Psy/Educ 6600: Unit 5 Homework

ANOVA - With Repeated Measures

Your Name

Spring 2020

Contents

PREPARATION

Packages

Make sure the packages are **installed** *(Package tab)*

```
library(magrittr)
library(tidyverse)    # Loads several very helpful 'tidy' packages
library(readxl)       # Read in Excel datasets
library(furniture)    # Nice tables (by our own Tyson Barrett)
library(afex)         # Analysis of Factorial Experiments
library(emmeans)      # Estimated marginal means (Least-squares means)
library(lsmeans)      # Least-Squares Means
library(multcomp)     # Simultaneous Inference in General Parametric Models
library(pander)       # Formats tables
```

SECTION B

Datasets

```r
memory_wide <- data.frame(id = 1:6,
                          digit  = c(6, 8, 7, 8, 6, 7),
                          letter = c(5, 7, 7, 5, 4, 6),
                          mixed  = c(6, 5, 4, 8, 7, 5)) %>%
  dplyr::mutate(id = factor(id))


caffiene_wide <- data.frame(block  = 1:6,
                           mg_0   = c(25, 19, 22, 15, 16, 20),
                           mg_100 = c(16, 15, 19, 11, 14, 23),
                           mg_200 = c( 6, 14,  9,  5,  9, 11),
                           mg_300 = c( 8, 18,  9, 10, 12, 13)) %>%
  dplyr::mutate(block = factor(block))


audience_wide <- data.frame(id     = 1:12,
                            one    = c(131, 109, 115, 110, 107, 111,
                                       100, 115, 130, 118, 125, 135),
                            twenty = c(130, 124, 110, 108, 115, 117,
                                       102, 120, 119, 122, 118, 130),
                            large  = c(135, 126, 108, 122, 111, 121,
                                       107, 132, 128, 130, 133, 135))%>%
  dplyr::mutate(id = factor(id))

textbook_wide <- data.frame(block = 1:9,
                            A = c(17,  8,  6, 12, 19, 14, 10,  7, 12),
                            B = c(15,  6,  5, 10, 20, 13,  7,  7, 11),
                            C = c(20, 11, 10, 14, 20, 15, 14, 11, 15),
                            D = c(18,  7,  6, 13, 18, 15, 10,  6, 13))%>%
  dplyr::mutate(block = factor(block))
```

memory_wide

```r
memory_wide
```

```
  id digit letter mixed
1  1     6      5     6
2  2     8      7     5
3  3     7      7     4
4  4     8      5     8
5  5     6      4     7
6  6     7      6     5
```

Restructure from wide to long format

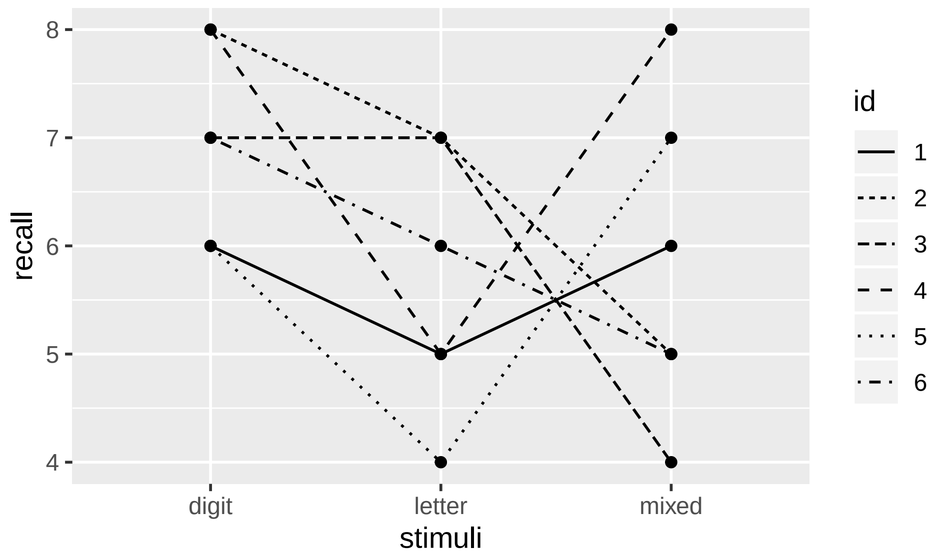
```r
memory_long <- memory_wide %>%
  tidyr::pivot_longer(cols = c(digit, letter, mixed),
                      names_to = "stimuli",
                      names_ptypes = list(stimuli = factor()),
                      values_to = "recall")

psych::headTail(memory_long)
```

```
    id stimuli recall
1    1   digit      6
2    1  letter      5
3    1   mixed      6
4    2   digit      8
5 <NA>    <NA>    ...
6    5   mixed      7
7    6   digit      7
8    6  letter      6
9    6   mixed      5
```

Person-Profile Plot

```r
memory_long %>%
  ggplot(aes(x = stimuli,
             y = recall,
             group = id,
             linetype = id)) +
  geom_point()+
  geom_line()
```



8
7
6
5
4
recall
digit
letter
mixed
stimuli
id
1
2
3
4
5
6

caffiene_wide

```
caffiene_wide
```

```
  block mg_0 mg_100 mg_200 mg_300
1     1   25     16      6      8
2     2   19     15     14     18
3     3   22     19      9      9
4     4   15     11      5     10
5     5   16     14      9     12
6     6   20     23     11     13
```

Restructure from wide to long format

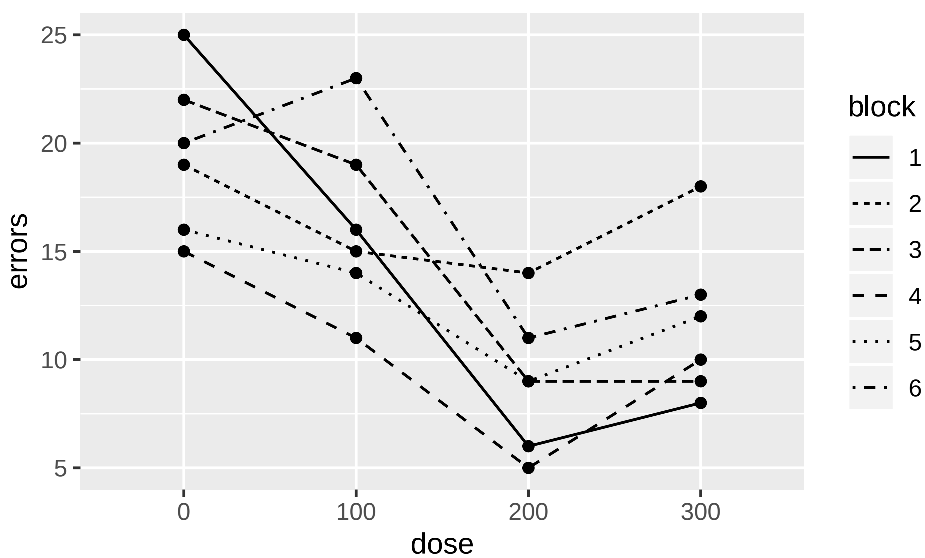
```
caffiene_long <- caffiene_wide %>%
  tidyr::pivot_longer(cols = c(mg_0, mg_100, mg_200, mg_300),
                      names_to = "dose",
                      names_prefix = "mg_",
                      names_ptypes = list(dose = factor()),
                      values_to = "errors")

psych::headTail(caffiene_long)
```

```
  block dose errors
1     1    0     25
2     1  100     16
3     1  200      6
4     1  300      8
5  <NA> <NA>    ...
6     6    0     20
7     6  100     23
8     6  200     11
9     6  300     13
```

Person-Profile Plot

```
caffiene_long %>%
  ggplot(aes(x = dose,
             y = errors,
             group = block,
             linetype = block)) +
  geom_point()+
  geom_line()
```


errors
25
20
15
10
5
0
100
200
300
dose
block
1
2
3
4
5
6

`audience_wide` - Repeated Measures Design: Effect of Audience Size on Blood Pressure

TEXTBOOK QUESTION: *A psychophysiologist wishes to explore the effects of public speaking on the systolic blood pressure of young adults. Three conditions are tested. The subject must vividly imagine delivering a speech to one person, to a small class of 20 persons, or to a large audience consisting of hundreds of fellow students. Each subject has his or her systolic blood pressure measured (mmHg) under all three conditions. Two subjects are randomly assigned to each of the six possible treatment orders. The data appear in the following table:*

```
   id one twenty large
1   1 131    130   135
2   2 109    124   126
3   3 115    110   108
4   4 110    108   122
5   5 107    115   111
6   6 111    117   121
7   7 100    102   107
8   8 115    120   132
9   9 130    119   128
10 10 118    122   130
11 11 125    118   133
12 12 135    130   135
```

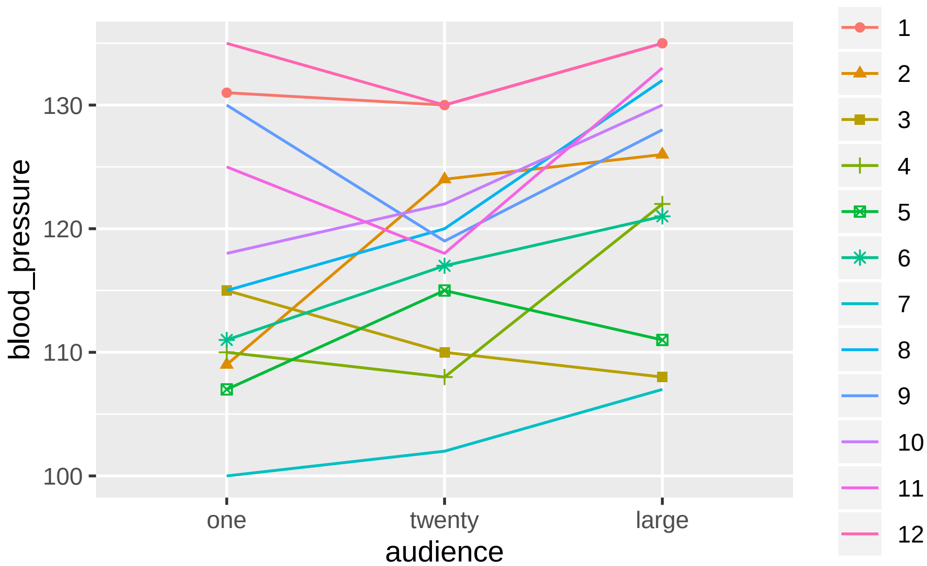
Restructure from wide to long format

```
    id audience blood_pressure
1    1      one            131
2    1   twenty            130
3    1    large            135
4    2      one            109
5 <NA>     <NA>            ...
6   11    large            133
7   12      one            135
8   12   twenty            130
9   12    large            135
```

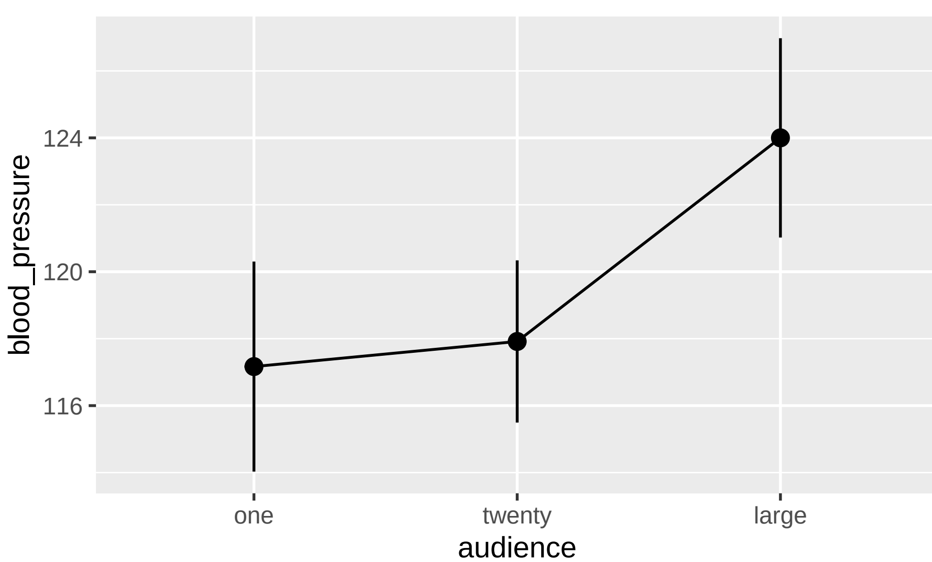
Summary Statistics

	one	twenty	large
blood_pressure	n = 12	n = 12	n = 12
	117.2 (10.9)	117.9 (8.4)	124.0 (10.3)

Person-Profile Plot



Means Plot



15B-3a/b/c RM ANOVA: no sphericity correction, but both effect sizes

TEXTBOOK QUESTION: *(a) Perform an RM ANOVA on the blood pressure data and write the results in words, as they would appear in a journal article. Does the size of the audience have a significant effect on blood pressure at the .05 level?* ~~*(Hint : Subtract 100 from every entry in the preceding table before computing any of the SS's. This will make your work easier without changing any of the SS components or F ratios.)*~~ *(b) What might you do to minimize the possibility of carryover effects?*

DIRECTIONS: Perform a Repeated Measures ANOVA for blood pressure under the three condiditons to determine if the size of the imagine audience has an effect. Request no correction for violations of sphericity (`correction = "none"`) and both effect sizes (`es = c("ges", "pes")`). Save this model as a name `fit_audience` and run the name (without `$Anova`) to see the brief output.

```
# RM ANOVA: no correction for lack of sphericity  <-- NAME AND SAVE
```

15B-3c RM ANOVA: display all Sums-of-Squares components

TEXTBOOK QUESTION: *(c) Calculate* η^2_{RM} *from the F ratio you calculated in part a. Does this look like a large effect? How could this effect size be misleading in planning future experiments?*

DIRECTIONS: Request all the Sums-of-Squares (SS's) by adding `$aov` at the end of the model name `fit_audience`.

```
# RM ANOVA: display all Sums-of-Squares components
```

15B-3d RM ANOVA: post hoc with Fisher's LSD correction

TEXTBOOK QUESTION: *(d) Test all the pairs of means with protected t tests using the error term from the RM ANOVA. Which pairs differ significantly at the .01 level?*

DIRECTIONS: Conduct all possible post hoc pairwise tests on `fit_audience` using Fisher's LSD.

```
# RM ANOVA: post hoc all pairwise tests with Fisher's LSD correction
```

Means Plot (model based)

DIRECTIONS: Construct a means plot of `fit_audience` using `emmeans::emmip(~ RM_var)` to help interpret the direction of any significant differences.

```
# RM ANOVA: means plot
```

`textbook_wide` - Matched Design: Effect of Textbook on Student Quiz Scores

TEXTBOOK QUESTION: *A statistics professor wants to know if it really matters which textbook she uses to teach her course. She selects four textbooks that differ in approach and then matches her 36 students into blocks of four based on their similarity in math background and aptitude. Each student in each block is randomly assigned to a different text. At some point in the course, the professor gives a surprise 20-question quiz. The number of questions each student answers correctly appears in the following table:*

```
  block  A  B  C  D
1     1 17 15 20 18
2     2  8  6 11  7
3     3  6  5 10  6
4     4 12 10 14 13
5     5 19 20 20 18
6     6 14 13 15 15
7     7 10  7 14 10
8     8  7  7 11  6
9     9 12 11 15 13
```

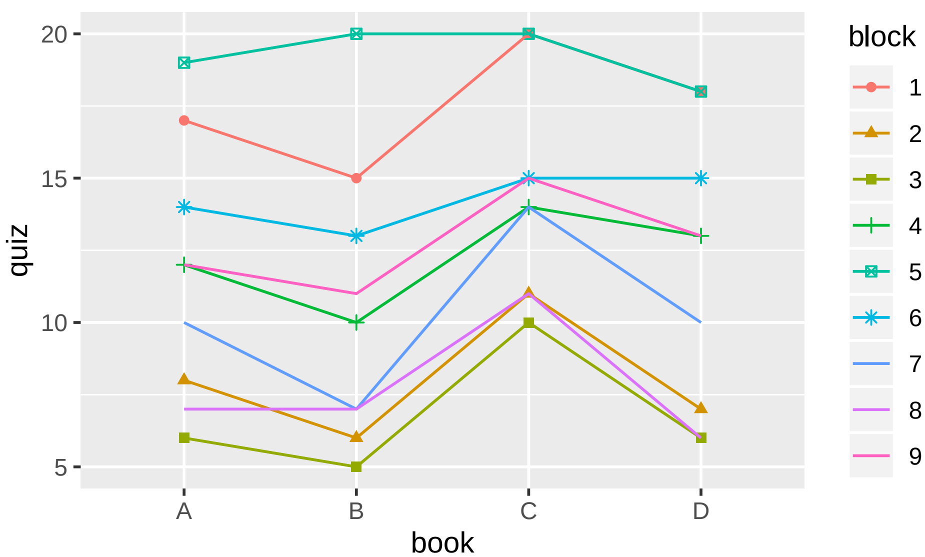
Restructure from wide to long format

```
  block book quiz
1     1    A   17
2     1    B   15
3     1    C   20
4     1    D   18
5  <NA> <NA>  ...
6     9    A   12
7     9    B   11
8     9    C   15
9     9    D   13
```

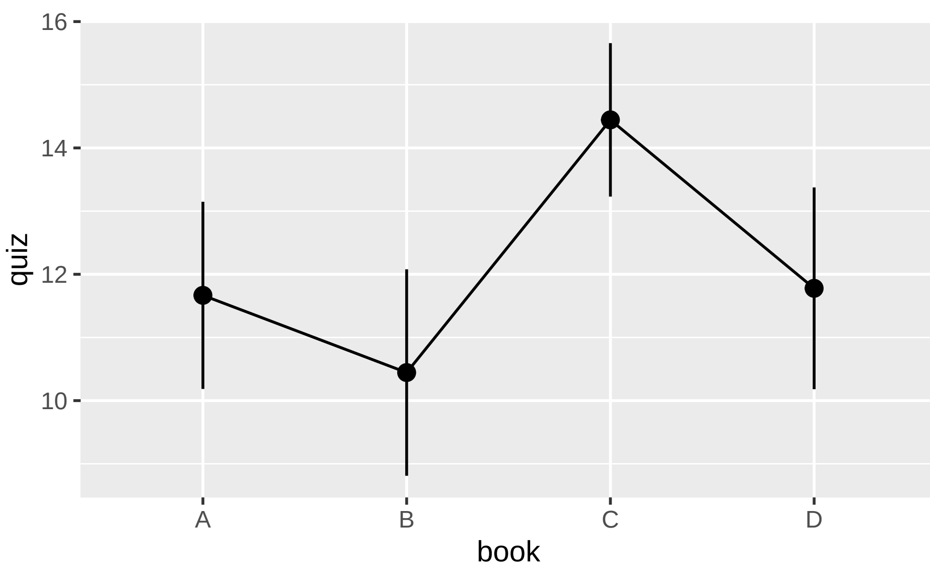
Summary Statistics

	A	B	C	D
quiz	n = 9 11.7 (4.4)	n = 9 10.4 (4.9)	n = 9 14.4 (3.6)	n = 9 11.8 (4.8)

Person-Profile Plot



Means Plot



15B-4a RM ANOVA: display all Sums-of-Squares components

TEXTBOOK QUESTION: *(a) Perform an RM ANOVA on the data, and present the results of your ANOVA in a summary table. Does it make a difference which textbook the professor uses? (b) Considering your answer to part a, what type of error could you be making (Type I or Type II)?*

DIRECTIONS: Perform a Repeated Measures ANOVA for quiz scores under the four books to determine if the text has an effect. Make sure to save your model (`fit_textbook`), so that you can add `$aov` at the end of the name to extract all the Sums-of-Squares.

```
# RM ANOVA: display all Sums-of-Squares components
```

15B-4c RM ANOVA: GG correction for lack of sericity

TEXTBOOK QUESTION: *(c) Would your F ratio from part a be significant at the .01 level if you were to assume a maximum violation of the sphericity assumption? Explain.*

DIRECTIONS: Run the name of the model `fit_textbook` alone to extract the adjusted degrees of freedom and F-test. The sums-of-squares for the corrected test are the same as for the uncorrected you just did.

```
# RM ANOVA: GG correction for lack of sphericity
```

15B-4d RM ANOVA: post-hoc with Tukey's HSD correction

TEXTBOOK QUESTION: *(d) Test all the pairs of means with Tukey's HSD, using the error term from the RM ANOVA. Which pairs differ significantly at the .05 level?*

DIRECTIONS: Conduct all possible post hoc pairwise tests on `fit_audience` using Tukey's HSD.

```
# RM ANOVA: post hoc all pairwise tests with Tukey's HSD correction
```

Means Plot (model based)

DIRECTIONS: Construct a means plot of `fit_audience` using `emmeans::emmip(~ RM_var)` to help interpret the direction of any significant differences.

15B-5a 1-Way ANOVA (treat studnets as independent)

TEXTBOOK QUESTION: *(a) Perform a one-way independent-groups ANOVA on the data from Exercise 4.*

DIRECTIONS: Perform the ANOVA with the `book` as an between-subjects factor, instead of a within-subjects factor (ignoring matching) for quiz scores to determine if the text has an effect. Make sure to save your model (`fit_book1way`), so that you can add `$aov` at the end of the name to extract all the Sums-of-Squares.

```
# 1-way ANOVA: 1 between-subject factor
```

TEXTBOOK QUESTION: *(b) Does choice of text make a significant difference when the groups of subjects are considered to be independent (i.e., the matching is ignored)? (c) Comparing your solution to this exercise with your solution to Exercise 4, which part of the F ratio remains unchanged? What can you say about the advantages of matching in this case?*

`memory_wide` - Repeated Measures Design: Stimuli's Effect on Memory Recall

TEXTBOOK QUESTION: *A neuropsychologist is exploring short-term memory deficits in people who have suffered damage to the left cerebral hemisphere. He suspects that memory for some types of material will be more affected than memory for other types. To test this hypothesis he presented six brain-damaged subjects with stimuli consisting of strings of digits, strings of letters, and strings of digits and letters mixed. The longest string that each subject in each stimulus condition could repeat correctly is presented in the following table. (One subject was run in each of the six possible orders.)*

	id	digit	letter	mixed
1	1	6	5	6
2	2	8	7	5
3	3	7	7	4
4	4	8	5	8
5	5	6	4	7
6	6	7	6	5

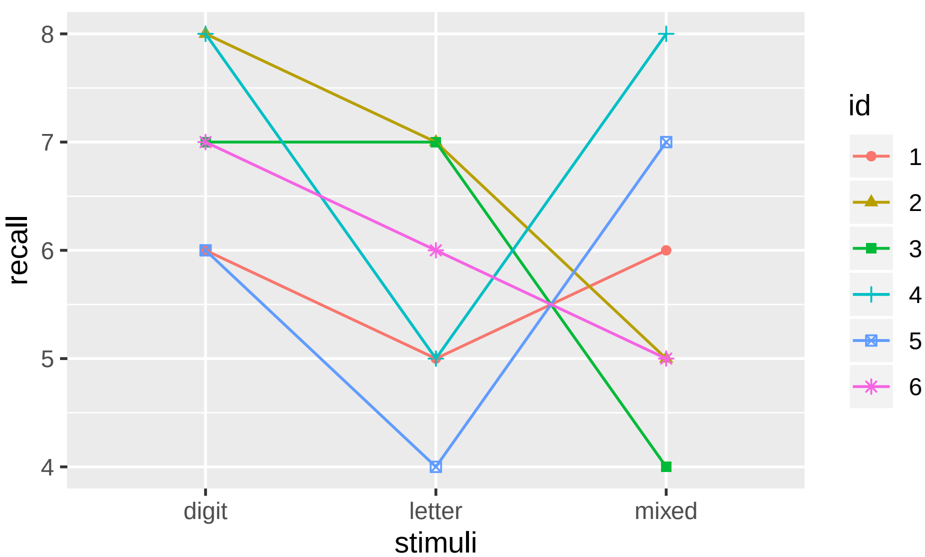
Restructure from wide to long format

	id	stimuli	recall
1	1	digit	6
2	1	letter	5
3	1	mixed	6
4	2	digit	8
...	<NA>	<NA>	...
15	5	mixed	7
16	6	digit	7
17	6	letter	6
18	6	mixed	5

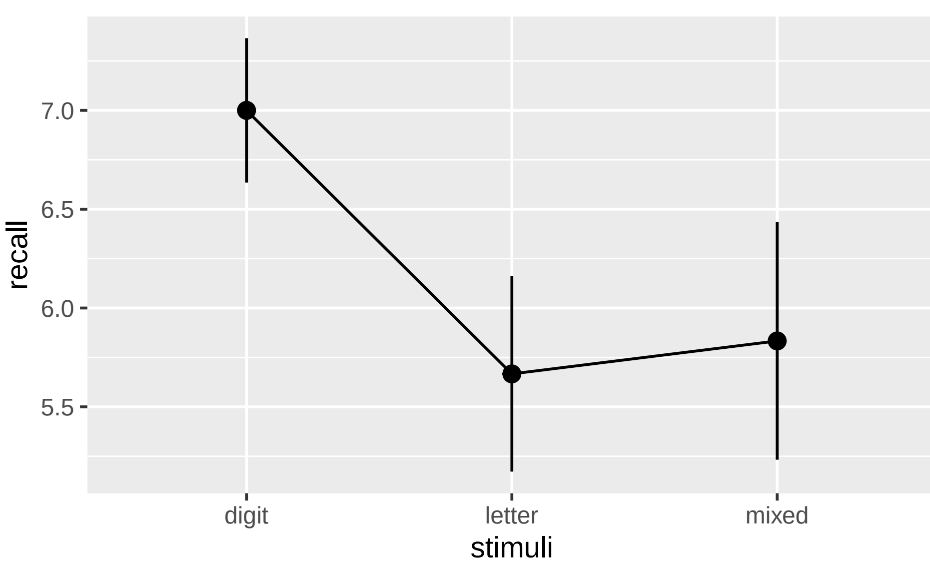
Summary Statistics

	digit	letter	mixed
recall	n = 6	n = 6	n = 6
	7.0 (0.9)	5.7 (1.2)	5.8 (1.5)

Person-Profile Plot



Means Plot



15B-6a RM ANOVA: with sphericity test and corrections

TEXTBOOK QUESTION: *(a) Perform an RM ANOVA. Is your calculated F value significant at the .05 level?*

DIRECTIONS: Perform a Repeated Measures ANOVA for recall under the three stimuli to determine if the type of stimuli has an effect. Save it as the name `fit_memory` and then use the `summary()` function display additional output.

```
# RM ANOVA: Mauchle Tests for Sphericity and Corrections applied
```

15B-6b RM ANOVA: GG corretion for lack of sphericity

TEXTBOOK QUESTION: *(b) Would your conclusion in part a change if you could not assume that sphericity exists in the population underlying this experiment? Explain. (c) Based on the graph you drew of these data for Exercise 15A2, would you say that the RM ANOVA is appropriate for these data? Explain.*

DIRECTIONS: Run the name of the model `fit_memory` alone to extract the adjusted degrees of freedom and F-test. The sums-of-squares for the corrected test are the same as for the uncorrected you just did.

```
# RM ANOVA: GG correction for lack of sphericity
```

15B-6d RM ANOVA: post-hoc with Fisher's LDS correction

TEXTBOOK QUESTION: *(d) Test all the possible pairs of means with separate matched t tests (or two-group RM ANOVAs) at the .01 level.*

DIRECTIONS: Conduct all possible post hoc pairwise tests on `fit_memory` using Fisher's LSD.

```
# RM ANOVA: post hoc all pairwise tests with Fisher's LSD correction
```

Means Plot (model based)

DIRECTIONS: Construct a means plot of `fit_audience` using `emmeans::emmip(~ RM_var)` to help interpret the direction of any significant differences.

```
# RM ANOVA: means plot
```

SECTION C

Import Data, Define Factors, and Compute New Variables

Import Data, Define Factors, and Compute New Variables

- Make sure the **dataset** is saved in the same *folder* as this file
- Make sure the that *folder* is the **working directory**

  NOTE: I added the second line to convert all the variables names to lower case. I still kept the `F` as a capital letter at the end of the five factor variables.

```
ihno_clean <- read_excel("Ihno_dataset.xls") %>%
  dplyr::rename_all(tolower) %>%
  dplyr::mutate(genderF = factor(gender,
                                levels = c(1, 2),
                                labels = c("Female",
                                           "Male"))) %>%
  dplyr::mutate(majorF = factor(major,
                               levels = c(1, 2, 3, 4,5),
                               labels = c("Psychology",
                                          "Premed",
                                          "Biology",
                                          "Sociology",
                                          "Economics"))) %>%
  dplyr::mutate(reasonF = factor(reason,
                                levels = c(1, 2, 3),
                                labels = c("Program requirement",
                                           "Personal interest",
                                           "Advisor recommendation"))) %>%
  dplyr::mutate(exp_condF = factor(exp_cond,
                                  levels = c(1, 2, 3, 4),
                                  labels = c("Easy",
                                             "Moderate",
                                             "Difficult",
                                             "Impossible"))) %>%
  dplyr::mutate(coffeeF = factor(coffee,
                                levels = c(0, 1),
                                labels = c("Not a regular coffee drinker",
                                           "Regularly drinks coffee")))  %>%
  dplyr::mutate(hr_base_bps = hr_base / 60)
```

`ihno_clean` - Repeated Measures Design: Effect of Time (expereiment) on Anxiety levels (performed INDEPENDENTLY by GENDER)

TEXTBOOK QUESTION: *(a) Use Split File to perform separate RM ANOVAs for men and women to test for a significant change in anxiety level over time (baseline, prequiz, and postquiz). Use Options to request pairwise tests. Write up the results in APA style.*

```r
ihno_clean %>%
  dplyr::select(sub_num, anx_base, anx_pre, anx_post) %>%
  head(n = 4)
```

```
# A tibble: 4 x 4
  sub_num anx_base anx_pre anx_post
    <dbl>    <dbl>   <dbl>    <dbl>
1       1       17      22       20
2       2       17      19       16
3       3       19      14       15
4       4       19      13       16
```

Restructure from wide to long format

```r
#Restructure: wide-to-long
ihno_anx_long <- ihno_clean %>%
  tidyr::pivot_longer(cols = c(anx_base, anx_pre, anx_post),
                      names_to = "time",
                      names_ptypes = list(time = factor()),
                      names_prefix = "anx_",
                      values_to = "anxiety") %>%
  dplyr::arrange(sub_num, time)
```

```r
ihno_anx_long %>%
  dplyr::select(sub_num, time, anxiety) %>%
  head(n = 12)
```

```
# A tibble: 12 x 3
   sub_num time  anxiety
     <dbl> <fct>   <dbl>
 1       1 base       17
 2       1 pre        22
 3       1 post       20
 4       2 base       17
 5       2 pre        19
 6       2 post       16
 7       3 base       19
 8       3 pre        14
 9       3 post       15
10       4 base       19
11       4 pre        13
12       4 post       16
```

15C-1a RM ANOVA (twice): with sphericity test and corrections

RESTRICT to just FEMALES

DIRECTIONS: Perform a Repeated Measures ANOVA for anxiety at all three time points to determine if the experiment had an effect. Make sure to preceed the ANOVA with a `dplyr::filter()` step to restrict to just `genderF == "Female`. Save it as the name `fit_anx_female` and then use the `summary()` function display additional output.

```
# RM ANOVA: Mauchle Tests for Sphericity with and without corrections applied
```

DIRECTIONS: If, and only if, the omnibus F test yielded evidence of at least one time point having a different average anxiety FOR WOMEN, follow up with post hoc pairs tests based on the ANOVA model.

```
# RM ANOVA: post hoc all pairwise tests with Fisher's LSD correction
```

Means Plot (model based)

DIRECTIONS: If, and only if, the omnibus F test yielded evidence of at least one time point having a different average anxiety FOR WOMEN construct a means plot of `fit_audience` using `emmeans::emmip(~ RM_var)` to help interpret the direction of any significant differences.

```
# Means Plot: model based
```

RESTRICT to just MALES

DIRECTIONS: Perform a Repeated Measures ANOVA for anxiety at all three time points to determine if the experiment had an effect. Make sure to preceed the ANOVA with a `dplyr::filter()` step to restrict to just `genderF == "Male`. Save it as the name `fit_anx_male` and then use the `summary()` function display additional output.

```
# RM ANOVA: Mauchle Tests for Sphericity with and without corrections applied
```

DIRECTIONS: If, and only if, the omnibus F test yielded evidence of at least one time point having a different average anxiety FOR MEN, follow up with post hoc pairs tests based on the ANOVA model.

```
# RM ANOVA: post hoc all pairwise tests with Fisher's LSD correction
```

Means Plot (model based)

DIRECTIONS: If, and only if, the omnibus F test yielded evidence of at least one time point having a different average anxiety FOR MEN, construct a means plot of `fit_audience` using `emmeans::emmip(~ RM_var)` to help interpret the direction of any significant differences.

```
# Means Plot: model based
```

15C-1b Paired t-Tests: choose 2 at a time

TEXTBOOK QUESTION: *(b) Using ANALYZE/Compare Means , perform matched t tests for each pair of RM levels, and then compare these p values to those produced in the Pairwise Comparisons results box of the RM ANOVA.*

DIRECTIONS: If, and only if, the omnibus F test yielded evidence of at least one time point having a different average anxiety FOR WOMEN, follow up with post hoc pairs tests NOT based on the ANOVA model. Instead, increase your `dplyr::filter()` to include requiring only 2 of the 3 time points (eg. `time %in% c("baseline", "pre-quiz")`). You will have to do this 3 times, as there are three ways to choose a pair from three options.

```
# Paired T-test: filter - women & baseline/pre-quiz
```

```
# Paired T-test: filter - women & baseline or post-quiz
```

```
# Paired T-test: filter - women & pre-quiz/post-quiz
```

DIRECTIONS: If, and only if, the omnibus F test yielded evidence of at least one time point having a different average anxiety FOR MEN, follow up with post hoc pairs tests NOT based on the ANOVA model. Instead, increase your `dplyr::filter()` to include requiring only 2 of the 3 time points (eg. `time %in% c("baseline", "pre-quiz")`). You will have to do this 3 times, as there are three ways to choose a pair from three options.

```
# Paired T-test: filter - men & baseline/pre-quiz
```

```
# Paired T-test: filter - men & baseline or post-quiz
```

```
# Paired T-test: filter - men & pre-quiz/post-quiz
```

`ihno_clean` - Repeated Measures Design: Effect of experiemnt (with vs without the experimental item) on Stat Quiz

TEXTBOOK QUESTION: *Perform an RM ANOVA to determine whether there is a significant difference in mean scores between the experimental stats quiz and the regular stats quiz. Compare this F ratio with the matched t value you obtained from computer exercise #3 in Chapter 11.*

```
ihno_clean %>%
  dplyr::select(sub_num, statquiz, exp_sqz) %>%
  head(n = 5)
```

```
# A tibble: 5 x 3
  sub_num statquiz exp_sqz
    <dbl>    <dbl>   <dbl>
1       1        6       7
2       2        9      11
3       3        8       8
4       4        7       8
5       5        6       6
```

Restructure from wide to long format

```
ihno_statquiz_long <- ihno_clean %>%
  tidyr::pivot_longer(cols = c(statquiz, exp_sqz),
                      names_to = "quiz_type",
                      names_ptypes = list(time = factor()),
                      values_to = "quiz_score") %>%
  dplyr::mutate(quiz_type = quiz_type %>%
                  forcats::fct_recode("Regular" = "statquiz",
                                      "Experimental" = "exp_sqz"))
```

```
ihno_statquiz_long %>%
  dplyr::select(sub_num, quiz_type, quiz_score) %>%
  head(n = 10)
```

```
# A tibble: 10 x 3
   sub_num quiz_type    quiz_score
     <dbl> <fct>             <dbl>
 1       1 Regular               6
 2       1 Experimental          7
 3       2 Regular               9
 4       2 Experimental         11
 5       3 Regular               8
 6       3 Experimental          8
 7       4 Regular               7
 8       4 Experimental          8
 9       5 Regular               6
10       5 Experimental          6
```

15C-3 RM ANOVA vs. Paired t-test: only 2 groups

DIRECTIONS: Perform a Repeated Measures ANOVA for recall under the three stimuli to determine if the type of stimuli has an effect. Do not save this model as a name; just run it without nameing/saving it.

> NOTE: When the measure is only repeated twice, sphericity can not be violated, so no such test are performed.

```
# RM ANOVA: no correction for lack of sphericity
```

DIRECTIONS: Alternatively, since there are only two measures, you can run this same analysis as a paired t.test, using `t.test()`. Make sure you include `paired = TRUE`.

```
# Matched t-test: paired = TRUE
```