

HW#4 - solution

Example: Sleepig-Dog data

- Interesting
 - $(\mu_3 + \mu_4) - (\mu_1 + \mu_2)$: the difference between with/without H
 - $(\mu_1 + \mu_3) - (\mu_2 + \mu_4)$: the difference between high/low CO2
 - $(\mu_1 + \mu_4) - (\mu_2 + \mu_3)$: the influence of H on CO2 pressure differences

$$\begin{bmatrix} (\mu_3 + \mu_4) - (\mu_1 + \mu_2) \\ (\mu_1 + \mu_3) - (\mu_2 + \mu_4) \\ (\mu_1 + \mu_4) - (\mu_2 + \mu_3) \end{bmatrix} = \begin{bmatrix} -1 & -1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix} \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{bmatrix} = \mathbf{C}\boldsymbol{\mu}$$

```
dog<-read.csv("./sleeping-dog.csv")
```

```
C1<-dog$TRT3+dog$TRT4-dog$TRT1-dog$TRT2 ## H effect
C2<-dog$TRT1+dog$TRT3-dog$TRT2-dog$TRT4 ## CO2 effect
C3<-dog$TRT1+dog$TRT4-dog$TRT2-dog$TRT3 ## CO2 & H interaction
C.tot<-data.frame(C1=C1,C2=C2,C3=C3)
library(ICSNP)
```

```
## Loading required package: mvtnorm
```

```
## Loading required package: ICS
```

```
HotellingsT2(C.tot)
```

```
##
## Hotelling's one sample T2-test
##
## data: C.tot
## T.2 = 34.375, df1 = 3, df2 = 16, p-value = 3.318e-07
## alternative hypothesis: true location is not equal to c(0,0,0)
```

```
t.test(C1) ## H effect
```

```
##
## One Sample t-test
##
## data: C1
## t = 9.3945, df = 18, p-value = 2.315e-08
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
## 162.5056 256.1260
## sample estimates:
## mean of x
## 209.3158
```

```

t.test(C2) ## C02 effect

##
## One Sample t-test
##
## data: C2
## t = -3.6315, df = 18, p-value = 0.001909
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
## -94.79510 -25.31017
## sample estimates:
## mean of x
## -60.05263

t.test(C3) ## C02 & H interaction

##
## One Sample t-test
##
## data: C3
## t = -0.64127, df = 18, p-value = 0.5294
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
## -54.68998 29.11103
## sample estimates:
## mean of x
## -12.78947

library(car)

## Warning: package 'car' was built under R version 3.4.4
## Loading required package: carData
## Warning: package 'carData' was built under R version 3.4.4

dog.lm<-lm(cbind(TRT1,TRT2,TRT3,TRT4)~.,data=dog)
trt.data<-data.frame(H=c("WithOut","WithOut","With","With"),CO2=c("H","L","H",
"L"))
summary(Anova(dog.lm,idata=trt.data,idesign=~H+CO2+H*CO2))

##
## Type II Repeated Measures MANOVA Tests:
##
## -----
##
## Term: (Intercept)
##
## Response transformation matrix:
## (Intercept)
## TRT1 1

```

```

## TRT2          1
## TRT3          1
## TRT4          1
##
## Sum of squares and products for the hypothesis:
##          (Intercept)
## (Intercept)   58520475
##
## Multivariate Tests: (Intercept)
##          Df test stat approx F num Df den Df    Pr(>F)
## Pillai          1  0.98061 859.5344      1    17 5.3631e-16 ***
## Wilks           1  0.01939 859.5344      1    17 5.3631e-16 ***
## Hotelling-Lawley 1 50.56085 859.5344      1    17 5.3631e-16 ***
## Roy            1 50.56085 859.5344      1    17 5.3631e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## -----
##
## Term: Dog
##
## Response transformation matrix:
##          (Intercept)
## TRT1          1
## TRT2          1
## TRT3          1
## TRT4          1
##
## Sum of squares and products for the hypothesis:
##          (Intercept)
## (Intercept)   64151.24
##
## Multivariate Tests: Dog
##          Df test stat approx F num Df den Df    Pr(>F)
## Pillai          1 0.0525151 0.9422377      1    17 0.34531
## Wilks           1 0.9474849 0.9422377      1    17 0.34531
## Hotelling-Lawley 1 0.0554257 0.9422377      1    17 0.34531
## Roy            1 0.0554257 0.9422377      1    17 0.34531
##
## -----
##
## Term: H
##
## Response transformation matrix:
##          H1
## TRT1  -1
## TRT2  -1
## TRT3   1
## TRT4   1

```

```

##
## Sum of squares and products for the hypothesis:
##      H1
## H1 832448.9
##
## Multivariate Tests: H
##           Df test stat approx F num Df den Df      Pr(>F)
## Pillai      1  0.837858 87.84661      1      17 3.9676e-08 ***
## Wilks       1  0.162142 87.84661      1      17 3.9676e-08 ***
## Hotelling-Lawley 1  5.167447 87.84661      1      17 3.9676e-08 ***
## Roy         1  5.167447 87.84661      1      17 3.9676e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## -----
##
## Term: Dog:H
##
## Response transformation matrix:
##      H1
## TRT1 -1
## TRT2 -1
## TRT3  1
## TRT4  1
##
## Sum of squares and products for the hypothesis:
##      H1
## H1 8685.307
##
## Multivariate Tests: Dog:H
##           Df test stat  approx F num Df den Df Pr(>F)
## Pillai      1 0.0511562 0.9165424      1      17 0.3518
## Wilks       1 0.9488438 0.9165424      1      17 0.3518
## Hotelling-Lawley 1 0.0539143 0.9165424      1      17 0.3518
## Roy         1 0.0539143 0.9165424      1      17 0.3518
##
## -----
##
## Term: C02
##
## Response transformation matrix:
##      C021
## TRT1      1
## TRT2     -1
## TRT3      1
## TRT4     -1
##
## Sum of squares and products for the hypothesis:
##      C021

```

```

## C021 68520.05
##
## Multivariate Tests: C02
##           Df test stat approx F num Df den Df    Pr(>F)
## Pillai      1 0.4583549 14.38586      1    17 0.0014532 **
## Wilks       1 0.5416451 14.38586      1    17 0.0014532 **
## Hotelling-Lawley 1 0.8462273 14.38586      1    17 0.0014532 **
## Roy        1 0.8462273 14.38586      1    17 0.0014532 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## -----
##
## Term: Dog:C02
##
## Response transformation matrix:
##      C021
## TRT1      1
## TRT2     -1
## TRT3      1
## TRT4     -1
##
## Sum of squares and products for the hypothesis:
##      C021
## C021 12553.73
##
## Multivariate Tests: Dog:C02
##           Df test stat approx F num Df den Df    Pr(>F)
## Pillai      1 0.1342287  2.63567      1    17 0.12288
## Wilks       1 0.8657713  2.63567      1    17 0.12288
## Hotelling-Lawley 1 0.1550394  2.63567      1    17 0.12288
## Roy        1 0.1550394  2.63567      1    17 0.12288
##
## -----
##
## Term: H:C02
##
## Response transformation matrix:
##      H1:C021
## TRT1      -1
## TRT2       1
## TRT3       1
## TRT4      -1
##
## Sum of squares and products for the hypothesis:
##      H1:C021
## H1:C021 3107.842
##
## Multivariate Tests: H:C02

```

```

##              Df test stat  approx F num Df den Df  Pr(>F)
## Pillai          1 0.0224327 0.3901073      1    17 0.54054
## Wilks           1 0.9775673 0.3901073      1    17 0.54054
## Hotelling-Lawley 1 0.0229475 0.3901073      1    17 0.54054
## Roy             1 0.0229475 0.3901073      1    17 0.54054
##
## -----
##
## Term: Dog:H:C02
##
## Response transformation matrix:
##      H1:C021
## TRT1      -1
## TRT2       1
## TRT3       1
## TRT4      -1
##
## Sum of squares and products for the hypothesis:
##      H1:C021
## H1:C021 600.3947
##
## Multivariate Tests: Dog:H:C02
##              Df test stat  approx F num Df den Df  Pr(>F)
## Pillai          1 0.0044136 0.07536367      1    17 0.78699
## Wilks           1 0.9955864 0.07536367      1    17 0.78699
## Hotelling-Lawley 1 0.0044332 0.07536367      1    17 0.78699
## Roy             1 0.0044332 0.07536367      1    17 0.78699
##
## Univariate Type II Repeated-Measures ANOVA Assuming Sphericity
##
##              Sum Sq num Df Error SS den Df  F value    Pr(>F)
## (Intercept) 14630119      1   289357    17 859.5344 5.363e-16 ***
## Dog           16038      1   289357    17   0.9422 0.345312
## H            208112      1    40274    17  87.8466 3.968e-08 ***
## Dog:H         2171      1    40274    17   0.9165 0.351802
## C02          17130      1    20243    17  14.3859 0.001453 **
## Dog:C02       3138      1    20243    17   2.6357 0.122884
## H:C02         777      1    33858    17   0.3901 0.540536
## Dog:H:C02     150      1    33858    17   0.0754 0.786990
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

```

DATA dog;
INFILE 'sleeping-dog.csv' DELIMITER=', ' FIRSTOBS=2;
  INPUT ID trt1-trt4 @@;
RUN;

PROC GLM data =dog;
  CLASS ID;
  MODEL TRT1 TRT2 TRT3 TRT4 = ;
  REPEATED H 2, CO2 2 / PRINTE SUMMARY;
  QUIT;
RUN;

```

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no H Effect
H = Type III SSCP Matrix for H
E = Error SSCP Matrix

S=1 M=-0.5 N=8

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.16940251	88.26	1	18	<.0001
Pillai's Trace	0.83059749	88.26	1	18	<.0001
Hotelling-Lawley Trace	4.90310036	88.26	1	18	<.0001
Roy's Greatest Root	4.90310036	88.26	1	18	<.0001

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no CO2 Effect
H = Type III SSCP Matrix for CO2
E = Error SSCP Matrix

S=1 M=-0.5 N=8

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.57715417	13.19	1	18	0.0019
Pillai's Trace	0.42284583	13.19	1	18	0.0019
Hotelling-Lawley Trace	0.73263931	13.19	1	18	0.0019
Roy's Greatest Root	0.73263931	13.19	1	18	0.0019

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no H*CO2 Effect
H = Type III SSCP Matrix for H*CO2
E = Error SSCP Matrix

S=1 M=-0.5 N=8

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.97766408	0.41	1	18	0.5294
Pillai's Trace	0.02233592	0.41	1	18	0.5294
Hotelling-Lawley Trace	0.02284621	0.41	1	18	0.5294
Roy's Greatest Root	0.02284621	0.41	1	18	0.5294

The GLM Procedure
Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
H	1	208112.2237	208112.2237	88.26	<.0001
Error(H)	18	42445.0263	2358.0570		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CO2	1	17130.01316	17130.01316	13.19	0.0019
Error(CO2)	18	23381.23684	1298.95760		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
H*CO2	1	776.96053	776.96053	0.41	0.5294
Error(H*CO2)	18	34008.28947	1889.34942		