

Psych 218, Assignment 2 (Part B) Multiple Comparisons in One-factor Between Subjects ANOVA

Study: 178 healthy boys ages 8 - 18 with a diagnosis of ADHD participated in a study examining the effects of three ADHD medications on heart functioning. Boys were randomly assigned to one of four conditions: DRUG A, DRUG B, DRUG C, and NO medication. The dependent variable in this problem is each boy's average resting heart rate.

Assume that in each of the five scenarios below you wish to maintain a familywise Type I error rate of .05. Each scenario is self-contained. Use SPSS for your data analyses and generate the output as requested in each question below. ATTACH YOUR OUTPUT TO THIS DOCUMENT. Be sure to use the multiple-comparison decision chart to help you choose the best procedure.

1. Scenario One: These two hypotheses were stated before data collection:

Hypothesis 1: Boys taking DRUG C have a higher heart rate than boys taking DRUG A. Write the null hypothesis for this comparison:
 $H_0: \mu_C - \mu_A = 0$

Hypothesis 2: Boys taking NO ADHD medication will have a lower heart rate than boys taking an ADHD medication. Write the null hypothesis for this comparison:
 $H_0: \frac{\mu_A + \mu_B + \mu_C}{3} - \mu_D = 0$

2. Is it useful to carry out the overall (omnibus) ANOVA F test before you examine any planned comparisons? YES (NO) Why or why not?
 It is not necessarily necessary for omnibus ANOVA F test before carrying out other tests.

3. Are these two comparisons orthogonal (independent)? Demonstrate how you arrive at an answer to this question.
 Contrast coefficients: (1, 0, -1, 0)
 Sum of squares: $(1-1) + (0-0) + (-1-1) + (0-0) = 0$
 Sum of coefficients $\neq 0$, so comparisons are not independent.

4. Which multiple comparison procedure is optimal for testing these two hypotheses?
 The Bonferroni adjusted test

4. Show the computation of t_{obs} for Ψ_1 . (Assume H0V)

$$\bar{Y}_1 = \frac{(1)(18.70) + (1)(17.0) + (-1)(17.18) + (-1)(17.0)}{4} = 17.45$$

$$s^2 = \frac{1(18.70 - 17.45)^2 + 1(17.0 - 17.45)^2 + 1(17.18 - 17.45)^2 + 1(17.0 - 17.45)^2}{4-1} = 2.7945$$

$$s = 1.672$$

a. Find the t_{crit} that you will use to test this comparison: $t_{crit} = 2.160$
 adjusted $\alpha = .05 / 2 = .025$

1. What is the correct p-value for this comparison? $p = .0001$ (adjusted, $p = 0.0002$)

2. What statistical decision will you make for Ψ_1 ? On what do you base this decision?
 I will fail to reject the null hypothesis because $t_{obs} < t_{crit}$ (1.5943 < 2.160). Also, $p > \alpha = .05$ (0.0002 > .05) or $|t_{obs}| < |t_{crit}|$ (1.5943 < 2.160).
 t_{obs} adjusted, t_{crit} not adjusted

3. Construct the 95% CI for Ψ_1 . (Assume H0V)

$$\bar{Y}_1 \pm t_{crit} \cdot s \cdot \sqrt{\frac{1}{n_1} + \frac{1}{n_2}} = 17.45 \pm 2.160(1.672)\sqrt{\frac{1}{4} + \frac{1}{4}} = 17.45 \pm 2.687$$

$$CI = (14.763, 20.137)$$

5. SPSS output for Scenario 1: Mark the obtained test statistic assuming H0V for each of these comparisons (use labels Ψ_1 and Ψ_2). Do the same thing for the tests that do NOT assume H0V, but use the labels Ψ_3 and Ψ_4 for these tests.

2. Scenario Two: Now assume you planned to compare each group to each other (pairwise), with no other comparisons planned.

3. How many of these comparisons are there? (Show your formula and result.)
 $\frac{4(4-1)}{2} = 6$

4. Write the contrast coefficients for the comparison of NO DRUG = DRUG C (Ψ_3) and for the comparison of DRUG A = DRUG B (Ψ_4)
 $\Psi_3: H_0: \mu_D - \mu_C = 0$ coefficients: (0, 0, 0, -1)
 $\Psi_4: H_0: \mu_A - \mu_B = 0$ coefficients: (1, 1, 0, 0)

5. Are comparisons 3 and 4 independent? If so write so independent? Support your answer.
 $(0-0) + (0-0) + (-1-0) + (0-0) = 0$
 sum of coefficients $= 0$, so comparisons are independent.

6. Is the entire set of comparisons independent? Show how you know.
 No.
 Example: $(-1-1) + (0-0) + (0-0) + (-1-0) = -3$
 $H_0: \mu_A - \mu_B = 0$ coefficients: (1, 1, 0, 0)
 Ψ_3 coefficients: (0, 0, 0, -1)
 sum of coefficients $\neq 0$, so comparisons are not independent.
 Thus, set of comparisons is not independent.

Note: your work on this question should lead you to conclude that this is not a SET of independent comparisons! Be sure you know why the matter.

6. If you are willing to assume H0V, which multiple comparison procedure is optimal for testing the comparisons in Scenario 2?

Tukey's Honestly Significant Difference

7. Which procedure is optimal if you do NOT want to assume H0V?
 Games-Howell

1. On your SPSS output mark the test of the null hypothesis $p < .05$. Label it Ψ_3 and Ψ_4 . Mark the test you will use if you do NOT wish to assume H0V, and label it Ψ_3 and Ψ_4 .

2. Do NOT assume H0V. Can you reject the null hypothesis for Ψ_3 ? On what do you base this decision?
 No, we can't reject the null hypothesis for Ψ_3 based on p -value > alpha level, $.0004 > .05$.

3. State the correct p-value for Ψ_3 . $p = .0004$. This is the p-value you compare to the familywise alpha level.

3. Scenario Three: Assume now that you plan to test hypotheses that the boys taking NO medication have a lower average heart rate than boys taking DRUG A or those taking DRUG B or those taking DRUG C (separate comparisons).

a. How many comparisons must be carried out to test these null hypotheses that correspond to each of these research hypotheses? Show the formula you use.
 $k - 1 = 3$

b. Which is the appropriate multiple comparison procedure to use for each of these tests?
 Dunnett's test

c. Show the contrast coefficients for the comparison of WLS, NO DRUG + DRUG C.
 $\mu_1 - \mu_2 - \mu_3 + \mu_4$
 contrast coefficients: (1, -1, -1, 1)

d. Show your computation of the t obtained for WLS.
 $t = \frac{\bar{y}_W - \bar{y}_{WLS}}{s\sqrt{\frac{1}{n_W} + \frac{1}{n_{WLS}}}}$
 $t = \frac{13.2 - 12.1}{0.8\sqrt{\frac{1}{20} + \frac{1}{20}}} = 2.625$

e. What is the critical value for this test (assuming HCV)? (Use the table provided on the class website.)
 $t_{(3, 0.05)} = 2.353$

f. SPSS output - mark the value of the obtained test statistic and the p value, assuming HCV. Label them **WLSNO**. Mark the value of the obtained test statistic and the p -value for the test that does NOT assume HCV and label them **WLS**.
 There is no normally test statistic to mark.

g. What is your statistical decision? (Do you reject the null hypothesis for WLS?) On what do you base your decision?
 we can reject the null hypothesis based on $t_{(3, 0.05)} = 2.353 < 2.625$
 Also, $p < 0.05$ in the SPSS output.

4. Scenario 4: Now assume that you have to a priori hypotheses concerning these data. Is it useful to carry out the omnibus F test before testing any comparison that looks interesting to you? Why or why not?
 Yes. It sets a null hypothesis that all population means are equal, so we can find out if any (though not which) population means differ from each other) are significantly different, if there is any difference to be identified with post hoc procedures.

a. On your SPSS output mark the obtained value of the omnibus F test (assuming HCV) and the p -value. Label them **OMNIBUSF** and **OMNIBUSP**.
 $F = 11.408$, $p = 0.000$

b. Does your F test suggest that you should bother to carry out any post hoc test of interest to you? Why or why not? Explain.
 Yes, $p < 0.05$ ($0.000 < 0.05$), so we can reject the null hypothesis that all population means are the same and use post-hoc tests to identify potentially significant differences.

c. Compute the critical value that should be used for testing a post hoc comparison. Assume that complex and pairwise comparisons might be investigated.
 $t_{(3, 0.05)} = 2.353$
 $t_{(3, 0.025)} = 3.182$
 $t_{(3, 0.01)} = 4.541$

5. Scenario 5: You are interested in testing only pairwise comparisons (post hoc) in the omnibus F test useful to you? YES, NO.
 Yes, because it allows us to identify which specific groups differ.

Which data analysis procedure would be useful in this case?
 Tukey's Honestly Significant Difference

Label your output to indicate the test of the comparison of Males to Males. Use the label "male pairwise comp".

generated an SPSS output, but my version of SPSS could not compute the contrast. I would point this out to you using the one about the above example. There are not more if I should have in the end I generated output procedures.

SPSS Output: Descriptives, ANOVA, Contrast Coefficients, Contrast Tests, Post Hoc Tests.

Group	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Drug A	20	11.2500	1.00000	.25000	10.5000	12.0000	9.00	13.00
Drug B	20	11.1000	1.10000	.22909	10.6411	11.5589	7.00	13.00
Drug C	20	11.1500	1.15000	.23000	10.6700	11.6300	8.00	13.00
NO	20	12.1000	1.00000	.25000	11.6000	12.6000	9.00	13.00
Total	178	11.3090	1.04647	.08209	11.1469	11.4711	7.00	13.00

ANOVA

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3743.237	3	1247.746	114.882	.000
Within Groups	38936.214	174	223.795		
Total	42679.451	177			

Contrast Coefficients

Contrast	Drug A	Drug B	Drug C	NO
1	1	1	1	1
2	1	1	1	-1

Contrast Tests

Model	Sum of Squares	df	Mean Square	F	Sig.	Partial η^2
1	3743.237	3	1247.746	114.882	.000	.921
2	3743.237	3	1247.746	114.882	.000	.921
3	3743.237	3	1247.746	114.882	.000	.921
4	3743.237	3	1247.746	114.882	.000	.921

Post Hoc Tests

male pairwise comp

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Drug C	20	11.1500	1.15000	.23000	10.6700	11.6300	8.00	13.00
NO	20	12.1000	1.00000	.25000	11.6000	12.6000	9.00	13.00
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2	3743.237	3	1247.746	114.882	.000	.921
3	3743.237	3	1247.746	114.882	.000	.921
4	3743.237	3	1247.746	114.882	.000	.921

Post Hoc Tests

male pairwise comp

SPSS Output: Descriptives, ANOVA, Contrast Coefficients, Contrast Tests, Post Hoc Tests.

Group	Drug	Mean Difference (μ)	Std. Error	Sig.	95% Confidence Interval		
					Lower Bound	Upper Bound	
Group A	Drug B	1.84291	2.74252	.318	-4.4224	11.2822	
	Drug C	-1.21717	2.74252	.472	-8.4740	6.0390	
	MD	1.84291	2.74252	.318	-4.4224	11.2822	
Group B	Drug A	-1.84291	2.74252	.318	-11.2822	6.6027	
	Drug C	-4.99918	2.74252	.004	-11.2822	1.3041	
	MD	3.15627	2.74252	.002	-2.2474	11.2822	
Group C	Drug A	1.21717	2.74252	.472	-8.4740	6.0390	
	Drug B	4.99918	2.74252	.004	1.3041	11.2822	
	MD	3.78201	2.74252	.008	-0.8220	10.4740	
MD	Drug A	-1.84291	2.74252	.318	-11.2822	6.6027	
	Drug B	-4.99918	2.74252	.004	-11.2822	1.3041	
	Drug C	3.15627	2.74252	.002	-2.2474	11.2822	
Group D	Drug A	Drug B	1.84291	2.74252	.318	-4.4224	11.2822
		Drug C	-1.21717	2.74252	.472	-8.4740	6.0390
		MD	1.84291	2.74252	.318	-4.4224	11.2822
	Drug B	Drug A	-1.84291	2.74252	.318	-11.2822	6.6027
		Drug C	-4.99918	2.74252	.004	-11.2822	1.3041
		MD	3.15627	2.74252	.002	-2.2474	11.2822
	Drug C	Drug A	1.21717	2.74252	.472	-8.4740	6.0390
		Drug B	4.99918	2.74252	.004	1.3041	11.2822
		MD	3.78201	2.74252	.008	-0.8220	10.4740
Group E	Drug A	Drug B	1.84291	2.74252	.318	-4.4224	11.2822
		Drug C	-1.21717	2.74252	.472	-8.4740	6.0390
		MD	1.84291	2.74252	.318	-4.4224	11.2822
	Drug B	Drug A	-1.84291	2.74252	.318	-11.2822	6.6027
		Drug C	-4.99918	2.74252	.004	-11.2822	1.3041
		MD	3.15627	2.74252	.002	-2.2474	11.2822
	Drug C	Drug A	1.21717	2.74252	.472	-8.4740	6.0390
		Drug B	4.99918	2.74252	.004	1.3041	11.2822
		MD	3.78201	2.74252	.008	-0.8220	10.4740
Group F	Drug A	Drug B	1.84291	2.74252	.318	-4.4224	11.2822
		Drug C	-1.21717	2.74252	.472	-8.4740	6.0390
		MD	1.84291	2.74252	.318	-4.4224	11.2822
	Drug B	Drug A	-1.84291	2.74252	.318	-11.2822	6.6027
		Drug C	-4.99918	2.74252	.004	-11.2822	1.3041
		MD	3.15627	2.74252	.002	-2.2474	11.2822
	Drug C	Drug A	1.21717	2.74252	.472	-8.4740	6.0390
		Drug B	4.99918	2.74252	.004	1.3041	11.2822
		MD	3.78201	2.74252	.008	-0.8220	10.4740
Group G	Drug A	Drug B	1.84291	2.74252	.318	-4.4224	11.2822
		Drug C	-1.21717	2.74252	.472	-8.4740	6.0390
		MD	1.84291	2.74252	.318	-4.4224	11.2822
	Drug B	Drug A	-1.84291	2.74252	.318	-11.2822	6.6027
		Drug C	-4.99918	2.74252	.004	-11.2822	1.3041
		MD	3.15627	2.74252	.002	-2.2474	11.2822
	Drug C	Drug A	1.21717	2.74252	.472	-8.4740	6.0390
		Drug B	4.99918	2.74252	.004	1.3041	11.2822
		MD	3.78201	2.74252	.008	-0.8220	10.4740

* This mean difference is significant at the .05 level.
 a. Dunnett's tests treat the group as a control, and compare all other groups against it.

$$\mu = \frac{\sum_{i=1}^k x_i}{k}$$

$$\mu = \frac{1}{k} \sum_{i=1}^k x_i$$

... (faint text)