**STAT 5309**

**LAB 5**

**\*\*CONTENTS: 2-FACTOR DESIGNS–INTERACTIONS –**

**Due: Mar 8**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| 1. **PRACTICE**   **##-------------------------------2-FACTOR DESIGN: 1 Quantitative factor---------------**   |  |  |  |  | | --- | --- | --- | --- | | Temp  Type | 15 70 125 | | | | 1 | 130 155  74 180 | 34 40  80 75 | 20 70  82 58 | | 2 | 150 188  159 126 | 136 122  106 115 | 25 70  58 45 | | 3 | 138 110  168 160 | 174 120  150 139 | 96 104  82 60 |   #data: Battery life  type <- rep (c(1,2,3), each=12)  temp <- rep( c(1,2,3), each=4, times=3)  life <- c(130,155,74,180,34,40, 80, 75, 20, 70, 82, 58, 150, 188, 159, 126, 136, 122, 106, 115, 25, 70, 58, 45, 138, 110, 168, 160, 174, 120, 150, 139, 96, 104, 82, 60)  battery <- data.frame(type,temp,life)  temp <- factor(temp)  type <- factor(type)  attach(type, temp, life)  #---------------treatment means------------  tapply(life, list(type,temp), mean)   |  | | --- | | 15 70 125  1 134.75 57.25 57.5  2 155.75 119.75 49.5  3 144.00 145.75 85.5 |   model.tables(battery.mod,type="mean")   |  | | --- | | Tables of means  Grand mean    105.5278  type  type  1 2 3  83.17 108.33 125.08  temp  temp  1 2 3  144.83 107.58 64.17  type:temp  temp  type 1 2 3  1 134.75 57.25 57.50  2 155.75 119.75 49.50  3 144.00 145.75 85.50 |  |  | | --- | | **Question 1**: Which combination give the longest battery life? |   #Interaction.plot  interaction.plot(type, temp, life, pch=19)    ##-------------------Linear model----------------------  battery.mod <- aov(life ~ type\*temp, data=battery)   |  | | --- | | Df Sum Sq Mean Sq F value Pr(>F)  type 2 10684 5342 7.911 0.00198 \*\*  temp 2 39119 19559 28.968 1.91e-07 \*\*\*  type:temp 4 9614 2403 3.560 0.01861 \*  Residuals 27 18231 675  ---  Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1 |   #-------------Stripchart/Boxplot---------------  Stripchart(life ~ temp, vertical=TRUE, pch=16)  temp.means <- tapply(life, temp, mean)  lines(temp.means) #just the temp, better is the boxplot()       |  | | --- | | **Question : Which combination levels give the longest battery life?** |   **##--------------------------2-FACTOR DESIGN: 2 Quantitative factors----------------------------**  **Data: CO emmisions experiment data.** A data frame with 18 observations . There **are 2 factors**  .Eth : a factor with 3 levels 0.1 0.2 0.3.  Ratio: a factor with 3 levels 14 15 16.  CO: a numeric vector  library(daewr)  data(COdata)   |  | | --- | | Eth Ratio CO  1 0.1 14 66  2 0.1 15 72  3 0.1 16 68  4 0.2 14 78  5 0.2 15 80  6 0.2 16 66  7 0.3 14 90  8 0.3 15 75  9 0.3 16 60  10 0.1 14 62  11 0.1 15 67  12 0.1 16 66  13 0.2 14 81  14 0.2 15 81  15 0.2 16 69  16 0.3 14 94  17 0.3 15 78  18 0.3 16 58 |   CO.mod <-aov(CO ~Eth \*Ratio, data=COdata) # Linear model with interaction  summary.aov(CO.mod)   |  | | --- | | Df Sum Sq Mean Sq F value Pr(>F)  Eth 2 324.0 162.0 31.36 8.79e-05 \*\*\*  Ratio 2 652.0 326.0 63.10 5.07e-06 \*\*\*  Eth:Ratio 4 678.0 169.5 32.81 2.24e-05 \*\*\*  Residuals 9 46.5 5.2  ---  Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1 |  |  | | --- | | **Question : Is the interaction factor is significant”** |   **#Include the power.**  summary.aov(CO.mod,split= list(Eth=list(Linear=1, Quadratic=2, Cubic=3, Quartic=4)))   |  | | --- | | Df Sum Sq Mean Sq F value Pr(>F)  Eth 2 324.0 162.0 31.355 8.79e-05 \*\*\*  Eth: Linear 1 81.0 81.0 15.677 0.00331 \*\*  Eth: Quadratic 1 243.0 243.0 47.032 7.41e-05 \*\*\*  Eth: Cubic 1  Eth: Quartic 1  Ratio 2 652.0 326.0 63.097 5.07e-06 \*\*\*  Eth:Ratio 4 678.0 169.5 32.806 2.24e-05 \*\*\*  Eth:Ratio: Linear 2 24.0 12.0 2.323 0.15370  Eth:Ratio: Quadratic 2 654.0 327.0 63.290 5.00e-06 \*\*\*  Eth:Ratio: Cubic 0 0.0  Eth:Ratio: Quartic 0 0.0  Residuals 9 46.5 5.2  ---  Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1 |   **Note:** We expect the model might contain the quadratic term of Eth.  #-----------------------------Box plots-Interaction plots-------------------------  boxplot(CO ~ Eth)  boxplot(CO~ Ratio)  boxplot(CO ~ Eth + Ratio)     |  | | --- | | **Question: Which combination gives the lowest CO emission?** |   interaction.plot( Eth,Ratio, CO)  interaction.plot( Ratio,Eth, CO)    ##------------**model.tables:**  Row means, Column means, Grand mean.  model.tables(CO.mod, type=”means”, se=T)   |  | | --- | | Tables of means  Grand mean    72.83333  Eth  Eth  0.1 0.2 0.3  66.83 75.83 75.83  Ratio  Ratio  14 15 16  78.5 75.5 64.5  Eth:Ratio  Ratio  Eth 14 15 16  0.1 64.0 69.5 67.0  0.2 79.5 80.5 67.5  0.3 92.0 76.5 59.0  Standard errors for differences of means  Eth Ratio Eth:Ratio  1.312 1.312 2.273  replic. 6 6 2 |   **Note**: Combination level (0.3 , 14) has the largest value. Check the Box plot.  **##-----------------------TukeyHSD(): Multiple Comparison-----------------------------------**   |  | | --- | | > TukeyHSD(CO.mod, data=COdata)  Tukey multiple comparisons of means  95% family-wise confidence level  $Eth  diff lwr upr p adj  0.2-0.1 9 5.335954 12.664046 0.0001956  0.3-0.1 9 5.335954 12.664046 0.0001956  0.3-0.2 0 -3.664046 3.664046 1.0000000  $Ratio  diff lwr upr p adj  15-14 -3 -6.664046 0.6640457 0.1093568  16-14 -14 -17.664046 -10.3359543 0.0000056  16-15 -11 -14.664046 -7.3359543 0.0000405  $`Eth:Ratio` |   **Notes:**  TukeyHSD() might include the differences between **interactions**  #---------------------Plot TukeyHSD --------------------------  CO.Tukey<-TukeyHSD(CO.mod, data=COdata)  par(mfrow=c(2,2))  plot(results)    **##------------------------- Sum Square Interaction----------------------**  **#--------------------------2-Factor Design; Interaction-----------------------------**   |  | | --- | | > summary(CO.mod)  Df Sum Sq Mean Sq F value Pr(>F)  Eth 2 324.0 162.0 31.36 8.79e-05 \*\*\*  Ratio 2 652.0 326.0 63.10 5.07e-06 \*\*\*  Eth:Ratio 4 678.0 169.5 32.81 2.24e-05 \*\*\*  Residuals 9 46.5 5.2  ---  Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1 |   **##-------------EXTRA: Response Surface Model (RSM)**  >library(rsm)  > Eth.num<- rep(c(.1, .2, .3), each=3,times=2) # Eth in numeric  > Ratio.num <- rep( c(14, 15, 16), each=1, times=6) # Ratio in numeric  > COdata.num <- data.frame(Eth.num, Ratio.num,CO)  > CO.rsm.mod<- rsm(CO ~ SO(Eth.num, Ratio.num), data=COdata.num)  > summary(CO.rsm.mod)   |  | | --- | | > summary(CO.rsm.mod)  Call:  rsm(formula = CO ~ SO(Eth.numeric, Ratio.numeric), data = CO.data.num)  Estimate Std. Error t value Pr(>|t|)  (Intercept) -1013.5000 284.7158 -3.5597 0.003926  Eth.numeric 1575.0000 143.2928 10.9915 1.278e-07  Ratio.numeric 131.0000 37.9222 3.4544 0.004766  Eth.numeric:Ratio.numeric -90.0000 8.9268 -10.0820 3.279e-07  Eth.numeric^2 -450.0000 126.2438 -3.5645 0.003891  Ratio.numeric^2 -4.0000 1.2624 -3.1685 0.008093    (Intercept) \*\*  Eth.numeric \*\*\*  Ratio.numeric \*\*  Eth.numeric:Ratio.numeric \*\*\*  Eth.numeric^2 \*\*  Ratio.numeric^2 \*\*  ---  Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1  Multiple R-squared: 0.955, Adjusted R-squared: 0.9363  F-statistic: 50.95 on 5 and 12 DF, p-value: 1.146e-07  Analysis of Variance Table  Response: CO  Df Sum Sq Mean Sq F value Pr(>F)  FO(Eth.numeric, Ratio.numeric) 2 831.0 415.50 65.1765 3.588e-07  TWI(Eth.numeric, Ratio.numeric) 1 648.0 648.00 101.6471 3.279e-07  PQ(Eth.numeric, Ratio.numeric) 2 145.0 72.50 11.3725 0.001697  Residuals 12 76.5 6.37  Lack of fit 3 30.0 10.00 1.9355 0.194443  Pure error 9 46.5 5.17  Stationary point of response surface:  Eth.numeric Ratio.numeric  -0.9 26.5  Eigenanalysis:  $values  [1] 0.4950549 -454.4950549  $vectors  [,1] [,2]  Eth.numeric 0.09939545 -0.99504801  Ratio.numeric -0.99504801 -0.09939545 |  1. **EXERCISE**     (a) Set up the data frame. There are 36 data points. Create a factor “temp”, 3 levels. Create a factor pressure, 3 levels. Create a vector for the response “yield”. Create a data frame, named “process”.  (b) Build a linear model,using aov(). Are the pressure means are significant?  Are the temp means are significant. Is the interaction significant.  (c) Perform boxplot, of yield vs temp, yield vs pressure, yield vs temp and pressure  (d) Perform a residuals assumption check.    Skip (a)-(d) above. Answer (a) and (b) below   1. Set up the data frame (as in Prob 1), with factors “temp”, “content”, response vectors named “warpage” and data frame named “copperplate”.   Build a linear model, using aov(). Answer part (a) Check the interaction.  (b) Build a Response Model Surface (RSM) with warpage as response, use rsm(). |