Stat 322 (F17) - Assignment #2

**SOLUTIONS ( /40)**

*(Due Wed. Nov. 1 at 4:00 pm in appropriate STAT 322 slot in assignment box #15 outside the Math Tutorial Centre (MC 4066/4067). Electronic submissions or in-class submissions will not be accepted.*

1) An education researcher wishes to examine how external clues influence student performance on an exam. Two different exams, one with simple questions and one with difficult questions, were each printed on three different coloured paper; red, green and blue. 18 undergraduate students were randomly assigned to the six different exam combinations. The results (grade on exam out of 100) are presented in the table below, and are found in the *A2Q1.txt* dataset on LEARN. The data may be imported into R using the *read.table* function:

*>name=read.table(“A1Q2.txt”.header=TRUE)*

You will first need to copy the file to the current working directory, which can be found with the *>getwd()* command.

**Question type**

**Colour Simple Difficult**

Red 72, 84, 88 46, 54, 61

Green 91, 88, 88 43, 51, 38

Blue 85, 80, 84 66, 60, 60

1. **[3]** Provide the model associated with this factorial design.



b) **[3]** Create an interaction plot in R and briefly comment on what you see.

> interaction.plot(Colour,Question,Grade)



It appears there may be some degree of interaction present, as the difference in grade between simple and difficult questions is larger for the green colour exam than for the other colours.

c) **[3]** Create an ANOVA table in R that includes both main effects terms and interaction terms.

The command *>anova(lm(response~A+B+A\*B))* will generate the appropriate ANOVA table.

> col\_fac\_aov = anova(lm(Grade~Colour+Question+Colour\*Question))

> col\_fac\_aov

Analysis of Variance Table

Response: Grade

Df Sum Sq Mean Sq F value Pr(>F)

Colour 2 124.0 62.0 1.9510 0.184655

Question 1 4386.7 4386.7 138.0437 6.117e-08 \*\*\*

Colour:Question 2 460.4 230.2 7.2448 0.008643 \*\*

Residuals 12 381.3 31.8

d) **[3]** Does the effect of exam colour on grade depend on question type?

The question is asking whether there is a significant interaction effect. From the ANOVA table the associated value of the test statistic and p-value are 7.2448 and 0.008643, respectively. Since the p-value is less than 0.05, we reject the null hypothesis of no interaction and conclude that there is significant interaction between colour and question type in their effect on grade. So to directly answer the question posed: Yes, the effect of exam colour on grade depends on question type.

e) **[6]** The colour red has been associated with an increase in blood pressure and anxiety. **For the simple question type**, is there a difference the effect of the red colour and the average effect of the other colours on exam performance? Answer this question by creating a 95% confidence interval for the appropriate contrast.



95% confidence interval for θ:



Since the interval contains zero, we conclude that there is no significant difference in the effect of red and the average effect of the other two colours on grade.

f) **[3]** Calculate the contribution to the SS(Colour) of the red exam grades.



Contribution of the red colour to this sum of squares:



g) **[3]** Calculate the contribution to the SS(Res) of the green/difficult treatment combination grades.



2) The following is the ANOVA table generated for a modified version of the dentist study in exercise 5 page 48 of the course notes (data from dentists 11 and 12 have been omitted from the analysis leaving *n* = 60 observations). Please read the introduction in the course notes to familiarize yourself with the study.

> dentist\_aov=anova(lm(pain~brand+desensization+dentist+ brand\*desensization))

> dentist\_aov

Analysis of Variance Table

Response: pain

Df Sum Sq Mean Sq F value Pr(>F)

brand 2 2.172 1.0862 \*\*\*\*\* \*\*\*\*\*

desensization 1 2.091 2.0907 \*\*\*\*\* \*\*\*\*\*

dentist 9 58.073 6.4526 \*\*\*\*\* \*\*\*\*\*

brand:desensization 2 4.090 2.0452 \*\*\*\*\* \*\*\*\*\*

Residuals \* \*\*\*\*\* \*\*\*\*\*

a) **[2]** What is the role of the dentist variate in this experimental design?

Since each dentist carried out all 6 treatment combinations, this is a blocked design with dentists as blocks.

b) **[4]** R yields the following output for the sample standard deviation of the response:

> sd(pain)

[1] 1.393528

Use this value to calculate SS(Res) and MS(Res) (recall that the sample standard deviation is a function of SS(Tot), not SS(Res))



SS(Res) = SS(Tot)-SS(A)-SS(B)-SS(A\*B)-SS(Block)

= 114.573 – 2.127 – 2.093 – 4.09 - 58.073 = **48.19**

MS(Res) = 48.19/45 = **1.071**

c) [**10]** Complete the ANOVA table, including F values and p-values (using the *pf* function in R), and summarize your conclusions regarding all main effects and interaction effect.

> MS\_Res = 1.071

> MS\_Brand = 1.0862

> MS\_Des = 2.0907

> MS\_int = 4.09

> MS\_Dentist = 6.4526

> MS\_int = 2.0452

> F\_brand=MS\_Brand/MS\_Res

> F\_Des=MS\_Des/MS\_Res

> F\_int=MS\_int/MS\_Res

> F\_block=MS\_Dentist/MS\_Res

> F\_brand

[1] **1.014192**

> F\_Des

[1] **1.952101**

> F\_int

[1] **1.909617**

> F\_block

[1] **6.024837**

> 1-pf(F\_brand,2,45)

[1] **0.3708345**

> 1-pf(F\_Des,1,45)

[1] **0.1692124**

> 1-pf(F\_int,2,45)

[1] **0.1599502**

> 1-pf(F\_block,9,45)

[1] **1.661498e-05**

From above values:

Analysis of Variance Table

Response: pain

Df Sum Sq Mean Sq F value Pr(>F)

brand 2 2.172 1.0862 **1.0141 .3708**

desensization 1 2.091 2.0907 **1.9521 .1692**

dentist 9 58.073 6.4526 **6.0248 1.6615e-05**

brand:desensization 2 4.090 2.0452 **1.9096 .1600**

Residuals **45 48.19** **1.071**

Conclusions:

As all main effects and interaction effect p-values are above 0.05, we conclude that there is no significant interaction and no significant effect of either brand or absence/presence of desensitizer on post-operative pain.

(Note, however, that there is a significant block effect, which means in this context that there is a significant difference among dentists in their effect on patient pain levels. I’d take my chances with dentist #9 ☺)