# Homework 6

Peyton Hall

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Load Libraries

```
library(nlme)
library(tidyr)
library(multcomp) # for glht
```

```
## Loading required package: mvtnorm

## Loading required package: survival

## Loading required package: TH.data

## Loading required package: MASS

##
## Attaching package: 'TH.data'

## The following object is masked from 'package:MASS':
##
##     geyser
```

1. A researcher would like to test the effects of two drugs (A and B) on treating Breast cancer. The researcher recruited 10 patients and assigned drug A randomly to 5 of them and drug B to the other 5. The researcher measured the Oncotype DX score to those 10 patients at three times: Immediately after taking the drugs, 1 year after the drugs, and 5 years after. The Oncotype DX score of 15 or below means that no or low recurrence risk, the score of 21-25 means a medium risk of recurrence, and the score of 26-100 means a high risk of recurrence. Use the 0.05 significance level to test if there is a significant mean score difference between drug A and B, and if there is a significant mean score difference between the three times, and if there is a significant interaction between drug and time. Drug, Subject, RightAfter, OneYear, FiveYear 1, 22, 20, 15 2, 16, 12, 10 A 3, 23, 11, 10 4, 25, 14, 12 5, 26, 18, 16 6, 25, 21, 21 7, 20, 18, 19 B 8, 35, 27, 26 9, 39, 35, 36 10, 27, 27, 25

Question 1 Code

```
Drug1 <- c(rep("A", 5), rep("B", 5))
Subject <- 1:10
RightAfter <- c(22, 16, 23, 25, 26, 25, 20, 35, 39, 27)
OneYear <- c(20, 12, 11, 14, 18, 21, 18, 27, 35, 27)
FiveYear <- c(15, 10, 10, 12, 16, 21, 19, 26, 36, 25)
question_one_data <- data.frame(Drug1, Subject, RightAfter, OneYear, FiveYear)
question_one_data
```

```
##    Drug1 Subject RightAfter OneYear FiveYear
## 1      A       1         22      20       15
## 2      A       2         16      12       10
## 3      A       3         23      11       10
## 4      A       4         25      14       12
## 5      A       5         26      18       16
## 6      B       6         25      21       21
## 7      B       7         20      18       19
## 8      B       8         35      27       26
## 9      B       9         39      35       36
## 10     B      10         27      27       25
```

```r
# c) use lme (linear mixed effects) and anova()
library(nlme)
library(tidyr)
long_data <- pivot_longer(question_one_data, cols = c("RightAfter", "OneYear", "FiveYear"),
                          names_to = "Time", values_to = "Score")
# convert Time to a factor to avoid error in glht fucntion
long_data$Time <- factor(long_data$Time, levels = c("RightAfter", "OneYear", "FiveYear"))
# Convert Drug1 to a factor in the long_data DataFrame
long_data$Drug1 <- factor(long_data$Drug1)
# fit linear mixed-effects model using nlme
model1 <- lme(Score~Drug1+Time+Drug1*Time, random=~1+Time|Subject, data= long_data)
anova(model1)
```

```
##             numDF denDF   F-value p-value
## (Intercept)     1    16 125.72432  <.0001
## Drug1           1     8  20.13944  0.0020
## Time            2    16  31.34159  <.0001
## Drug1:Time      2    16   9.01366  0.0024
```

```r
# i)
right_after_data <- long_data[long_data$Time == "RightAfter",]
one_year_data <- long_data[long_data$Time == "OneYear",]
five_year_data <- long_data[long_data$Time == "FiveYear",]
posthoc_rightafter <- lme(Score~Drug1, random =~1|Subject, data = right_after_data)
posthoc_oneyear <- lme(Score~Drug1, random =~1|Subject, data = one_year_data)
posthoc_fiveyear <- lme(Score~Drug1, random =~1|Subject, data = five_year_data)
posthoc_rightafter<-glht(posthoc_rightafter, linfct = mcp (Drug1 ="Tukey"))
posthoc_oneyear<-glht(posthoc_oneyear, linfct = mcp (Drug1 ="Tukey"))
posthoc_fiveyear<-glht(posthoc_fiveyear, linfct = mcp (Drug1 ="Tukey"))
summary(posthoc_rightafter)
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = Score ~ Drug1, data = right_after_data, random = ~1 |
##     Subject)
##
## Linear Hypotheses:
```

```
##             Estimate Std. Error z value Pr(>|z|)
## B - A == 0     6.80       3.86   1.762   0.0781 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)
```

```r
summary(posthoc_oneyear)
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = Score ~ Drug1, data = one_year_data, random = ~1 |
##     Subject)
##
## Linear Hypotheses:
##             Estimate Std. Error z value Pr(>|z|)
## B - A == 0     10.6        3.4   3.118  0.00182 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)
```

```r
summary(posthoc_fiveyear)
```

```
##
##   Simultaneous Tests for General Linear Hypotheses
##
## Multiple Comparisons of Means: Tukey Contrasts
##
##
## Fit: lme.formula(fixed = Score ~ Drug1, data = five_year_data, random = ~1 |
##     Subject)
##
## Linear Hypotheses:
##             Estimate Std. Error z value Pr(>|z|)
## B - A == 0   12.800      3.197   4.004 6.23e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## (Adjusted p values reported -- single-step method)
```

a) What type of design is this? two-way mixed repeated measure
b) Formulate the null and alternative hypotheses for testing the main effect of drug using symbols. $H_0 : \mu_{\text{score drug A}} = \mu_{\text{score drug B}}$ vs $H_a : \mu_{\text{score drug A}} \neq \mu_{\text{score drug B}}$
c) What is the F statistic and p-value testing the main effect of drug? f = 20.13944; p-value = 0.0020
d) What conclusion can you make based on the p-value in b)? Reject H0; there is evidence to support the claim that there is a significant mean score difference between drug A and B.
e) Formulate the null and alternative hypotheses for testing the main effect of time using symbols. $H_0 : \mu_{\text{Right After}} = \mu_{\text{One Year}} = \mu_{\text{Five Year}}$ vs $H_a$ : At least one mean differs
f) What is the F statistic and p-value for testing the main effect of time? f = 31.34159; p-value <.0001 Reject H0; there is evidence to support the claim that there is a significant mean score difference between the three times.

g) What conclusion can you make about whether there is a significant mean score difference between the three times? Due to the low p-value of <.0001, there is a significant mean score difference between the three times.
h) Is there a significant interaction between time and drug? What is the p-value for that? There is a significant interaction between time and drug. The p-value is 0.0024.
i) If there is a significant interaction, we need to separate the data file. Please separate the data by timing:

a. For the timing of Right After, is there a significant mean score difference between drug A and B? What is that p-value? p-value = 0.0781. i.e. > 0.05, so there is no significant mean score difference between Drug A and Drug B immediately after administration.
b. For the timing of One year after, is there a significant mean score difference between drug A and B? What is that p-value? p-value = 0.00182. i.e. < 0.05, so there is a significant mean score difference between Drug A and Drug B one year after administration.
c. For the timing of Five year After, is there a significant mean score difference between drug A and B? What is that p-value? p-value = 6.23e-05 (0.0000623). i.e. < 0.05, so there is a significant mean score difference between Drug A and Drug B five years after administration.

2. A physician would like to see if different doses of two drugs A and B have significantly different effect on reducing headache. The physician recruited 10 patients and randomly assigned drug A to 5 of them and B to the other five. The physician prescribed one pill for the low dose and two pills for the high dose and asked the patients to take the low dose first and measured their pain scores after, and then to take the high dose and measured their pain scores after. The higher score, the more pain. Use the 0.05 significance level to test if there is the pain scale is significantly different between drug A and B, between the high and low doses, and if there is a significant interaction between the type of drug and the dose. Individuals, LowDose, HighDose 1, 52, 50 2, 61, 58 A 3, 59, 51 4, 37, 34 5, 49, 41 6, 43, 33 7, 32, 30 B 8, 21, 20 9, 29, 21 10, 26, 22

$H_0 : \mu_{\text{Pain Drug A}} = \mu_{\text{Pain Drug B}}$ vs $H_a : \mu_{\text{Pain Drug A}} \neq \mu_{\text{Pain Drug B}}$ $H_0 : \mu_{\text{High Dose}} = \mu_{\text{Low Dose}}$ vs $H_a : \mu_{\text{High Dose}} \neq \mu_{\text{Low Dose}}$ Question 2 Code

```
Drug2 <- c(rep("A", 5), rep("B", 5))
Individuals <- 1:10
LowDose <- c(52, 61, 59, 37, 49, 43, 32, 21, 29, 26)
HighDose <- c(50, 58, 51, 34, 41, 33, 30, 20, 21, 22)
question_two_data <- data.frame(Drug2, Individuals, LowDose, HighDose)
question_two_data
```

```
##    Drug2 Individuals LowDose HighDose
## 1      A           1      52       50
## 2      A           2      61       58
## 3      A           3      59       51
## 4      A           4      37       34
## 5      A           5      49       41
## 6      B           6      43       33
## 7      B           7      32       30
## 8      B           8      21       20
## 9      B           9      29       21
## 10     B          10      26       22
```

```
# b) use lme and anova()
# reshape data to long format to model dose effects separately
```

```r
question_two_long <- reshape(question_two_data, varying = list(c("LowDose", "HighDose")),
                              v.names = "PainScore", times = c("Low", "High"),
                              timevar = "Dose", direction = "long", new.row.names = 1:20)
# DV = PainScore; IV = Drug2 and Dose
model2<-lme(PainScore~Drug2+Dose+Drug2*Dose, random=~1+Dose|Individuals, data= question_two_long)
anova(model2)
```

```
##             numDF denDF   F-value p-value
## (Intercept)     1     8 199.59589  <.0001
## Drug2           1     8  19.40837  0.0023
## Dose            1     8  20.26169  0.0020
## Drug2:Dose      1     8   0.00844  0.9291
```

a) What type of design is this? two-way mixed repeated measure
b) What is the F statistic and p-value for comparing the drug A and B? f = 19.40837; p-value = 0.0023
c) What conclusion can you make based on the p-value in a)? Reject H0; there is evidence to support the claim that the pain scale is significantly different between drug A and B.
d) What is the F statistic and p-value for comparing the high and low dosage? f = 20.26169; p-value = 0.0020
e) What conclusion can you make based on the p-value in c)? Reject H0; there is evidence to support the claim that the pain scale is significantly different between the high and low doses.
f) What is the F statistic and p-value for the interaction? Is there a significant interaction? f = 0.00844; p-value = 0.9291 There is no significant interaction between the type of drug and the dose.

3. Food scientists would like to test the difference of pasta's taste while cooking under different temperature and different cooking time. They designed the experiment to cook 16 plates of pasta, with 4 under high temperature and long cooking time, 4 under high temperature and short cooking time, 4 under medium temperature and long cooking time, and 4 under medium temperature and short cooking time. At the end of the experiment, they measured the taste scores of the 16 plates of pasta. The higher score, the better pasta. Use the 0.05 significance level to compare if there is a significant difference cooking under the two temperature levels, and with the two different time, and if there is a significant interaction between temperature and time. The data of taste scores is here: MedTemp, HighTemp Short Cooking Time, 62,59,41,33, 82,96,95,90 Long Cooking Time, 32,31,45,67, 89,76,88,82

Question 3 Code

```r
Time <- rep(c("Short Cooking Time", "Long Cooking Time"), each = 8)
Temperature <- rep(c("MedTemp", "HighTemp"), each = 4)
Scores <- c(62, 59, 41, 33, 82, 96, 95, 90, 32, 31, 45, 67, 89, 76, 88, 82)
data3 <- data.frame(Time, Temperature, Scores)
data3
```

```
##                  Time Temperature Scores
## 1  Short Cooking Time     MedTemp     62
## 2  Short Cooking Time     MedTemp     59
## 3  Short Cooking Time     MedTemp     41
## 4  Short Cooking Time     MedTemp     33
## 5  Short Cooking Time    HighTemp     82
## 6  Short Cooking Time    HighTemp     96
## 7  Short Cooking Time    HighTemp     95
## 8  Short Cooking Time    HighTemp     90
## 9   Long Cooking Time     MedTemp     32
```

```
## 10  Long Cooking Time     MedTemp     31
## 11  Long Cooking Time     MedTemp     45
## 12  Long Cooking Time     MedTemp     67
## 13  Long Cooking Time    HighTemp     89
## 14  Long Cooking Time    HighTemp     76
## 15  Long Cooking Time    HighTemp     88
## 16  Long Cooking Time    HighTemp     82
```

```
# c) use aov() function due to it being two-way ANOVA
# DV = taste scores
model3 <- aov(Scores~Time+Temperature+Time*Temperature, data = data3)
summary(model3)
```

```
##                  Df Sum Sq Mean Sq F value   Pr(>F)    
## Time              1    144     144   1.039    0.328    
## Temperature       1   6724    6724  48.520 1.51e-05 ***
## Time:Temperature  1      4       4   0.029    0.868    
## Residuals        12   1663     139                     
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

a) What type of design is this? (Note this was from one of our previous class) two-way ANOVA
b) Formulate the null and alternative hypotheses for comparing the mean scores between the short and long cooking time $H_0 : \mu_{\text{Short Term}} = \mu_{\text{Long Term}}$ vs $H_a : \mu_{\text{Short Term}} \neq \mu_{\text{Long Term}}$
c) What is the test statistic and p-value for a)? f = 1.039; p-value = 0.328
d) What conclusion can you draw based on the p-value in b)? Fail to reject H0; there is no evidence to support the claim that there is a significant difference in cooking under the two different times.
e) What is the test statistic and p-value for comparing the mean scores between the medium and high temperature levels? f = 48.520; p-value = 1.51e-05 (i.e. 0.0000151)
f) What conclusion can you draw based on the p-value in d)? There is evidence to support the claim that there is a significant difference cooking under the two temperature levels.
g) Is there a significant interaction between cooking time and temperature? What is the p-value? There is no significant interaction between cooking time and temperature because the p-value of 0.868 is greater than the significance level.

4. The researcher would like to know the effects of pedagogy A and B on improving students' performance in reading. He recruited 8 students. He trained all 8 students with A and measured their performance in month 1 and then month
5. He then trained all of them with B and measured their performance in a different test in month 1 and the month 2. The data is below. Use the 0.05 significance level to test the main effect of pedagogy and main effect of time, and the interaction. Students, Pedagogy A, Pedagogy B Month 1, Month 2, Month 1, Month 2 1, 67, 66, 82, 88 2, 71, 73, 83, 86 3, 72, 75, 88, 84 4, 79, 77, 89, 82 5, 77, 75, 91, 90 6, 65, 72, 90, 89 7, 63, 60, 95, 88 8, 62, 61, 97, 93

Question 4 Code

```
Students <- 1:8
Pedagogy<-rep(c("Pedagogy A","Pedagogy B"), each =16) # total data points
Pedagogy<-as.factor(Pedagogy)
month<-rep(c("Month 1","Month 2"),each=8) # number of observations in column
Performance<-c(67,71,72,79,77,65,63,62, 66,73,75,77,75,72,60,61,
               82,83,88,89,91,90,95,97, 88,86,84,82,90,89,88,93)
myperformance<-data.frame(Students,Pedagogy,month,Performance)
myperformance
```

```
##    Students   Pedagogy   month Performance
## 1         1 Pedagogy A Month 1          67
## 2         2 Pedagogy A Month 1          71
## 3         3 Pedagogy A Month 1          72
## 4         4 Pedagogy A Month 1          79
## 5         5 Pedagogy A Month 1          77
## 6         6 Pedagogy A Month 1          65
## 7         7 Pedagogy A Month 1          63
## 8         8 Pedagogy A Month 1          62
## 9         1 Pedagogy A Month 2          66
## 10        2 Pedagogy A Month 2          73
## 11        3 Pedagogy A Month 2          75
## 12        4 Pedagogy A Month 2          77
## 13        5 Pedagogy A Month 2          75
## 14        6 Pedagogy A Month 2          72
## 15        7 Pedagogy A Month 2          60
## 16        8 Pedagogy A Month 2          61
## 17        1 Pedagogy B Month 1          82
## 18        2 Pedagogy B Month 1          83
## 19        3 Pedagogy B Month 1          88
## 20        4 Pedagogy B Month 1          89
## 21        5 Pedagogy B Month 1          91
## 22        6 Pedagogy B Month 1          90
## 23        7 Pedagogy B Month 1          95
## 24        8 Pedagogy B Month 1          97
## 25        1 Pedagogy B Month 2          88
## 26        2 Pedagogy B Month 2          86
## 27        3 Pedagogy B Month 2          84
## 28        4 Pedagogy B Month 2          82
## 29        5 Pedagogy B Month 2          90
## 30        6 Pedagogy B Month 2          89
## 31        7 Pedagogy B Month 2          88
## 32        8 Pedagogy B Month 2          93
```

```
# b)
model4<-lme(Performance~Pedagogy+month+Pedagogy:month, random = ~ 1|Students, data=myperformance)
anova(model4)
```

```
##                numDF denDF  F-value p-value
## (Intercept)        1    21 6491.785  <.0001
## Pedagogy           1    21   91.278  <.0001
## month              1    21    0.146  0.7062
## Pedagogy:month     1    21    0.329  0.5726
```

a) What is the design? two-way fixed repeated measure
b) What is the test statistic and p-value for comparing the pedagogies?
c) What conclusion can you make with the p value in b)? f = 91.278; p-value = <.0001 Reject H0; there is evidence to support the claim that the mean performances between pedagogy a and pedagogy b differ.
d) What is the test statistic and p-value for comparing the timing? f = 0.146; p-value = 0.7062
e) What conclusion can you make with the p-value in d)? Fail to reject H0; there is not enough evidence to support the claim that month 1 and month 2 performances differ.
f) What is the p-value for testing the interaction? Is the interaction significant? p-value = 0.5726 There is not enough evidence to support the claim that there is a significant interaction.

5. An online retailer wants to get the best from its employees, as well as improving their working experience. Currently, employees in the retailer's order fulfilment center are not provided with any kind of entertainment whilst they work (e.g., no background music). However, the retailer wants to know whether providing music, which a few employees have requested, would lead to greater productivity. He recruited a sample of 15 volunteers and split them into three treatment groups: a) a control group that didn't listen to music; b) a treatment group who listened to music but had no choice of what they listened to; and c) a second treatment group who listened to music and had a choice of what they listened to. The data of their productivities is provided on D2L. The data is not normally distributed. Use the 0.05 significance level to test that if there is any significant difference in their productivities among the three groups.

Question 5 Code

```r
library(readxl)
EmployeeMusic <- read_excel("~/Desktop/STAT 301/Week 6/EmployeeMusic.xlsx")

# DV = Productivity, IV = Music
kruskal.test(Productivity~Music, data = EmployeeMusic)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  Productivity by Music
## Kruskal-Wallis chi-squared = 0.093644, df = 2, p-value = 0.9543
```

Step 1: State the null and alternative hypotheses in symbols $H_0 : \eta_{\text{ProductivityA}} = \eta_{\text{ProductivityB}} = \eta_{\text{ProductivityC}}$ vs $H_a$ : At least two medians are different Step 2: Choose Kruskal-Wallis rank sum test Step 3: What is the test statistic and p-value from R? chi-squared = 0.093644; p-value = 0.9543 Step 4: State your decision to H0 and explain the decision in the context Fail to reject H0; there is not enough evidence to support the claim that productivities among the three groups are not equivalent.