# STAT 222 Spring 2022 HW10

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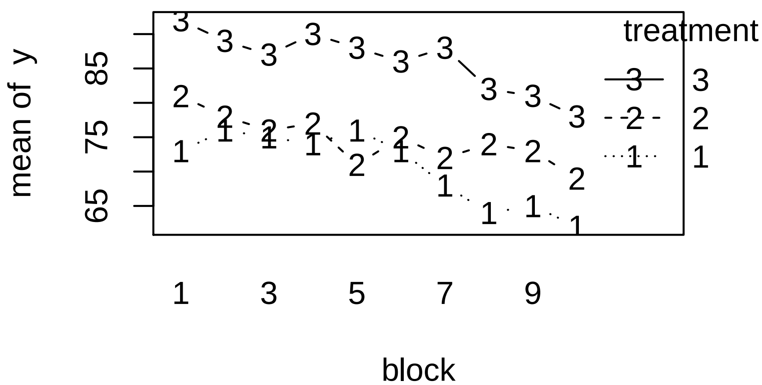
## Question 1 — Auditor Training

```r
auditor = read.table("http://www.stat.uchicago.edu/~yibi/s222/AuditorTraining", header=T)
```

### Q1a — 2 points

```r
auditor$treatment = as.factor(auditor$treatment)
auditor$block = as.factor(auditor$block)

with(auditor, interaction.plot(block,treatment,y,type='b'))
```




```r
# ggplot(data = auditor, mapping = aes(x=block, y=y,color = treatment)) +
#   geom_line() + geom_point() + xlab("Block") + ylab("Response")
```

It is not reasonable to assume no treatment-block interaction since the lines are not parallel.

### Q1b — 3 points

```r
lm <- lm(data = auditor, y~treatment+block)
anova(lm)
## Analysis of Variance Table
##
## Response: y
##           Df  Sum Sq Mean Sq  F value          Pr(>F)
## treatment  2 1295.00  647.50 103.7537 0.0000000001315 ***
## block      9  433.37   48.15   7.7157       0.0001316 ***
```

```
## Residuals 18  112.33    6.24
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
mean(~y,data=auditor)
## [1] NA
sort(mean(y~treatment,data=auditor))
## numeric(0)
```

$$SS_{trt} = b\sum_{i=1}^{g}(\bar{y}_{i\cdot} - \bar{y}_{\cdot\cdot})^2$$

$$= 10 * ((70.6 - 77.1)^2 + (74.6 - 77.1)^2 + (86.1 - 77.1)^2) = 1295$$

## Q1c — 4 points

```
lmemmeans <- emmeans(lm,~treatment)
sprintf("Tukey's HSD: %f",qtukey(1-0.05,3,18)/sqrt(2) * sqrt(6.24*((1/10)+(1/10)))) # hsd
## [1] "Tukey's HSD: 2.851122"
summary(contrast(lmemmeans,method="pairwise",adjust="tukey"),infer=c(T,T), level=0.95)
##  contrast estimate   SE df lower.CL upper.CL t.ratio p.value
##  1 - 2        -4.0 1.12 18    -6.85    -1.15  -3.580  0.0058
##  1 - 3       -15.5 1.12 18   -18.35   -12.65 -13.874  <.0001
##  2 - 3       -11.5 1.12 18   -14.35    -8.65 -10.294  <.0001
##
## Results are averaged over the levels of: block
## Confidence level used: 0.95
## Conf-level adjustment: tukey method for comparing a family of 3 estimates
## P value adjustment: tukey method for comparing a family of 3 estimates
```

## Q1d — 4 points

```
lm1 <- lm(data = auditor,y~treatment)
anova(lm1)
## Analysis of Variance Table
##
## Response: y
##           Df Sum Sq Mean Sq F value        Pr(>F)
## treatment  2 1295.0  647.50  32.037 0.00000007441 ***
## Residuals 27  545.7   20.21
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
sprintf("New Tukey's HSD: %f",qtukey(1-0.05,3,27)/sqrt(2) * sqrt(20.21*((1/10)+(1/10)))) # h
## [1] "New Tukey's HSD: 4.984801"
lm1emmeans <- emmeans(lm1,~treatment)
summary(contrast(lm1emmeans,method="pairwise",adjust="tukey"),infer=c(T,T), level=0.95)
##  contrast estimate   SE df lower.CL upper.CL t.ratio p.value
##  1 - 2        -4.0 2.01 27    -8.98    0.985  -1.990  0.1341
```

```
##  1 - 3       -15.5 2.01 27   -20.48  -10.515  -7.709  <.0001
##  2 - 3       -11.5 2.01 27   -16.48   -6.515  -5.720  <.0001
##
## Confidence level used: 0.95
## Conf-level adjustment: tukey method for comparing a family of 3 estimates
## P value adjustment: tukey method for comparing a family of 3 estimates
```

Only the latter two pairs are significant (1-3),(2-3).

# Question 2

```
mydata = read.table("http://users.stat.umn.edu/~gary/book/fcdae.data/pr13.4", header=T)
```

## Q2a — 2 points

It is a Latin Squares design with two squares reusing columns (grader block).

## Q2b — 2 points

```
lm2 <- lm(score~as.factor(exam)+as.factor(student)+as.factor(grader),data = mydata)
anova(lm2)
## Analysis of Variance Table
##
## Response: score
##                    Df Sum Sq Mean Sq F value    Pr(>F)
## as.factor(exam)     4 1889.9  472.48 33.9639 4.246e-11 ***
## as.factor(student)  9 5050.3  561.15 40.3376 5.785e-15 ***
## as.factor(grader)   4  443.3  110.83  7.9669 0.0001417 ***
## Residuals          32  445.2   13.91
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

No because the p value for the exams treatment is significantly smaller than 0.05,0.01,etc. This means that we can reject the null that the effect of different exams on score is zero, and so we conclude that exams are not equivalent in the level difficulty since exams have an effect on score.

## Q2c — 4 points

```
lm2emmeans <- emmeans(lm2,~exam)
summary(contrast(lm2emmeans,method=list(c_1 = c(-1,0,1/3,1/3,1/3),c_2 = c(0,-1,1/3,1/3,1/3))
##  contrast estimate   SE df
##  c_1           8.1 1.36 32
##  c_2          -9.8 1.36 32
##
## Results are averaged over the levels of: student, grader
bonf <- qt(0.05/2/2,32,lower.tail = F)
```

```r
se <- sqrt(13.91 * ((3*(((1/3)^2)/10)) + (1/10))) #se
bonf*se
## [1] 3.202874
```

```r
sprintf("CI C1: (%f, %f)",8.1-bonf*se,8.1+bonf*se)
## [1] "CI C1: (4.897126, 11.302874)"
sprintf("CI C2: (%f, %f)",-9.8-bonf*se,-9.8+bonf*se)
## [1] "CI C2: (-13.002874, -6.597126)"
```

From contrast 1, since the 95% CI only contains positive values, we can conclude that exam A is more difficult than the old exams with previous exams having higher average scores than exam A. From contrast 2, sinec the 95% CI only contains negative values, we can conclude that exam B is easier than old exams with previous exams having lower average scores than exam B.

## Q2d — 4 points

```r
sprintf("Tukey's HSD: %f",qtukey(1-0.05,5,32)/sqrt(2) * sqrt(13.91*((1/10)+(1/10)))) # hsd
## [1] "Tukey's HSD: 4.819316"
lm2est <- emmeans(lm2,~grader)
summary(contrast(lm2est,method="pairwise",adjust="tukey"),infer=c(F,F), level=0.95)
##  contrast estimate   SE df
##  1 - 2        -2.6 1.67 32
##  1 - 3         0.6 1.67 32
##  1 - 4         1.3 1.67 32
##  1 - 5         6.5 1.67 32
##  2 - 3         3.2 1.67 32
##  2 - 4         3.9 1.67 32
##  2 - 5         9.1 1.67 32
##  3 - 4         0.7 1.67 32
##  3 - 5         5.9 1.67 32
##  4 - 5         5.2 1.67 32
##
## Results are averaged over the levels of: exam, student
```

```
  5      4       3       1      2
59.5    64.7    65.4    66.0   68.6
       -----------------------------
----------------------------
```