CRD with a Covariate

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Create Dataframe

```
gain<-data.frame(trt=c("A","A","A","A","A",
                       "B","B","B","B","B",
                       "C","C","C","C","C"),
                 in_weight=c(350,400,360,350,340,
                             390,340,410,430,390,
                             400,320,330,390,420),
                 gain=c(970,1000,980,980,970,
                        990, 950,980,990,980,
                        990,940,930,1000,1000),
                 stringsAsFactors = TRUE)


print(gain) #See the Data
```

```
##    trt in_weight gain
## 1    A        350  970
## 2    A        400 1000
## 3    A        360  980
## 4    A        350  980
## 5    A        340  970
## 6    B        390  990
## 7    B        340  950
## 8    B        410  980
## 9    B        430  990
## 10   B        390  980
## 11   C        400  990
## 12   C        320  940
## 13   C        330  930
## 14   C        390 1000
## 15   C        420 1000
```

ANOVA test

```
contrasts(gain$trt)<-contr.SAS # Set contrasts like SAS?

tm<-lm(gain ~ in_weight + trt, data=gain) # Fit the linear model
summary(tm)
```

```
##
## Call:
## lm(formula = gain ~ in_weight + trt, data = gain)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -16.615  -4.066   0.000   3.319  17.121
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 747.16484   30.30957  24.651 5.61e-11 ***
## in_weight     0.60440    0.08063   7.496 1.21e-05 ***
## trt1         15.25275    6.22916   2.449   0.0323 *
## trt2         -6.08791    6.36135  -0.957   0.3591
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 9.73 on 11 degrees of freedom
## Multiple R-squared:  0.8406, Adjusted R-squared:  0.7971
## F-statistic: 19.34 on 3 and 11 DF,  p-value: 0.0001078
```

```
fm<-aov(gain ~ in_weight + trt, data=gain) # Fit the ANOVA
summary(fm) #ANOVA table SS I
```

```
##             Df Sum Sq Mean Sq F value   Pr(>F)
## in_weight    1   4441    4441   46.91 2.77e-05 ***
## trt          2   1051     525    5.55   0.0216 *
## Residuals   11   1041      95
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#install.packages("car")
car::Anova(tm,type="III") #Anova table with SS III
```

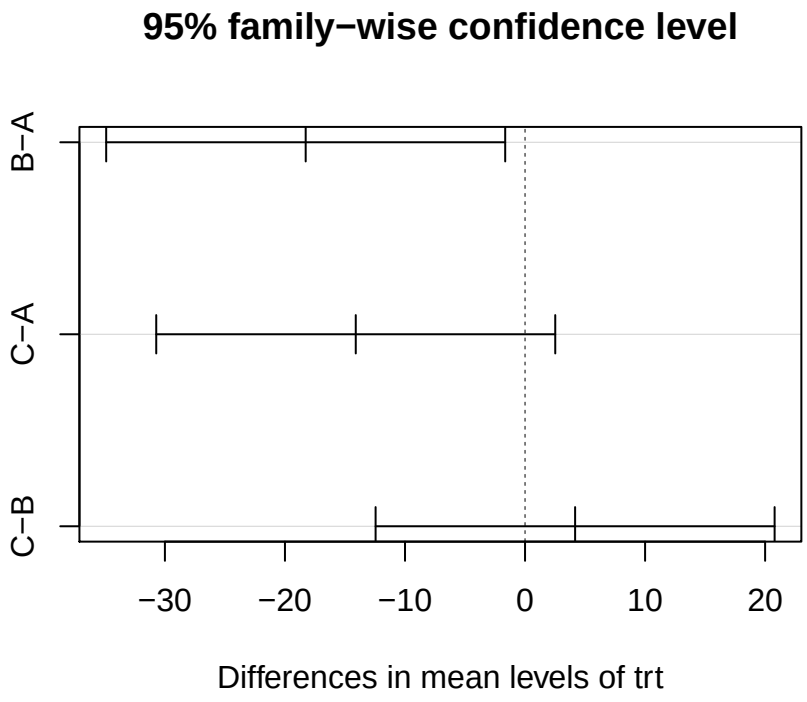
```
## Anova Table (Type III tests)
##
## Response: gain
##             Sum Sq Df  F value    Pr(>F)
## (Intercept)  57526  1 607.6778 5.614e-11 ***
## in_weight     5319  1  56.1840 1.207e-05 ***
## trt           1051  2   5.5499   0.02155 *
## Residuals     1041 11
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Multiple comparisons

```
TukeyHSD(fm,"trt")          # Tukey test for multiple comparisons
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = gain ~ in_weight + trt, data = gain)
##
## $trt
##           diff       lwr       upr     p adj
## B-A -18.273292 -34.89314 -1.653444 0.0315687
## C-A -14.102484 -30.72233  2.517363 0.0991696
## C-B   4.170807 -12.44904 20.790655 0.7808618
```

```
plot(TukeyHSD(fm,"trt"))    # Plot for tukey test
```




```
aggregate(gain$gain, by=list(gain$trt), FUN = mean) # Means by group
```

```
##   Group.1   x
## 1       A 980
## 2       B 978
## 3       C 972
```

```
lsmeans::lsmeans(tm,"trt")          #LSM for treatment
```

```
##  trt   lsmean       SE df lower.CL upper.CL
##  A   988.8645 4.509065 11 978.9401 998.7889
##  B   967.5238 4.570173 11 957.4649 977.5827
##  C   973.6117 4.356524 11 964.0231 983.2004
##
## Confidence level used: 0.95
```

Plot for differences

```
library(multcomp)
par(mar=c(4,4,6,2)) # Change parameters for the plot margins
tuk <- multcomp::glht(fm, linfct=multcomp::mcp(trt="Tukey")) # Fit the general Linear Hypotheses
plot(multcomp::cld(tuk, level=0.05),col="lightgrey") # Plot the mean differences
```