10 Initialize R

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

```r
options(contrasts=c("contr.sum","contr.poly") )
library(car)
```

1. The data for this section can be loaded into R with the following command:

```r
load(file=url("http://psycserv.mcmaster.ca/bennett/psy710/datasets/vigilance09.Rdata"))
```

`vigilance.mat` is a matrix that contains the data from eight subjects who participated in an experiment that measured the effects of caffeine and theanine (an amino acid commonly found in tea) on a test of vigilance and alertness (higher numbers correspond to better vigilance/alertness). On four separate days, each subject was tested after consuming a drink that contained caffeine, theanine, both substances, or neither substances (i.e., water). In other words, the study used a 2x2 within-subject factorial design, with the factors being caffeine (present vs. absent) and theanine (present vs. absent).

(a) Conduct an ANOVA to evaluate the main effects of caffeine and theanine and the caffeine × theanine interaction.

```r
vigilance.mat[1,]
## none caffeine theanine both
## 51 52 44 53
caffeine <- as.factor(c("no","yes","no","yes"))
theanine <- as.factor(c("no","no","yes","yes"))
(vig.idata <- data.frame(caffeine, theanine))
## caffeine theanine
## 1 no no
## 2 yes no
## 3 no yes
## 4 yes yes
vig.mlm.01 <- lm(vigilance.mat~1)
vig.aov.01 <- Anova(vig.mlm.01, idata=vig.idata, idesign=~caffeine*theanine, type="III")
summary(vig.aov.01, multivariate=FALSE)
##
## Univariate Type III Repeated-Measures ANOVA Assuming Sphericity
##
##            SS num Df Error SS den Df  F     Pr(>F)
## (Intercept) 79401   1 50.375  7 11033.4069 1.868e-12 ***
2. The data for this section can be loaded into R with the following command:

```r
load(file=url("http://psycserv.mcmaster.ca/bennett/psy710/datasets/facedata.Rdata"))
```

An experiment is done to measure the effects on stimulus orientation and contrast polarity on face perception. The data are in the data frame `face.data`. Face orientation was either upright or inverted (i.e., upside-down). Contrast polarity was either positive (i.e., normal) or negative (i.e., like a photographic negative). All combinations were combined in a 2x2 factorial design, and each subject was tested in all conditions in a random order. The dependent variable was efficiency, which can be thought of as “sensitivity” (i.e., higher numbers are better).

(a) Conduct an analysis of variance (on log10-transformed efficiency) to evaluate the main effects of orientation and contrast, and the interaction.

```r
# log10_transformed_z <- log10(z)

face.mat <- as.matrix(log10(face.data)) # log transform!
# make factors:
contrast <- as.factor(c("pos","neg","pos","neg"))
orientation <- as.factor(c("up","up","inv","inv"))
# following 2 lines make the same factors:
# contrast<-gl(n=2,k=1,length=4,labels=c("pos","neg"))
# orientation<-gl(n=2,k=2,length=4,labels=c("up","inv"))
# save in data.frame:
( face.idata <- data.frame(contrast,orientation) )

## contrast orientation
## 1 pos up
## 2 neg up
## 3 pos inv
## 4 neg inv

# same order as columns in our data frame:
names(face.data)
## [1] "pos.up" "neg.up" "pos.inv" "neg.inv"

# do anova:
library(car)
face.mlm <- lm(face.mat~1) # no between-S variables
face.aov <- Anova(face.mlm,idata=face.idata,idesign=~contrast*orientation,type="III")
summary(face.aov,multivariate=F)
```

```r
## Univariate Type III Repeated-Measures ANOVA Assuming Sphericity
##
## SS num Df Error SS den Df F Pr(>F)
## (Intercept) 19.8106 1 0.0198334 5 4994.2389 1.074e-08 ***
## contrast 0.0362 1 0.0150441 5 12.0402 0.017851 *
## orientation 0.0127 1 0.0037316 5 17.0635 0.009078 **
## contrast:orientation 0.0000 1 0.0077816 5 0.0005 0.983485
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```
Answer: The main effects of contrast, \([F(1, 5) = 12.04, p = 0.017]\), and orientation, \([F(1, 5) = 17.06, p = 0.009]\) are significant, but the interaction is not \([F(1, 5) = 0.005, p = 0.98]\). Note that we do not need to worry about the sphericity assumption in this case. Why not?

(b) Conduct a linear contrast that tests the hypothesis that performance in the negative-inverted condition is worse than the average performance in the negative-upright and positive-upright conditions.

```r
colMeans(face.mat)
##   pos.up neg.up pos.inv neg.inv
## -0.8464758 -0.9245295 -0.8928966 -0.9702496
10^colMeans(face.mat)
##   pos.up neg.up pos.inv neg.inv
## 0.1424047 0.1189790 0.1279686 0.1070904
myC <- c(1/2, 1/2, 0, -1)
the.scores <- face.mat %*% myC
t.test(the.scores, alternative="greater")
```

Answer: I created the contrast weights and stored them in `myC`. Next, I used the weights to create one composite score for each subject. Note that the composite score equals the mean of conditions 1 and 2 minus the mean of condition 4. Finally, I conducted a directional (one-tailed) \(t\) test on the composite scores. If the hypothesis is true, then the composite scores were drawn from a population that had a mean greater than zero (i.e., \(\mu > 0\)). Therefore, the null hypothesis is that \(\mu \leq 0\) (i.e., the alternative hypothesis is \(\mu > 0\)). The test was significant \([t(5) = 7.26, p = 0.0003, \text{one-tailed}]\), so I reject the null hypothesis.

3. The data for this section can be loaded into R with the following command:

```r
> load(url("http://psycserv.mcmaster.ca/bennett/psy710/datasets/trackbox09.Rdata"))
```

“Discovery Day” is a day set aside by the United States Naval Postgraduate School in Monterey, California, to invite the general public into its laboratories. On Discovery Day, 21 October 1995, data on reaction time and hand-eye coordination were collected on 118 members of the public who visited the Human Systems Integration Laboratory. The age and sex of each subject were also recorded. Visitors were mostly in family groups.

A rotary pursuit tracking experiment was done to examine motor learning and hand-eye coordination. The equipment was a rotating disk with a 3/4-inch target spot. In the “Circle” condition, the target spot moved at a constant speed in a circular path. In the “Box” condition, the target spot moved at various
speeds as it moved along a box-shaped path. The subject’s task was to maintain contact with the target spot with a metal wand. Four trials were recorded for each of 108 subjects. Each trial lasted 15 s, and the total contact time during each was recorded. The data from the Box condition are stored in track.data.

The variables are sex, age, subject, time1, time2, time3, time4. The dependent variable, the amount of time the subject maintained contact with the target on each trial, is in the variables time1-4.

(a) Use a split-plot ANOVA to evaluate the main effects of sex and time, and the sex × time interaction. If there the interaction is significant, then evaluate the simple main effect of time for each sex. (An example of a split-plot ANOVA is given in section 12.2 of my notes on chapter 12.)

Answer: The analysis of this split-plot design is similar to the one used to analyze a one-way within-subject design. The only difference is that, in this case, we have to include the between-subject variable sex in the formula in lm:

```r
track.mat <- as.matrix(track.data[,4:7])
time <- as.factor(c("t1","t2","t3","t4"))
(track.idata <- data.frame(time))

track.mlm <- lm(track.mat ~ 1 + sex,data=track.data)
track.aov <- Anova(track.mlm,idata=track.idata,idesign="~time,type="III")
summary(track.aov,multivariate=F)
```

```
## Univariate Type III Repeated-Measures ANOVA Assuming Sphericity
##
## Source SS num Df Error SS den Df F Pr(>F)
## (Intercept) 2559.74 1 973.34 68 178.8301 < 2e-16 ***
## sex 98.95 1 973.34 68 6.9128 0.01057 *
## time 51.26 3 108.03 204 32.2636 < 2e-16 ***
## sex:time 4.50 3 108.03 204 2.8301 0.03951 *
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Mauchly Tests for Sphericity
##
## Test statistic  p-value
## time       0.84312 0.044266
## sex:time   0.84312 0.044266
##
## Greenhouse-Geisser and Huynh-Feldt Corrections
## for Departure from Sphericity
##
## GG eps Pr(>F[GG])
## time  0.89104     1.662e-15 ***
## sex:time  0.89104     0.04588 *
```
Answer: The sex x time interaction is significant, even when we use the GG or HF corrections, so we have to analyze the simple main effect of time for each sex:

```r
track.male <- track.mat[track.data$sex=='M',]
track.female <- track.mat[track.data$sex=='F',]
track.male.mlm <- lm(track.male ~ 1)
track.male.aov <- Anova(track.male.mlm,idata=track.idata,idesign=~time,type="III")
track.female.mlm <- lm(track.female ~ 1)
track.female.aov <- Anova(track.female.mlm,idata=track.idata,idesign=~time,type="III")
summary(track.male.aov,multivariate=F)
```

```r
## Univariate Type III Repeated-Measures ANOVA Assuming Sphericity
##
##    SS   num Df Error SS  den Df F  Pr(>F)
## (Intercept) 2672.56     1    778.97   45 154.39 3.8e-16 ***
## time        59.72      3    69.54 135  38.64 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

## Mauchly Tests for Sphericity
##
## Test statistic p-value
## time     0.63173 0.0012106

## Greenhouse-Geisser and Huynh-Feldt Corrections for Departure from Sphericity
##
## GG eps  Pr(>F[GG])
## time    0.77143 1.706e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

## HF eps  Pr(>F[HF])
## time    0.8157138 3.420737e-15
```

Summary (track.female.aov, multivariate=F)

```r
```

Warning: HF eps > 1 treated as 1

```r
```
## (Intercept) 628.53 1  194.368 23 74.3756 1.154e-08 ***
## time 11.27 3  38.491 69 6.7313 0.0004751 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Mauchly Tests for Sphericity
##
## Test statistic p-value
## time 0.83505 0.56196
##
## Greenhouse-Geisser and Huynh-Feldt Corrections
## for Departure from Sphericity
##
## GG eps Pr(>F[GG])
## time 0.89967 0.0008014 ***
##
## HF eps Pr(>F[HF])
## time 1.030754 0.0004751107

**Answer:** The simple main effect of time/trial is significant both for males ($F(3,135) = 38.6, \hat{\epsilon} = 0.815, p < .001$) and females ($F(3,69) = 6.73, \hat{\epsilon} = 1, p < .001$). In both cases I’ve reported the HF-corrected $p$ values (though it makes little difference in the case of females).

(b) Conduct a test that examines whether the linear trend of performance (across levels of time) differs for males and females.

**Answer:** I used `contr.poly` to create contrast weights for evaluating a linear trend. Then I used these weights to transform the four dependent measures into a single, linear trend score for each subject. Finally, I evaluated the null hypothesis that the linear trend scores did not differ between males and females. The test was done two ways. First, I used a two-tailed $t$ test that assumed equal variance across groups. Second, I conducted an ANOVA with `sex` as a between-subjects factor. These two tests are equivalent: the $F$ obtained in the ANOVA is the same as the squared value of $t$ obtained in the $t$ test. Both tests reject the null hypothesis of no difference between groups. Therefore, the linear trend differed across groups – i.e., there was an interaction between `sex` and linear trend.

```
( lin.contrast <- contr.poly(n=4)[,1] )
## [1] -0.6708204 -0.2236068  0.2236068  0.6708204
lin.scores <- track.mat %*% lin.contrast
t.test (lin.scores~track.data$sex, var.equal=TRUE)
```

```r
## Two Sample t-test
##
## data:  lin.scores by track.data$sex
## t = -2.3253, df = 68, p-value = 0.02305
```
```r
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##   -0.9647486  -0.0736457
## sample estimates:
## mean in group F  mean in group M
##    0.5878995   1.1070967

linear.aov.01 <- aov(lin.scores ~ track.data$sex)
summary(linear.aov.01)
```

```
## Df Sum Sq Mean Sq F value  Pr(>F)
track.data$sex    1 4.25  4.251  5.407 0.023 *
Residuals        68 53.47  0.786
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```