GA15 solutions

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Problem 1

a)

```
d<-c(19,22,20,18,25,20,21,33,27,40,16,15,18,26,17)
d1<-data.frame(matrix(c(d,rep(1,5),rep(2,5),rep(3,5)), byrow=FALSE, nrow=15, ncol=2))
colnames(d1)<-c('res','group')
d1$group<-factor(d1$group, labels = c(1,2,3))
print(d1)
```

```
##    res group
## 1   19     1
## 2   22     1
## 3   20     1
## 4   18     1
## 5   25     1
## 6   20     2
## 7   21     2
## 8   33     2
## 9   27     2
## 10  40     2
## 11  16     3
## 12  15     3
## 13  18     3
## 14  26     3
## 15  17     3
```

```
lm<-lm(res~group, data=d1)
anova(lm)
```

```
## Analysis of Variance Table
##
## Response: res
##           Df Sum Sq Mean Sq F value  Pr(>F)
## group      2 260.93 130.467  4.0061 0.04648 *
## Residuals 12 390.80  32.567
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

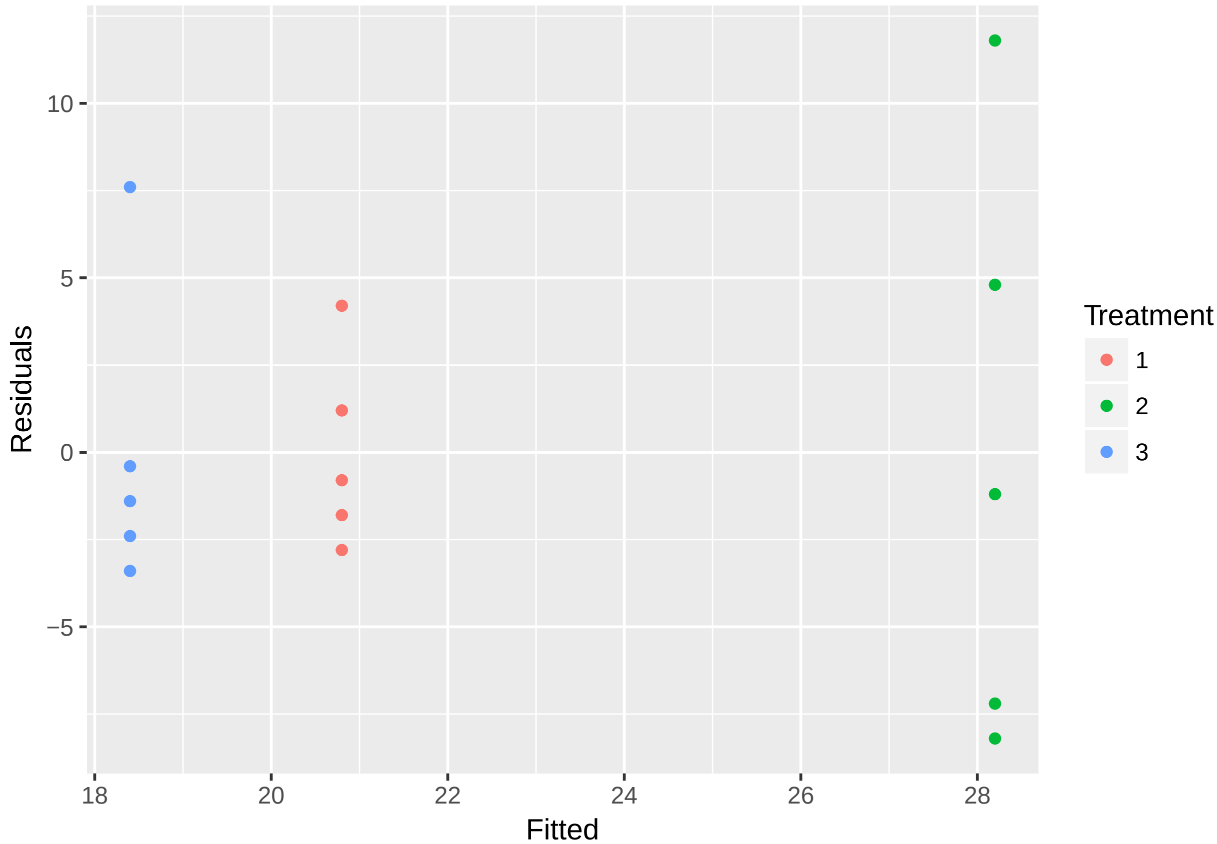
p-value $= 0.046 < 0.05 \Rightarrow$ We reject H_0 so the response time depends on the circuit type.

b)

```
library(ggplot2)
```

```
## Warning: package 'ggplot2' was built under R version 3.4.4
```

```
d1_res<-data.frame(Fitted=fitted(lm), Residuals=resid(lm), Treatment=d1$group)
ggplot(d1_res, aes(Fitted,Residuals, colour=Treatment))+geom_point()
```



We can see that residuals of treatments 1 and 2 are equally distributed around the 0 line. The residuals of treatment 1 locate mostly under the line but the sample size is too small to make an interpretation worthwhile.

c)

```
c(lower = mean(d1$res[d1$group==3])-qt(0.025,12, lower.tail = FALSE)*sqrt(32.567/5),
  upper = mean(d1$res[d1$group==3])+qt(0.025,12, lower.tail = FALSE)*sqrt(32.567/5))
```

```
##    lower    upper
## 12.83937 23.96063
```

d)

```
c(lower = mean(d1$res[d1$group==1])-mean(d1$res[d1$group==2])
  - qt(0.025,12, lower.tail = FALSE)*sqrt(2*32.567/5), upper =
    mean(d1$res[d1$group==1])-mean(d1$res[d1$group==2])
  +qt(0.025,12, lower.tail = FALSE)*sqrt(2*32.567/5))
```

```
##       lower       upper
## -15.2639147   0.4639147
```

0 belongs to this CI so the mean differences of response time for circuits 1 and 2 are equal with confidence level 95%.

e)

```
LSD <- qt(0.025, 12, lower.tail = FALSE)*sqrt(2*32.567/5)
for (i in 1:2){
  for (j in (i+1):3){
```

```r
    if (mean(d1$res[d1$group==i])-mean(d1$res[d1$group==j])>LSD){

      print(paste('mean treatment',as.character(i),
                  'differs from mean treatment', as.character(j)))
    }
  }
}
```

```
## [1] "mean treatment 2 differs from mean treatment 3"
```

Bonus Problem

```r
d0<-c(29.7,26.7,26.8,27.1,28.3,30,23.9,35.4,31.6)
d2<-data.frame(matrix(c(d0,rep(1,5),rep(2,4)), byrow=FALSE, nrow=9, ncol=2))
colnames(d2)<-c('points','group')
d2$group<-factor(d2$group, labels = c(1,2))
print(d2)
```

```
##   points group
## 1   29.7     1
## 2   26.7     1
## 3   26.8     1
## 4   27.1     1
## 5   28.3     1
## 6   30.0     2
## 7   23.9     2
## 8   35.4     2
## 9   31.6     2
```

```r
lm2<-lm(points~group, data=d2)
anova(lm2)
```

```
## Analysis of Variance Table
##
## Response: points
##           Df Sum Sq Mean Sq F value Pr(>F)
## group      1 13.945  13.944  1.2971 0.2922
## Residuals  7 75.255  10.751
```

```r
t.test(d2$points[d2$group==1], d2$points[d2$group==2],
       alternative="two.sided", var.equal = TRUE)
```

```
##
##  Two Sample t-test
##
## data:  d2$points[d2$group == 1] and d2$points[d2$group == 2]
## t = -1.1389, df = 7, p-value = 0.2922
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -7.70602  2.69602
## sample estimates:
## mean of x mean of y
##    27.720    30.225
```

p-value $= 0.2922 > 0.05 \Rightarrow$ difference in means is not significant.

$$\text{F-value} = 1.2971 = (-1.1389)^2 = \text{t}^2$$