Initialize R by entering the following commands at the prompt. You must type the commands exactly as shown.

```r
options(contrasts=c("contr.sum","contr.poly"),digits=4 ) # set definition of contrasts
do(file=url("http://psycserv.mcmaster.ca/bennett/psy710/p3/abData.Rdata") )
```

1. An experiment used a crossed factorial design to evaluate the effects of two factors, A and B, on a dependent variable, y. Factors A and B each had three levels, and n = 8 subjects were assigned randomly to each combination of A and B. The data are stored in the data frame abData, which should be used to answer all parts of this question.

   (a) Calculate the mean of each cell. Then calculate the marginal means for each level of A and B.

   ```r
   with(abData,tapply(y,list(A,B),mean)) # cell means
   ## b1 b2 b3
   ## a1 38.24 48.77 48.45
   ## a2 46.36 51.66 51.52
   ## a3 54.82 51.73 49.79
   with(abData,tapply(y,list(A),mean)) # marginal means for A
   ## a1 a2 a3
   ## 45.15 49.85 52.11
   with(abData,tapply(y,list(B),mean)) # marginal means for B
   ## b1 b2 b3
   ## 46.48 50.72 49.92
   ```

   (b) Conduct an ANOVA to evaluate the main effects of A and B and the A × B interaction. Record the results of your ANOVA (i.e., write the ANOVA table).

   ```r
   ab.lm.01 <- lm(y~A+B+A:B,data=abData)
anova(ab.lm.01)
   ## Analysis of Variance Table
   ## Response: y
   ## Df Sum Sq Mean Sq F value Pr(>F)
   ## A 2 605 302.5 6.52 0.0027 **
   ## B 2 244 122.1 2.63 0.0798 .
   ## A:B 4 578 144.6 3.12 0.0210 *
   ## Residuals 63 2921 46.4
   ## ---
   ## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
   ```

   (c) Explain the null and alternative hypotheses that are evaluated by your ANOVA.

   (d) Does a significant A × B interaction affect your interpretation of the main effects? Why or why not?

   (e) When should you analyze simple main effects?

     **Answer:** We will discuss the answers to the previous three question in class.

2. An experiment was conducted to assess the effects of three therapies: rational-emotive therapy (RET), client-centered therapy (CCT), and behaviour modification (BMOD). Three therapists were used, and each therapist treated five clients with each method of therapy. Each client rated the effectiveness of the therapy. The data are stored in the data frame therapy.data. The dependent variable is rating, and the experimental factors are therapist and treatment.
(a) Use the analysis of variance to evaluate main effects and interaction of therapist and types of therapy (i.e., treatment). Print the ANOVA table.

```r
names(therapy.data)
## [1] "rating"  "therapist" "treatment"
therapy.aov.01 <- aov(rating~therapist*treatment,data=therapy.data)
summary(therapy.aov.01)
## Df Sum Sq Mean Sq F value Pr(>F)
## therapist 2 43.3 21.7 2.47 0.099 .
## treatment 2 120.0 60.0 6.84 0.003 **
## therapist:treatment 4 66.7 16.7 1.90 0.132
## Residuals 36 316.0 8.8
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

(b) Calculate the effect size for the two main effects and the interaction.

```r
N <- 45  # overall N
p.omega.sqrd.therapist <- 2*(2.47 - 1) / (2*(2.47 - 1) + N)
(cohens.f.therapist <- sqrt( p.omega.sqrd.therapist / (1-p.omega.sqrd.therapist) ) )
## [1] 0.2556
p.omega.sqrd.treatment <- 2*(6.84 - 1) / (2*(6.84 - 1) + N)
(cohens.f.treatment <- sqrt( p.omega.sqrd.treatment / (1-p.omega.sqrd.treatment) ) )
## [1] 0.5095
p.omega.sqrd.interaction <- 4*(1.90 - 1) / (4*(1.90 - 1) + N)
(cohens.f.interaction <- sqrt( p.omega.sqrd.interaction / (1-p.omega.sqrd.interaction) ) )
## [1] 0.2828
# cohen's f of 0.1, 0.25, and 0.4 represent small, medium, and large effect sizes
```

3. The same experiment described in question 1 was conducted, but some of the recruited subjects did not finish the experiment and their data were discarded, resulting in an unbalanced design. The data are stored in the data frame `abUnbalanced` which should be used to answer all parts of this question.

(a) Verify that the data are unbalanced.

```r
with(abUnbalanced,tapply(y,list(A,B),length))
## b1  b2  b3
## a1  4  8  6
## a2  8  8  8
## a3  8  8  8
```

(b) Evaluate the main effects using Type I sums of squares.
The 1st row in each ANOVA table is a test using Type I (sequential) sums of squares for each main effect:

Type I SS for factor A:
q3.lm.01 <- lm(y~A+B+A:B, data=abUnbalanced)
anova(q3.lm.01) # inspect 1st row

## Analysis of Variance Table
## Response: y
## Df Sum Sq Mean Sq F value Pr(>F)
## A 2 319 159.7 3.29 0.044 *
## B 2 215 107.4 2.21 0.119
## A:B 4 135 33.7 0.70 0.599
## Residuals 57 2764 48.5

# Type I SS for factor B:
q3.lm.02 <- lm(y~B+A+A:B, data=abUnbalanced)
anova(q3.lm.02) # inspect 1st row

## Analysis of Variance Table
## Response: y
## Df Sum Sq Mean Sq F value Pr(>F)
## B 2 159 79.6 1.64 0.203
## A 2 375 187.4 3.86 0.027 *
## B:A 4 135 33.7 0.70 0.599
## Residuals 57 2764 48.5

(c) What hypotheses concerning group means are being evaluated by Type I sums of squares? How do the hypotheses differ from the ones evaluated by Type III sums of squares?

**Answer:** We will discuss the answer to this question in class.