Name:

ANOVA with Repeated Measures

*Please complete the following exercises. Feel free to work with classmates, but each student must turn in **UNIQUE** work, not photocopies or identical replicates. When applicable, use **APA format** in communicating your results in text. **Show your work!** If any question involves any math at all, show your work. When it doubt, write it out. Always show more than you think you need.*

1) WRITE-UP - Textbook Problems

Cohen Chap		Exercises	Pts	Off
15	A	*2, 4, 5	5	
	B	*3, *4, 5, *6	5	
	C	1, 3	5	
16	A	*2, *4, 5	2	
	B	*4 , 5, 8	3	
	C	1a, 2a, 3a	5	

2) SUMMARY – Supplementary Reading

		Pts	Off
Half Page	Read the Unit 5 Journal Article on Canvas. Summarize any mention or use/abuse of the concepts in the above chapters.	5	

3) R SYNTAX – Section B & C: add to the skeleton R notebook and knit to .pdf & upload

Cohen Chap		Exercises	Pts	Off
15	B	3, 4, 5, 6	5	
	C	1, 3	5	
16	B	4 ,5, 8	5	
	C	1a, 2a, 3a	5	

Grading

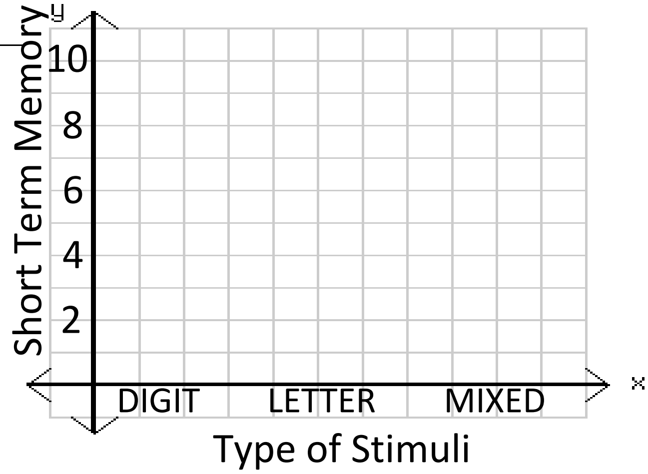
		Earned	Possible
CORRECTNESS	*a subset of spot-checked items: must show work, especially items from back of book or done in class*		50
COMPLETENESS	*more than one item is missing or skipped: 25/50 roughly half the assignment is completed: 10/50*		50
			100

15	A	2. Visual examination for interaction

The data in the following table are from an experiment on short-term memory involving three types of stimuli: digits, letters, and a mixture of digits and letters.

Draw a **graph** of these data (1 line per subject) and…

Subject	Digit	Letter	Mixed
1	6	5	6
2	8	7	5
3	7	7	4
4	8	5	8
5	6	4	7
6	7	6	5



Describe the **degree of the interaction** between the various pairs of levels.

15	A	4. RM ANOVA – calculations by hand

In exercise 12A #7, eight subjects were tested for problem-solving performance in each of four drug conditions, yielding the following means and standard deviations:

	Marijuana	Amphetamine	Valium	Alcohol
M	7	8	5	4
SD	3.25	3.95	3.16	2.07

Grand Mean
$$\bar{x}_G = \frac{\sum_{i=1}^{k} \bar{x}_i}{k}$$

If the **SAME** eight subjects were tested in all four conditions, and if the $\mathbf{SS_{sub} = 190.08}$, how large would the **F ratio** for the RM ANOVA be?

Formula 12.7
$$MS_{RM} = n\frac{\sum(\bar{x}_i - \bar{x}_G)^2}{k-1}$$

Formula 15.2B
$$df_{RM} = c - 1$$

Formula 15.3A
$$SS_{RM} = MS_{RM} \cdot df_{RM}$$

Formula 12.5B
$$MS_W = \frac{\sum s_i^2}{k}$$

Formula 12.4B
$$df_W = n_T - k$$

Formula 12.9
$$SS_W = MS_W \cdot df_W$$

Formula 15.1
$$SS_{inter} = SS_{WG} - SS_{sub}$$

Formula 15.2C
$$df_{inter} = (n-1)(c-1)$$

Formula 15.3B
$$MS_{inter} = \frac{SS_{inter}}{df_{inter}}$$

Formula 15.4
$$F_{RM} = \frac{MS_{RM}}{MS_{inter}}$$

F_{RM} (______ , ______) = ____________

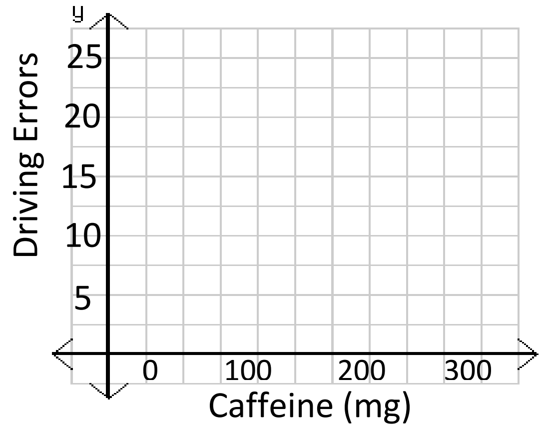
15 A 5. 1-way RM ANOVA – calculations by hand

In exercise 13B #16, independent groups of subjects performed a video game after being given one of four possible doses of caffeine (including zero). In this exercise, we will imagine that the subjects had been matched into blocks of four before being randomly assigned to one dosage level or another.

Block #	0 mg	100 mg	200 mg	300 mg	mean
1	25	16	6	8	**13.75**
2	19	15	14	18	**16.5**
3	22	19	9	9	**14.75**
4	15	11	5	10	**10.25**
5	16	14	9	12	**12.75**
6	20	23	11	13	**16.75**
mean	**19.5**	**16.3333**	**9**	**11.6667**	**14.125**

a) **Graph** these data, with caffeine amount on the x-axis and the blocks represented by separate lines. The outcome is the number of driving errors each subject makes in the video simulation game.

Describe the **general trend** of the data with respect to caffeine dosage.



Does the amount of the subject-by-dosage-level interaction look relatively **large or small**?

b) Calculate the **F ratio** for a one-way RM ANOVA on these data.

Formula 14.3: $SS = n_T \times \sigma^2(M's)$

$$\sigma^2(all\ 24\ values) = 28.03, \quad \sigma^2(4\ column\ means) = 16.52, \quad \sigma^2(6\ subject\ means) = 4.99$$

Formula 15.1
$SS_{inter} = SS_{Tot} - SS_{RM} - SS_{sub}$

Formula 15.2C
$df_{inter} = (n-1)(c-1)$

Formula 15.3B
$MS_{inter} = \frac{SS_{inter}}{df_{inter}}$

Formula 15.2B
$df_{RM} = c - 1$

Formula 15.3A
$MS_{RM} = \frac{SS_{RM}}{df_{RM}}$

Formula 15.4
$F_{RM} = \frac{MS_{RM}}{MS_{inter}}$

F_{RM} (______ , ______) = ___________ , p = ___________

Can the null hypothesis be rejected at the **.05 level**? F_{crit}(____, _____) = __________ ☐ yes ☐ no

At the **.01 level**? F_{crit}(____, _____) = __________ ☐ yes ☐ no

15	B	3. 1-way RM ANOVA	Code: R notebook

A psycophysiologist 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 are in the textbook.)

a) Perform an RM ANOVA on the blood pressure data and write the **results in words**, as they would appear in a journal article.
(Note: you will need to over-ride the defualt and make No correction for spericity violations)

~~~
```{r}
# RM ANOVA: type 3 SS, no correction for lack of Spericity
fit_audience <- audience_long %>%
  afex::aov_4(blood_pressure ~ 1 + (audience|id),
              data = .,
              anova_table = list(correction = "none",
                                 es = c("ges", "pes")))

fit_audience
```
~~~

F_{RM} (____ , ____) = __________ , p = ______

Does the size of the audience have a **significant effect** on blood pressure at the .05 level? ☐ yes ☐ no

b) What might you do to minimize the possibility of **carryover effect**?

c) Calculate the $\boldsymbol{\eta^2_{RM}}$ from the F ratio you calculated in part a.

(note the two values from R, but also calculate by hand)

☐ ges = general eta-squared = __________

☐ pes = partial eta-squared = __________

Formula 15.5

$$\eta^2_{RM} = \frac{SS_{RM}}{SS_{RM} + SS_{S*RM}}$$

$\boldsymbol{\eta^2_{RM}}$ =

Does this look like a **large** effect? ☐ yes ☐ no

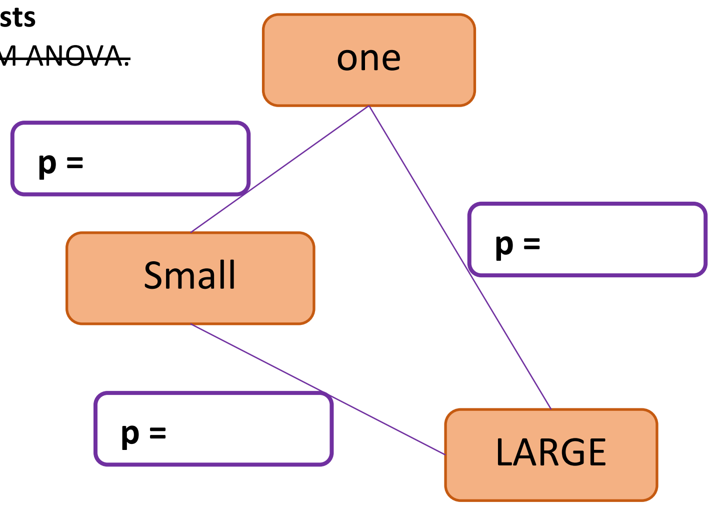
How could this effect size be **misleading** in planning future experiments?

☐ yes
☐ no

d) Test all the pairs of means with **protected t tests** (Fisher's LSD) ~~using the error term from the RM ANOVA.~~

~~~
```{r}
# RM ANOVA: post hoc all pairwise tests
fit_audience %>%
  emmeans::emmeans(~ audience) %>%
  pairs(adjust = "none")
```
~~~

Which pairs **differ** significantly at the **.05 level**?



15	B	4. 1-way RM ANOVA	Code: R notebook

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 appear in the table in the textbook.

a) Perform an RM ANOVA on the data, and present the results of your ANOVA in a **summary table**.

```{r}
# RM ANOVA: display all Sums-of-Squares components
fit_textbook <- textbook_long %>%
  afex::aov_4(quiz ~ 1 + (book|block),
              data = .)

fit_textbook$aov
```

Source	SS	df	MS	F	p
RM = ____________________					
Residual: (RM x Sub)					

Does it **make a difference** which textbook the professor uses?

☐ yes
☐ no

b) Considering your answer to part a, what **type of error** could you be making?

☐ type I
☐ type II

c) If ~~you were to assume a maximum violation of~~ the **sphericity assumption** was corrected for using the **Greenhouse-Geisser (afex default)** epsilon adjustment to the degrees of freedom.
Note: the sum-of-squares remain the same, the degrees of freedom do change…

```{r}
# RM ANOVA: GG correction for lack of Spericity
fit_textbook
```

Source	SS	df	MS	F	p
RM = ____________________					
Residual: (RM x Sub)					

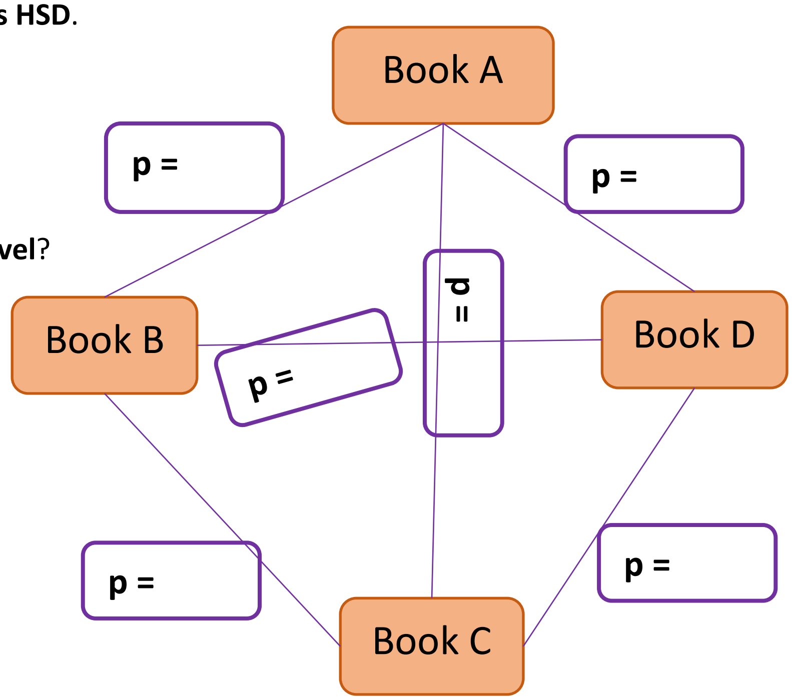
Would your F ratio from part (a) be significant at the **.01 level?**

☐ yes
☐ no

d) Test **all the pairs of means with Tukey's HSD**.

```{r}
# RM ANOVA: post hoc all pairwise tests
#           with Tukey's HSD correction
fit_textbook %>%
  emmeans::emmeans(~ book) %>%
  pairs(adjust = "tukey")
```

Which pairs differ significantly at the **.05 level**?



15 B	5. 1-way independent groups ANOVA vs. RM ANOVA	**Code: R notebook**

a) Continue with #4…Perform an 1-way Independent groups ANOVA on the data.

```{r}
# 1-way ANOVA: 1 between-subject factor
fit_book1way <- textbook_long %>%
  afex::aov_4(quiz ~ book + (1|id),
              data = .)

fit_book1way$aov
```

Source	SS	df	MS	F	p
Between-Group = ___________					
Within-Group = Residual					

b) Does the choice of **text make a significant difference** when the groups of subjects are considered to be independent (i.e., the matching is ignored)?

☐ yes

☐ no

c) **Compare** 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?

15	B	6. 1-way RM ANOVA	Code: R notebook

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 a table in the textbook. (One subject was run in each of the six possible orders.)

a) Perform an RM ANOVA (assume sphericity IS NOT violated)

F_{RM} (_____ , _____) = _______ , p = _______

Is your calculated F value significant at the **.05 level**?

☐ yes ☐ no

b) Would your conclusion in part a **change** if you could **not assume that sphericity** exists in the population underlying this experiment?

F_{RM} (_____ , _____) = _______ , p = _______

☐ yes ☐ no

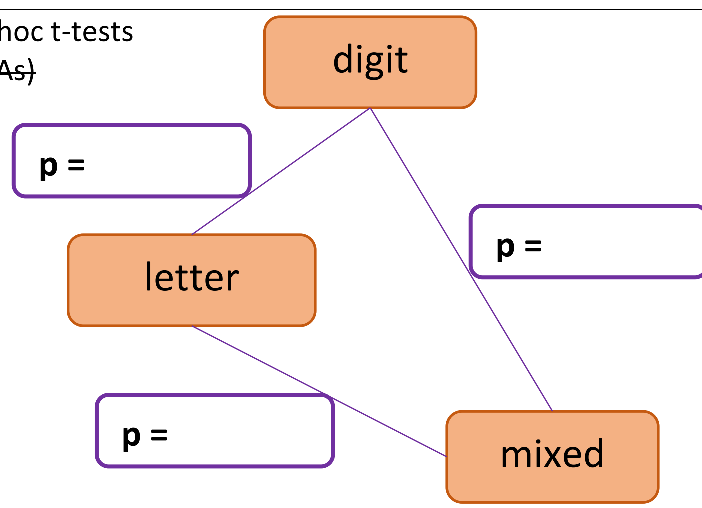
Explain.

c) Based on the **graph you drew** of these data for exercise 15A #2, would you say that the RM ANOVA is appropriate for these data?

☐ yes ☐ no

Explain.

d) Test **all the possible pairs** of means with post-hoc t-tests ~~separate matched t tests (or two-group ANOVAs)~~ **Fisher's LSD** at the **.01 level.**



15	C	1. RM anxiety over time – separately by gender	Code: R notebook

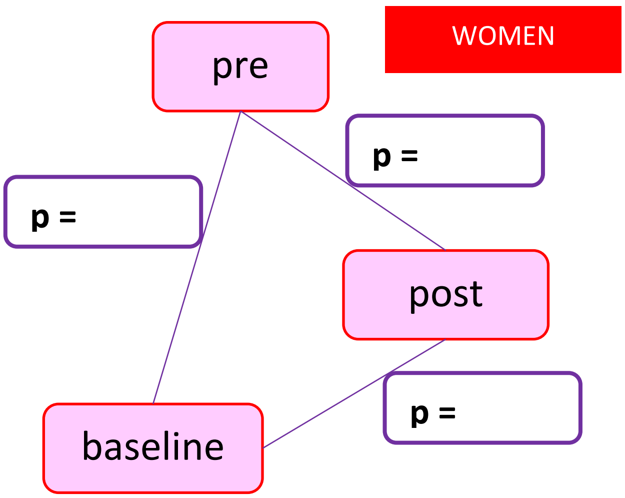
a) Use **SPLIT FILE** to perform **separate** RM ANOVAs for **men and women** to test for a significant change in **anxiety level over time** (baseline, pre-quiz, and post-quiz). Request **pairwise tests** and fill out the ~~table~~ FIGURES below with the appropriate **p-values** **<u>IF the omnibus F-test was significant</u>**.

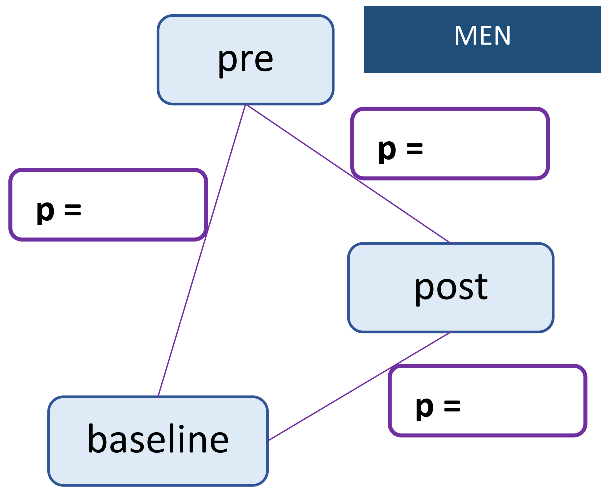
F_{RM} (_____ , _____) = ________

p = __________

F_{RM} (_____ , _____) = ________

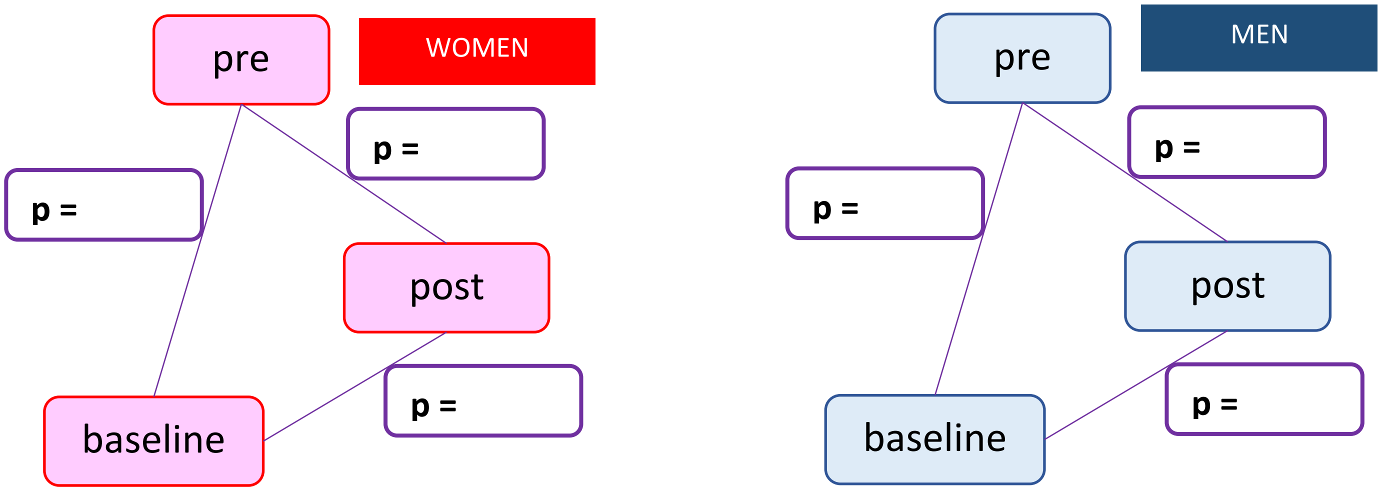
p = __________





Write up your results in **APA style**.

b) Perform **matched t tests** for each pair of RM levels, STILL BY GENDER. Fill out the table below with the appropriate **p-values <u>IF the omnibus F-test was significant.</u>**



Compare these **p values** to those produced in the ***Pairwise Comparisons*** results box of the RM ANOVA output produced for part (a) above.

15	**C**	**3. RM stats quiz – experimental quiz vs. regular stats quiz**

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. **Code: R notebook**

Compare this F ratio with the **matched t value** you obtained from exercise #3 in chapter 11 C.

RM ANOVA: F(______ , ______) = ____________ , p = ___________

Matched pair: t(_____) = ____________ , p = ___________

16	A	2. Mixed Design ANOVA – calculations by hand

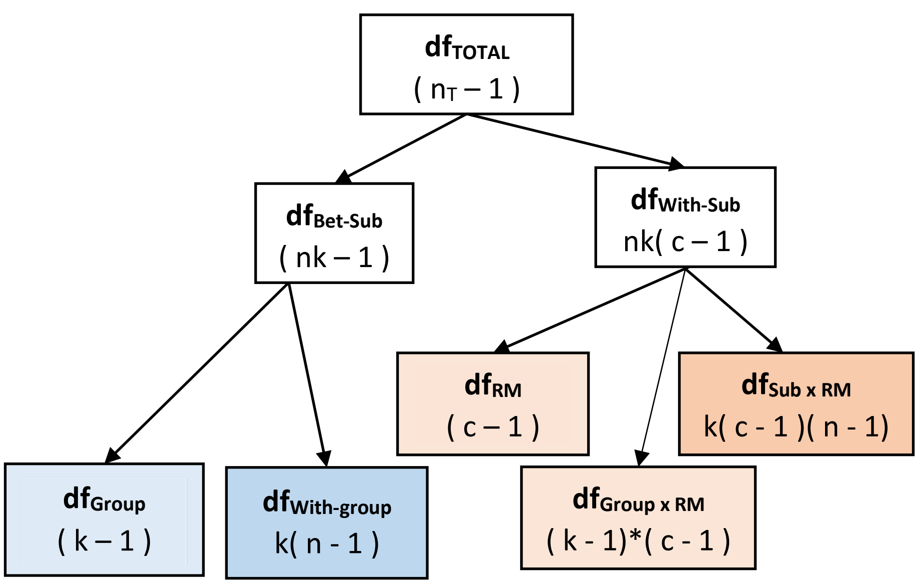
A researcher tested two groups of subjects – six alcohol abusers and six moderate social drinkers – on a reaction time task. Each subject was measured twice: before and after drinking 4 ounces of vodka. A mixed-design ANOVA produced the following SS components:

$SS_{groups} = 88,\ SS_{with-grp} = 1380,$ AND $SS_{RM} = 550,\ SS_{G\ x\ RM} = 2.0,\ SS_{S\ x\ RM} = 134$

Complete the analysis and present the results in a **summary table**.

Source	SS	df	MS	F	p
Between-Subjects					
Groups = ______________					
Residual: Within-Groups					
Within-Subjects					
RM = ________________					
INTER: Group x RM					
Residual: INTER(Sub x RM)					
Total					

F_{CV} (______ , ______) = ____________

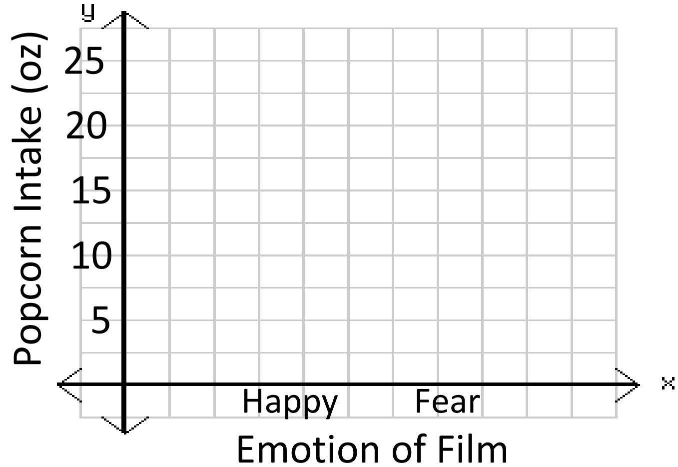


16	A	**4.RM plots – viewing interactions**

The following table shows the number of ounces of popcorn consumed by each subject while viewing two emotion-evoking films, one evoking happiness and one evoking fear. Half the subjects ate a meal just before the film (preload condition), whereas the others did not (no load condition).

Graph the data for all the subjects on one graph. → **Let the repeated measure by the x-axis**
(Make a key to show the between-subject groups with color, shape, and linetypes)

	Happiness	**Fear**
Preload	10	12
	13	16
	8	11
	16	17
No Load	26	20
	19	14
	27	20
	20	15



a) Does there appear to be about the same amount of **subject x treatment** interaction in each group?

☐ yes ☐ no

b) Does there appear to be a considerable amount of **group x repeated-measure** interaction?

☐ yes ☐ no

16	A	**5.Source of RM variation**

If you calculate an RM ANOVA and then assign the subjects to subgroups to create a mixed design, the observed F ratio for the **RM factor may get considerably larger.** Under which of the following conditions is this likely?

☐ a) The degrees of freedom associated with the error term are reduced considerably.

☐ b) There is a good deal of subject x RM treatment interaction

☐ c) There is a good deal of (sub)group x RM treatment interaction

☐ d) There is a good deal of subject-to-subject variabilibty

16	B	4. Mixed Design ANOVA –	Code: R notebook

In exercise 15 B #2 subjects performed a clerical task under three noise conditions. Now suppose a new group of subject is added to study the effects of the same three conditions on the performance of a simpler, more mechanical task. The data is presented in the textbook.

a) Perform a mixed-design ANOVA, and display the results in a **summary table.**

```
```{r}
# Mixed ANOVA: no correction for spericity and both effect sizes
fit_tasks <- tasks_long %>%
  afex::aov_4(completed ~ type_task + (noise|id),
              data = .,
              anova_table = list(correction = "none",
                                 es = c("ges", "pes")))

fit_tasks$aov
```
```

Source	SS	df	MS	F	p
Between-Subjects					
Groups = ______________					
Residual: Within-Groups					
Within-Subjects					
RM = ______________					
INTER: Group x RM					
Residual: INTER(Sub x RM)					
Total					

b) Calculate the **generalized eta squared** for the main effect of the **type-of-task** factor.
For simplicity: DO NOT correct for violations of spericity.
(record the two values from R by running the model's name "fit_tasks", but also calculate by hand)

☐ ges = general eta-squared = __________

☐ pes = partial eta-squared = __________

Formula 16.8

$$Grp\ assigned: \eta^2_{gen} = \frac{SS_{Grp}}{SS_{Grp} + SS_{WithGrp} + SS_{Sub*RM}}$$

$\eta^2_{Gen} =$

Does this look like a **large effect size**?

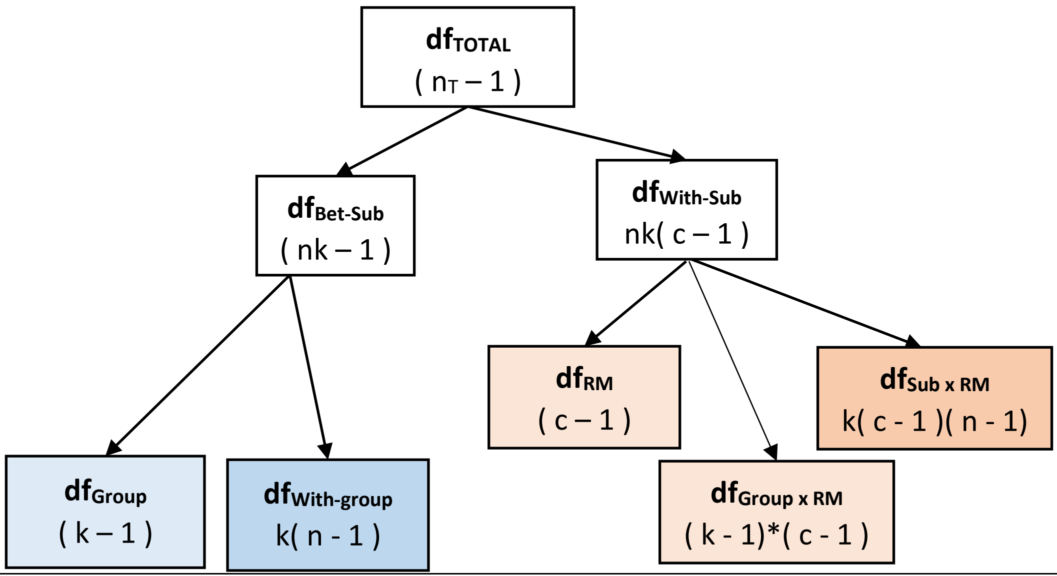
☐ yes ☐ no

Explain.

16	A	5. Mixed Design ANOVA	Code: R notebook

Dr. Jones is investigating various conditions that affect mental effort – which, in this experiment, involves solving anagrams. Subjects were randomly assigned to one of three experimental conditions. Subjects in the first group were told that they would not be getting feedback on their performance. Subjects in the second and third groups were told they would get feedback, but only subjects in the third group were told (erroneously) that anagram solving was highly correlated with intelligence and creativity (Dr. Jones hoped this information would produce ego involvement). The list of anagrams given to each subject contained a random mix of problems at four levels of difficulty determined by the number of letters presented (five, six, seven, or eight). The number of anagrams correctly solved by each subject in each condition and at the each difficulty level is given in the textbook.

a) Draw a **degrees of freedom tree** for this experiment.



b) Perform a mixed analysis of variance, and display the results in a summary table.

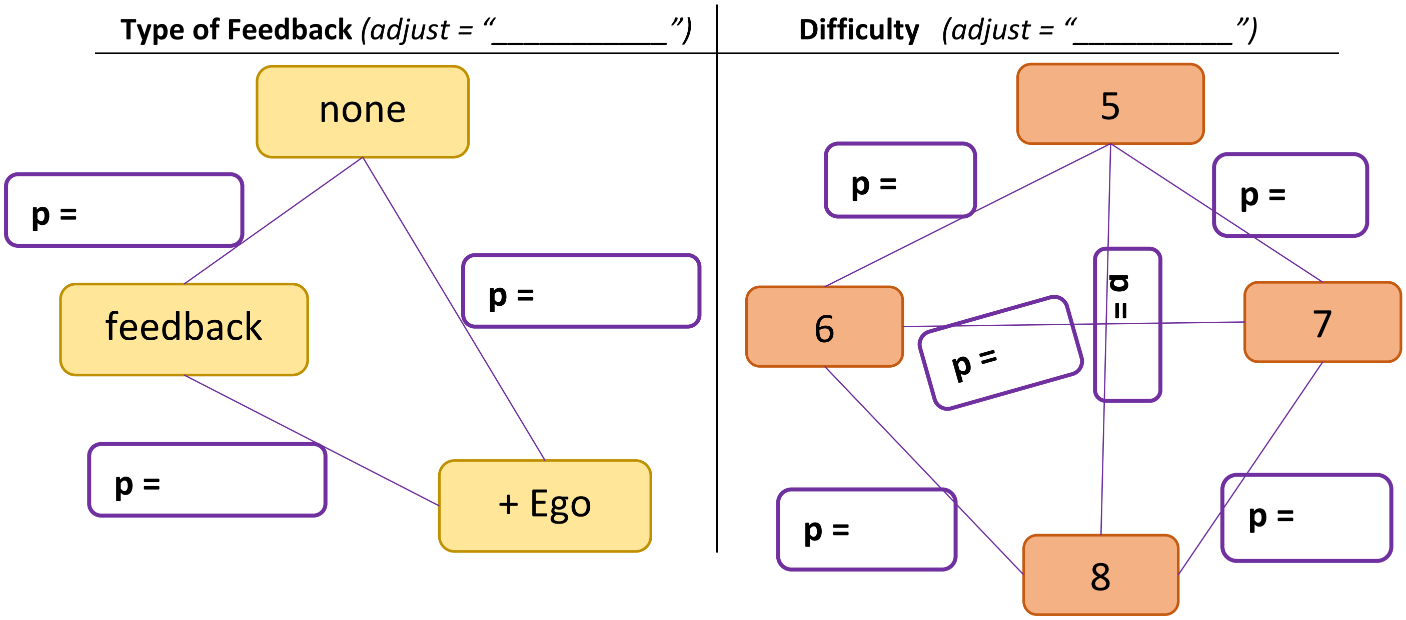
Source	SS	df	MS	F	p
Between-Subjects					
Groups = ______________					
Residual: Within-Groups					
Within-Subjects					
RM = ________________					
INTER: Group x RM					
Residual: INTER(Sub x RM)					
Total					

Would any of your conclusions change if you do **not assume sphericity**?

☐ yes ☐ no

Explain.

c) Perform post hoc pairwise comparisons for both main effects, using the appropriate error term from part b in each case.



Explain why these follow-up tests are appropriate given your results in part b.

Briefly state the conclusion of this analysis.

16	A	8. Mixed Design ANOVA	Code: R notebook

Exercise 15B #6 described a neuropsychologist studying subjects with brain damage to the left cerebral hemisphere. Such a study would probably include a group of subjects with damage to the right hemisphere and a group of control subjects without brain damage. The data the previous exercise, along with data for the two comparison groups just mentioned are presented below.

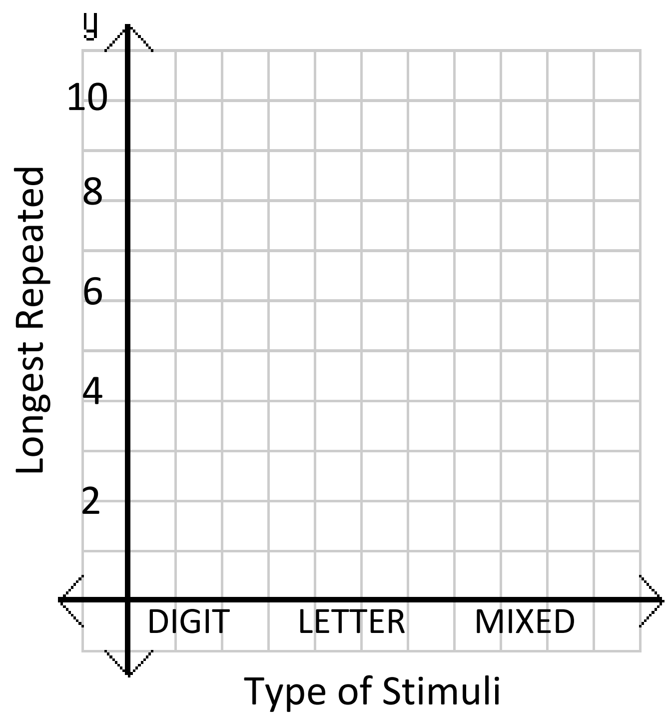
Perform a mixed-design ANOVA and test the **three F ratios at the .05 level**.

Source	SS	df	MS	F	p
Between-Subjects					
Groups = ____________					
Residual: Within-Groups					
Within-Subjects					
RM = ______________					
INTER: Group x RM					
Residual: INTER(Sub x RM)					
Total					

<u>**What**</u> can you **conclude** about the effects of brain damage on short-term recall for these types of stimuli?

a) Draw a **graph** of these data, subject by subject.
(Make a key to show the between-subject groups with color, shape, and linetypes)

	Digit	Letter	Mixed
LEFT Brain Damage	6	5	6
	8	7	5
	7	7	4
	8	5	8
	6	4	7
	7	6	5
RIGHT Brain Damage	9	8	6
	8	8	7
	9	7	8
	7	8	8
	7	6	7
	9	8	9
CONTROL no Damage	8	8	7
	10	9	9
	9	10	8
	9	7	9
	8	8	8
	10	10	9



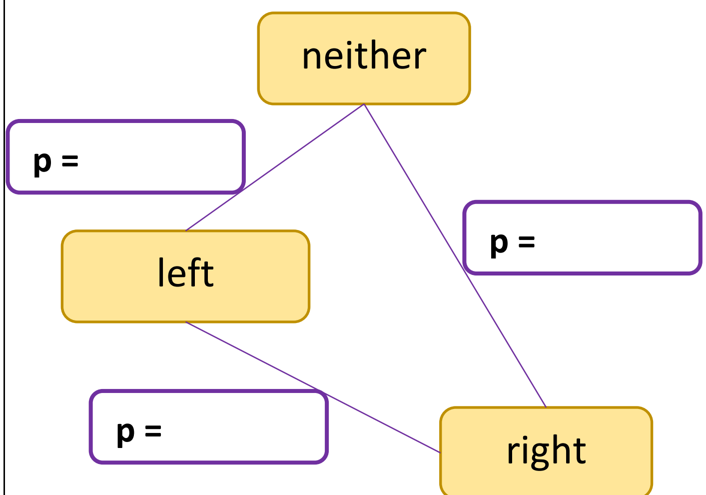
Do the **assumptions** of the mixed-design ANOVA seem **reasonable** in this case?

☐ yes ☐ no

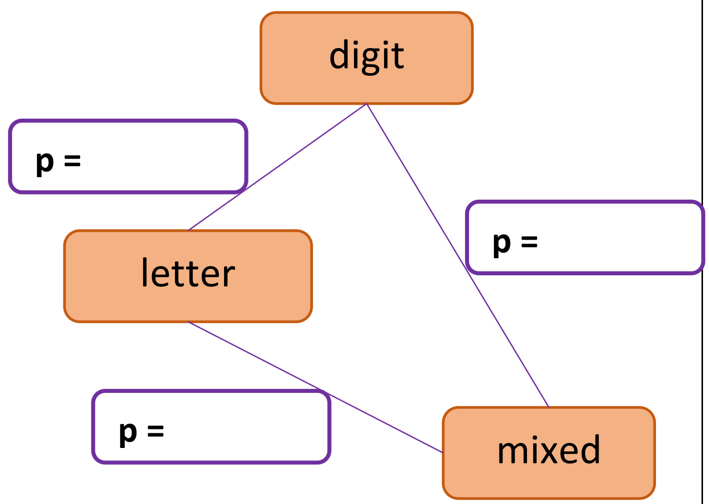
Explain.

b) Perform **post hoc pairwise** comparisons for <u>both</u> main effects.

Brain Damage *(adjust = "____________")*



Stimuli *(adjust = "____________")*



Briefly state the conclusion of this analysis.

16	C	1. Anxiety: Time x Major	Code: R notebook

a) Perform a mixed-design ANOVA with the **three anxiety measures** as the RM levels, and **major** as the between-subjects factor. Request a plot of the cell means, and post hoc test for both the RM factor (LSD) and for major (Tukey). Report the **results** of the ANOVA in **APA style**.

16	C	2. Heart Rate: time x gender	Code: R notebook

a) Perform a mixed-design ANOVA with the **three heart-rate measures** as the RM levels and **gender** as the between-subjects factor. Request a plot of the cell means and post hoc test for the RM factor (LSD). Report the **results** of the ANOVA in **APA style**.

16	C	3. Stat Quizzes: time x Experimental condition **Code: R notebook**

a) Perform a mixed-design ANOVA with the **two 10-point quizzes (statquiz & exp_sqz)** as the RM levels and **exp_cond** as the between-subjects factor. Request a plot of the cell means. Report the **results** of the ANOVA in **APA style**. If the interaction is significant, explain the pattern you see in the plot of the cell means.