Two-Way Example using Contrasts (Hard Way)

This example is for illustration! This data represents 2 Varieties and 3 Tillage methods for a total of 6 Treatment combinations. We start with a one-way model (with 6 trts) and test for main effects and interactions using contrasts (hard way). We will use this same data in another example and specify the two way structure directly (easy way).

Legend:

1. Trt1 = Var1, Till1
2. Trt2 = Var1, Till2
3. Trt3 = Var1, Till3
4. Trt4 = Var2, Till1
5. Trt5 = Var2, Till2
6. Trt6 = Var2, Till3

```
library(car)
library(emmeans)
InData <- read.csv("~/Dropbox/STAT512/Lectures/ExpDesign2/ED2_2wayData.csv")
str(InData)
```

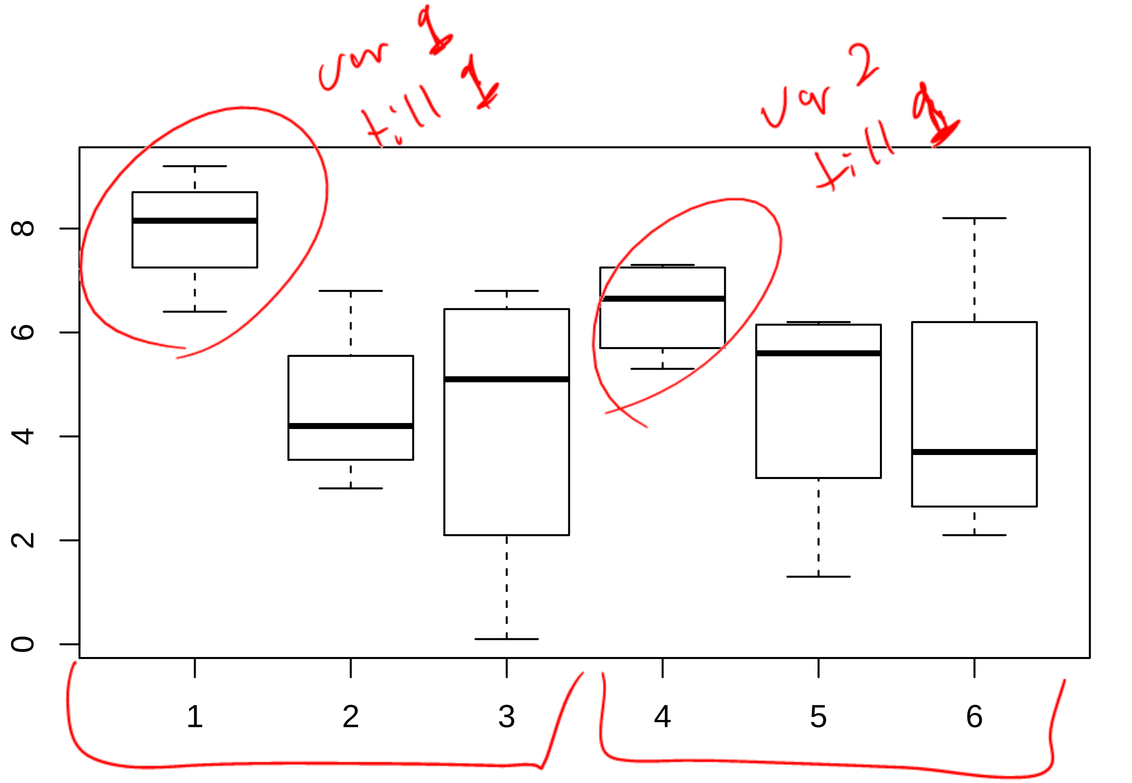
```
## 'data.frame':    24 obs. of  4 variables:
##  $ trt : int  1 2 3 4 5 6 1 2 3 4 ...
##  $ till: int  1 2 3 1 2 3 1 2 3 1 ...
##  $ var : int  1 1 1 2 2 2 1 1 1 2 ...
##  $ resp: num  9.2 4.1 4.1 7.3 5.1 8.2 8.1 6.8 6.1 6.1 ...
```

```
#Important: Need to define trt as.factor!
InData$trt <- as.factor(InData$trt)
aggregate(resp ~ trt, data = InData, FUN = mean)
```

```
##   trt  resp
## 1   1 7.975
## 2   2 4.550
## 3   3 4.275
## 4   4 6.475
## 5   5 4.675
## 6   6 4.425
```

one-way

```
boxplot(resp ~ trt, data = InData)
```



One-way ANOVA (Standard Parameterization)

Here we use our standard approach for a one-way ANOVA. Use anova() and lsmeans() to address research questions. Note that when ignoring the factorial structure and running all pairwise comparisons (using lsmeans), none of the comparisons are significant at the alpha = 0.05 level.

```
Model1 <- lm(resp ~ trt, data = InData)
anova(Model1)
```

```
## Analysis of Variance Table
##
## Response: resp
##           Df Sum Sq Mean Sq F value Pr(>F)
## trt        5 45.002  9.0004  2.0557 0.1189
## Residuals 18 78.808  4.3782
```

FTR diff in trt's

```
emmeans(Model1, pairwise ~ trt)
```

```
## $emmeans
##  trt emmean       SE df lower.CL  upper.CL
##  1    7.975 1.046207 18 5.777001 10.172999
##  2    4.550 1.046207 18 2.352001  6.747999
##  3    4.275 1.046207 18 2.077001  6.472999
##  4    6.475 1.046207 18 4.277001  8.672999
##  5    4.675 1.046207 18 2.477001  6.872999
##  6    4.425 1.046207 18 2.227001  6.622999
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate      SE df t.ratio p.value
##  1 - 2       3.425 1.47956 18   2.315  0.2385
##  1 - 3       3.700 1.47956 18   2.501  0.1756
##  1 - 4       1.500 1.47956 18   1.014  0.9073
```

```
##   1 - 5       3.300 1.47956 18   2.230  0.2721
##   1 - 6       3.550 1.47956 18   2.399  0.2080
##   2 - 3       0.275 1.47956 18   0.186  1.0000
##   2 - 4      -1.925 1.47956 18  -1.301  0.7808
##   2 - 5      -0.125 1.47956 18  -0.084  1.0000
##   2 - 6       0.125 1.47956 18   0.084  1.0000
##   3 - 4      -2.200 1.47956 18  -1.487  0.6763
##   3 - 5      -0.400 1.47956 18  -0.270  0.9998
##   3 - 6      -0.150 1.47956 18  -0.101  1.0000
##   4 - 5       1.800 1.47956 18   1.217  0.8233
##   4 - 6       2.050 1.47956 18   1.386  0.7348
##   5 - 6       0.250 1.47956 18   0.169  1.0000
##
## P value adjustment: tukey method for comparing a family of 6 estimates
```

$\binom{6}{2} = 15$ comparison

no surprise that pairwise not signif

Cell Means (No Intercept) Parameterization

Note that the estimated coefficients now represent the treatment means directly. We then use this parameterization to test orthogonal contrasts using lht() from the car package. These contrasts are discussed in more detail in the notes.

no intercept

```r
Model2 <- lm(resp ~ trt - 1, data = InData)
summary(Model2)
```

```
##
## Call:
## lm(formula = resp ~ trt - 1, data = InData)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -4.175 -1.188 -0.025  1.275  3.775
##
## Coefficients:
##      Estimate Std. Error t value Pr(>|t|)
## trt1    7.975      1.046   7.623 4.84e-07 ***
## trt2    4.550      1.046   4.349 0.000387 ***
## trt3    4.275      1.046   4.086 0.000693 ***
## trt4    6.475      1.046   6.189 7.67e-06 ***
## trt5    4.675      1.046   4.469 0.000297 ***
## trt6    4.425      1.046   4.230 0.000504 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.092 on 18 degrees of freedom
## Multiple R-squared:  0.9042, Adjusted R-squared:  0.8723
## F-statistic: 28.31 on 6 and 18 DF,  p-value: 3.123e-08
```

y's

```r
Cvar <- c(-1, -1, -1, 1, 1, 1)
Ctill1 <- c(2, -1, -1, 2, -1, -1)
Ctill2 <- c(0, -1, 1, 0, -1, 1)
Cint1 <- c(-2, 1, 1, 2, -1, -1)
Cint2 <- c(0, 1, -1, 0, -1, 1)
lht(Model2, Cvar)
```

variety

```
## Linear hypothesis test
##
## Hypothesis:
## - trt1 - trt2 - trt3  + trt4  + trt5  + trt6 = 0
##
## Model 1: restricted model
## Model 2: resp ~ trt - 1
##
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1     19 79.808
## 2     18 78.807  1    1.0004 0.2285 0.6384
```

F = stat

variety

H_0: var 1 = var 2

```
lht(Model2, Ctill1)
```

```
## Linear hypothesis test
##
## Hypothesis:
## 2 trt1 - trt2 - trt3  + 2 trt4 - trt5 - trt6 = 0
##
## Model 1: restricted model
## Model 2: resp ~ trt - 1
##
##   Res.Df     RSS Df Sum of Sq      F   Pr(>F)
## 1     19 118.958
## 2     18  78.807  1     40.15 9.1705 0.007227 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Till 1 vs

Till 2 & 3

```
lht(Model2, Ctill2)
```

```
## Linear hypothesis test
##
## Hypothesis:
## - trt2  + trt3 - trt5  + trt6 = 0
##
## Model 1: restricted model
## Model 2: resp ~ trt - 1
##
##   Res.Df    RSS Df Sum of Sq     F Pr(>F)
## 1     19 79.083
## 2     18 78.807  1   0.27563 0.063 0.8047
```

```
lht(Model2, Cint1)
```

```
## Linear hypothesis test
##
## Hypothesis:
## - 2 trt1  + trt2  + trt3  + 2 trt4 - trt5 - trt6 = 0
##
## Model 1: restricted model
## Model 2: resp ~ trt - 1
##
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1     19 82.383
## 2     18 78.807  1    3.5752 0.8166 0.3781
```

```r
lht(Model2, Cint2)
```

```
## Linear hypothesis test
##
## Hypothesis:
## trt2 - trt3 - trt5  + trt6 = 0
##
## Model 1: restricted model
## Model 2: resp ~ trt - 1
##
##   Res.Df    RSS Df Sum of Sq     F Pr(>F)
## 1     19 78.808
## 2     18 78.807  1  0.000625 1e-04 0.9906
```

```r
#Simultaneous Test #1
lht(Model2, rbind(Ctill1, Ctill2))
```

```
## Linear hypothesis test
##
## Hypothesis:
## 2 trt1 - trt2 - trt3  + 2 trt4 - trt5 - trt6 = 0
## - trt2  + trt3 - trt5  + trt6 = 0
##
## Model 1: restricted model
## Model 2: resp ~ trt - 1
##
##   Res.Df     RSS Df Sum of Sq      F  Pr(>F)
## 1     20 119.233
## 2     18  78.807  2    40.426 4.6167 0.02407 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

F-stat for Till

```r
#Simultaneous Test #2
lht(Model2, rbind(Cint1, Cint2))
```

```
## Linear hypothesis test
##
## Hypothesis:
## - 2 trt1  + trt2  + trt3  + 2 trt4 - trt5 - trt6 = 0
## trt2 - trt3 - trt5  + trt6 = 0
##
## Model 1: restricted model
## Model 2: resp ~ trt - 1
##
##   Res.Df    RSS Df Sum of Sq      F Pr(>F)
## 1     20 82.383
## 2     18 78.807  2    3.5758 0.4084 0.6707
```

F-stat for interaction