Math 3080 § 1.	**Straw Example:**	Name: Example
Treibergs	**Randomized Block ANOVA**	Jan. 23, 2014

Today's example was motivated from problem 13.11.9 of Walpole, Myers, Myers and Ye, *Probability and Statistics for Engineers and Scientists, 7th ed.*, Prentice Hall 2002. It is an example of a randomized block fixed effects model.

The ANOVA table shows that the effect of diets are very significantly different. The simultaneous confidence intervals show that all of the diets differ significantly at the $\alpha = .05$ level except the control and F diets don't differ significantly The plot of residuals vs. fitted values shows that the variances are fairly uniform. The QQ-normal plot of the standardized residuals follows the 45° line nicely indicating that there is no evidence that normality assumption is violated.

Dunnett's test is similar to the simultaneous CI's for all pairs of differences of means. Except, the only differences being considered are those with the control, namely, $\mathcal{H}_0 : \mu_i - \mu_0 = 0$ for $i = 1, 2, \ldots, k$ where μ_0 is the control. Then the critical value for one or two sided CI's are available. From a table Walpole *et al,* for a two-sided interval with $k = 3$ means other than the control, $J = 6$ blocks (observations per treatment), $\nu = 15$ d.f. for MSE and $\alpha = .05$, $d(3, 6, .05) = 2.24$. The CI takes the form

$$\overline{X_{i\cdot}} - \overline{X_{0\cdot}} - d(\alpha, k, \nu)\sqrt{\frac{2MSE}{J}} \le \mu_i - \mu_0 \le \overline{X_{i\cdot}} - \overline{X_{0\cdot}} + d(\alpha, k, \nu)\sqrt{\frac{2MSE}{J}}$$

Note that Dunnett's test show that only diet A differs significantly from the control.

Data Set Used in this Analysis :

```
# Math 3080 - 1      Straw Data       1-23-14
# Treibergs
#
# From Walpole, Myers, Myers & Ye, "Probability and Statistics for Engineers and
# Scientists," 7th ed., Prentice hall, Upper Saddle River, NJ, 2002, p. 516.
# A Study for VPI Department of Animal Science tried several treatments to
# improve nutrition of sheep. Treatments: control, urea at feeding, ammonia treated straw
# and urea treated straw. The blocks were sheep separated by relative weight.
# The percent dry matter was measured. Use a randomized block ANOVA to test for
# differences in diet.
Diet Weight Percent
C 1 3.268000000e+001
C 2 3.622000000e+001
C 3 3.636000000e+001
C 4 4.095000000e+001
C 5 3.499000000e+001
C 6 3.389000000e+001
F 1 3.590000000e+001
F 2 3.873000000e+001
F 3 3.755000000e+001
F 4 3.464000000e+001
F 5 3.736000000e+001
F 6 3.435000000e+001
A 1 4.943000000e+001
A 2 5.350000000e+001
A 3 5.286000000e+001
```

```
A 4 4.500000000e+001
A 5 4.720000000e+001
A 6 4.976000000e+001
T 1 4.658000000e+001
T 2 4.282000000e+001
T 3 4.541000000e+001
T 4 4.508000000e+001
T 5 4.381000000e+001
T 6 4.740000000e+001
```

R Session:

```
R version 2.14.0 (2011-10-31)
Copyright (C) 2011 The R Foundation for Statistical Computing
ISBN 3-900051-07-0
Platform: i386-apple-darwin9.8.0/i386 (32-bit)

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  Natural language support but running in an English locale

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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 1.42 (5933) i386-apple-darwin9.8.0]

[Workspace restored from /home/1004/ma/treibergs/.RData]
[History restored from /home/1004/ma/treibergs/.Rhistory]

> tt=read.table("M3082DataStraw.txt",header=T)
> tt
   Diet Weight Percent
1     C      1   32.68
2     C      2   36.22
3     C      3   36.36
4     C      4   40.95
5     C      5   34.99
6     C      6   33.89
7     F      1   35.90
8     F      2   38.73
9     F      3   37.55
10    F      4   34.64
11    F      5   37.36
12    F      6   34.35
```
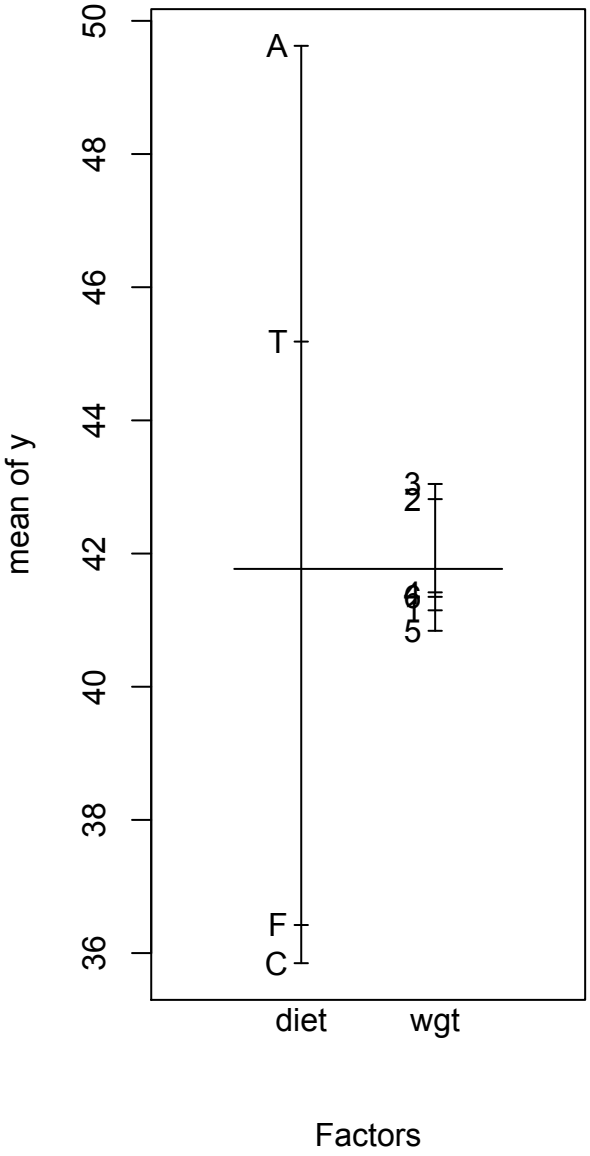
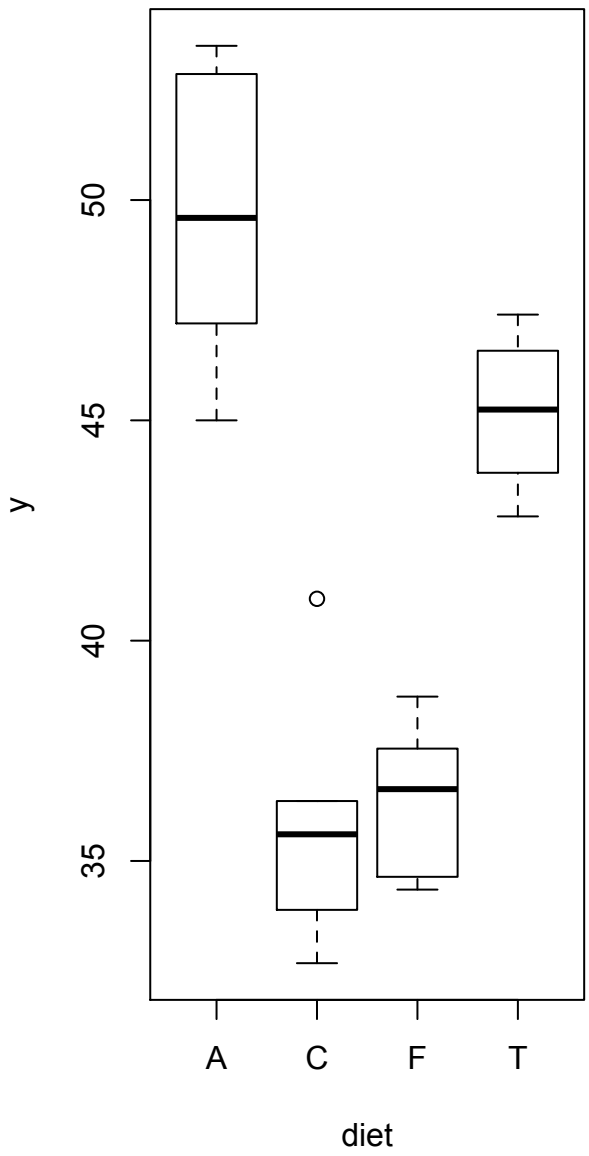
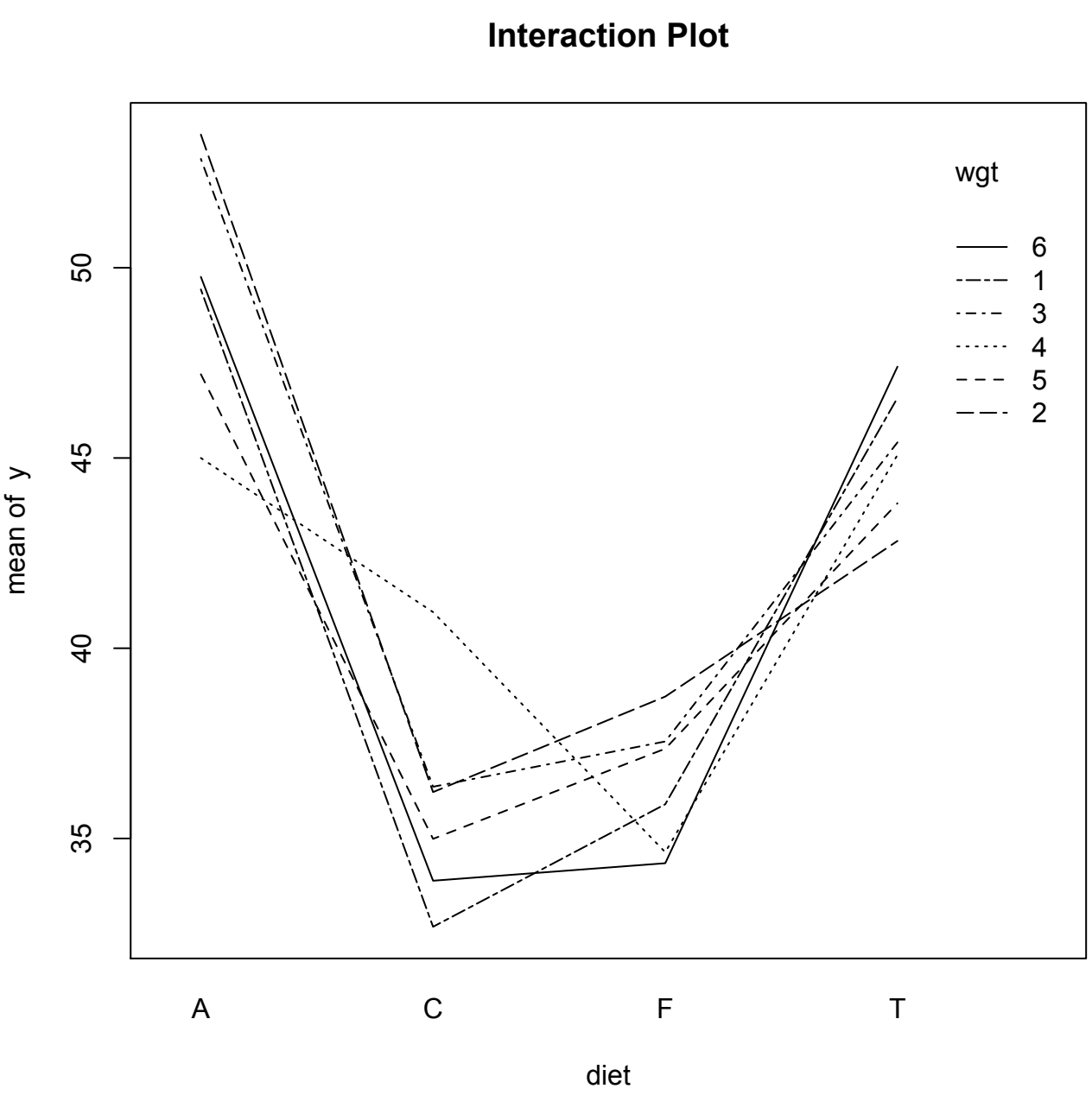

```
13    A      1   49.43
14    A      2   53.50
15    A      3   52.86
16    A      4   45.00
17    A      5   47.20
18    A      6   49.76
19    T      1   46.58
20    T      2   42.82
21    T      3   45.41
22    T      4   45.08
23    T      5   43.81
24    T      6   47.40
> attach(tt)
> diet=factor(Diet); wgt = factor(Weight); y=Percent
> ###################################### DESIGN AND BOX PLOT ####################
>
> layout(matrix(1:2,ncol=2))
> tt2=data.frame(diet,wgt,y); plot.design(tt2)
> plot(y~diet)
>
> ################################## INTERACTION PLOT ############################
> layout(matrix(1,ncol=1))
>
> interaction.plot(diet,wgt,y,main="Interaction Plot")
>
> ######################## RUN ANOVA ###############################################
> t1=aov(y~diet+wgt)
> summary(t1)
            Df Sum Sq Mean Sq F value   Pr(>F)
diet         3  822.1  274.05  38.649 2.69e-07 ***
wgt          5   17.1    3.42   0.482    0.784
Residuals   15  106.4    7.09
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

> print(t1)
Call:
   aov(formula = y ~ diet + wgt)

Terms:
                     diet      wgt Residuals
Sum of Squares  822.1360  17.1038  106.3597
Deg. of Freedom        3        5        15

Residual standard error: 2.662827
Estimated effects may be unbalanced
```

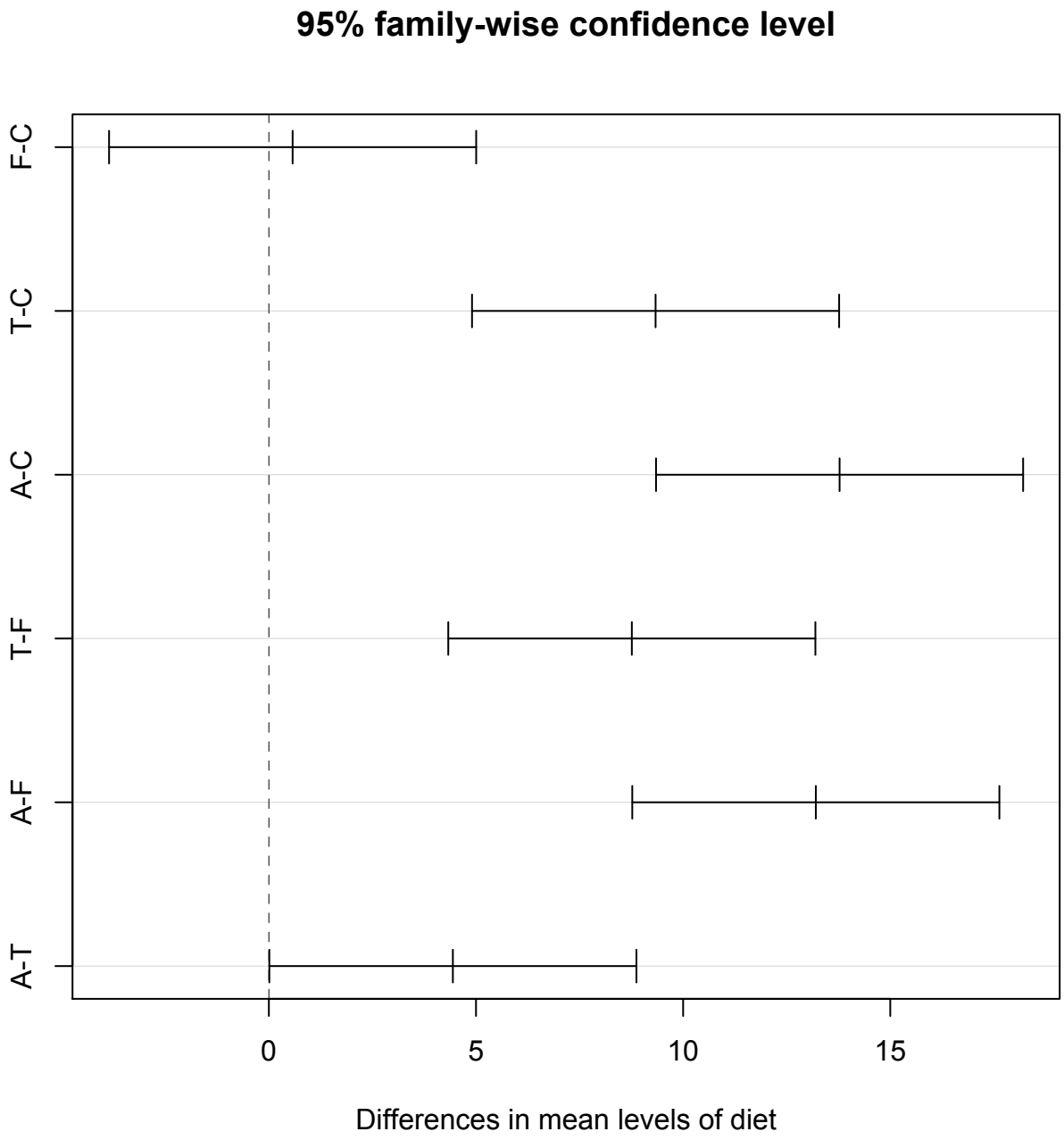
```
> ###################### TUKEY'S SIMULTANEOUS CI ON DIFFERENCES OF MEANS #######
> sort(tapply(y,diet,mean))
       C        F        T        A
35.84833 36.42167 45.18333 49.62500
> t2=TukeyHSD(t1,which="diet",ordered=T)
> plot(t2)
> print(t2)
  Tukey multiple comparisons of means
    95% family-wise confidence level
    factor levels have been ordered

Fit: aov(formula = y ~ diet + wgt)

$diet
          diff        lwr       upr     p adj
F-C  0.5733333 -3.8576348  5.004302 0.9816308
T-C  9.3350000  4.9040318 13.765968 0.0001131
A-C 13.7766667  9.3456985 18.207635 0.0000011
T-F  8.7616667  4.3306985 13.192635 0.0002214
A-F 13.2033333  8.7723652 17.634302 0.0000019
A-T  4.4416667  0.0106985  8.872635 0.0493509
>
> ################### PRINT ESTIMATED EFFECTS AND MEANS ##############################
> model.tables(t1)
Tables of effects

diet
     A      C      F      T
 7.855 -5.921 -5.348  3.414

wgt
      1       2       3       4       5       6
-0.6221  1.0479  1.2754 -0.3521 -0.9296 -0.4196

> model.tables(t1,"means",se=T)
Tables of means
Grand mean

41.76958

diet
    A     C     F     T
49.63 35.85 36.42 45.18

wgt
    1     2     3     4     5     6
41.15 42.82 43.05 41.42 40.84 41.35

Standard errors for differences of means
         diet   wgt
        1.537 1.883
replic.     6     4
```

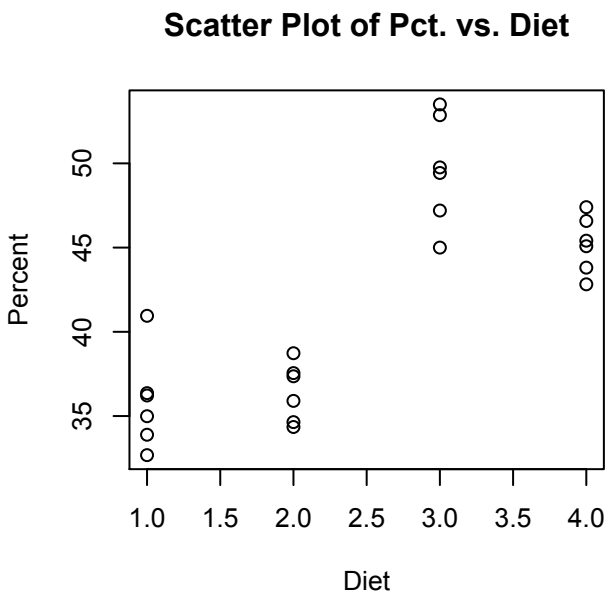
```
> ################################## DIAGNOSTIC PLOTS ################################
> layout(matrix(1:4,ncol=2))
> plot(rep(1:4,each=6),Percent,xlab="Diet",main="Scatter Plot of Pct. vs. Diet")
> plot(rstandard(t1)~fitted(t1),ylab="Standardized Residuals",xlab="Predicted Values",
  ylim=max(abs(rstandard(t1)))*c(-1,1))
> abline(h=c(0,-2,2),lty=c(2,2,3))
> plot(fitted(t1)~y,ylab="y hat");abline(0,1,lty=5)
> qqnorm(rstandard(t1),ylab="Standardized Residuals",
  ylim=max(abs(rstandard(t1)))*c(-1,1));abline(0,1,lty=5)

> ###################### DUNNETT'S TEST FOR DIFFERENCES WITH CONTROL #################
> #
> # Dunnett's comparison to control
>
> MSE=106.3597
> dunn =2.24
> # From table of Critical Values Comparing to Control.for 2-sided .05 sig k=3 nu=15 df
> means=tapply(y,diet,mean)
> means
       A        C        F        T
49.62500 35.84833 36.42167 45.18333
>
> ############## CI for alpha_i -alpha_control  ######################################
> ######### diet=C is the control ###################################################

> means-means[2]-dunn*sqrt(2*MSE/6)
         A           C           F           T
  0.4391203 -13.3375464 -12.7642131  -4.0025464
> means-means[2]+dunn*sqrt(2*MSE/6)
       A        C        F        T
27.11421 13.33755 13.91088 22.67255
>
> ################# Only  alpha_A - alpha_C is significant. ############################
>
```

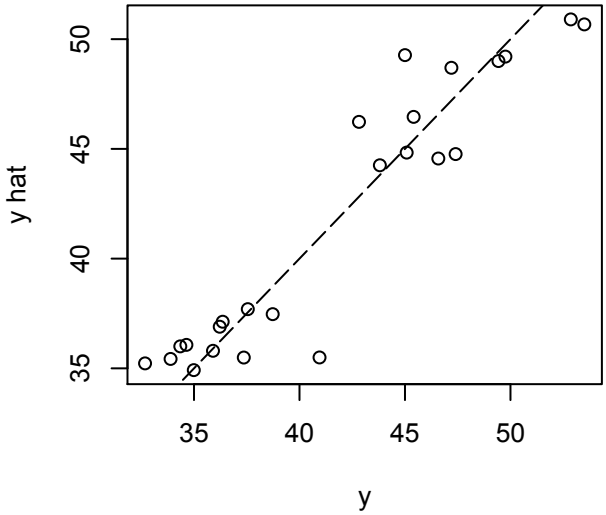

mean of y
36
38
40
42
44
46
48
50
A
T
F
C
3
2
5
diet
wgt
Factors

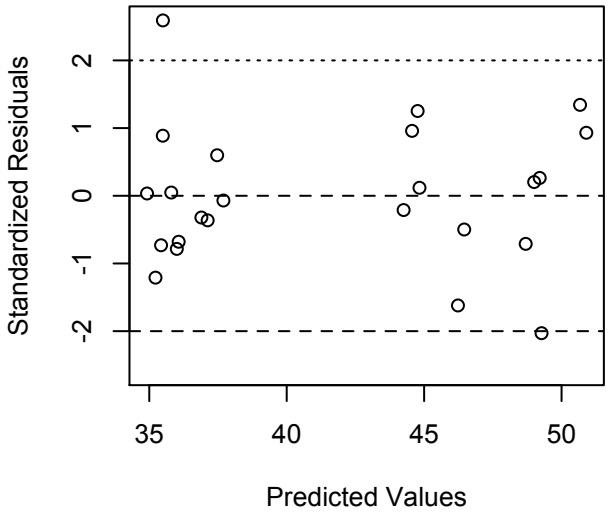

y
35
40
45
50
A
C
F
T
diet

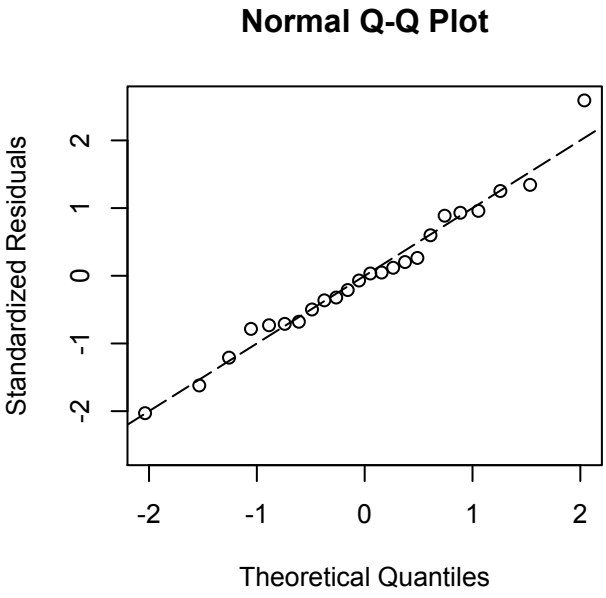

Interaction Plot
wgt
6
1
3
4
5
2
mean of y
35
40
45
50
A
C
F
T
diet


95% family-wise confidence level
F-C
T-C
A-C
T-F
A-F
A-T
0
5
10
15
Differences in mean levels of diet


Scatter Plot of Pct. vs. Diet
Percent
35
40
45
50
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Diet


y hat
35
40
45
50
35
40
45
50
y


Standardized Residuals
-2
-1
0
1
2
35
40
45
50
Predicted Values


Normal Q-Q Plot
Standardized Residuals
-2
-1
0
1
2
-2
-1
0
1
2
Theoretical Quantiles