SIGCSE_2021

October 23, 2020

1 This file contains the data analysis that accompanies the following SIGCSE2021 paper:

1.1 Cordova, L., Carver, J., Walia, G., and Gershmel, N. "A Comparison of Inquiry-Based Conceptual Feedback vs. Traditional Detailed Feedback Mechanisms in Software Testing Education: An Empirical Investigation." *Proceedings of the 52nd Technical Sympoisumn on Computer Science Education (SIGCSE 2021)*. To appear.

Read in data files with raw data:
* StudyData.csv contains the data from the assignments during the courses
* SurveyData.csv contains the results from the post-study survey

[1]:
```
StudyData <- read.csv("StudyData.csv")
SurveyData <- read.csv("SurveyData.csv")
```

1.2 Analyze data for Assignment 1 alone. This assignment serves as the pre-test

These tests are 2-way ANOVAs using the following factors
* Factor 1 - Study (Spring/Summer)
* Factor 2 - Treatment (Raw/Conceptual)

1.2.1 First create a slice of the data in A1 that contains only data from assignment 1

[2]:
```
A1 = StudyData[StudyData$Assignment. == c("1"),]
```

1.2.2 Second, compute means for Table 2 in paper

[3]:
```
A1_Raw_Line_mean <- mean(A1[A1$TreatmentInt == "1", c("Line")])
A1_Conceptual_Line_mean <- mean(A1[A1$TreatmentInt == "2", c("Line")])
A1_Raw_Branch_mean <- mean(A1[A1$TreatmentInt == "1", c("Branch")])
A1_Conceptual_Branch_mean <- mean(A1[A1$TreatmentInt == "2", c("Branch")])
A1_Raw_Conditional_mean <- mean(A1[A1$TreatmentInt == "1", c("Conditional")])
A1_Conceptual_Conditional_mean <- mean(A1[A1$TreatmentInt == "2",␣
↪c("Conditional")])
A1_Raw_Redundancies_mean <- mean(A1[A1$TreatmentInt == "1", c("Redundancies")])
A1_Conceptual_Redundancies_mean <- mean(A1[A1$TreatmentInt == "2",␣
↪c("Redundancies")])
```

```
A1_Raw_AssignmentGrade_mean <- mean(A1[A1$TreatmentInt == "1",␣
↪c("AssignmentGrade")])
A1_Conceptual_AssignmentGrade_mean <- mean(A1[A1$TreatmentInt == "2",␣
↪c("AssignmentGrade")])
```

Create a Data Frame to easily display the results that appear in Table 2 in the paper

[4]:
```
Pre_test <- data.frame(c("Line Coverage", "Branch Coverage", "Conditional␣
↪Coverage", "Redundant Tests","Assignment Grade"),
                                        ␣
↪c(A1_Raw_Line_mean,A1_Raw_Branch_mean,A1_Raw_Conditional_mean,A1_Raw_Redundancies_mean,A1_R
                                        ␣
↪c(A1_Conceptual_Line_mean,A1_Conceptual_Branch_mean,A1_Conceptual_Conditional_mean,A1_Conce
colnames(Pre_test) <- c("Dependent Variable", "Treatment A␣
↪(Detailed)","Treatement B (Conceptual)")
Pre_test
```

A data.frame: 5 × 3

Dependent Variable <fct>	Treatment A (Detailed) <dbl>	Treatement B (Conceptual) <dbl>
Line Coverage	0.3507143	0.3574194
Branch Coverage	0.3628571	0.3493548
Conditional Coverage	0.3510714	0.3661290
Redundant Tests	4.8571429	4.9032258
Assignment Grade	57.9464286	58.4274194

1.2.3 Third compute ANOVAs using the two factors listed above:

- Factor 1 - Study (Spring/Summer)
- Factor 2 - Treatment (Raw/Conceptual)

[5]:
```
line_anova1 <- aov(A1$Line~A1$Study. * A1$TreatmentInt, data= A1)
branch_anova1 <- aov(A1$Branch~A1$Study. * A1$TreatmentInt, data= A1)
conditional_anova1 <- aov(A1$Conditional~A1$Study. * A1$TreatmentInt, data= A1)
redundant_anova1 <- aov(A1$Redundancies~A1$Study. * A1$TreatmentInt, data= A1)
grade_anova1 <- aov(A1$AssignmentGrade~A1$Study. * A1$TreatmentInt, data= A1)
cat("------------------------------------------------------------------------------\n")
cat("Line ANOVA")
summary(line_anova1)
cat("------------------------------------------------------------------------------\n")
cat("Branch ANOVA")
summary(branch_anova1)
cat("------------------------------------------------------------------------------\n")
cat("Conditional ANOVA")
summary(conditional_anova1)
cat("------------------------------------------------------------------------------\n")
cat("Redundant ANOVA")
summary(redundant_anova1)
```

```r
cat("-----------------------------------------------------------------------------\n")
cat("Grade ANOVA")
summary(grade_anova1)
```

```
-----------------------------------------------------------------------------
Line ANOVA
                          Df Sum Sq Mean Sq F value Pr(>F)
A1$Study.                  1 0.0004 0.00042   0.016  0.900
A1$TreatmentInt            1 0.0007 0.00068   0.026  0.873
A1$Study.:A1$TreatmentInt  1 0.0412 0.04125   1.563  0.217
Residuals                 55 1.4515 0.02639


-----------------------------------------------------------------------------
Branch ANOVA
                          Df Sum Sq  Mean Sq F value Pr(>F)
A1$Study.                  1 0.0220 0.021979   0.817  0.370
A1$TreatmentInt            1 0.0030 0.002992   0.111  0.740
A1$Study.:A1$TreatmentInt  1 0.0009 0.000926   0.034  0.854
Residuals                 55 1.4803 0.026915


-----------------------------------------------------------------------------
Conditional ANOVA
                          Df Sum Sq  Mean Sq F value Pr(>F)
A1$Study.                  1 0.0137 0.013671   0.650  0.424
A1$TreatmentInt            1 0.0031 0.003078   0.146  0.704
A1$Study.:A1$TreatmentInt  1 0.0084 0.008425   0.400  0.530
Residuals                 55 1.1574 0.021043


-----------------------------------------------------------------------------
Redundant ANOVA
                          Df Sum Sq Mean Sq F value Pr(>F)
A1$Study.                  1    4.0   4.007   0.593 0.4445
A1$TreatmentInt            1    0.0   0.047   0.007 0.9341
A1$Study.:A1$TreatmentInt  1   24.6  24.613   3.644 0.0615 .
Residuals                 55  371.5   6.755
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1


-----------------------------------------------------------------------------
Grade ANOVA
                          Df Sum Sq Mean Sq F value Pr(>F)
A1$Study.                  1    4.3    4.27   0.173  0.679
A1$TreatmentInt            1    3.3    3.26   0.132  0.718
```

```
A1$Study.:A1$TreatmentInt  1   67.6   67.58   2.733  0.104
Residuals                 55 1360.1   24.73
```

1.3 Analyze data for Assignments 2-4 alone. These assignments serve as the main study.

These tests are 3-way ANOVAs using the following factors
* Factor 1 - Study (Spring/Summer)
* Factor 2 - Treatment (Raw/Conceptual)
* Factor 3 - Assignment (2/3/4)

1.3.1 First create a slice of the data in A2_4 that contains only data from assignments 2-4

[6]:
```
A2_4 = StudyData[StudyData$Assignment. %in% c("2","3","4"),]
```

1.3.2 Second, compute means for Table 3 in paper

[7]:
```
A2_4_Raw_Line_mean <- mean(A2_4[A2_4$TreatmentInt == "1", c("Line")])
A2_4_Conceptual_Line_mean <- mean(A2_4[A2_4$TreatmentInt == "2", c("Line")])
A2_4_Raw_Branch_mean <- mean(A2_4[A2_4$TreatmentInt == "1", c("Branch")])
A2_4_Conceptual_Branch_mean <- mean(A2_4[A2_4$TreatmentInt == "2", c("Branch")])
A2_4_Raw_Conditional_mean <- mean(A2_4[A2_4$TreatmentInt == "1",␣
 ↪c("Conditional")])
A2_4_Conceptual_Conditional_mean <- mean(A2_4[A2_4$TreatmentInt == "2",␣
 ↪c("Conditional")])
A2_4_Raw_Redundancies_mean <- mean(A2_4[A2_4$TreatmentInt == "1",␣
 ↪c("Redundancies")])
A2_4_Conceptual_Redundancies_mean <- mean(A2_4[A2_4$TreatmentInt == "2",␣
 ↪c("Redundancies")])
A2_4_Raw_AssignmentGrade_mean <- mean(A2_4[A2_4$TreatmentInt == "1",␣
 ↪c("AssignmentGrade")])
A2_4_Conceptual_AssignmentGrade_mean <- mean(A2_4[A2_4$TreatmentInt == "2",␣
 ↪c("AssignmentGrade")])
```

Create a Data Frame to easily display the results that appear in Table 3 in the paper

[8]:
```
Main_study <- data.frame(c("Line Coverage", "Branch Coverage", "Conditional␣
 ↪Coverage", "Redundant Tests","Assignment Grade"),
                        ␣
 ↪c(A2_4_Raw_Line_mean,A2_4_Raw_Branch_mean,A2_4_Raw_Conditional_mean,A2_4_Raw_Redundancies_m
                        ␣
 ↪c(A2_4_Conceptual_Line_mean,A2_4_Conceptual_Branch_mean,A2_4_Conceptual_Conditional_mean,A2
colnames(Main_study) <- c("Dependent Variable", "Treatment A␣
 ↪(Detailed)","Treatement B (Conceptual)")
Main_study
```

A data.frame: 5 × 3

Dependent Variable <fct>	Treatment A (Detailed) <dbl>	Treatement B (Conceptual) <dbl>
Line Coverage	0.4341667	0.5506452
Branch Coverage	0.4311905	0.5267742
Conditional Coverage	0.4535714	0.5751613
Redundant Tests	4.8571429	3.3333333
Assignment Grade	60.3720238	68.2661290

1.3.3 Third compute ANOVAs using the three factors listed above:

- Factor 1 - Study (Spring/Summer)
- Factor 2 - Treatment (Raw/Conceptual)
- Factor 3 - Assignment (2/3/4)

[9]:
```
line_anova2 <- aov(A2_4$Line~A2_4$Study. * A2_4$TreatmentInt * A2_4$Assignment.
 ↪, data= A2_4)
branch_anova2 <- aov(A2_4$Branch~A2_4$Study. * A2_4$TreatmentInt *␣
 ↪A2_4$Assignment., data= A2_4)
conditional_anova2 <- aov(A2_4$Conditional~A2_4$Study. * A2_4$TreatmentInt *␣
 ↪A2_4$Assignment., data= A2_4)
redundant_anova2 <- aov(A2_4$Redundancies~A2_4$Study. * A2_4$TreatmentInt *␣
 ↪A2_4$Assignment., data= A2_4)
grade_anova2 <- aov(A2_4$AssignmentGrade~A2_4$Study. * A2_4$TreatmentInt *␣
 ↪A2_4$Assignment., data= A2_4)
cat("----------------------------------------------------------------------------\n")
cat("Line ANOVA")
summary(line_anova2)
cat("----------------------------------------------------------------------------\n")
cat("Branch ANOVA")
summary(branch_anova2)
cat("----------------------------------------------------------------------------\n")
cat("Conditional ANOVA")
summary(conditional_anova2)
cat("----------------------------------------------------------------------------\n")
cat("Redundant ANOVA")
summary(redundant_anova2)
cat("----------------------------------------------------------------------------\n")
cat("Grade ANOVA")
summary(grade_anova2)
```

```
----------------------------------------------------------------------------
Line ANOVA

                                                Df Sum Sq Mean Sq F value
A2_4$Study.                                      1  0.012  0.0117   0.418
A2_4$TreatmentInt                                1  0.596  0.5958  21.248
A2_4$Assignment.                                 1  0.034  0.0339   1.209
A2_4$Study.:A2_4$TreatmentInt                    1  0.036  0.0356   1.268
```

```
A2_4$Study.:A2_4$Assignment.                       1  0.028  0.0282   1.006
A2_4$TreatmentInt:A2_4$Assignment.                 1  0.106  0.1064   3.793
A2_4$Study.:A2_4$TreatmentInt:A2_4$Assignment.   1  0.053  0.0526   1.877
Residuals                                        169  4.738  0.0280
                                                   Pr(>F)
A2_4$Study.                                        0.5188
A2_4$TreatmentInt                                7.92e-06 ***
A2_4$Assignment.                                   0.2731
A2_4$Study.:A2_4$TreatmentInt                      0.2617
A2_4$Study.:A2_4$Assignment.                       0.3174
A2_4$TreatmentInt:A2_4$Assignment.                 0.0531 .
A2_4$Study.:A2_4$TreatmentInt:A2_4$Assignment.   0.1725
Residuals
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

-----------------------------------------------------------------------------
Branch ANOVA

                                                  Df Sum Sq Mean Sq F value
A2_4$Study.                                        1  0.007  0.0073   0.274
A2_4$TreatmentInt                                  1  0.406  0.4055  15.160
A2_4$Assignment.                                   1  0.182  0.1817   6.792
A2_4$Study.:A2_4$TreatmentInt                      1  0.038  0.0382   1.427
A2_4$Study.:A2_4$Assignment.                       1  0.068  0.0678   2.536
A2_4$TreatmentInt:A2_4$Assignment.                 1  0.193  0.1926   7.202
A2_4$Study.:A2_4$TreatmentInt:A2_4$Assignment.   1  0.000  0.0001   0.003
Residuals                                        169  4.521  0.0267
                                                   Pr(>F)
A2_4$Study.                                      0.601413
A2_4$TreatmentInt                                0.000142 ***
A2_4$Assignment.                                 0.009976 **
A2_4$Study.:A2_4$TreatmentInt                    0.233876
A2_4$Study.:A2_4$Assignment.                     0.113161
A2_4$TreatmentInt:A2_4$Assignment.               0.008006 **
A2_4$Study.:A2_4$TreatmentInt:A2_4$Assignment. 0.958058
Residuals
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

-----------------------------------------------------------------------------
Conditional ANOVA

                                                  Df Sum Sq Mean Sq F value
A2_4$Study.                                        1  0.135  0.1345   5.112
A2_4$TreatmentInt                                  1  0.664  0.6644  25.251
A2_4$Assignment.                                   1  0.036  0.0356   1.354
A2_4$Study.:A2_4$TreatmentInt                      1  0.001  0.0014   0.055
```

```
A2_4$Study.:A2_4$Assignment.                    1  0.011  0.0105   0.401
A2_4$TreatmentInt:A2_4$Assignment.              1  0.040  0.0402   1.530
A2_4$Study.:A2_4$TreatmentInt:A2_4$Assignment.  1  0.006  0.0063   0.238
Residuals                                     169  4.447  0.0263
                                                Pr(>F)
A2_4$Study.                                      0.025 *
A2_4$TreatmentInt                             1.27e-06 ***
A2_4$Assignment.                                 0.246
A2_4$Study.:A2_4$TreatmentInt                    0.816
A2_4$Study.:A2_4$Assignment.                     0.527
A2_4$TreatmentInt:A2_4$Assignment.               0.218
A2_4$Study.:A2_4$TreatmentInt:A2_4$Assignment.   0.626
Residuals
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
-----------------------------------------------------------------------------
Redundant ANOVA

                                               Df Sum Sq Mean Sq F value
A2_4$Study.                                     1    0.2    0.17   0.039
A2_4$TreatmentInt                               1  102.4  102.36  23.308
A2_4$Assignment.                                1    0.5    0.54   0.124
A2_4$Study.:A2_4$TreatmentInt                   1    8.6    8.65   1.969
A2_4$Study.:A2_4$Assignment.                    1    0.8    0.78   0.178
A2_4$TreatmentInt:A2_4$Assignment.              1    2.1    2.12   0.482
A2_4$Study.:A2_4$TreatmentInt:A2_4$Assignment.  1    0.7    0.66   0.150
Residuals                                     169  742.2    4.39
                                                Pr(>F)
A2_4$Study.                                      0.844
A2_4$TreatmentInt                             3.07e-06 ***
A2_4$Assignment.                                 0.726
A2_4$Study.:A2_4$TreatmentInt                    0.162
A2_4$Study.:A2_4$Assignment.                     0.674
A2_4$TreatmentInt:A2_4$Assignment.               0.488
A2_4$Study.:A2_4$TreatmentInt:A2_4$Assignment.   0.699
Residuals
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
-----------------------------------------------------------------------------
Grade ANOVA

                                               Df Sum Sq Mean Sq F value
A2_4$Study.                                     1      1     0.8   0.026
A2_4$TreatmentInt                               1   2753  2753.3  90.240
A2_4$Assignment.                                1     48    47.7   1.562
A2_4$Study.:A2_4$TreatmentInt                   1      5     4.8   0.156
```

```
A2_4$Study.:A2_4$Assignment.                  1     25    24.6   0.806
A2_4$TreatmentInt:A2_4$Assignment.            1    133   132.5   4.344
A2_4$Study.:A2_4$TreatmentInt:A2_4$Assignment.  1      2     1.8   0.057
Residuals                                   169   5156    30.5
                                            Pr(>F)
A2_4$Study.                                 0.8722
A2_4$TreatmentInt                           <2e-16 ***
A2_4$Assignment.                            0.2130
A2_4$Study.:A2_4$TreatmentInt               0.6937
A2_4$Study.:A2_4$Assignment.                0.3705
A2_4$TreatmentInt:A2_4$Assignment.          0.0387 *
A2_4$Study.:A2_4$TreatmentInt:A2_4$Assignment. 0.8109
Residuals
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

1.4 Analyze data for Assignment 5 alone. This assignment serves as the post-test These tests are 2-way ANOVAs using the following factors

- Factor 1 - Study (Spring/Summer)
- Factor 2 - Treatment (Raw/Conceptual)

1.4.1 First create a slice of the data in A5 that contains only data from assignment 5

[10]:
```
A5 = StudyData[StudyData$Assignment. == c("5"),]
```

1.4.2 Second, compute means for Table 4 in paper

[11]:
```
A5_Raw_Line_mean <- mean(A5[A5$TreatmentInt == "1", c("Line")])
A5_Conceptual_Line_mean <- mean(A5[A5$TreatmentInt == "2", c("Line")])
A5_Raw_Branch_mean <- mean(A5[A5$TreatmentInt == "1", c("Branch")])
A5_Conceptual_Branch_mean <- mean(A5[A5$TreatmentInt == "2", c("Branch")])
A5_Raw_Conditional_mean <- mean(A5[A5$TreatmentInt == "1", c("Conditional")])
A5_Conceptual_Conditional_mean <- mean(A5[A5$TreatmentInt == "2",␣
 ↪c("Conditional")])
A5_Raw_Redundancies_mean <- mean(A5[A5$TreatmentInt == "1", c("Redundancies")])
A5_Conceptual_Redundancies_mean <- mean(A5[A5$TreatmentInt == "2",␣
 ↪c("Redundancies")])
A5_Raw_AssignmentGrade_mean <- mean(A5[A5$TreatmentInt == "1",␣
 ↪c("AssignmentGrade")])
A5_Conceptual_AssignmentGrade_mean <- mean(A5[A5$TreatmentInt == "2",␣
 ↪c("AssignmentGrade")])
```

Create a Data Frame to easily display the results that appear in Table 4 in the paper

[12]:
```
Post_test <- data.frame(c("Line Coverage", "Branch Coverage", "Conditional␣
↪Coverage", "Redundant Tests","Assignment Grade"),
                        ␣
↪c(A5_Raw_Line_mean,A5_Raw_Branch_mean,A5_Raw_Conditional_mean,A5_Raw_Redundancies_mean,A5_R
                        ␣
↪c(A5_Conceptual_Line_mean,A5_Conceptual_Branch_mean,A5_Conceptual_Conditional_mean,A5_Conce
colnames(Post_test) <- c("Dependent Variable", "Treatment A␣
↪(Detailed)","Treatement B (Conceptual)")
Post_test
```

A data.frame: 5 × 3

Dependent Variable <fct>	Treatment A (Detailed) <dbl>	Treatement B (Conceptual) <dbl>
Line Coverage	0.3789286	0.6877419
Branch Coverage	0.3867857	0.6935484
Conditional Coverage	0.4482143	0.7258065
Redundant Tests	4.2857143	2.2903226
Assignment Grade	60.3125000	78.9516129

1.4.3 Third compute ANOVAs using the two factors listed above:

- Factor 1 - Study (Spring/Summer)
- Factor 2 - Treatment (Raw/Conceptual)

[13]:
```
line_anova5 <- aov(A5$Line~A5$Study. * A5$TreatmentInt, data= A5)
branch_anova5 <- aov(A5$Branch~A5$Study. * A5$TreatmentInt, data= A5)
conditional_anova5 <- aov(A5$Conditional~A5$Study. * A5$TreatmentInt, data= A5)
residual_anova5 <- aov(A5$Redundancies~A5$Study. * A5$TreatmentInt, data= A5)
grade_anova5 <- aov(A5$AssignmentGrade~A5$Study. * A5$TreatmentInt, data= A5)
cat("------------------------------------------------------------------------------\n")
cat("Line ANOVA")
summary(line_anova5)
cat("------------------------------------------------------------------------------\n")
cat("Branch ANOVA")
summary(branch_anova5)
cat("------------------------------------------------------------------------------\n")
cat("Conditional ANOVA")
summary(conditional_anova5)
cat("------------------------------------------------------------------------------\n")
cat("Residual ANOVA")
summary(residual_anova5)
cat("------------------------------------------------------------------------------\n")
cat("Grade ANOVA")
summary(grade_anova5)
```

```
------------------------------------------------------------------------------
Line ANOVA

                          Df Sum Sq Mean Sq F value   Pr(>F)
A5$Study.                  1 0.0062  0.0062   0.234    0.631
```

```
A5$TreatmentInt            1 1.4072  1.4072  52.635 1.44e-09 ***
A5$Study.:A5$TreatmentInt  1 0.0007  0.0007   0.026    0.873
Residuals                 55 1.4705  0.0267
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
-----------------------------------------------------------------------------
Branch ANOVA
                          Df Sum Sq Mean Sq F value   Pr(>F)
A5$Study.                  1 0.0803  0.0803   3.136   0.0821 .
A5$TreatmentInt            1 1.3719  1.3719  53.583 1.13e-09 ***
A5$Study.:A5$TreatmentInt  1 0.0013  0.0013   0.051   0.8229
Residuals                 55 1.4082  0.0256
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
-----------------------------------------------------------------------------
Conditional ANOVA
                          Df Sum Sq Mean Sq F value   Pr(>F)
A5$Study.                  1 0.0134  0.0134   0.669    0.417
A5$TreatmentInt            1 1.1389  1.1389  56.896 4.87e-10 ***
A5$Study.:A5$TreatmentInt  1 0.0243  0.0243   1.216    0.275
Residuals                 55 1.1010  0.0200
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
-----------------------------------------------------------------------------
Residual ANOVA
                          Df Sum Sq Mean Sq F value   Pr(>F)
A5$Study.                  1   5.08    5.08   1.491 0.227320
A5$TreatmentInt            1  57.93   57.93  17.001 0.000127 ***
A5$Study.:A5$TreatmentInt  1   2.28    2.28   0.670 0.416568
Residuals                 55 187.39    3.41
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
-----------------------------------------------------------------------------
Grade ANOVA
                          Df Sum Sq Mean Sq F value   Pr(>F)
A5$Study.                  1     50      50   1.282    0.262
A5$TreatmentInt            1   5093    5093 131.480 3.31e-16 ***
A5$Study.:A5$TreatmentInt  1      8       8   0.219    0.642
Residuals                 55   2131      39
---
```

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

1.5 Analyze post-study survey

Analyze the results of the post-study survey to determine whether there are any differences between the responses from the students in the two treaments. This data analysis uses a series t-tests to compare the two groups. Use the 'na.rm = TRUE' argument to ignore rows where the response is missing.

1.5.1 First, compute the means for each group for each question

[14]:
```
Q1_G1_mean <- mean(SurveyData[SurveyData$Group=="1",c("Q1")], na.rm = TRUE)
Q1_G2_mean <- mean(SurveyData[SurveyData$Group=="2",c("Q1")], na.rm = TRUE)
Q2_G1_mean <- mean(SurveyData[SurveyData$Group=="1",c("Q2")], na.rm = TRUE)
Q2_G2_mean <- mean(SurveyData[SurveyData$Group=="2",c("Q2")], na.rm = TRUE)
Q3_G1_mean <- mean(SurveyData[SurveyData$Group=="1",c("Q3")], na.rm = TRUE)
Q3_G2_mean <- mean(SurveyData[SurveyData$Group=="2",c("Q3")], na.rm = TRUE)
Q4_G1_mean <- mean(SurveyData[SurveyData$Group=="1",c("Q4")], na.rm = TRUE)
Q4_G2_mean <- mean(SurveyData[SurveyData$Group=="2",c("Q4")], na.rm = TRUE)
Q5_G1_mean <- mean(SurveyData[SurveyData$Group=="1",c("Q5")], na.rm = TRUE)
Q5_G2_mean <- mean(SurveyData[SurveyData$Group=="2",c("Q5")], na.rm = TRUE)
Q6_G1_mean <- mean(SurveyData[SurveyData$Group=="1",c("Q6")], na.rm = TRUE)
Q6_G2_mean <- mean(SurveyData[SurveyData$Group=="2",c("Q6")], na.rm = TRUE)
Q7_G1_mean <- mean(SurveyData[SurveyData$Group=="1",c("Q7")], na.rm = TRUE)
Q7_G2_mean <- mean(SurveyData[SurveyData$Group=="2",c("Q7")], na.rm = TRUE)
Q8_G1_mean <- mean(SurveyData[SurveyData$Group=="1",c("Q8")], na.rm = TRUE)
Q8_G2_mean <- mean(SurveyData[SurveyData$Group=="2",c("Q8")], na.rm = TRUE)
Q9_G1_mean <- mean(SurveyData[SurveyData$Group=="1",c("Q9")], na.rm = TRUE)
Q9_G2_mean <- mean(SurveyData[SurveyData$Group=="2",c("Q9")], na.rm = TRUE)
```

Create a Data Frame to easily display the results that appear in Table 5 in the paper

[15]:
```
Survey_Results <- data.frame(c("1","2","3","4","5","6","7","8","9"),
                 ␣
 ↪c(Q1_G1_mean,Q2_G1_mean,Q3_G1_mean,Q4_G1_mean,Q5_G1_mean,Q6_G1_mean,Q7_G1_mean,Q8_G1_mean,Q
                 ␣
 ↪c(Q1_G2_mean,Q2_G2_mean,Q3_G2_mean,Q4_G2_mean,Q5_G2_mean,Q6_G2_mean,Q7_G2_mean,Q8_G2_mean,Q
colnames(Survey_Results) <- c("Question", "Treatment A (Detailed)","Treatement␣
 ↪B (Conceptual)")
Survey_Results
```

A data.frame: 9 × 3

Question	Treatment A (Detailed)	Treatement B (Conceptual)
<fct>	<dbl>	<dbl>
1	3.571429	5.818182
2	4.250000	5.212121
3	3.750000	5.515152
4	3.178571	4.848485
5	3.428571	5.606061
6	3.821429	5.969697
7	3.892857	5.787879
8	5.142857	6.212121
9	3.400000	6.212121

1.5.2 Second, compare the means of the two groups using t-tests

[16]:
```r
Q1 <- t.
↪test(SurveyData[SurveyData$Group=="1",c("Q1")],SurveyData[SurveyData$Group=="2",c("Q1")])
Q2 <- t.
↪test(SurveyData[SurveyData$Group=="1",c("Q2")],SurveyData[SurveyData$Group=="2",c("Q2")])
Q3 <- t.
↪test(SurveyData[SurveyData$Group=="1",c("Q3")],SurveyData[SurveyData$Group=="2",c("Q3")])
Q4 <- t.
↪test(SurveyData[SurveyData$Group=="1",c("Q4")],SurveyData[SurveyData$Group=="2",c("Q4")])
Q5 <- t.
↪test(SurveyData[SurveyData$Group=="1",c("Q5")],SurveyData[SurveyData$Group=="2",c("Q5")])
Q6 <- t.
↪test(SurveyData[SurveyData$Group=="1",c("Q6")],SurveyData[SurveyData$Group=="2",c("Q6")])
Q7 <- t.
↪test(SurveyData[SurveyData$Group=="1",c("Q7")],SurveyData[SurveyData$Group=="2",c("Q7")])
Q8 <- t.
↪test(SurveyData[SurveyData$Group=="1",c("Q8")],SurveyData[SurveyData$Group=="2",c("Q8")])
Q9 <- t.
↪test(SurveyData[SurveyData$Group=="1",c("Q9")],SurveyData[SurveyData$Group=="2",c("Q9")])
```

Create a Data Frame to easily display the results of the t-tests

[17]:
```r
Survey_Results_ttest <- data.frame(c("1","2","3","4","5","6","7","8","9"),
                                    ␣
↪c(Q1$statistic,Q2$statistic,Q3$statistic,Q4$statistic,Q5$statistic,Q6$statistic,Q7$statisti
                                     c(Q1$p.value,Q2$p.value,Q3$p.value,Q4$p.value,Q5$p.
↪value,Q6$p.value,Q7$p.value,Q8$p.value,Q9$p.value))
colnames(Survey_Results_ttest) <- c("Question", "t statistic","p-value")
Survey_Results_ttest
```

A data.frame: 9 × 3

Question	t statistic	p-value
<fct>	<dbl>	<dbl>
1	-5.724869	7.079943e-07
2	-2.654544	1.019262e-02
3	-3.560479	9.172575e-04
4	-3.597007	8.255129e-04
5	-4.869711	1.295436e-05
6	-5.645153	5.421435e-07
7	-4.070769	2.191574e-04
8	-2.940463	5.799037e-03
9	-3.272722	8.185621e-03