Analysis of Variance Review

Review Sheet for Exam 3 on Psy 216 Website

1

I've created these Powerpoint Slides to help you prepare for the Exam.

The first group of slides lets you test yourself on identifying ANOVA designs: read the problem description and answer the question: "What is the design?"

Identify which type of ANOVA you think it is: Independent measures or Repeated Measures Design.

Click on the slide and the answer appears.

Go on to the next slide.

The second group of slides are for practicing filling out ANOVA source tables. Some of the tables are Independent Measures ANOVA source tables and some are Repeated Measures source tables.

Let me know if either of these exercises help you prepare.

2

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16. Recent research indicates that the effectiveness of anti-depressant medication is directly related to the severity of the depression (Khan, Brodhead, Kolts, & Brown, 2005). Based on pre-treatment depression scores, patients were divided into four groups based on their level of depression. After receiving the antidepressant medication, depression scores were measured again and the amount of improvement was recorded for each patient. The following data are similar to the results of the study.

a. Do the data indicate significant differences among the four levels of severity? Test with $\alpha = .05$.
b. Compute η^2, the percentage of variance explained by the group differences.

What is the design?

Independent Measures

Low Moderate	High Moderate	Moderately Severe	Severe	
0	1	4	5	$N = 16$
2	3	6	6	$G = 48$
2	2	2	6	$\Sigma X^2 = 204$
0	2	4	3	
$M = 1$	$M = 2$	$M = 4$	$M = 5$	
$T = 4$	$T = 8$	$T = 16$	$T = 20$	
$SS = 4$	$SS = 2$	$SS = 8$	$SS = 6$	

3

4. A company researcher examines the sales performance of $n = 5$ new employees at the real estate firm. To see if there is a significant trend toward improvement, the number of homes sold is recorded each month for the first 3 months of employment. The data are as follows:

Person	Month 1	Month 2	Month 3
A	1	3	4
B	4	6	8
C	3	3	5
D	2	4	7
E	0	4	6

a. Compute the mean number of sales that were made in each month.

b. Is there a significant change in sales performance with more experience? Test at the .05 level of significance.

What is the design?   Repeated Measures

4

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19. There is some evidence that high school students justify cheating in class on the basis of poor teacher skills or low levels of teacher caring (Murdock, Miller, and Kohlhardt, 2004). Students appear to rationalize their illicit behavior based on perceptions of how their teachers view cheating. Poor teachers are thought not to know or care whether students cheat, so cheating in their classes is okay. Good teachers, on the other hand, do care and are alert to cheating, so students tend not to cheat in their classes. Following are hypothetical data similar to the actual research results. The scores represent judgments of the acceptability of cheating for the students in each sample. Use an ANOVA with = .05 to determine whether there are significant differences in student judgments depending on how they see their teachers.

Poor Teacher	Average Teacher	Good Teacher	
$n = 6$	$n = 8$	$n = 10$	$N = 24$
$M = 6$	$M = 2$	$M = 2$	$G = 72$
$SS = 30$	$SS = 33$	$SS = 42$	$\Sigma X^2 = 393$

What is the design?   Independent Measures

5

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2. A psychologist would like to examine how the rate of presentation affects people's ability to memorize a list of words. A list of 20 words is prepared. For one group of subjects the list is presented at the rate of one word every $\frac{1}{2}$ second. The next group gets one word every second. The third group has one word every 2 seconds, and the fourth group has one word every 3 seconds. After the list is presented, the psychologist asks each person to recall the entire list. The dependent variable is the number of errors in recall. The data from this experiment are as follows:

$\frac{1}{2}$ Second	1 Second	2 Seconds	3 Seconds	
4	0	3	0	$G = 32$
6	2	1	2	$\Sigma X^2 = 104$
2	2	2	1	
4	0	2	1	
$T = 16$	$T = 4$	$T = 8$	$T = 4$	
$SS = 8$	$SS = 4$	$SS = 2$	$SS = 2$	

a. Can the psychologist conclude that the rate of presentation has a significant effect on memory? Test at the .05 level.

b. Use Tukey's HSD test to determine which rates of presentation are statistically different and which are not.

What is the design?   Independent Measures

6

40. A psychologist is asked by a dog food manufacturer to deter-mine if animals will show a preference among three new food mixes recently developed. The psychologist takes a sample of n = 6 dogs. They are deprived of food overnight and presented simultaneously with three bowls of the mixes on the next morning. After 10 minutes, the bowls are removed, and the amount of food (in ounces) consumed is determined for each type of mix. The data are as follows:

Subject	Mix 1	2	3
1	3	2	1
2	0	5	1
3	2	7	3
4	1	6	5
5	1	2	3
6	3	0	3

Is there evidence for a significant preference? Test at the .05 level of significance.

What is the design?   Repeated Measures

7

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8. A developmental psychologist is examining problem-solving ability for grade school children. Random samples of 5-year- old, 6-year-old, and 7-year-old children are obtained with n = 3 in each sample. Each child is given a standardized problem-solving task, and the psychologist records the number of errors. These data are as follows:

5-Year-Olds	6-Year-Olds	7-Year-Olds	
5	6	0	$G = 30$
4	4	1	$\Sigma X^2 = 138$
6	2	2	
$T = 15$	$T = 12$	$T = 3$	
$SS = 2$	$SS = 8$	$SS = 2$	

What is the design?   Independent Measures

8

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12. A scientist tests two drugs for their effects on insomnia. A sam-ple of $n = 10$ insomniacs is pretested with a placebo before bedtime, and the latency to onset of sleep is measured to serve as a baseline. A week later, the subjects receive the first drug before bedtime, and the time that lapses between drug admin-istration and sleep onset is measured again. Finally, a week later the second drug is tested in the same fashion. The latency to sleep onset (in minutes) is presented for each subject on every test. The data are as follows:

Subject	Pretest	Drug 1	Drug 2
E.B.	136	24	33
K.F.	92	107	21
T.Z.	117	98	111
J.R.	65	51	49
R.E.	129	29	37
A.G.	172	112	70
P.S.	89	122	145
D.W.	84	22	16
L.K.	140	95	27
C.Y.	73	67	77

What is the design?

Repeated Measures

Is there a significant effect on latency? Test at the .05 level of significance.

9

A social psychologist would like to examine the relationship between personal appearance and authority. A special questionnaire is prepared which requires very careful attention to instructions in order to fill it in correctly. Three random samples of college students are obtained. For the first group the psychologist dresses very casually (blue jeans and T-shirt) when the questionnaire is administered. For the second sam-ple, the psychologist wears a suit, and for the third sample the psychologist wears a very"scientific" laboratory coat. The psychologist records the number of errors made by each individual while completing the questionnaire. These data are as follows:

Blue Jeans	Suit	Lab Coat	
5	3	1	
2	3	0	$G = 30$
2	0	1	$\Sigma X^2 = 86$
4	2	2	
2	2	1	
$T = 15$	$T = 10$	$T = 5$	
$SS = 8$	$SS = 6$	$SS = 2$	

Should the psychologist conclude that appearance had an influence on the amount of attention people paid to the instructions? Test at the .05 level of significance.

What is the design?　　Independent Measures

10

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14. An industrial psychologist examines the effect of hourly wages and piecework pay on productivity. A random sample of $n = 12$ workers is studied. These workers are assembling small cir-cuit boards for appliances and are getting paid at an hourly rate. The psychologist records the number of circuit boards assembled in 1 day for this pay schedule. The workers are later switched to a piecework rate in which they get paid according to the number of circuit boards assembled, not the number of hours worked. Again, the number of boards assembled is re-corded for 1 day. The results are as follows:

Subject	Hourly Rate	Piecework
1	74	82
2	59	70
3	70	63
4	67	91
5	79	87
6	61	75
7	80	96
8	72	68
9	69	60
10	57	67
11	70	74
12	71	79

What is the design?

Repeated Measures

11

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14. A researcher would like to systematically evaluate the effects of food deprivation on learning. Five groups of rats are selected with each group receiving a different level of depri-vation before testing. The scores for these rats are as follows:

Hours of Deprivation

6	12	18	24	30
9	10	18	14	7
7	8	16	12	9
10	17	23	17	13
12	14	24	20	16
13	18	21	19	15

a. Can the researcher conclude that the level of deprivation has an effect on learning performance? Test at the .05 level of significance.

b. Sketch a graph showing the mean learning score for each treatment condition. Describe the relation between hours of deprivation and learning.

c. Use Tukey's HSD test to determine which treatment con-ditions are different.

What is the design?　　Independent Measures

12

Slide 13

*10. A psychologist would like to demonstrate that the combination of two drugs can often produce much different effects than either of the drugs taken separately. Four random samples are selected with $n = 5$ in each sample. One group is given a sugar pill (no drug), one group is given drug A, another group is given drug B, and the final group is given drugs A and B together. Each person is then given a logic test measuring basic reasoning ability. The data are summarized as follows:

Sugar Pill	Drug A	Drug B	Drugs A and B	
$T = 0$	$T = 5$	$T = 5$	$T = 20$	$\Sigma X^2 = 122$
$SS = 7$	$SS = 8$	$SS = 7$	$SS = 10$	

a. Can the psychologist conclude that there are any significant differences among the treatments? Test at the .05 level.

b. Use Tukey's HSD test to determine which treatments are different.

What is the design?   Independent Measures

13

Slide 14

*13. A sample of 14-week-old infants is studied in a perception experiment. The infants are presented with three line drawings successively for 5 minutes each. The designs vary in their complexity. The researcher records how much time (in seconds) is spent viewing each of the stimuli. The data are as follows:

Infant	Amount of Complexity Low	Moderate	High
A	63	112	39
B	210	73	80
C	94	314	83
D	219	232	115
E	54	396	76
F	120	352	100
G	195	409	206

Is there a significant preference among the three stimuli? Test at the .01 level of significance.

What is the design?   Repeated Measures

14

Slide 15

13. In a paired-associate learning task, subjects are required to learn pairs of words. The first word in each pair is called the stimulus word, and the second is the response word. On each trial, the experimenter presents the stimulus word and asks the subject to recall the correct response. If the subject fails, the correct response word is given, and the experimenter continues through the list. The dependent variable is the number of times the experimenter must go through the entire list before the subject can recall all response words perfectly. This task often is used to demonstrate the effectiveness of mental imagery as an aid to memory. In a typical experiment, subjects in one group are instructed to form a mental image combining the two words in each pair. A second group is instructed to form a sentence that uses both of the words. A third group receives no special instructions. The data from this experiment are as follows:

No Instructions			Images			Sentences		
6	7	5	3	6	5	5	8	6
5	8	10	5	3	4	4	5	8
8	9	10	4	5	3	5	10	9
4	8	8	3	8	3	6	7	6
5	10	7	5	4	6	8	8	6

What is the design?   Independent Measures

15

Slide 16

17. Do weather conditions affect people's moods? To examine this question, a researcher selected three samples of college students and administered a mood inventory questionnaire to each student. One group was tested on a dreary, overcast, and drizzly day. The second group was tested during a violent thunderstorm, and the third group was tested on a bright sunny day. The data are as follows:

Dreary		Stormy		Bright	
6	9	8	12	13	10
10	12	10	6	6	13
5	7	8	9	10	8
12	8	14	10	9	12
7	10	7	7	15	11
9	14	8	12	13	16
13	10	16	8	14	9
8	8	10	11	18	14

Do these data indicate that weather has an effect on mood? Test at the .05 level of significance.

What is the design?   Independent Measures

16

Slide 17

*15. A school administrator would like to know whether students tend to select college majors that are consistent with their skills. A sample of $n = 12$ psychology majors and a sample of $n = 12$ English majors are selected. Each of these students completed a verbal abilities test when he/she first entered college. The scores for these two samples are as follows:

Psychology			English		
18	14	21	19	23	16
17	20	19	22	19	21
15	18	13	20	18	15
16	21	14	19	16	23

a. Use an analysis of variance to determine whether these data indicate any significant difference in verbal ability for English versus psychology majors. Test with $\alpha = .05$.
b. Use a t test to determine whether there is any mean difference between the two populations. Again, test at the .05 level of significance. (*Note:* You should find $F = t^2$.)

What is the design?   Independent Measures

17

Slide 18

The following slides are for practicing filling out ANOVA source tables. Some of the source tables are Independent Measures ANOVA source tables and some are Repeated Measures source tables. Try to fill the table out yourself and then go to the next slide, which has the source table completely filled out. However, before you look up the answers:

1. First translate everything you can from the written problem description into numbers. For example, if the problem tells you the number of treatments is 4, write down "k = 4". Do the same for every number mentioned in the problem description.
2. Second, try to diagram the study. In other words, draw the data table that we set up before we do an ANOVA. This will help you see how many subjects there are and how many scores overall.
3. Figure out and fill out the degrees of freedom (the df's) for the whole source table.
4. Now, work backwards or forwards from what you know in the source table to what you don't know. For example, if you know the MSbetween is 40 and the dfbetween are 2 then the SSbetween must be 80, because SSbetween/dfbetween is equal to MSbetween, and so on.

18

*19. A manufacturer of business machines would like to compare the four most popular brands of electric typewriters. A sample of eight typists is selected, and each typist spends 15 minutes testing each of the four typewriters and then rates its performance. The manufacturer would like to know if there are any significant differences among the four brands. The data from this study were examined using an analysis of variance. The results are shown in the following summary table. Fill in all missing values.

Source	SS	df	MS	
Between treatments	270	___	___	F = 9.00
Within treatments	___	___		
Between subjects	___	___		
Error	___	___	___	
Total	680	___		

19

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Source	SS	df	MS	
Between treatments	270	3	90	F = 9.00
Within treatments	416	28		
Between subjects	(206)	(7)		
Error	(210)	(21)	10	
Total	680	31		

20

9. A researcher would like to know whether infants can be affected by alcohol consumed by a mother during pregnancy. A sample of 24 pregnant rats is obtained. The researcher randomly divides these rats into four groups with $n = 6$ in each group. All groups receive the same diet of rat chow but during the last 2 weeks of pregnancy one group has $\frac{1}{4}$ ounce of vodka mixed with their food. The second group receives $\frac{1}{2}$ ounce, the third group receives 1 ounce, and the final group has no alcohol. One of the offspring of each rat is randomly selected to be weighed at birth. The data were examined using an ANOVA, and the results are summarized in the following table. Fill in all missing values.

Source	SS	df	MS	
Between treatments	___	___	10	F = ___
Within treatments	40	___	___	
Total	___	___		

21

7

9. A researcher would like to know whether infants can be affected by alcohol consumed by a mother during pregnancy. A sample of 24 pregnant rats is obtained. The researcher randomly divides these rats into four groups with $n = 6$ in each group. All groups receive the same diet of rat chow but during the last 2 weeks of pregnancy one group has $\frac{1}{4}$ ounce of vodka mixed with their food. The second group receives $\frac{1}{2}$ ounce, the third group receives 1 ounce, and the final group has no alcohol. One of the offspring of each rat is randomly selected to be weighed at birth. The data were examined using an ANOVA, and the results are summarized in the following table. Fill in all missing values.

Source	SS	df	MS	
Between treatments	30	3	10	$F = 5.00$
Within treatments	40	20	2	
Total	70	23		

22

To determine the long-term effectiveness of relaxation training on anxiety, a researcher uses a repeated measures study. A random sample of n =10 subjects is first tested for the severity of anxiety with a standardized test. In addition to this pretest, subjects are tested again 1 week, 1 month, 6 months, and 1 year after treatment. The investigator used ANOVA to evaluate these data, and portions of the results are presented in the following summary table. Fill in the missing values. (Hint: Start with the df values.)

Source	SS	df	MS	
Between treatments	___	___	___	$F = 5$
Within treatments	500	___		
Between subjects	___	___		
Error	___	___	10	
Total	___	___		

23

To determine the long-term effectiveness of relaxation training on anxiety, a researcher uses a repeated measures study. A random sample of n =10 subjects is first tested for the severity of anxiety with a standardized test. In addition to this pretest, subjects are tested again 1 week, 1 month, 6 months, and 1 year after treatment. The investigator used ANOVA to evaluate these data, and portions of the results are presented in the following summary table. Fill in the missing values. (Hint: Start with the df values.)

Source	SS	df	MS	
Between treatments	200	4	50	$F = 5$
Within treatments	500	45		
Between subjects	(999)	(9)		
Error	(140)	(36)	10	
Total	700	49		

24

5. A teacher studies the effectiveness of a reading skills course on comprehension. A sample of n = 20 students is studied. The instructor assesses their comprehension with a standardized reading test. The test is administered at the beginning of the course, at midterm, and at the end of the course. The instructor uses analysis of variance to determine whether or not a significant change has occurred in the students' reading performance. The following summary table presents a portion of the ANOVA results. Provide the missing values in the table. (Start, with df values.)

Source	SS	df	MS	
Between treatments	___	___	18	F = 9.0
Within treatments	170	___		
Between subjects	___	___		
Error	___	___	___	
Total	___	___		

25

5. A teacher studies the effectiveness of a reading skills course on comprehension. A sample of n = 20 students is studied. The instructor assesses their comprehension with a standardized reading test. The test is administered at the beginning of the course, at midterm, and at the end of the course. The instructor uses analysis of variance to determine whether or not a significant change has occurred in the students' reading performance. The following summary table presents a portion of the ANOVA results. Provide the missing values in the table. (Start, with df values.)

Source	SS	df	MS	
Between treatments	36	2	18	F = 9.0
Within treatments	170	57		
Between subjects	(94)	(19)		
Error	(76)	(38)	2.0	
Total	206	59		

26

22. A developmental psychologist is examining the development of language skills from age to age 5. Four different groups of children are obtained, one for each age, with n = 15 children in each group. Each is child is given a language skills assessment test. The resulting data were analyzed with an ANOVA to test for mean differences between age groups. The results of the ANOVA are presented in the following table. Fill in all missing values.

Source	SS	df	MS	
Between Treatments	81	___	___	F = ___
Within Treatments	___	___	___	
Total	249	___		

27

22. A developmental psychologist is examining the development of language skills from age to age 5. Four different groups of children are obtained, one for each age, with n = 15 children in each group. Each is child is given a language skills assessment test. The resulting data were analyzed with an ANOVA to test for mean differences between age groups. The results of the ANOVA are presented in the following table. Fill in all missing values.

Source	SS	df	MS	
Between Treatments	81	3	27	F = 22.31
Within Treatments	68	56	1.21	
Total	249	59		

28