Two-Way Example as Factorial (Easy Way)

This example is for illustration! This data represents 2 Varieties and 3 Tillage methods for a total of 6 Treatment combinations.

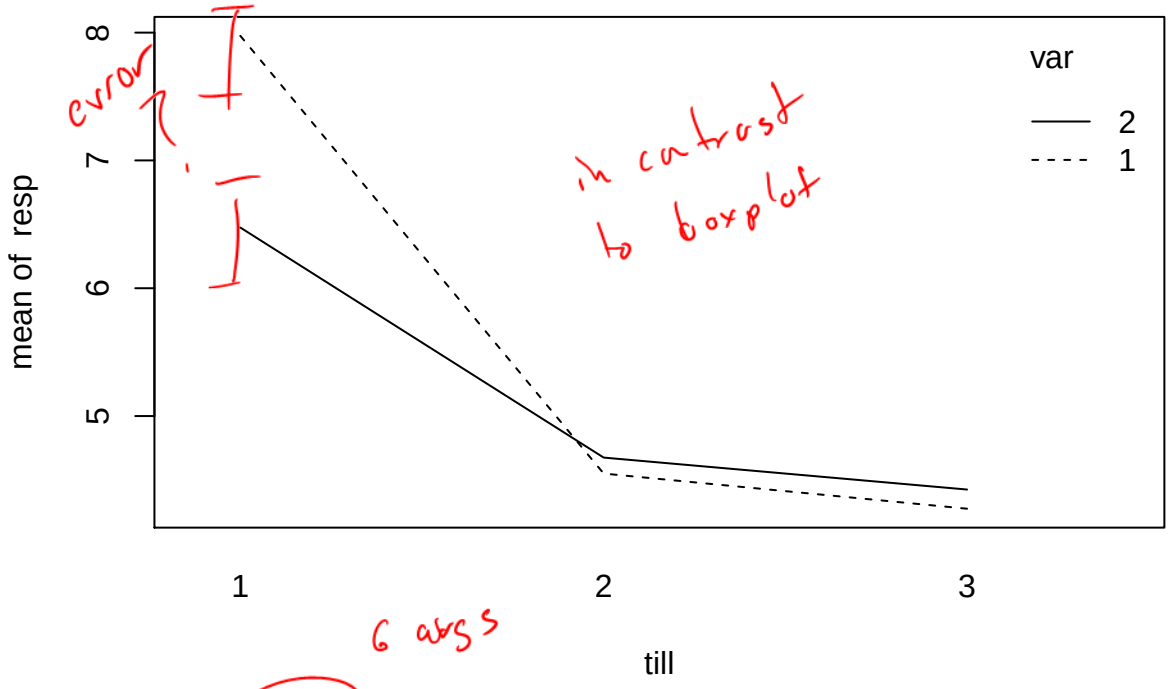
```
library(car)
library(emmeans)
InData <- read.csv("~/Dropbox/STAT512/Lectures/ExpDesign2/ED2_2wayData.csv")
str(InData)
```

```
## '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 ...
```

```
table(InData$var,InData$till)
```

```
##
##     1 2 3
##   1 4 4 4
##   2 4 4 4
```

```
#Important: Need to define till, var as.factors!
InData$till <- as.factor(InData$till)
InData$var <- as.factor(InData$var)
with(interaction.plot(till, var, resp), data = InData)
```




```
aggregate(resp ~ till*var, data = InData, FUN = mean)
```

```
##   till var  resp
## 1    1   1 7.975
## 2    2   1 4.550
```

```
## 3    3   1 4.275
## 4    1   2 6.475
## 5    2   2 4.675
## 6    3   2 4.425
```

For Illustration: Comparing Type 1, 2, 3 ANOVA tables with Default Contrasts

The default contrasts in R do not sum to zero. Hence the Type3 tests are meaningless! For illustration, we look at the coefficients table from the summary() output as well as the model.matrix. But this information is not usually required to address typical research questions!

```
Model1 <- lm(resp ~ till*var, data = InData)
anova(Model1)
```

```
## Analysis of Variance Table
##
## Response: resp
##           Df Sum Sq Mean Sq F value  Pr(>F)
## till       2 40.426 20.2129  4.6167 0.02407 *
## var        1  1.000  1.0004  0.2285 0.63839
## till:var   2  3.576  1.7879  0.4084 0.67074
## Residuals 18 78.808  4.3782
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Anova(Model1, type = 2)
```

```
## Anova Table (Type II tests)
##
## Response: resp
##           Sum Sq Df F value  Pr(>F)
## till      40.426  2  4.6167 0.02407 *
## var        1.000  1  0.2285 0.63839
## till:var   3.576  2  0.4084 0.67074
## Residuals 78.807 18
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Anova(Model1, type = 3)
```

```
## Anova Table (Type III tests)
##
## Response: resp
##              Sum Sq Df F value    Pr(>F)
## (Intercept) 254.402  1 58.1067 4.842e-07 ***
## till         33.995  2  3.8823   0.03965 *
## var           4.500  1  1.0278   0.32411
## till:var      3.576  2  0.4084   0.67074
## Residuals    78.808 18
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(Model1)
```

```
##
## Call:
## lm(formula = resp ~ till * var, 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|)
## (Intercept)    7.975      1.046   7.623 4.84e-07 ***
## till2         -3.425      1.480  -2.315   0.0326 *
## till3         -3.700      1.480  -2.501   0.0223 *
## var2          -1.500      1.480  -1.014   0.3241
## till2:var2     1.625      2.092   0.777   0.4475
## till3:var2     1.650      2.092   0.789   0.4406
## ---
## 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:  0.3635, Adjusted R-squared:  0.1867
## F-statistic: 2.056 on 5 and 18 DF,  p-value: 0.1189
```

```
model.matrix(Model1)
```

```
##    (Intercept) till2 till3 var2 till2:var2 till3:var2
## 1            1     0     0    0          0          0
## 2            1     1     0    0          0          0
## 3            1     0     1    0          0          0
## 4            1     0     0    1          0          0
## 5            1     1     0    1          1          0
## 6            1     0     1    1          0          1
## 7            1     0     0    0          0          0
## 8            1     1     0    0          0          0
## 9            1     0     1    0          0          0
## 10           1     0     0    1          0          0
## 11           1     1     0    1          1          0
## 12           1     0     1    1          0          1
## 13           1     0     0    0          0          0
## 14           1     1     0    0          0          0
## 15           1     0     1    0          0          0
## 16           1     0     0    1          0          0
## 17           1     1     0    1          1          0
## 18           1     0     1    1          0          1
## 19           1     0     0    0          0          0
## 20           1     1     0    0          0          0
## 21           1     0     1    0          0          0
## 22           1     0     0    1          0          0
## 23           1     1     0    1          1          0
## 24           1     0     1    1          0          1
## attr(,"assign")
## [1] 0 1 1 2 3 3
```

```
## attr(,"contrasts")
## attr(,"contrasts")$till
## [1] "contr.treatment"
##
## attr(,"contrasts")$var
## [1] "contr.treatment"
```

```
getOption("contrasts")
```

```
##         unordered           ordered
## "contr.treatment"      "contr.poly"
```

```
contrasts(inData$till)
```

```
##   2 3
## 1 0 0
## 2 1 0
## 3 0 1
```

Standard Analysis

It is necessary to choose a contrasts setting that sums to zero (not the default used by R). For routine analysis, we are typically interested in the Type 3 tests and pairwise comparisons from emmeans. Now the Type3 ANOVA table matches the Type1 and 2 tables above (due to balance). Note: The warning from emmeans ("Results may be misleading due to involvement in interactions") will be displayed when considering comparisons of main effects in any model that includes an interaction.

```
options(contrasts = c("contr.sum", "contr.poly"))
contrasts(InData$till)
```

```
##   [,1] [,2]
## 1    1    0
## 2    0    1
## 3   -1   -1
```

```
Model2 <- lm(resp ~ till*var, data = InData)
Anova(Model2, type = 3)
```

```
## Anova Table (Type III tests)
##
## Response: resp
##             Sum Sq Df  F value    Pr(>F)
## (Intercept) 698.76  1 159.6001 2.195e-10 ***
## till         40.43  2   4.6167   0.02407 *
## var           1.00  1   0.2285   0.63839
## till:var      3.58  2   0.4084   0.67074
## Residuals    78.81 18
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
emmeans(Model2, pairwise ~ till)
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

```
## $emmeans
##  till emmean        SE df lower.CL upper.CL
##  1    7.2250 0.7397799 18  5.67078  8.77922
```

```
##  2    4.6125 0.7397799 18  3.05828  6.16672
##  3    4.3500 0.7397799 18  2.79578  5.90422
##
## Results are averaged over the levels of: var
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate       SE df t.ratio p.value
##  1 - 2      2.6125 1.046207 18   2.497  0.0557
##  1 - 3      2.8750 1.046207 18   2.748  0.0337
##  2 - 3      0.2625 1.046207 18   0.251  0.9660
##
## Results are averaged over the levels of: var
## P value adjustment: tukey method for comparing a family of 3 estimates
```

borderline

significant

```
emmeans(Model2, pairwise ~ var)

## NOTE: Results may be misleading due to involvement in interactions

## $emmeans
##  var   emmean        SE df lower.CL upper.CL
##  1   5.600000 0.6040278 18 4.330985 6.869015
##  2   5.191667 0.6040278 18 3.922651 6.460682
##
## Results are averaged over the levels of: till
## Confidence level used: 0.95
##
## $contrasts
##  contrast  estimate        SE df t.ratio p.value
##  1 - 2    0.4083333 0.8542243 18   0.478  0.6384
##
## Results are averaged over the levels of: till
```

FTR for ANOVA

```
emmeans(Model2, pairwise ~ till:var)
```

~ not significant interaction

```
## $emmeans
##  till var emmean       SE df lower.CL  upper.CL
##  1    1    7.975 1.046207 18 5.777001 10.172999
##  2    1    4.550 1.046207 18 2.352001  6.747999
##  3    1    4.275 1.046207 18 2.077001  6.472999
##  1    2    6.475 1.046207 18 4.277001  8.672999
##  2    2    4.675 1.046207 18 2.477001  6.872999
##  3    2    4.425 1.046207 18 2.227001  6.622999
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast  estimate      SE df t.ratio p.value
##  1,1 - 2,1    3.425 1.47956 18   2.315  0.2385
##  1,1 - 3,1    3.700 1.47956 18   2.501  0.1756
##  1,1 - 1,2    1.500 1.47956 18   1.014  0.9073
##  1,1 - 2,2    3.300 1.47956 18   2.230  0.2721
##  1,1 - 3,2    3.550 1.47956 18   2.399  0.2080
##  2,1 - 3,1    0.275 1.47956 18   0.186  1.0000
##  2,1 - 1,2   -1.925 1.47956 18  -1.301  0.7808
##  2,1 - 2,2   -0.125 1.47956 18  -0.084  1.0000
```

matches 6 trts one-way ANOVA

15 pairwise from oneway

```
##  2,1 - 3,2    0.125 1.47956 18   0.084  1.0000
##  3,1 - 1,2   -2.200 1.47956 18  -1.487  0.6763
##  3,1 - 2,2   -0.400 1.47956 18  -0.270  0.9998
##  3,1 - 3,2   -0.150 1.47956 18  -0.101  1.0000
##  1,2 - 2,2    1.800 1.47956 18   1.217  0.8233
##  1,2 - 3,2    2.050 1.47956 18   1.386  0.7348
##  2,2 - 3,2    0.250 1.47956 18   0.169  1.0000
##
## P value adjustment: tukey method for comparing a family of 6 estimates
```