Q4 (a-d) - Data 2: beers tasting

(a) Perform a two-way ANOVA to test the main effect of country and type , and for the interactions upon the rating. What conclusion do you have from this two-way ANOVA analysis ? How does this result connect to Q3-b.

```
# two way anova
ConT = lm(formula = rating ~ country * type, data = beers)
anova(ConT)
```

```
## Analysis of Variance Table
##
## Response: rating
##              Df Sum Sq Mean Sq F value    Pr(>F)
## country       2 0.3456 0.17281  1.2773 0.2935138
## type          1 2.5760 2.57602 19.0404 0.0001394 ***
## country:type  2 0.6353 0.31763  2.3477 0.1129074
## Residuals    30 4.0588 0.13529
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Conclusion: The value of F statistic is large for type, therefore F test for type produces a significant result for type whereas it doesn't produce a significant result for country and interaction term. We can conclude from the F test for type that variances between groups is larger than variances within groups, therefore type has a significant main effect. In contrast to that, country doesn't have a significant main effect and country&type together don't have significant interaction effect because F test for type is not statistically significant.

(b) Refit the data with a two-way ANOVA without the interaction term, give the ANOVA output. Checking the normality assumption before and after refitting as in Q1-c and state your conclusion.

```
# two way anova
Wi = lm(formula = rating ~ country+type, data = beers)
anova(Wi)
```

```
## Analysis of Variance Table
##
## Response: rating
##           Df Sum Sq Mean Sq F value    Pr(>F)
## country    2 0.3456 0.17281  1.1781 0.3208682
## type       1 2.5760 2.57602 17.5611 0.0002044 ***
## Residuals 32 4.6940 0.14669
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Comments: The F value is not large, therefore we can say that the F test is not significant. This concludes that between group variances are not significantly higher than inside group variances.

(c) Instead of examining the normal qq plot, now we consider to use the Shapiro-Wilk Normality Test (R built-in function: *shapiro.test*()) to evaluate the normality assumption for model without interaction term.

```
# shapiro test
shapiro.test(Wi$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  Wi$residuals
```

```
## W = 0.95046, p-value = 0.1081
```

Comments: With 0.05 significance level and p value 0.1081 and since the pvalue is greater than our significance level, we fail to reject the null hypothesis. We fail to reject that residuals are normally distributed.

(d) Find 95% TukeyHSD family-wise confidence interval for the difference of means of county. Try R command $TukeyHSD(aov(rating\ type + country, data = beers), which = "country")$. Does this result agree with the significance you have in the ANOVA output in Q4-b?

```r
TukeyHSD(aov(rating~type+country,data=beers), which="country")
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = rating ~ type + country, data = beers)
##
## $country
##                   diff        lwr       upr     p adj
## UK-Belgium  -0.1183333 -0.5025658 0.2658992 0.7317529
## USA-Belgium  0.1216667 -0.2625658 0.5058992 0.7189598
## USA-UK       0.2400000 -0.1442325 0.6242325 0.2884605
```

Comments: All 3 of the confidence intervals include the null hypothesis(0) which indicates that we fail to reject the null. Therefore we can conclude that there is no difference in treatment means among 3 levels. This result is the same with what we have found from the ANOVA output in Q4b.