HW-Week 7

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Problem 4.3

```
library(GAD)
```

```
## Loading required package: matrixStats
## Loading required package: R.methodsS3
## R.methodsS3 v1.8.2 (2022-06-13 22:00:14 UTC) successfully loaded. See ?R.methodsS3 for help.
```

```
chemical<-c(rep(1,5),rep(2,5),rep(3,5),rep(4,5))
bolt<-c(rep(seq(1,5),4))
obs <- c(73,68,74,71,67,73,67,75,72,70,75,68,78,73,68,73,71,75,75,69)
chemical<-as.fixed(chemical)
bolt<-as.fixed(bolt)
obs <- as.numeric(obs)
dat <- data.frame(chemical,bolt,obs)
dat
```

```
##    chemical bolt obs
## 1         1    1  73
## 2         1    2  68
## 3         1    3  74
## 4         1    4  71
## 5         1    5  67
## 6         2    1  73
## 7         2    2  67
## 8         2    3  75
## 9         2    4  72
## 10        2    5  70
## 11        3    1  75
## 12        3    2  68
## 13        3    3  78
## 14        3    4  73
## 15        3    5  68
## 16        4    1  73
## 17        4    2  71
## 18        4    3  75
## 19        4    4  75
## 20        4    5  69
```

```
str(dat)
```

```
## 'data.frame':    20 obs. of  3 variables:
##  $ chemical: Factor w/ 4 levels "1","2","3","4": 1 1 1 1 1 2 2 2 2 2 ...
##  $ bolt    : Factor w/ 5 levels "1","2","3","4",..: 1 2 3 4 5 1 2 3 4 5 ...
```

```
##  $ obs     : num  73 68 74 71 67 73 67 75 72 70 ...
```

```
model<-lm(obs~chemical+bolt,data=dat)
gad(model)
```

```
## Analysis of Variance Table
##
## Response: obs
##          Df Sum Sq Mean Sq F value    Pr(>F)
## chemical  3  12.95   4.317  2.3761    0.1211
## bolt      4 157.00  39.250 21.6055 2.059e-05 ***
## Residual 12  21.80   1.817
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Hypothesis:

$H_0 : \tau_i = 0$ for all i

$H_a : \tau_i \neq 0$ for some i

Model Equation:

$y_{ij} = \mu + \tau_i + \beta_j + e_{ij}$

where μ = grand mean, τ_i = Chemical effect, β_j = Bolt (block), e_{ij} = random error ~ N(0,σ^2)

P value (0.1211) > α (0.05) hence we fail to reject H_0.

There is no difference among the four chemical agents at $\alpha = 0.05$ level.

Problem 4.16

Calculate model parameters τ_i: Formula: $\tau_i = \mu_i - \mu$

```
obs <- c(73,68,74,71,67,73,67,75,72,70,75,68,78,73,68,73,71,75,75,69)
mean(obs)
```

```
## [1] 71.75
```

```
tau_1 <- mean(obs[1:5])-mean(obs)
tau_1
```

```
## [1] -1.15
```

```
tau_2 <- mean(obs[6:10])-mean(obs)
tau_2
```

```
## [1] -0.35
```

```
tau_3 <- mean(obs[11:15])-mean(obs)
tau_3
```

```
## [1] 0.65
```

```
tau_4 <- mean(obs[16:20])-mean(obs)
tau_4
```

```
## [1] 0.85
```

τ_1 = -1.15, τ_2 = -0.35, τ_3 = 0.65, τ_4 = 0.85

Calculate model parameters β_j: Formula: $\beta_j = \mu_j - \mu$

```
obs <- c(73,68,74,71,67,73,67,75,72,70,75,68,78,73,68,73,71,75,75,69)
beta_1 <- mean(c(73,73,75,73))-mean(obs)
beta_1
```

```
## [1] 1.75
```

```
beta_2 <- mean(c(68,67,68,71))-mean(obs)
beta_2
```

```
## [1] -3.25
```

```
beta_3 <- mean(c(74,75,78,75))-mean(obs)
beta_3
```

```
## [1] 3.75
```

```
beta_4 <- mean(c(71,72,73,75))-mean(obs)
beta_4
```

```
## [1] 1
```

```
beta_5 <- mean(c(67,70,68,69))-mean(obs)
beta_5
```

```
## [1] -3.25
```

β_1 = 1.75, β_2 = -3.25, β_3 = 3.75, β_4 = 1, β_5 = -3.25

Problem 4.22

```
library(GAD)
batch <- c(rep(1,5),rep(2,5),rep(3,5),rep(4,5),rep(5,5))
day <- c(rep(seq(1,5),5))
ingr <- c("A","B","D","C","E",
         "C","E","A","D","B",
         "B","A","C","E","D",
         "D","C","E","B","A",
         "E","D","B","A","C")
obs <- c(8,7,1,7,3,
         11,2,7,3,8,
         4,9,10,1,5,
         6,8,6,6,10,
         4,2,3,8,8)
batch <- as.fixed(batch)
day <- as.fixed(day)
ingr <- as.fixed(ingr)
obs <- as.numeric(obs)
data <- data.frame(batch,day,ingr,obs)
data
```

```
##    batch day ingr obs
## 1      1   1    A   8
## 2      1   2    B   7
## 3      1   3    D   1
## 4      1   4    C   7
## 5      1   5    E   3
## 6      2   1    C  11
## 7      2   2    E   2
## 8      2   3    A   7
```

```
## 9       2   4    D   3
## 10      2   5    B   8
## 11      3   1    B   4
## 12      3   2    A   9
## 13      3   3    C  10
## 14      3   4    E   1
## 15      3   5    D   5
## 16      4   1    D   6
## 17      4   2    C   8
## 18      4   3    E   6
## 19      4   4    B   6
## 20      4   5    A  10
## 21      5   1    E   4
## 22      5   2    D   2
## 23      5   3    B   3
## 24      5   4    A   8
## 25      5   5    C   8
```

```
str(data)
```

```
## 'data.frame':    25 obs. of  4 variables:
##  $ batch: Factor w/ 5 levels "1","2","3","4",..: 1 1 1 1 1 2 2 2 2 2 ...
##  $ day  : Factor w/ 5 levels "1","2","3","4",..: 1 2 3 4 5 1 2 3 4 5 ...
##  $ ingr : Factor w/ 5 levels "A","B","C","D",..: 1 2 4 3 5 3 5 1 4 2 ...
##  $ obs  : num  8 7 1 7 3 11 2 7 3 8 ...
```

```
model <- aov(obs~batch+day+ingr, data=data)
summary(model)
```

```
##             Df Sum Sq Mean Sq F value   Pr(>F)
## batch        4  15.44    3.86   1.235 0.347618
## day          4  12.24    3.06   0.979 0.455014
## ingr         4 141.44   35.36  11.309 0.000488 ***
## Residuals   12  37.52    3.13
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Hypothesis H_0: $\tau_i = 0$ for all i

H_a: $\tau_i \neq 0$ for some i, i=1,2,3,4,5

Model equation: $X_{ijk} = \mu + \tau_i + \beta_j + \alpha_k + e_{ijk}$

where, μ=grand mean, τ_i=Ingredients effect, β_j = Batch (block 1) α_k = Day (block 2), e_{ijk} = random error ~N(0,σ^2)

Conclusions:

Hence the p value (0.000488) of ingredients is highly significant and less than α=0.05 so we reject the null hypothesis H_0.

Therefore the effect of five different ingredients (A,B,C,D,E) on the reaction time of a chemical process is significantly different.

Source Code

```
library(GAD)
chemical<-c(rep(1,5),rep(2,5),rep(3,5),rep(4,5))
bolt<-c(rep(seq(1,5),4))
obs <- c(73,68,74,71,67,73,67,75,72,70,75,68,78,73,68,73,71,75,75,69)
```

```
chemical<-as.fixed(chemical)
bolt<-as.fixed(bolt)
obs <- as.numeric(obs)
dat <- data.frame(chemical,bolt,obs)
dat
str(dat)
model<-lm(obs~chemical+bolt,data=dat)
gad(model)

obs <- c(73,68,74,71,67,73,67,75,72,70,75,68,78,73,68,73,71,75,75,69)
mean(obs)
tau_1 <- mean(obs[1:5])-mean(obs)
tau_1
tau_2 <- mean(obs[6:10])-mean(obs)
tau_2
tau_3 <- mean(obs[11:15])-mean(obs)
tau_3
tau_4 <- mean(obs[16:20])-mean(obs)
tau_4

obs <- c(73,68,74,71,67,73,67,75,72,70,75,68,78,73,68,73,71,75,75,69)
beta_1 <- mean(c(73,73,75,73))-mean(obs)
beta_1
beta_2 <- mean(c(68,67,68,71))-mean(obs)
beta_2
beta_3 <- mean(c(74,75,78,75))-mean(obs)
beta_3
beta_4 <- mean(c(71,72,73,75))-mean(obs)
beta_4
beta_5 <- mean(c(67,70,68,69))-mean(obs)
beta_5

library(GAD)
batch <- c(rep(1,5),rep(2,5),rep(3,5),rep(4,5),rep(5,5))
day <- c(rep(seq(1,5),5))
ingr <- c("A","B","D","C","E",
         "C","E","A","D","B",
         "B","A","C","E","D",
         "D","C","E","B","A",
         "E","D","B","A","C")
obs <- c(8,7,1,7,3,
         11,2,7,3,8,
         4,9,10,1,5,
         6,8,6,6,10,
         4,2,3,8,8)
batch <- as.fixed(batch)
day <- as.fixed(day)
ingr <- as.fixed(ingr)
obs <- as.numeric(obs)
data <- data.frame(batch,day,ingr,obs)
data
str(data)
model <- aov(obs~batch+day+ingr, data=data)
```

```
summary(model)
```