Graeco Latin Square Example

This example is taken from Montgomery. The assembly time of a television component is compared using four methods (A,B,C,D). To reduce variability in the response the four methods are balanced with respected to: operator (column), order of assembly (row), workplace location (Greek letter), in a Graeco-Latin Square design.

```
library(car)
library(emmeans)
GLSData <- read.csv("C:/hess/STAT512/RNotes/ExpDesign1/ED1_GraecoLatinSquare.csv")
str(GLSData)
```

```
## 'data.frame':    16 obs. of  5 variables:
##  $ row   : int  1 1 1 1 2 2 2 2 3 3 ...
##  $ col   : int  1 2 3 4 1 2 3 4 1 2 ...
##  $ letter: Factor w/ 4 levels "alpha","beta",..: 2 4 3 1 1 3 4 2 3 1 ...
##  $ trt   : Factor w/ 4 levels "A","B","C","D": 3 2 4 1 2 3 1 4 1 4 ...
##  $ time  : int  11 10 14 8 8 12 10 12 9 11 ...
```

```
#Important: Need to define row and col as.factor!
GLSData$row <- as.factor(GLSData$row)
GLSData$col <- as.factor(GLSData$col)

Model1 <- lm(time ~ row + col + letter + trt, data = GLSData)
Anova(Model1, type = 3)
```

```
## Anova Table (Type III tests)
##
## Response: time
##             Sum Sq Df F value  Pr(>F)
## (Intercept) 88.923  1  9.7007 0.05269 .
## row          0.500  3  0.0182 0.99597
## col         19.000  3  0.6909 0.61572
## letter       7.500  3  0.2727 0.84288
## trt         95.500  3  3.4727 0.16690
## Residuals   27.500  3
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Model2 <- lm(time ~ trt, data = GLSData)
Anova(Model2, type = 3)
```

```
## Anova Table (Type III tests)
##
## Response: time
##             Sum Sq Df F value    Pr(>F)
## (Intercept) 306.25  1 67.4312 2.875e-06 ***
## trt          95.50  3  7.0092  0.005595 **
## Residuals    54.50 12
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

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

```
## $emmeans
```

```
##  trt emmean       SE df  lower.CL upper.CL
##  A     8.75 1.065559 12  6.428346 11.07165
##  B     7.75 1.065559 12  5.428346 10.07165
##  C    14.00 1.065559 12 11.678346 16.32165
##  D    11.50 1.065559 12  9.178346 13.82165
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate       SE df t.ratio p.value
##  A - B        1.00 1.506928 12   0.664  0.9087
##  A - C       -5.25 1.506928 12  -3.484  0.0204
##  A - D       -2.75 1.506928 12  -1.825  0.3091
##  B - C       -6.25 1.506928 12  -4.148  0.0064
##  B - D       -3.75 1.506928 12  -2.489  0.1126
##  C - D        2.50 1.506928 12   1.659  0.3850
##
## P value adjustment: tukey method for comparing a family of 4 estimates
```