Math 3080 § 1.	**Rail Data: One-Way**	Name: Example
Treibergs	**Random Effects ANOVA**	March 29, 2010

Data File Used in this Analysis:

```
# Math 3080 - 1        Track Data       March 25, 2010
#
# From Devore :"Probability and Statistics for Engineering
# and the Sciences, 5th ed.," (Duxbury 2000)
# Taken from "Zero-Force travel-Time Parameters for Ultrasonic
# Head-Waves in Railroad Rail," (Materials Evaluation 1985)
#
# The study measured certain waves that result from longitudinal
# stress in railroad rails. Three measurements were made on each
# of six rails which were randomly selected from a population of
# rails. The question of interest was whether there is variation
# in travel time among the rails. The experimental design is
# a random effects model in ANOVA to test for variability due to
# the rails "between rail variability."
#
# y + 66.1 = travel time (nanoseconds)
# A = rail
# B = replication
"y" "A" "B"
55  1  1
53  1  2
54  1  3
26  2  1
37  2  2
32  2  3
78  3  1
91  3  2
85  3  3
92  4  1
100 4  2
96  4  3
49  5  1
51  5  2
50  5  3
80  6  1
85  6  2
83  6  3
```

R Session:

```
R version 2.10.1 (2009-12-14)
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```
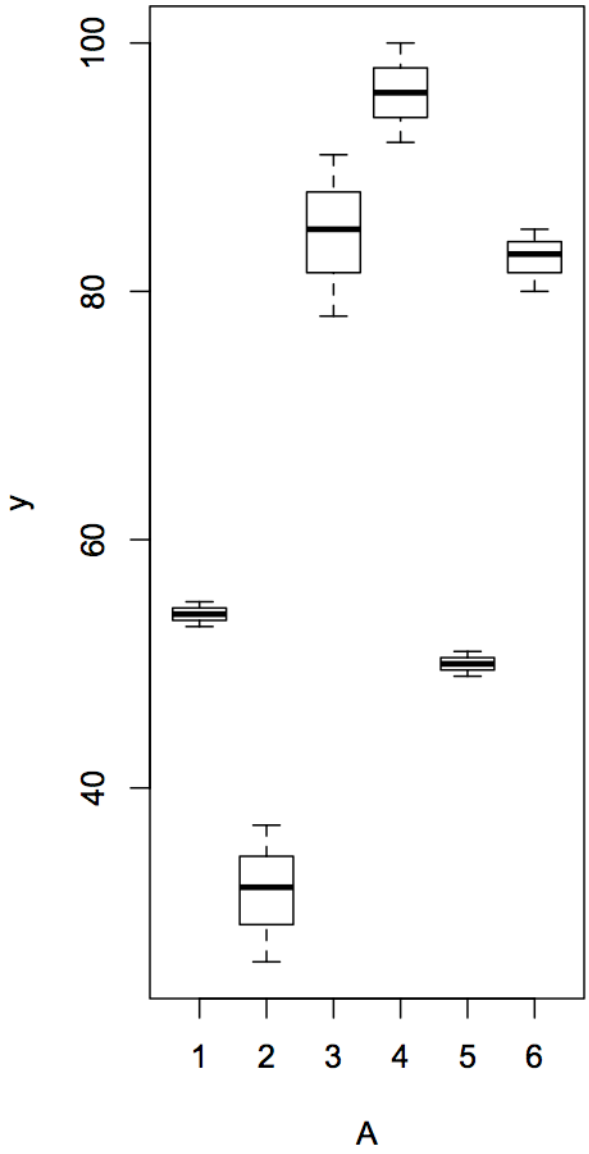
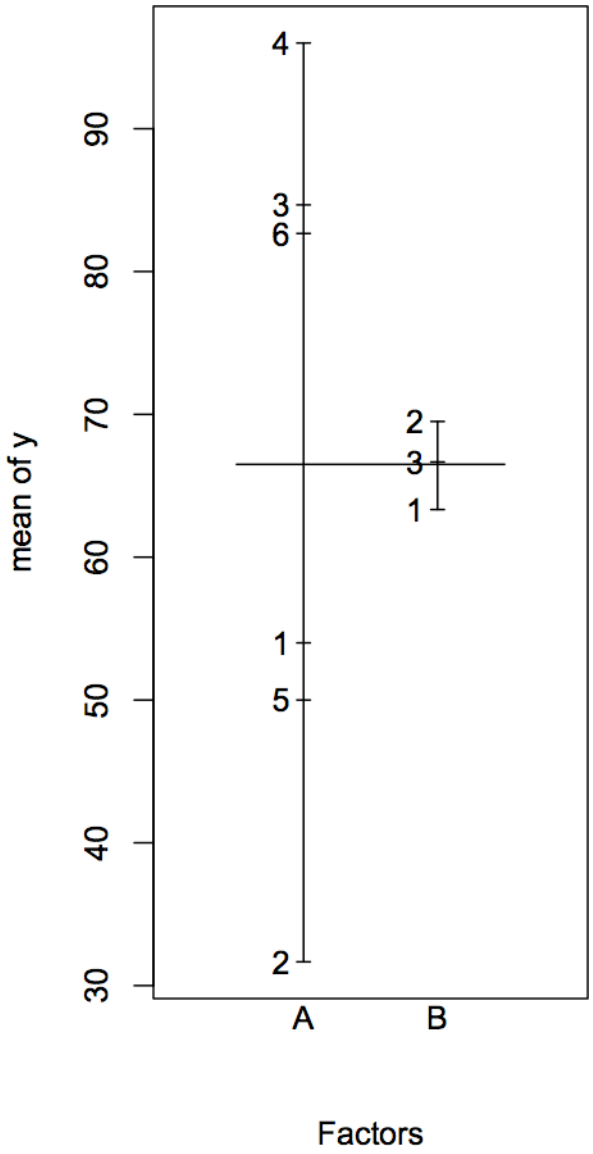
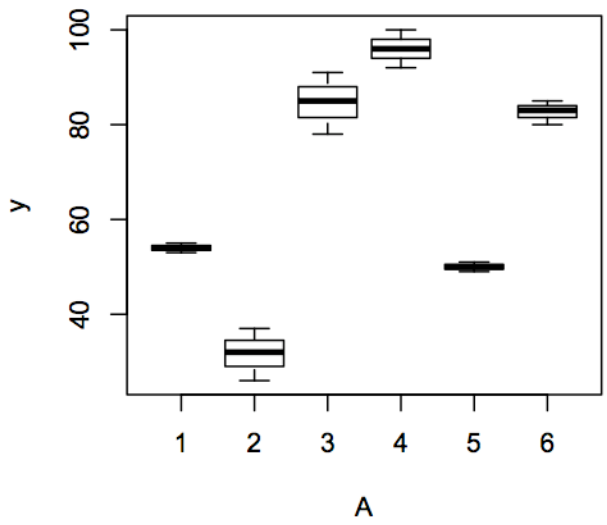

```
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
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("M3081DataRail.txt",header=TRUE)
> tt
     y A B
1   55 1 1
2   53 1 2
3   54 1 3
4   26 2 1
5   37 2 2
6   32 2 3
7   78 3 1
8   91 3 2
9   85 3 3
10  92 4 1
11 100 4 2
12  96 4 3
13  49 5 1
14  51 5 2
15  50 5 3
16  80 6 1
17  85 6 2
18  83 6 3
> attach(tt)
> A <- factor(A)
> B <- factor(B)

>#============================DISPLAY DATA AS MATRIX===============
> xtabs(y~A+B)
   B
A     1   2   3
  1  55  53  54
  2  26  37  32
  3  78  91  85
  4  92 100  96
  5  49  51  50
  6  80  85  83
```

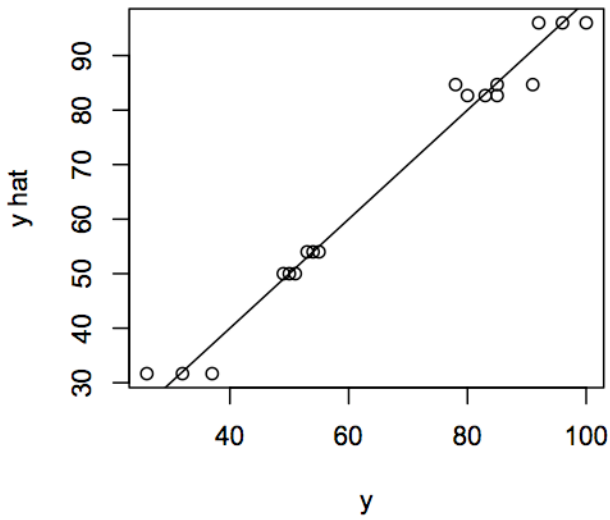
```
>#============================SUMMARY STATISTICS====================
> tapply(y,A,summary)
$`1`
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   53.0    53.5    54.0    54.0    54.5    55.0

$`2`
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  26.00   29.00   32.00   31.67   34.50   37.00

$`3`
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  78.00   81.50   85.00   84.67   88.00   91.00

$`4`
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
     92      94      96      96      98     100

$`5`
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   49.0    49.5    50.0    50.0    50.5    51.0

$`6`
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  80.00   81.50   83.00   82.67   84.00   85.00

> tapply(y,A,mean)
       1        2        3        4        5        6
54.00000 31.66667 84.66667 96.00000 50.00000 82.66667
> tapply(y,A,sd)
       1        2        3        4        5        6
1.000000 5.507571 6.506407 4.000000 1.000000 2.516611


>#==================================PLOT BOXPLOTS AND DESIGN================
> layout(matrix(1:2,ncol=2))
> plot(y~A)
> plot.design(data.frame(y,A,B))


>#==================================RUN ONE-WAY ANOVA=========================

> f2 <- aov(y~A);summary(f2)
            Df Sum Sq Mean Sq F value    Pr(>F)
A            5 9310.5 1862.10  115.18 1.033e-09 ***
Residuals   12  194.0   16.17
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1


>#======================SORT MEANS, TUKEY HSD, PLOT TUKEY HSD===============
```

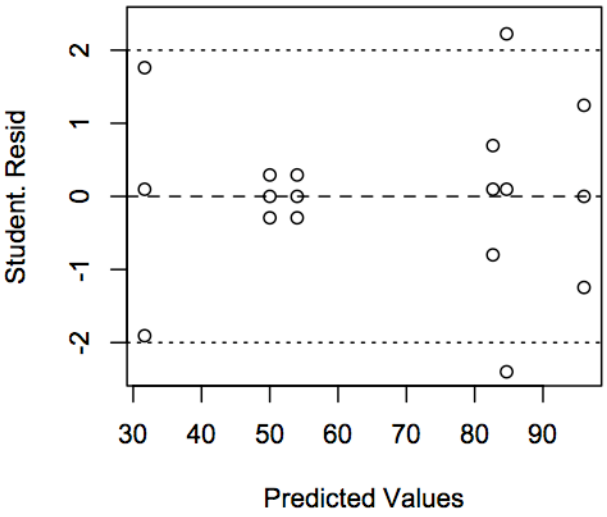
```
> sort(tapply(y,A,mean))
       2        5        1        6        3        4
31.66667 50.00000 54.00000 82.66667 84.66667 96.00000
> TukeyHSD(f2,ordered=TRUE)
  Tukey multiple comparisons of means
    95% family-wise confidence level
    factor levels have been ordered

Fit: aov(formula = y ~ A)

$A
        diff        lwr      upr     p adj
5-2 18.33333  7.3061553 29.36051 0.0012837
1-2 22.33333 11.3061553 33.36051 0.0002129
6-2 51.00000 39.9728220 62.02718 0.0000000
3-2 53.00000 41.9728220 64.02718 0.0000000
4-2 64.33333 53.3061553 75.36051 0.0000000
1-5  4.00000 -7.0271780 15.02718 0.8202141
6-5 32.66667 21.6394887 43.69384 0.0000044
3-5 34.66667 23.6394887 45.69384 0.0000023
4-5 46.00000 34.9728220 57.02718 0.0000001
6-1 28.66667 17.6394887 39.69384 0.0000176
3-1 30.66667 19.6394887 41.69384 0.0000087
4-1 42.00000 30.9728220 53.02718 0.0000003
3-6  2.00000 -9.0271780 13.02718 0.9882413
4-6 13.33333  2.3061553 24.36051 0.0152884
4-3 11.33333  0.3061553 22.36051 0.0427569


> par(las=1)
> plot(TukeyHSD(f2,ordered=TRUE));abline(v=0,lty=6)

>#================================DIAGNOSTIC PLOTS=========================
> par(las=0)
>
> layout(matrix(1:4,ncol=2))
> plot(y~A)
> plot(rstudent(f2)~fitted(f2),xlab="Predicted Values",ylab="Student. Resid",
  ylim=max(abs(rstudent(f2)))*c(-1,1));abline(h=c(0,-2,2),lty=c(2,3,3))
> plot(fitted(f2)~y,ylab="y hat");abline(0,1,lty=1)
> qqnorm(rstudent(f2),ylim=max(abs(rstudent(f2)))*c(-1,1),ylab="Student. Resid.")
> abline(0,1,lty=1);abline(h=c(0,-2,2),lty=c(2,3,3))

>#=========================JUST FOR FUN=====================================
> interaction.plot(A,B,y)
> interaction.plot(B,A,y)
>
```

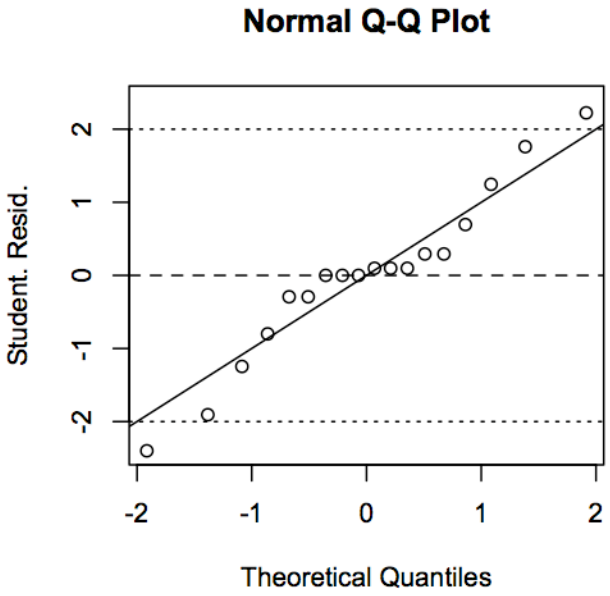

y
100
80
60
40
1
2
3
4
5
6
A

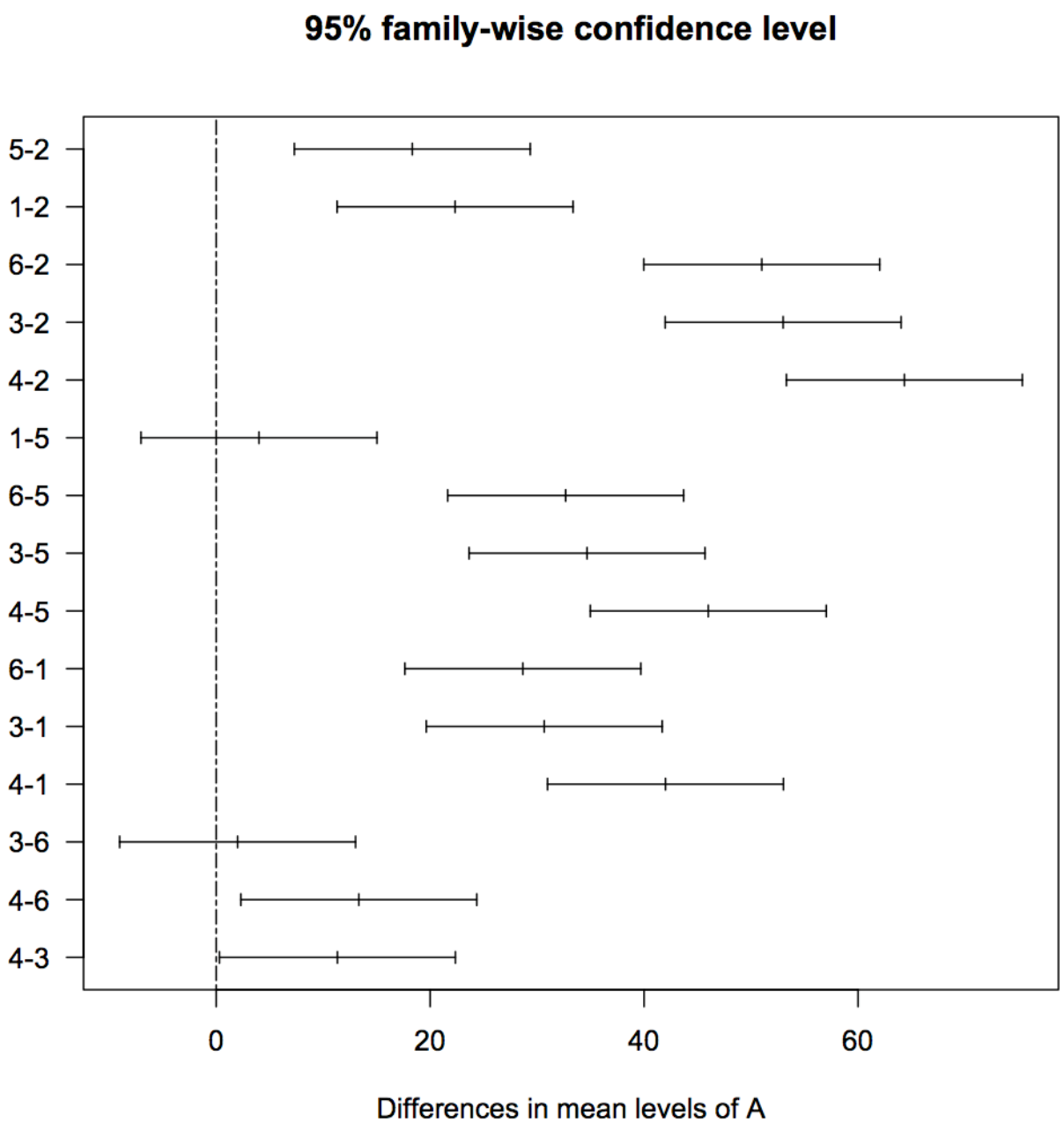

mean of y
90
80
70
60
50
40
30
4
3
6
2
3
1
1
5
2
A
B
Factors


y
40
60
80
100
1
2
3
4
5
6
A


y hat
30
40
50
60
70
80
90
40
60
80
100
y


Student. Resid
-2
-1
0
1
2
30
40
50
60
70
80
90
Predicted Values


Normal Q-Q Plot
Student. Resid.
-2
-1
0
1
2
-2
-1
0
1
2
Theoretical Quantiles


95% family-wise confidence level
5-2
1-2
6-2
3-2
4-2
1-5
6-5
3-5
4-5
6-1
3-1
4-1
3-6
4-6
4-3
0
20
40
60
Differences in mean levels of A