Data File Used in this Analysis:

```
# Math 3080 - 1       Leather Data              March 8, 2010
# Treibergs
#
#  Devore "Probability and Statistics for Engineering and the Sciences, 5th,"
# From "The Abrasion of Leather," (J. Inter. Soc. Leather Trades Chemists 1946)
# An investigation on how moisture affects wear in different positions in a
# rectangular pattern. This is 6 x 6 (x 6) Latin Square
#  A = row position
#  B = column position
#  C = treatment(1= 25%, 2 = 37%, 3 = 50%, 4 = 62%, 5 = 75%, 6 = 87%)rel humid
#  Y = wear
#
"A" "B" "C" "Y"
1 1 3 7.38
1 2 4 5.39
1 3 6 5.03
1 4 2 5.50
1 5 5 5.01
1 6 1 6.79
2 1 2 7.15
2 2 1 8.16
2 3 5 4.96
2 4 4 5.78
2 5 3 6.24
2 6 6 5.06
3 1 4 6.75
3 2 6 5.64
3 3 3 6.34
3 4 5 5.31
3 5 1 7.81
3 6 2 8.05
4 1 1 8.05
4 2 3 6.45
4 3 2 6.31
4 4 6 5.46
4 5 4 6.05
4 6 5 5.51
5 1 6 5.65
5 2 5 5.44
5 3 1 7.27
5 4 3 6.54
5 5 2 7.03
5 6 4 5.96
6 1 5 6.00
6 2 2 6.55
6 3 4 5.93
6 4 1 8.02
```

```
6 5 6 5.80
6 6 3 6.61
```

R Session:

```
R version 2.10.1 (2009-12-14)
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  Natural language support but running in an English locale

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Type 'q()' to quit R.

[R.app GUI 1.31 (5538) powerpc-apple-darwin8.11.1]

[Workspace restored from /Users/andrejstreibergs/.RData]

> tt <- read.table("M3081DataLeather.txt",header=TRUE)
> tt
   A B C    Y
1  1 1 3 7.38
2  1 2 4 5.39
3  1 3 6 5.03
4  1 4 2 5.50
5  1 5 5 5.01
6  1 6 1 6.79
7  2 1 2 7.15
8  2 2 1 8.16
9  2 3 5 4.96
10 2 4 4 5.78
11 2 5 3 6.24
12 2 6 6 5.06
13 3 1 4 6.75
14 3 2 6 5.64
15 3 3 3 6.34
16 3 4 5 5.31
17 3 5 1 7.81
18 3 6 2 8.05
19 4 1 1 8.05
20 4 2 3 6.45
21 4 3 2 6.31
```
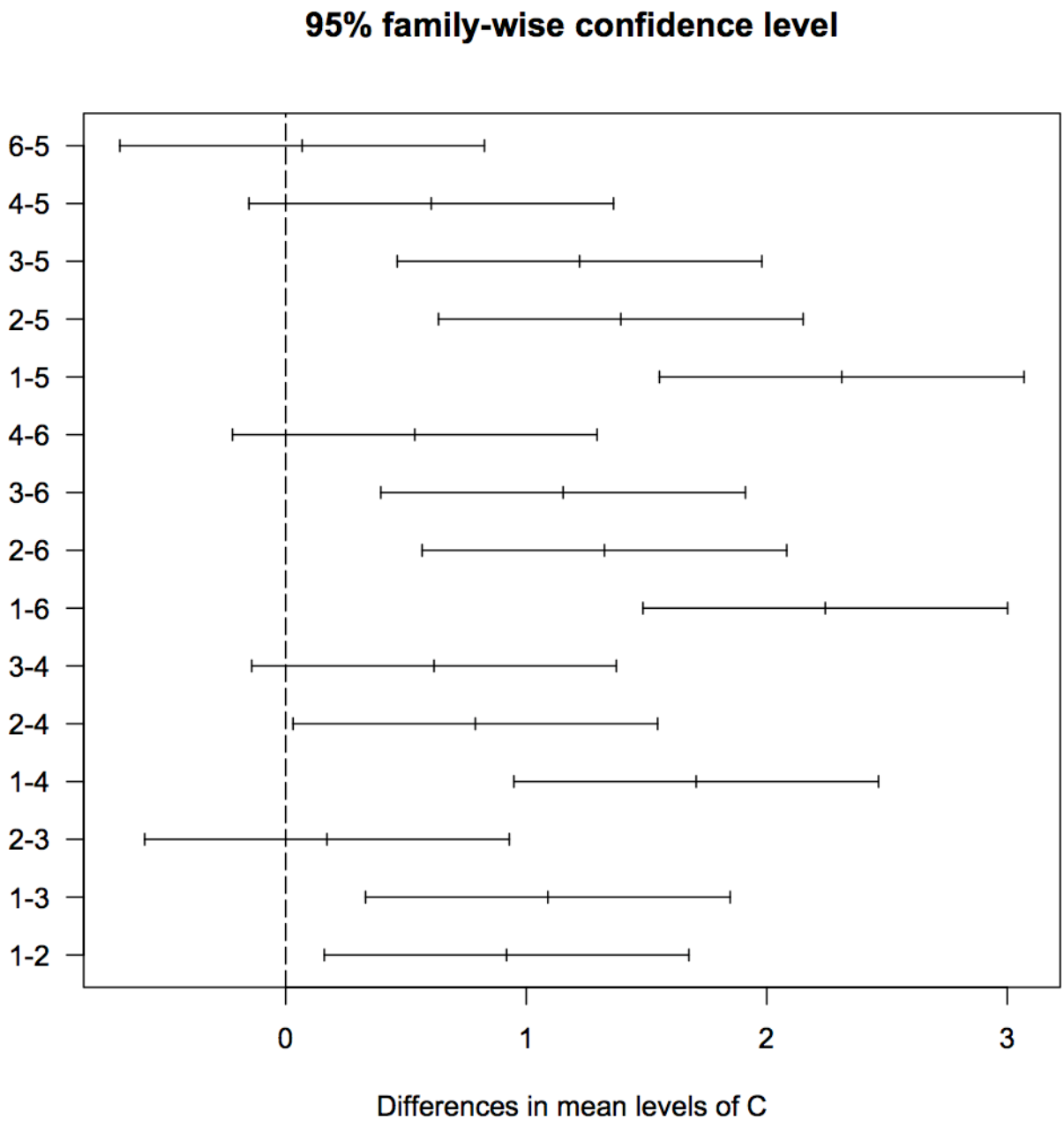

```
22 4 4 6 5.46
23 4 5 4 6.05
24 4 6 5 5.51
25 5 1 6 5.65
26 5 2 5 5.44
27 5 3 1 7.27
28 5 4 3 6.54
29 5 5 2 7.03
30 5 6 4 5.96
31 6 1 5 6.00
32 6 2 2 6.55
33 6 3 4 5.93
34 6 4 1 8.02
35 6 5 6 5.80
36 6 6 3 6.61
> attach(tt)

>#==============RANDOM LATIN SQUARE USED HERE FOR TREATMENT C============
> xtabs(C~A+B)
   B
A   1 2 3 4 5 6
  1 3 4 6 2 5 1
  2 2 1 5 4 3 6
  3 4 6 3 5 1 2
  4 1 3 2 6 4 5
  5 6 5 1 3 2 4
  6 5 2 4 1 6 3

> A <- factor(A)
> B <- factor(B)
> C <- factor(C)

>#============================DATA BY ROW AND COLUMN====================
> xtabs(Y~A+B)
   B
A      1    2    3    4    5    6
  1 7.38 5.39 5.03 5.50 5.01 6.79
  2 7.15 8.16 4.96 5.78 6.24 5.06
  3 6.75 5.64 6.34 5.31 7.81 8.05
  4 8.05 6.45 6.31 5.46 6.05 5.51
  5 5.65 5.44 7.27 6.54 7.03 5.96
  6 6.00 6.55 5.93 8.02 5.80 6.61
```

```
>#==================================RUN ANOVA============================
> f1 <- aov( Y~A+B+C);anova(f1)
Analysis of Variance Table

Response: Y
          Df  Sum Sq Mean Sq F value   Pr(>F)
A          5  2.1897  0.4379  2.5106  0.06407 .
B          5  2.5743  0.5149  2.9516  0.03731 *
C          5 23.5301  4.7060 26.9789 3.03e-08 ***
Residuals 20  3.4887  0.1744
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

>#==============================SUMMARIZE MEANS==========================
> tapply(Y,C,summary)
$`1`
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  6.790   7.405   7.915   7.683   8.042   8.160

$`2`
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  5.500   6.370   6.790   6.765   7.120   8.050

$`3`
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  6.240   6.368   6.495   6.593   6.592   7.380

$`4`
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  5.390   5.818   5.945   5.977   6.028   6.750

$`5`
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  4.960   5.085   5.375   5.372   5.493   6.000

$`6`
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  5.030   5.160   5.550   5.440   5.648   5.800
```

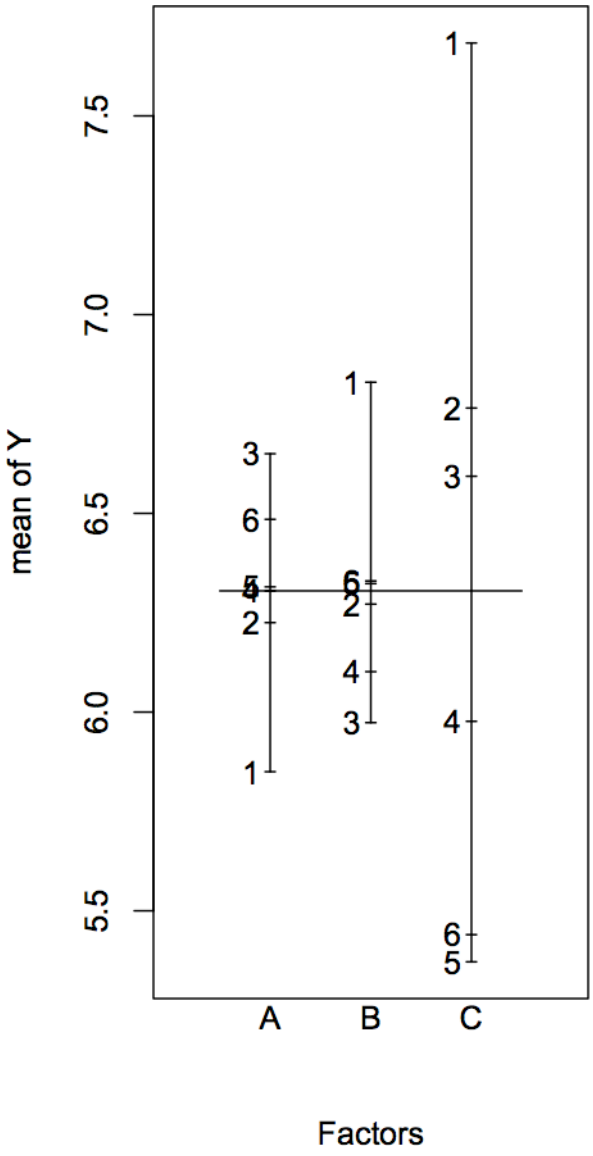
```
> model.tables(f1, "means", se=TRUE)
Tables of means
Grand mean

6.305

 A
A
    1     2     3     4     5     6
5.850 6.225 6.650 6.305 6.315 6.485

 B
B
    1     2     3     4     5     6
6.830 6.272 5.973 6.102 6.323 6.330

 C
C
    1     2     3     4     5     6
7.683 6.765 6.593 5.977 5.372 5.440

Standard errors for differences of means
             A      B      C
        0.2411 0.2411 0.2411
replic.      6      6      6



> model.tables(f1, "effects", se=TRUE)
Tables of effects

A
     1      2      3      4      5      6
-0.455 -0.080  0.345  0.000  0.010  0.180

B
      1       2       3       4       5       6
 0.5250 -0.0333 -0.3317 -0.2033  0.0183  0.0250

C
      1       2       3       4       5       6
 1.3783  0.4600  0.2883 -0.3283 -0.9333 -0.8650

Standard errors of effects
             A      B      C
        0.1705 0.1705 0.1705
replic.      6      6      6
>
```

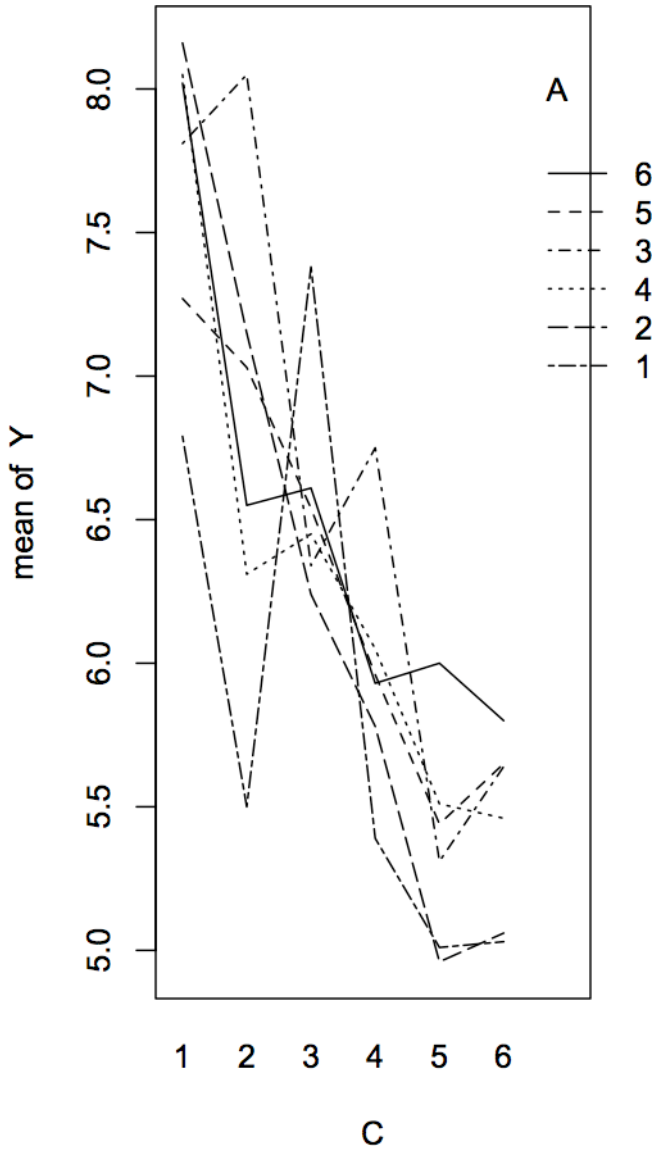
```
>#============================TUKEY HSD=============================
> sort(tapply(Y,C,mean))
       5        6        4        3        2        1
5.371667 5.440000 5.976667 6.593333 6.765000 7.683333

> TukeyHSD(f1,which="C",ordered=TRUE)
  Tukey multiple comparisons of means
    95% family-wise confidence level
    factor levels have been ordered

Fit: aov(formula = Y ~ A + B + C)

$C
          diff         lwr       upr     p adj
6-5 0.06833333 -0.68960522 0.8262719 0.9997113
4-5 0.60500000 -0.15293855 1.3629386 0.1683501
3-5 1.22166667  0.46372811 1.9796052 0.0007299
2-5 1.39333333  0.63539478 2.1512719 0.0001513
1-5 2.31166667  1.55372811 3.0696052 0.0000001
4-6 0.53666667 -0.22127189 1.2946052 0.2697646
3-6 1.15333333  0.39539478 1.9112719 0.0013767
2-6 1.32500000  0.56706145 2.0829386 0.0002818
1-6 2.24333333  1.48539478 3.0012719 0.0000001
3-4 0.61666667 -0.14127189 1.3746052 0.1545364
2-4 0.78833333  0.03039478 1.5462719 0.0385446
1-4 1.70666667  0.94872811 2.4646052 0.0000097
2-3 0.17166667 -0.58627189 0.9296052 0.9782473
1-3 1.09000000  0.33206145 1.8479386 0.0024825
1-2 0.91833333  0.16039478 1.6762719 0.0121211

>#=========================TUKEY HSD BY HAND==========================
> sort(tapply(Y,C,mean))
       5        6        4        3        2        1
5.371667 5.440000 5.976667 6.593333 6.765000 7.683333

> Q <- qtukey(.95,6,20)
> Q
[1] 4.445237
> HSD <- Q*sqrt(0.1744/6);HSD
[1] 0.7578661

>#=============HSD INTERVALS ABOUT THE MEANS============================
> sort(tapply(Y,C,mean))-HSD;sort(tapply(Y,C,mean));sort(tapply(Y,C,mean))+HSD
       5        6        4        3        2        1
4.613801 4.682134 5.218801 5.835467 6.007134 6.925467
       5        6        4        3        2        1
5.371667 5.440000 5.976667 6.593333 6.765000 7.683333
       5        6        4        3        2        1
6.129533 6.197866 6.734533 7.351199 7.522866 8.441199
```

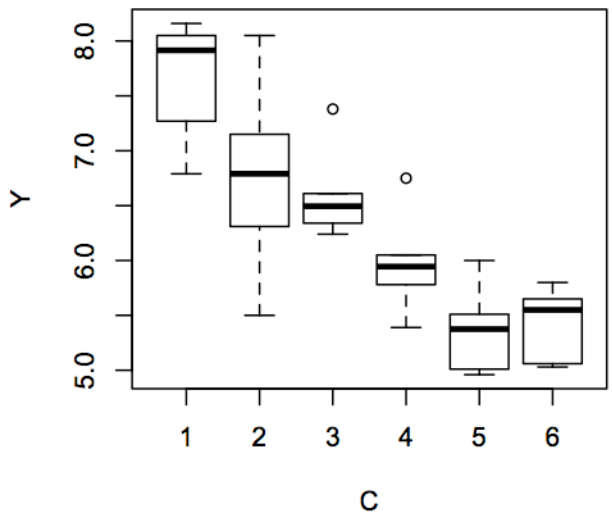
```
>#============================PLOT TUKEY HSD==========================
> par(las=1)
> plot(TukeyHSD(f1,which="C",ordered=TRUE))
> abline(v=0,lty=5)
```

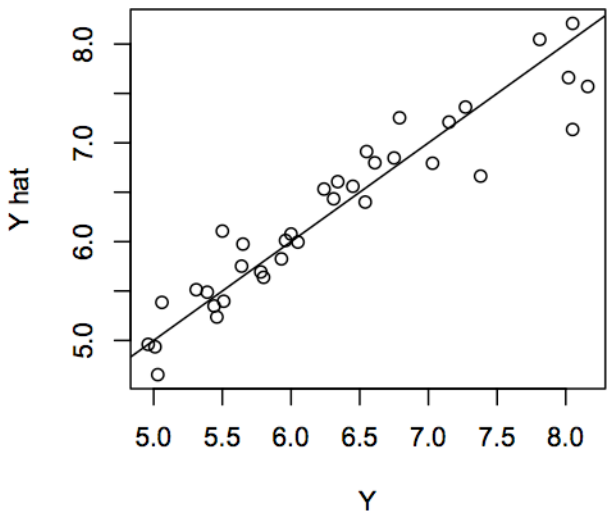


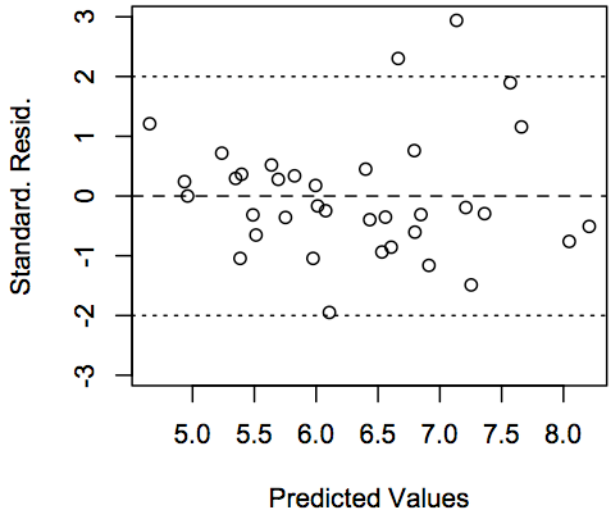
```
>#====================================PLOT DESIGN AND INTERACTION========
> par(las=0)
> layout(matrix(1:2,ncol=2))
> plot.design(data.frame(A,B,C,Y))
> interaction.plot(C,A,Y)

>#============================PLOT DIAGNOSTICS============================
> layout(matrix(1:4,ncol=2))
> plot(Y~C)
> plot(rstandard(f1)~fitted(f1),xlab="Predicted Values",ylab="Standard. Resid.",
  ylim=max(abs(rstandard(f1)))*c(-1,1));abline(h=c(0,-2,2),lty=c(2,3,3))
> plot(fitted(f1)~Y,ylab="Y hat");abline(0,1)
> qqnorm(rstandard(f1),ylab="Standard. Resid.",
  ylim=max(abs(rstandard(f1)))*c(-1,1));abline(h=c(0,-2,2),lty=c(2,3,3));abline(0,1)


>#============================SHAPIRO-WILK TEST FOR NORMALITY OF RESID.=====
> shapiro.test(rstandard(f1))

Shapiro-Wilk normality test

data:  rstandard(f1)
W = 0.9462, p-value = 0.07926

>
```

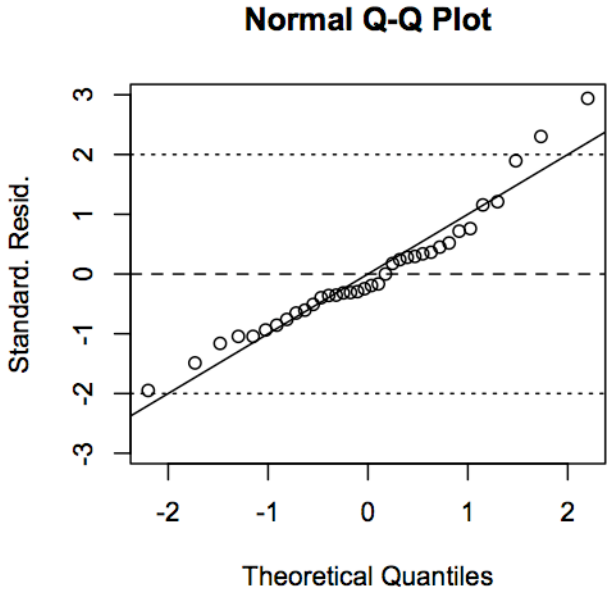

mean of Y
7.5
7.0
6.5
6.0
5.5
A
B
C
Factors


mean of Y
8.0
7.5
7.0
6.5
6.0
5.5
5.0
A
6
5
3
4
2
1
1 2 3 4 5 6
C


Y
5.0
6.0
7.0
8.0
1
2
3
4
5
6
C


Y hat
5.0
6.0
7.0
8.0
5.0
5.5
6.0
6.5
7.0
7.5
8.0
Y


Standard. Resid.
-3
-2
-1
0
1
2
3
5.0
5.5
6.0
6.5
7.0
7.5
8.0
Predicted Values


Normal Q-Q Plot
Standard. Resid.
-3
-2
-1
0
1
2
3
-2
-1
0
1
2
Theoretical Quantiles