the variance is $s_{ij}^2 = \frac{1}{n_{ij}-1} \sum_{k=1}^{n_{ij}} (y_{ijk} - \bar{y}_{ij})^2$, where $k = 1, ...n_{ij}$. Thus, Two Way ANOVA with interaction and heteroscedasticity and unbalanced sample can be written as $Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_{ij} + e_{ijk}$ where $e_{ijk} \sim N(0, \sigma_{ij}^2)$. The symbol μ is denoted for the general mean, symbol α is for the effect due to the i-th level of factor A (in this case is Group), then β_j is the effect due to the j-th level of factor B (in this case is Gender), while γ_{ijk} is the effect due to the interaction of factor A_i with factor B_j (in this case, it is the interaction of Group and Gender). Afterwards, proceed with calculating the standardized sum of squares $(\tilde{s})$ as follows:

   - The standardized sum of squares for the factor interaction, which is needed for testing the null hypothesis $H_{0AB} = \gamma_{ij} = 0$; (where $i = 1, 2, 3, 4$ and $j = 1, 2$) is

$\tilde{s}(\bar{y}_{11}, \bar{y}_{12}, ..., \bar{y}_{42}; s_{11}^2, s_{12}^2, ..., s_{42}^2) = \sum_{i=1}^{4}\sum_{j=1}^{2}\frac{n_{ij}}{s_{ij}^2}(\bar{y}_{ij} - \mu - \alpha_i - \beta_j)^2$.

- The standardized sum of square of the main effects A (in this case is Group) which is needed for testing the null hypothesis $H_{0A*} = \alpha_i + \gamma_{ij} = 0$; (where $i = 1, 2, 3, 4$ and $j = 1, 2$) is $\tilde{s}(\bar{y}_{11}, \bar{y}_{12}, ..., \bar{y}_{42}; s_{11}^2, s_{12}^2, ..., s_{42}^2) = \sum_{i=1}^{4}\sum_{j=1}^{2}\frac{n_{ij}}{s_{ij}^2}(\bar{y}_{ij} - \mu - \beta_j)^2$. Also, for testing the null hypothesis of the other main effect B (in this case is Gender, while at the same time considering the presence of interaction effect too), the identical formula for calculating $\tilde{s}$ is used.

2. Carry out a bootstrapping (ie a type of Monte Carlo method applied to the observed data) which is done by generating a number of datasets. Then, using the formula similar to the one in step (1) calculate their mean $\bar{y}_{Bootstrap.ij} \sim N(0, s_{ij}^2/n_{ij})$ and variance is $s_{Bootstrap.ij}^2 \sim s_{ij}^2\chi_{ij}^2$ by using the identical formula as in step 1.

3. Finally, in order to determine the decision for the hypotheses that have been stated in the beginning, then the p-value should be calculated. The first step for calculating the p-value is to compare $\tilde{s}_{Bootstrap}$ with the $\tilde{s}$. If $\tilde{s}_{Bootstrap} > \tilde{s}$ then set the value of $Q_k = 1$ where $k = 1, 2, ..., m$ indicates the number of iteration performed during bootstrapping. Thus, we will get as many as m of Q_k. Based on it, a Monte Carlo estimate of p-value will be obtained, by using the formula $\sum_{k=1}^{m} Q_k$.

An R package to conduct this parametric bootstrap approach is already available. The name of the package is *twowaytests* and the function used is *gpTwoway(method="gPB")* which was just published in by Osman Dag (2021). By using it, the p-value based on the parametric bootstrap approach as guided in the journal will be automatically counted. In this study, as an addition to using the package, the parametric bootstrap is also conducted by using step by step syntax. They result in the same, as long as the *set.seed()* formula which is set at the beginning is the same too. Because in the parametric bootstrap there is iteration and randomization process, so without having the same *set.seed()* it will be difficult to replicate the research.

In this study, *set.seed(27)* and iterations of $m = 1000$ are used. At the 5 percent significance level using available data, the output from using packages and from manual calculations shows the same p-value and result as follows:

Factor	P-value	Result
Group1	0	Reject
as.factor(sex)	0.9708	Not reject
Group1:as.factor(sex)	0.9815	Not reject

Table 5: The output for Parametric Bootstrap Approach for Two Way ANOVA with Heteroscedasticity and Unbalance Data

Based on the output above, it can be ascertained that Gender (Male and Female) is not proven to make a difference on the average level of Social Anxiety. Likewise, the interaction factor between Gender and Group also do not bring a different average level of Social Anxiety. Only Group alone (as the main factor) that has a significant difference on the average level of Social Anxiety. In other words, people coming from different Group will bring different effect of Social Anxiety scale. To know which groups (in pairs) that have different effects on Social Anxiety, a post-hoc test will be conducted.

3.4.5 Family-wise confidence level

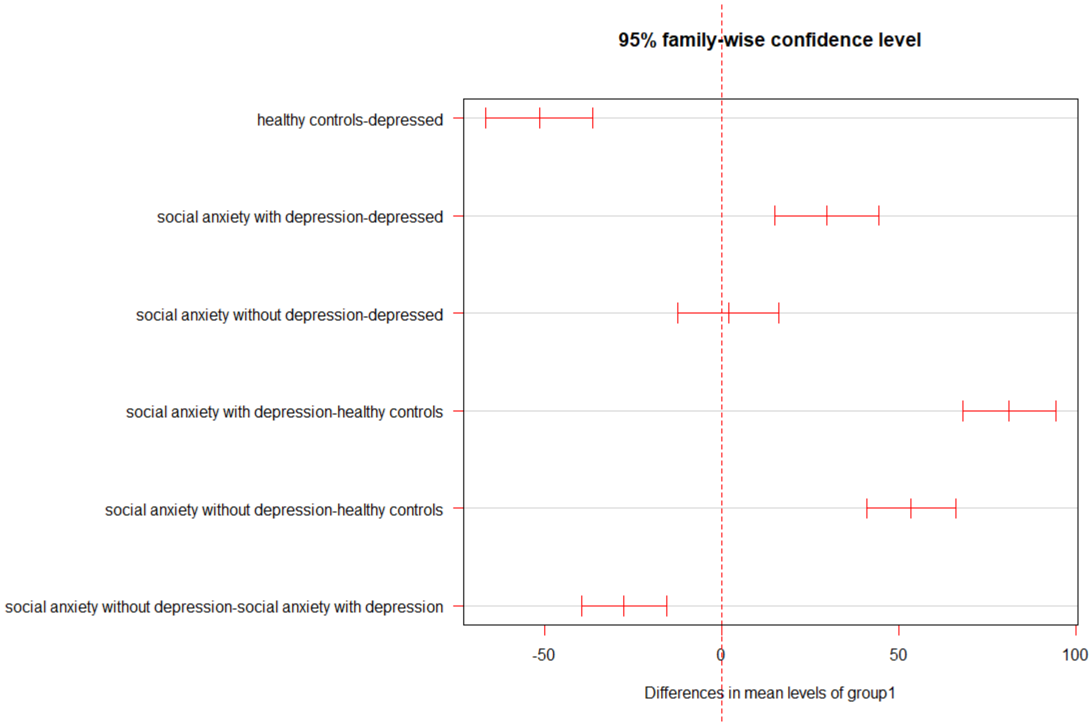

Figure 8: Tukey Test for Checking The Difference between Each Level in Group

With the evidence of no-interaction between the factors Group and Gender, the next step is to use the Tukey's test for family-wise confidence level. The figures 8 and 9 show the 95% family-wise confidence intervals for the each level of the Group and the Gender, respectively. Figure 8 confirms the result from table ??. The figure shows that for every pair of Group level brings difference on Social Anxiety at 95 percent confidence interval, except for one pair. That one pair is between people in the Social Anxiety Without Depression Group and in Depressed Group where there is no any significant difference seen in the level of Social Anxiety between those two Group. On the other side, figure 9 shows that at 95 percent confidence interval, there is no significant difference between Gender (Female and Male) on the average level of Social Anxiety because the interval based on this Tukey test includes the zero value. This is in accordance with the previous tests.

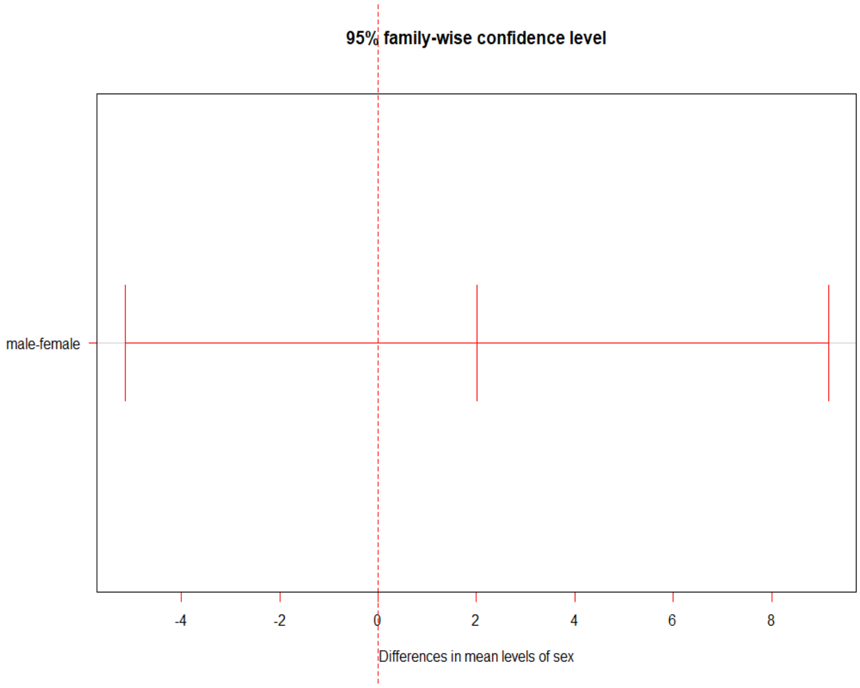

Figure 9: Tukey test for difference between Gender

4 Final Conclusion

Dataset	Homoscedasticity	Normality	Independence
Raw data	0.027 **	0.246	0.478
Transformed with Box-Cox	0.031 **	0.231	0.436
Transformed with Weighted Least Square	7.02×10^{-14} ***	0.246	0.47

Table 6: The Result of Assumption Testing on the Datasets

Table 4 shows the summary of the p-values from the Levene Test for Homoscedasticity, Wilk-Shapiro Test for Normality and Durbin-Watson Test for Independence in the Two-way ANOVA model using Type 3 Sum of Square based on raw data, transformed data using Box-Cox, and transformed data using Weighted Least Squares. It can be noticed as explained before that all the Levene Tests result in rejecting the null hypothesis at 5% level of significance and thus concluding heteroscdasticity even after transformations. So, the model suffers from asumption violation. It is thus ideal to go to another alternative method. In this case, the Parametric Bootstrap Approach for Two Way Anova with Heteroscedasticity and Unbalanced Data is chosen as the tool to analyze the hypotheses. Based on it, at 5% level of significance, it can be concluded that there is a statistically significant difference on the average level of Social Anxiety between Group. However, the difference is not significant for between Gender and for the interaction of Gender and Group. A Post-Hoc test has shown that indeed every pair of Group combination brings different level of Social Anxiety, except for only 1 pair which is between the Social Anxiety Without Depression Group and the Depressed Group that shows no significant difference.

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