final_project_419

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11/24/2021

Library

```
library(DataExplorer)
```

```
## Warning: package 'DataExplorer' was built under R version 4.1.2
```

```
library(MASS)
```

Approach: Remove point 8 and Treat Speed as numeric and Box-cox

- Treat Speed as numeric
- Transformation of response

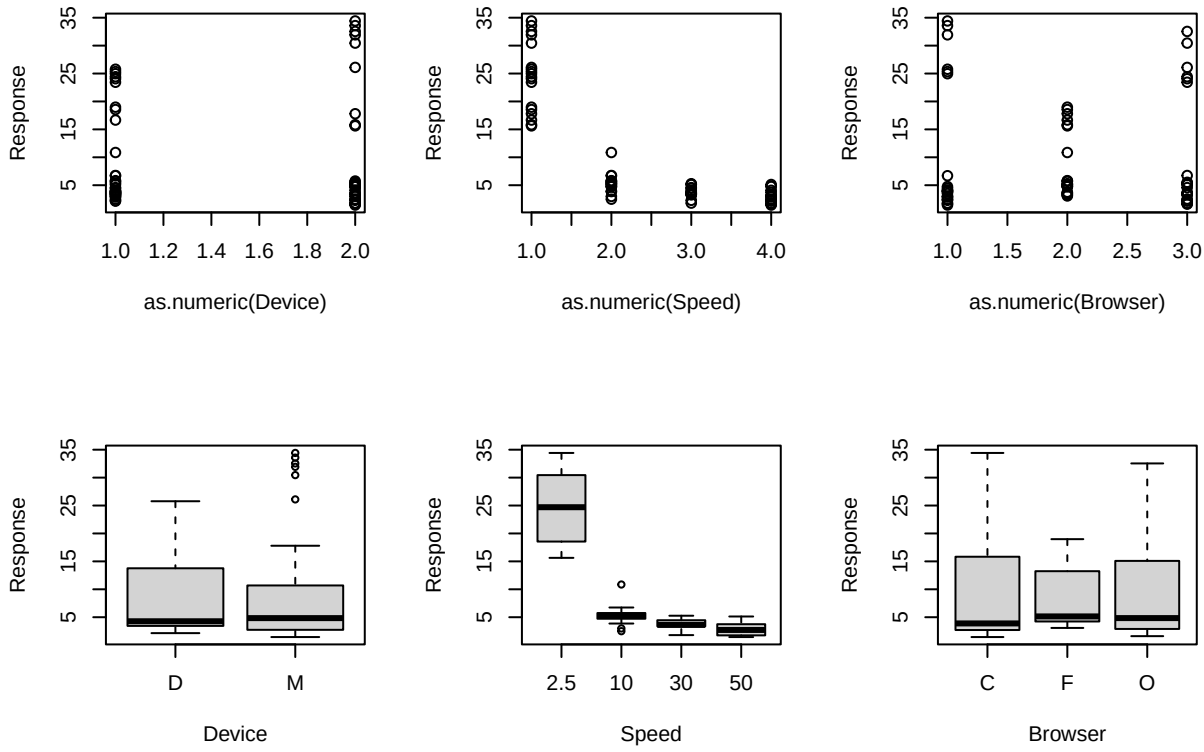
1. Import the data and clean the data set to fit into the model

```
df = read.csv("df.csv")

# Do initial Analysis and fit model
Response = c(df$Replicate.1,df$Replicate.2,df$Replicate.3)

# Change Speed to original speed numbers
df$Speed_f=as.factor(df$Speed)

df$Speed[df$Speed_f==1]=50
df$Speed[df$Speed_f==2]=30
df$Speed[df$Speed_f==3]=10
df$Speed[df$Speed_f==4]=2.5

# Save variables as a factor
df$Speed = as.factor(df$Speed)
df$Device = as.factor(df$Device)
df$Browser = as.factor(df$Browser)

# Reshape the df
new_df =
data.frame(Device = rep(df$Device,3),
```

```
Speed = rep(df$Speed,3),
Browser = rep(df$Browser,3),
Response,
replicate = as.factor(c(rep(1,24),rep(2,24),rep(3,24))))
```

1.1 EDA

```
# Create eda hmtl
# create_report(df)

# Create plots
par(mfrow=c(2,3))
plot(data= new_df, Response~ as.numeric(Device) + as.numeric(Speed)+as.numeric(Browser))
plot(data= new_df, Response~ (Device) + (Speed)+(Browser))
```



2. Fit into the model and Check the model with the model Assumptions and Tukey

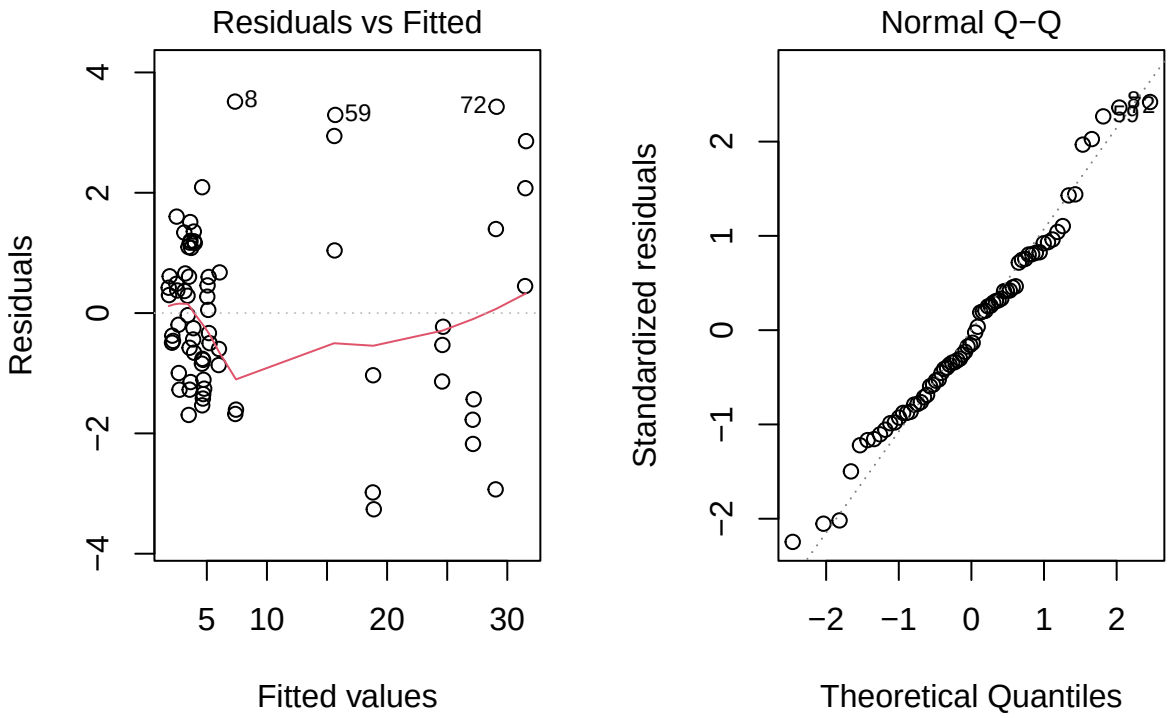
```
# Create a linear model with two way interaction effects
m1 <-lm(data=new_df, Response~(Device + Speed + Browser)^2 + replicate)
summary(m1)
```

```
##
## Call:
## lm(formula = Response ~ (Device + Speed + Browser)^2 + replicate,
##     data = new_df)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.2615 -1.0528 -0.2109  1.0512  3.5149
##
## Coefficients:
##                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)       27.12306    0.90071  30.113  < 2e-16 ***
## DeviceM            4.35889    0.98668   4.418 5.08e-05 ***
## Speed10          -22.51500    1.13932 -19.762  < 2e-16 ***
## Speed30          -24.00167    1.13932 -21.067  < 2e-16 ***
## Speed50          -24.65889    1.13932 -21.644  < 2e-16 ***
## BrowserF         -11.51625    1.10314 -10.440 2.30e-14 ***
## BrowserO          -2.54542    1.10314  -2.307 0.025044 *
## replicate2         0.02250    0.49334   0.046 0.963798
## replicate3         0.08000    0.49334   0.162 0.871808
## DeviceM:Speed10   -5.40000    1.13932  -4.740 1.70e-05 ***
## DeviceM:Speed30   -3.98667    1.13932  -3.499 0.000966 ***
## DeviceM:Speed50   -4.17889    1.13932  -3.668 0.000576 ***
## DeviceM:BrowserF  -1.15417    0.98668  -1.170 0.247436
## DeviceM:BrowserO   0.09417    0.98668   0.095 0.924334
## Speed10:BrowserF  14.25333    1.39538  10.215 4.97e-14 ***
## Speed30:BrowserF  13.09167    1.39538   9.382 8.97e-13 ***
## Speed50:BrowserF  13.64333    1.39538   9.778 2.25e-13 ***
## Speed10:BrowserO   3.92167    1.39538   2.810 0.006958 **
## Speed30:BrowserO   2.81667    1.39538   2.019 0.048703 *
## Speed50:BrowserO   1.91000    1.39538   1.369 0.176944
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.709 on 52 degrees of freedom
## Multiple R-squared:  0.9765, Adjusted R-squared:  0.968
## F-statistic: 113.9 on 19 and 52 DF,  p-value: < 2.2e-16
```

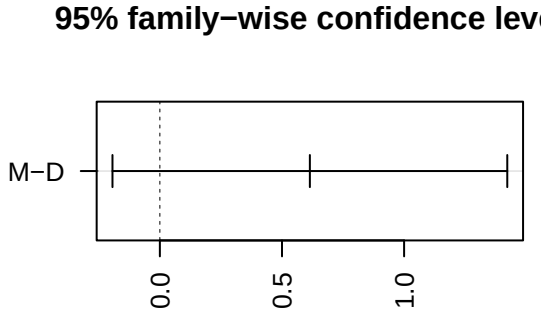
```
anova(m1)
```

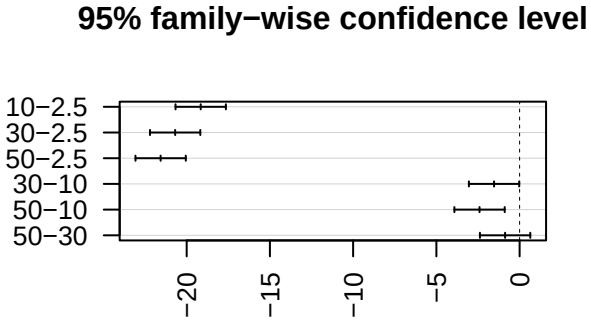
```
## Analysis of Variance Table
##
## Response: Response
##                Df Sum Sq Mean Sq  F value    Pr(>F)
## Device          1    6.8    6.79   2.3247 0.1333922
## Speed           3 5710.8 1903.59 651.7780 < 2.2e-16 ***
## Browser         2   46.4   23.21   7.9460 0.0009745 ***
## replicate       2    0.1    0.04   0.0140 0.9861143
## Device:Speed    3   74.3   24.77   8.4797 0.0001104 ***
## Device:Browser  2    5.8    2.90   0.9927 0.3774856
## Speed:Browser   6  474.9   79.15  27.1020 2.187e-14 ***
## Residuals      52  151.9    2.92
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

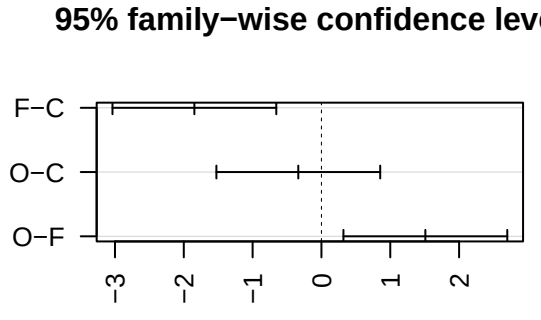
```
par(mfrow=c(1,2))
plot(m1,c(1,2))
```

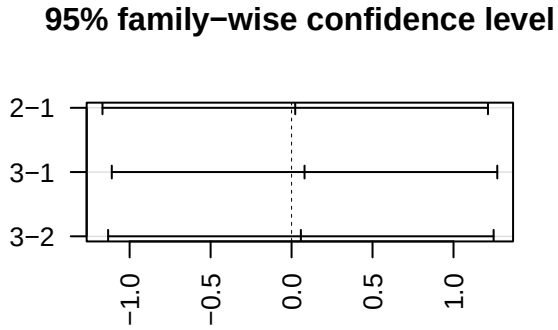



```
par(mfrow=c(2,2))
plot(TukeyHSD(aov(m1)),las=2)
```









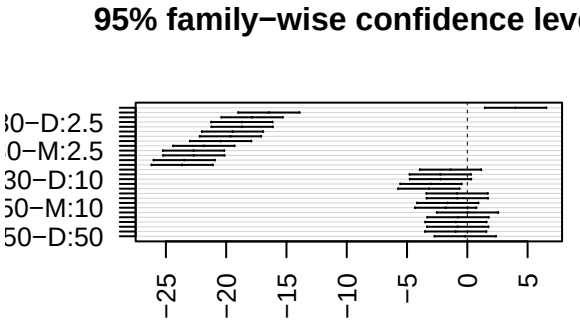

```
TukeyHSD(aov(m1))
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = m1)
##
## $Device
##          diff        lwr      upr     p adj
## M-D 0.6141667 -0.1941313 1.422465 0.1333922
##
## $Speed
##               diff        lwr          upr     p adj
## 10-2.5 -19.1566667 -20.668600 -17.64473339 0.0000000
## 30-2.5 -20.6922222 -22.204155 -19.18028895 0.0000000
## 50-2.5 -21.5638889 -23.075822 -20.05195561 0.0000000
## 30-10   -1.5355556  -3.047489  -0.02362228 0.0452395
## 50-10   -2.4072222  -3.919155  -0.89528895 0.0005442
## 50-30   -0.8716667  -2.383600   0.64026661 0.4272319
##
## $Browser
##         diff        lwr        upr     p adj
## F-C -1.84625 -3.0364793 -0.6560207 0.0013069
## O-C -0.33625 -1.5264793  0.8539793 0.7752172
## O-F  1.51000  0.3197707  2.7002293 0.0096095
```

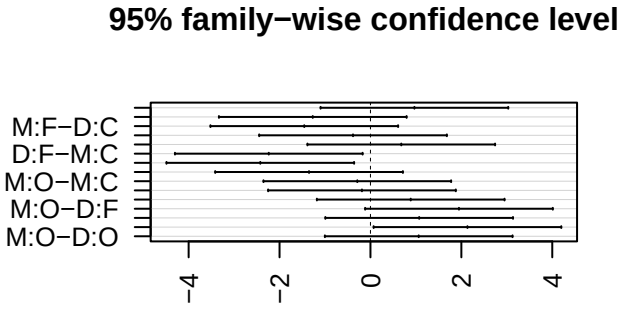
```
##
## $replicate
##       diff       lwr      upr     p adj
## 2-1 0.0225 -1.167729 1.212729 0.9988539
## 3-1 0.0800 -1.110229 1.270229 0.9856117
## 3-2 0.0575 -1.132729 1.247729 0.9925397
##
## $`Device:Speed`
##                      diff        lwr         upr     p adj
## M:2.5-D:2.5   4.00555556   1.461810   6.5493015 0.0001942
## D:10-D:2.5  -16.45666667 -19.000413 -13.9129208 0.0000000
## M:10-D:2.5  -17.85111111 -20.394857 -15.3073652 0.0000000
## D:30-D:2.5  -18.69888889 -21.242635 -16.1551430 0.0000000
## M:30-D:2.5  -18.68000000 -21.223746 -16.1362541 0.0000000
## D:50-D:2.5  -19.47444444 -22.018190 -16.9306985 0.0000000
## M:50-D:2.5  -19.64777778 -22.191524 -17.1040319 0.0000000
## D:10-M:2.5  -20.46222222 -23.005968 -17.9184763 0.0000000
## M:10-M:2.5  -21.85666667 -24.400413 -19.3129208 0.0000000
## D:30-M:2.5  -22.70444444 -25.248190 -20.1606985 0.0000000
## M:30-M:2.5  -22.68555556 -25.229301 -20.1418096 0.0000000
## D:50-M:2.5  -23.48000000 -26.023746 -20.9362541 0.0000000
## M:50-M:2.5  -23.65333333 -26.197079 -21.1095874 0.0000000
## M:10-D:10    -1.39444444  -3.938190   1.1493015 0.6675788
## D:30-D:10    -2.24222222  -4.785968   0.3015237 0.1216793
## M:30-D:10    -2.22333333  -4.767079   0.3204126 0.1281090
## D:50-D:10    -3.01777778  -5.561524  -0.4740319 0.0099469
## M:50-D:10    -3.19111111  -5.734857  -0.6473652 0.0052260
## D:30-M:10    -0.84777778  -3.391524   1.6959681 0.9636007
## M:30-M:10    -0.82888889  -3.372635   1.7148570 0.9677688
## D:50-M:10    -1.62333333  -4.167079   0.9204126 0.4821241
## M:50-M:10    -1.79666667  -4.340413   0.7470792 0.3514285
## M:30-D:30     0.01888889  -2.524857   2.5626348 1.0000000
## D:50-D:30    -0.77555556  -3.319301   1.7681904 0.9776717
## M:50-D:30    -0.94888889  -3.492635   1.5948570 0.9346661
## D:50-M:30    -0.79444444  -3.338190   1.7493015 0.9744656
## M:50-M:30    -0.96777778  -3.511524   1.5759681 0.9279356
## M:50-D:50    -0.17333333  -2.717079   2.3704126 0.9999988
##
## $`Device:Browser`
##                diff         lwr        upr     p adj
## M:C-D:C   0.9675000 -1.09667912  3.0316791 0.7346401
## D:F-D:C  -1.2691667 -3.33334578  0.7950124 0.4628240
## M:F-D:C  -1.4558333 -3.52001245  0.6083458 0.3101399
## D:O-D:C  -0.3833333 -2.44751245  1.6808458 0.9937241
## M:O-D:C   0.6783333 -1.38584578  2.7425124 0.9246500
## D:F-M:C  -2.2366667 -4.30084578 -0.1724876 0.0264498
## M:F-M:C  -2.4233333 -4.48751245 -0.3591542 0.0126633
## D:O-M:C  -1.3508333 -3.41501245  0.7133458 0.3925184
## M:O-M:C  -0.2891667 -2.35334578  1.7750124 0.9983437
## M:F-D:F  -0.1866667 -2.25084578  1.8775124 0.9998028
## D:O-D:F   0.8858333 -1.17834578  2.9500124 0.7998618
## M:O-D:F   1.9475000 -0.11667912  4.0116791 0.0748945
## D:O-M:F   1.0725000 -0.99167912  3.1366791 0.6423285
## M:O-M:F   2.1341667  0.06998755  4.1983458 0.0388256
```

```
## M:O-D:O  1.0616667 -1.00251245  3.1258458 0.6521451
##
## $`Speed:Browser`
##                       diff         lwr         upr     p adj
## 10:C-2.5:C  -25.21500000 -28.5902039 -21.8397961 0.0000000
## 30:C-2.5:C  -25.99500000 -29.3702039 -22.6197961 0.0000000
## 50:C-2.5:C  -26.74833333 -30.1235372 -23.3731295 0.0000000
## 2.5:F-2.5:C -12.09333333 -15.4685372  -8.7181295 0.0000000
## 10:F-2.5:C  -23.05500000 -26.4302039 -19.6797961 0.0000000
## 30:F-2.5:C  -24.99666667 -28.3718705 -21.6214628 0.0000000
## 50:F-2.5:C  -25.19833333 -28.5735372 -21.8231295 0.0000000
## 2.5:O-2.5:C  -2.49833333  -5.8735372   0.8768705 0.3440631
## 10:O-2.5:C  -23.79166667 -27.1668705 -20.4164628 0.0000000
## 30:O-2.5:C  -25.67666667 -29.0518705 -22.3014628 0.0000000
## 50:O-2.5:C  -27.33666667 -30.7118705 -23.9614628 0.0000000
## 30:C-10:C    -0.78000000  -4.1552039   2.5952039 0.9996548
## 50:C-10:C    -1.53333333  -4.9085372   1.8418705 0.9173533
## 2.5:F-10:C   13.12166667   9.7464628  16.4968705 0.0000000
## 10:F-10:C     2.16000000  -1.2152039   5.5352039 0.5644195
## 30:F-10:C     0.21833333  -3.1568705   3.5935372 1.0000000
## 50:F-10:C     0.01666667  -3.3585372   3.3918705 1.0000000
## 2.5:O-10:C   22.71666667  19.3414628  26.0918705 0.0000000
## 10:O-10:C     1.42333333  -1.9518705   4.7985372 0.9489270
## 30:O-10:C    -0.46166667  -3.8368705   2.9135372 0.9999982
## 50:O-10:C    -2.12166667  -5.4968705   1.2535372 0.5908681
## 50:C-30:C    -0.75333333  -4.1285372   2.6218705 0.9997523
## 2.5:F-30:C   13.90166667  10.5264628  17.2768705 0.0000000
## 10:F-30:C     2.94000000  -0.4352039   6.3152039 0.1442546
## 30:F-30:C     0.99833333  -2.3768705   4.3735372 0.9967405
## 50:F-30:C     0.79666667  -2.5785372   4.1718705 0.9995784
## 2.5:O-30:C   23.49666667  20.1214628  26.8718705 0.0000000
## 10:O-30:C     2.20333333  -1.1718705   5.5785372 0.5345643
## 30:O-30:C     0.31833333  -3.0568705   3.6935372 1.0000000
## 50:O-30:C    -1.34166667  -4.7168705   2.0335372 0.9660606
## 2.5:F-50:C   14.65500000  11.2797961  18.0302039 0.0000000
## 10:F-50:C     3.69333333   0.3181295   7.0685372 0.0208243
## 30:F-50:C     1.75166667  -1.6235372   5.1268705 0.8234652
## 50:F-50:C     1.55000000  -1.8252039   4.9252039 0.9116590
## 2.5:O-50:C   24.25000000  20.8747961  27.6252039 0.0000000
## 10:O-50:C     2.95666667  -0.4185372   6.3318705 0.1389905
## 30:O-50:C     1.07166667  -2.3035372   4.4468705 0.9940501
## 50:O-50:C    -0.58833333  -3.9635372   2.7868705 0.9999784
## 10:F-2.5:F  -10.96166667 -14.3368705  -7.5864628 0.0000000
## 30:F-2.5:F  -12.90333333 -16.2785372  -9.5281295 0.0000000
## 50:F-2.5:F  -13.10500000 -16.4802039  -9.7297961 0.0000000
## 2.5:O-2.5:F   9.59500000   6.2197961  12.9702039 0.0000000
## 10:O-2.5:F  -11.69833333 -15.0735372  -8.3231295 0.0000000
## 30:O-2.5:F  -13.58333333 -16.9585372 -10.2081295 0.0000000
## 50:O-2.5:F  -15.24333333 -18.6185372 -11.8681295 0.0000000
## 30:F-10:F    -1.94166667  -5.3168705   1.4335372 0.7118160
## 50:F-10:F    -2.14333333  -5.5185372   1.2318705 0.5759221
## 2.5:O-10:F   20.55666667  17.1814628  23.9318705 0.0000000
## 10:O-10:F    -0.73666667  -4.1118705   2.6385372 0.9998003
## 30:O-10:F    -2.62166667  -5.9968705   0.7535372 0.2764044
```

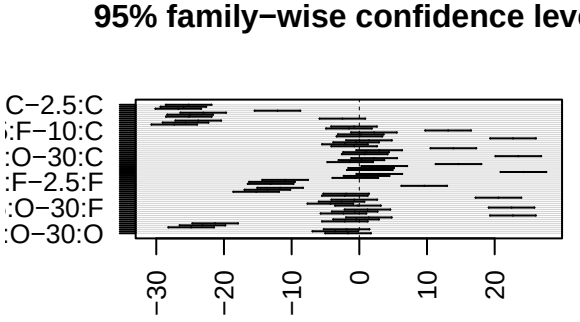
```
## 50:0-10:F    -4.28166667  -7.6568705  -0.9064628 0.0034716
## 50:F-30:F    -0.20166667  -3.5768705   3.1735372 1.0000000
## 2.5:0-30:F   22.49833333  19.1231295  25.8735372 0.0000000
## 10:0-30:F     1.20500000  -2.1702039   4.5802039 0.9847214
## 30:0-30:F    -0.68000000  -4.0552039   2.6952039 0.9999084
## 50:0-30:F    -2.34000000  -5.7152039   1.0352039 0.4424759
## 2.5:0-50:F   22.70000000  19.3247961  26.0752039 0.0000000
## 10:0-50:F     1.40666667  -1.9685372   4.7818705 0.9528368
## 30:0-50:F    -0.47833333  -3.8535372   2.8968705 0.9999974
## 50:0-50:F    -2.13833333  -5.5135372   1.2368705 0.5793725
## 10:0-2.5:0  -21.29333333 -24.6685372 -17.9181295 0.0000000
## 30:0-2.5:0  -23.17833333 -26.5535372 -19.8031295 0.0000000
## 50:0-2.5:0  -24.83833333 -28.2135372 -21.4631295 0.0000000
## 30:0-10:0    -1.88500000  -5.2602039   1.4902039 0.7474358
## 50:0-10:0    -3.54500000  -6.9202039  -0.1697961 0.0316242
## 50:0-30:0    -1.66000000  -5.0352039   1.7152039 0.8679064
```



Differences in mean levels of Device:Speed



Differences in mean levels of Device:Browser

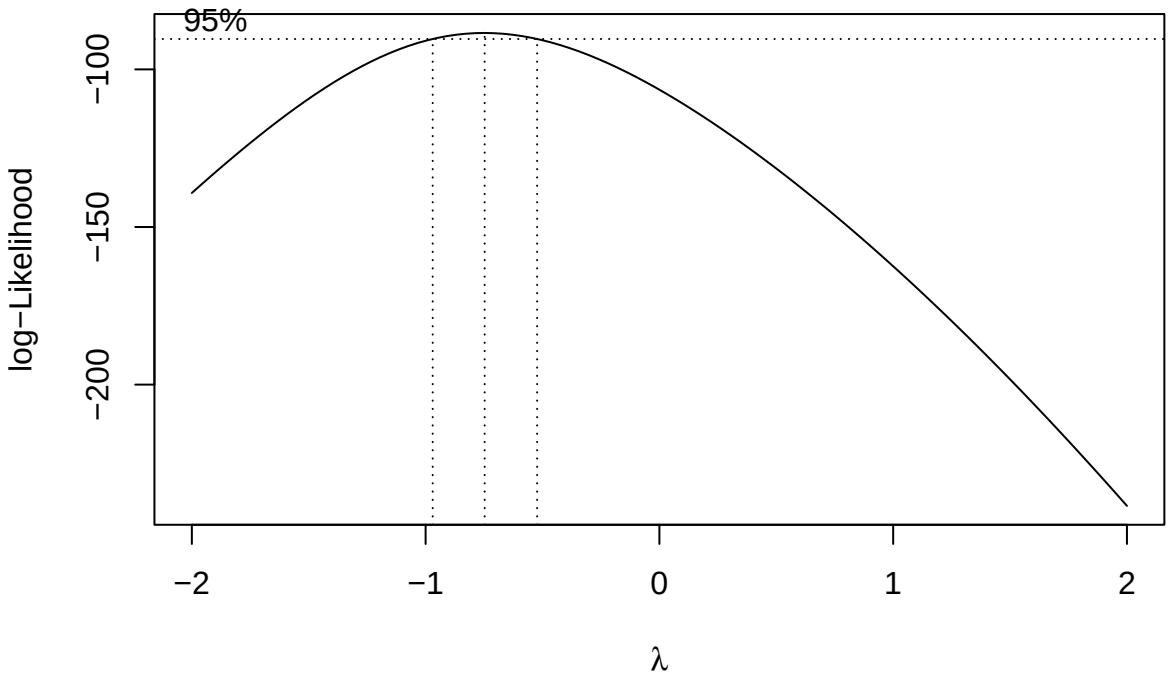


Differences in mean levels of Speed:Browser

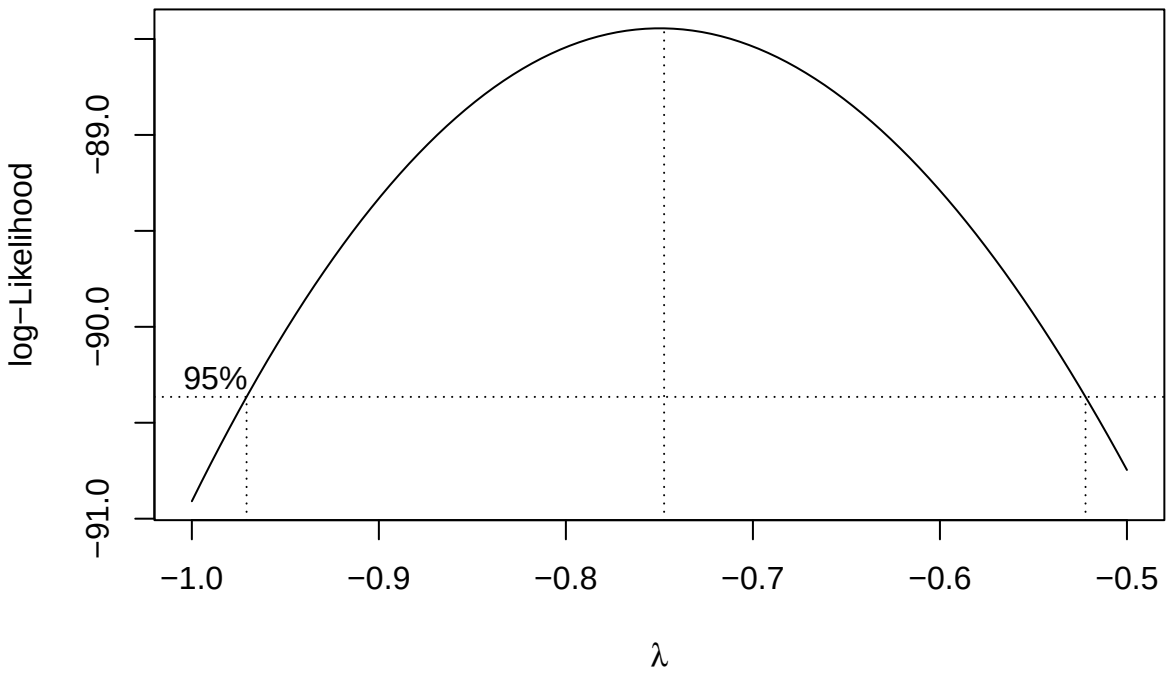
3. Boxcox Transformation

```
# Delete outlier
new_df_8_deleted <- new_df[-8,]

new_df_8_deleted$Speed <- as.numeric(as.character(new_df_8_deleted$Speed))
m1.1 <-lm(data=new_df_8_deleted, Response~(Device + Speed + Browser)^2 + replicate)
```

```r
# To see the exact best lambda:
lmod1_bc <- boxcox(m1.1)
```




```r
# Zoom in to select an easier to intepretate lambda
boxcox(m1.1, plotit=T, lambda = seq(-1, -0.5, by=0.1))
```




```
lambda <- lmod1_bc$x[which.max(lmod1_bc$y)]

# lambda is -0.747474747474747
paste0("lambda is ",lambda)
```

```
## [1] "lambda is -0.747474747474747"
```

```
# We will select a cleaner lambda for intepretation as -0.7
lambda <- -0.7
new_df_8_deleted['Response_t'] <- (new_df_8_deleted$Response^lambda - 1) / lambda
```

3.1 Fit the model after transformation and

```
m2 <-lm(data=new_df_8_deleted, Response_t~(Device + Speed + Browser)^2 + replicate)
summary(m2)
```

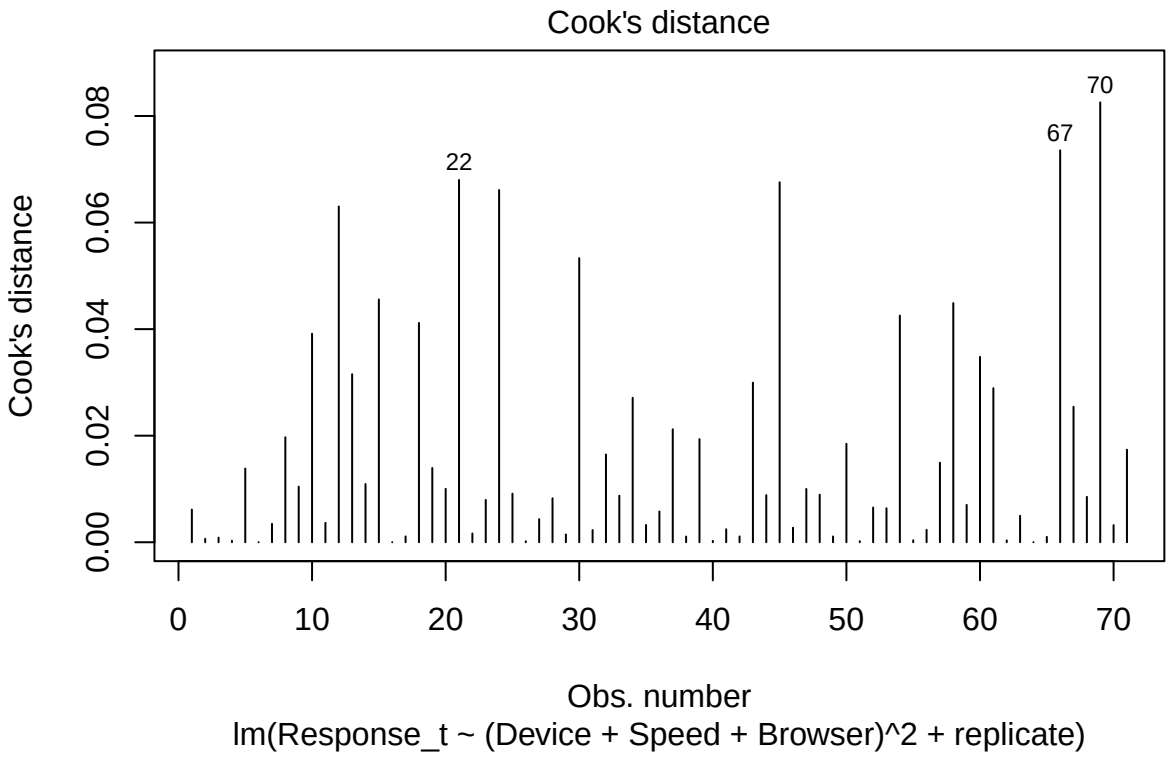
```
##
## Call:
## lm(formula = Response_t ~ (Device + Speed + Browser)^2 + replicate,
##     data = new_df_8_deleted)
##
## Residuals:
```

```
##       Min        1Q    Median        3Q       Max
## -0.285818 -0.079701 -0.004034  0.085380  0.253185
##
## Coefficients:
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)       1.216009   0.059070  20.586  < 2e-16 ***
## DeviceM          -0.112954   0.066623  -1.695  0.09527 .
## Speed            -0.010304   0.001686  -6.111 8.45e-08 ***
## BrowserF         -0.116709   0.074017  -1.577  0.12019
## BrowserO          0.035285   0.072006   0.490  0.62593
## replicate2        0.005479   0.038598   0.142  0.88761
## replicate3       -0.016579   0.038598  -0.430  0.66909
## DeviceM:Speed    -0.002127   0.001691  -1.257  0.21355
## DeviceM:BrowserF  0.218293   0.077195   2.828  0.00639 **
## DeviceM:BrowserO  0.103918   0.076278   1.362  0.17826
## Speed:BrowserF    0.005190   0.002075   2.500  0.01520 *
## Speed:BrowserO   -0.002781   0.002063  -1.348  0.18275
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1321 on 59 degrees of freedom
## Multiple R-squared:  0.7677, Adjusted R-squared:  0.7244
## F-statistic: 17.73 on 11 and 59 DF,  p-value: 7.403e-15
```

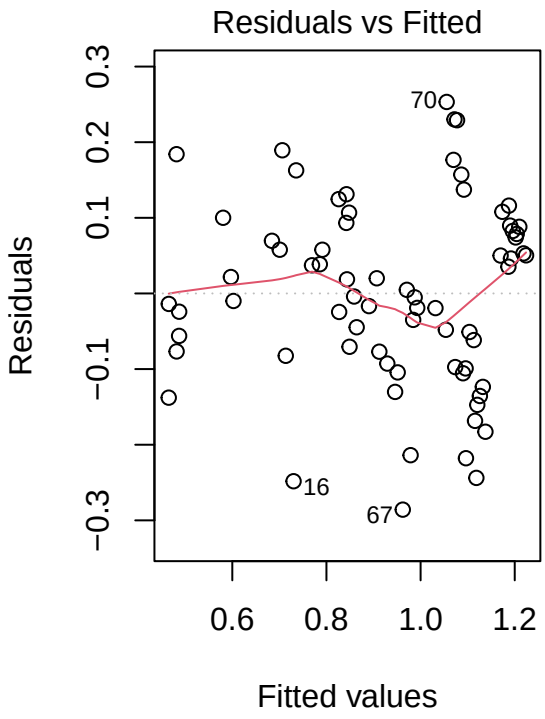
```
anova(m2)
```

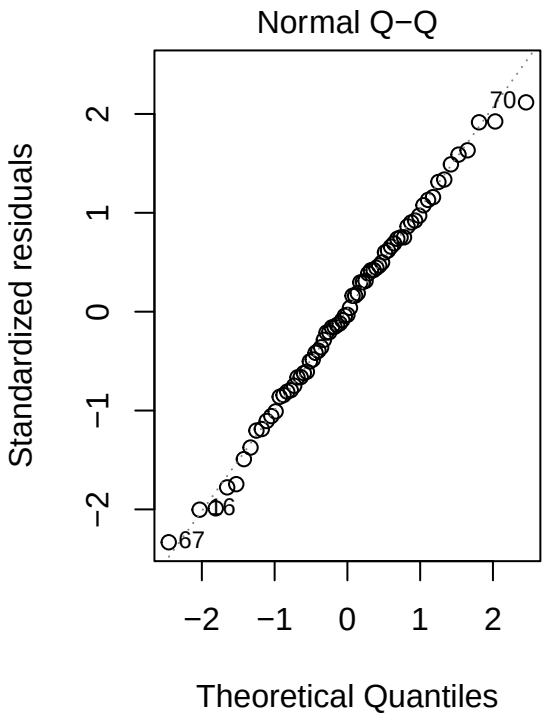
```
## Analysis of Variance Table
##
## Response: Response_t
##                Df  Sum Sq Mean Sq  F value    Pr(>F)
## Device          1 0.04866 0.04866   2.7880  0.100273
## Speed           1 2.74277 2.74277 157.1355 < 2.2e-16 ***
## Browser         2 0.18243 0.09121   5.2257  0.008138 **
## replicate       2 0.00784 0.00392   0.2247  0.799430
## Device:Speed    1 0.02425 0.02425   1.3893  0.243250
## Device:Browser  2 0.13270 0.06635   3.8013  0.027999 *
## Speed:Browser   2 0.26472 0.13236   7.5831  0.001172 **
## Residuals      59 1.02983 0.01745
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# Cook's distance
par(mfrow=c(1,1))
plot(m2,4)
```

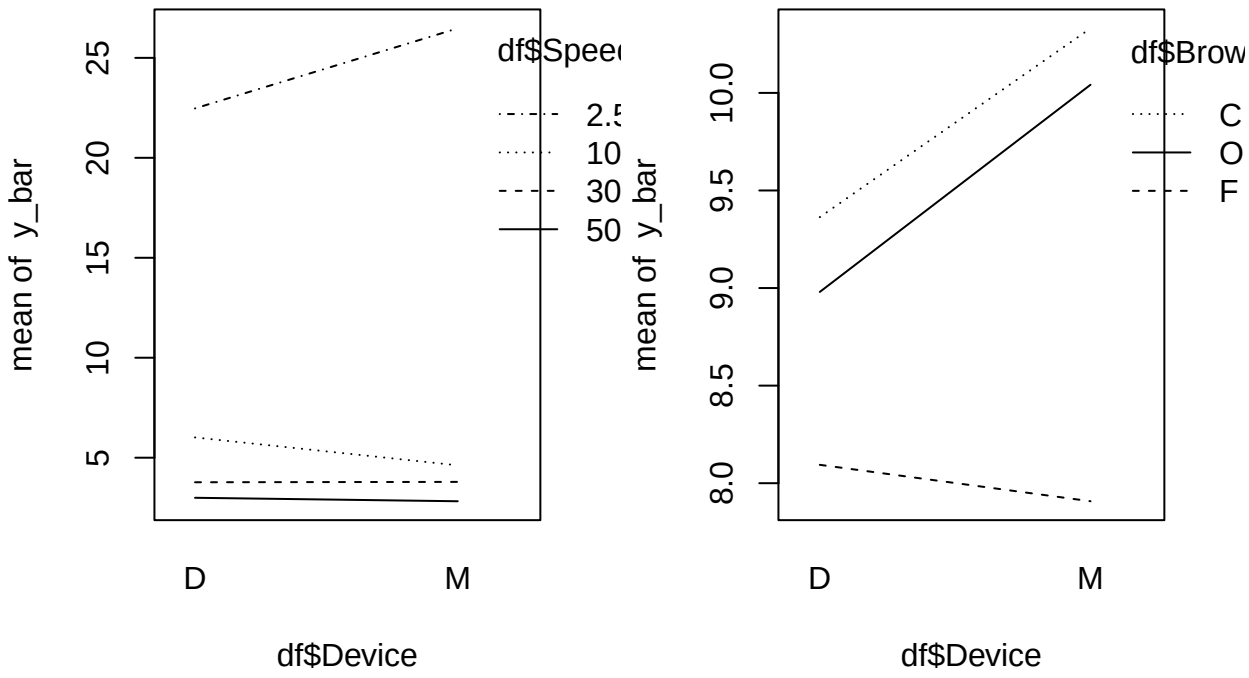



```
# Residual vs Fitted
par(mfrow=c(1,2))
plot(m2,c(1,2))
```

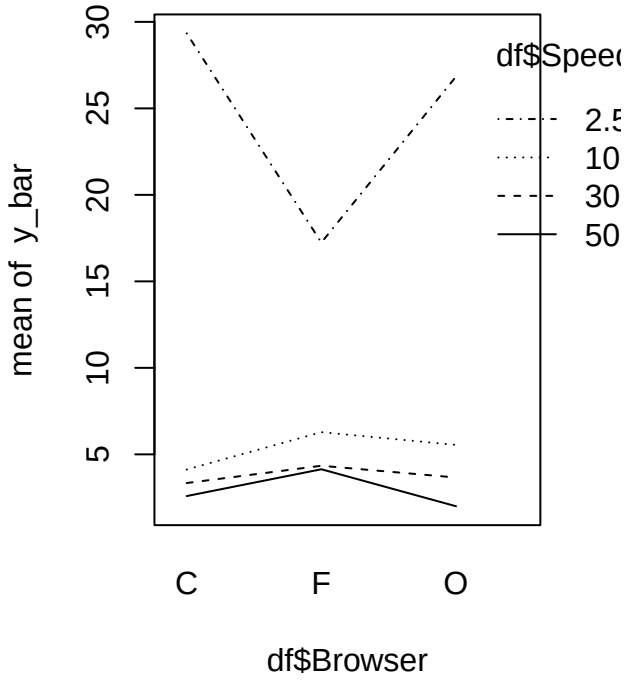





```
# Interaction plots
y_bar = (df$Replicate.1 + df$Replicate.2 + df$Replicate.3)/3
interaction.plot(df$Device, df$Speed, y_bar)
interaction.plot(df$Device, df$Browser, y_bar)
```




```
interaction.plot(df$Browser, df$Speed, y_bar)
```


mean of y_bar
30
25
20
15
10
5
C
F
O
df$Browser
df$Speed
2.5
10
30
50