**HOMEWORK #9**

Assumptions, Planned Contrasts and Post Hoc Procedures

**There are 40 questions for this homework.**

1. A Bonferroni correction is when:
2. You apply a criterion for significance based on the usual criterion for significance (.05) divided by the number of tests performed.
3. You divide the *F*-ratio by the number of tests performed.
4. The degrees of freedom are corrected to make the *F*-ratio less significant.
5. The error in the model is adjusted for the number of tests performed.
6. Levene’s test is used to test whether:
7. Data are normally distributed.
8. The variances in different groups are equal.
9. The assumption of sphericity has been met.
10. Group means differ.
11. Before running your analysis of differences between 3 independent groups, you test whether variances across groups in the overall analysis are equal. When you find that homogeneity of variance has been violated, all of the following provide an appropriate course of action EXCEPT:

* 1. Use Welch’s *F*-ratio when interpreting equality of means in the overall ANOVA.
  2. Use Brown-Forsythe F-ratio when interpreting equality of means in the overall ANOVA
  3. Use Games–Howell *post hoc* tests to analyze significance of differences between groups
  4. Ignore this finding if your sample size is greater than 30 and proceed with t-test post hoc analyses

1. A researcher wanted to see the effects of different learning strategies.

* A control group simply read the book (book)
* A second group read the book and completed the ‘end of chapter exercises’ (book and exercises)
* A third group read the book, did the end of chapter examples and also completed the web materials (all activities).

The researcher predicted that for contrast 1: the “all activities” and “book and exercises” groups would perform better than the control group (book) on a test to measure learning, but that for contrast 2: the “book and exercises” group would do worse than the “all activities” group. Which coding scheme would test these hypotheses in a set of planned comparisons?

a.



b.



c.



d.



1. A therapist was looking at the effects of an intervention on FIM levels. Three groups were used:

* control
* treatment 1
* treatment 2

Based on the output below, what should the researcher conclude? Questions 5 and 6 relate to this output





* 1. Homogeneity of variance assumption was met
  2. Homogeneity of variance assumption was not met
  3. Unable to tell from the information provided

1. What should the researcher conclude about the BDIDIF ANOVA output?
   1. There is no significant difference within groups
   2. There is a significant difference within groups
   3. There is a significant difference somewhere between the control, treatment 1 and treatment 2
   4. There is a significant difference between the control group and the treatment groups
2. What kind of trend does the following graph show?
3. Linear.
4. Quadratic.
5. Cubic.
6. Quartic.
7. An orthogonal contrast means that the contrasts that you choose to do following a significant ANOVA are:
   1. Related to each other
   2. Independent of each other
   3. Effectively controlling for Type I error
   4. Effectively controlling for Type II error
8. *Post hoc* tests are used under which of the following conditions?

When there is a large Type I error

When there are no specific hypotheses about specific comparisons decided before the experiment

When the familywise error is large

To test contrasts when the planned contrasts are not significant

1. Under what conditions would planned comparisons be used?

a. When specific hypotheses have been generated prior to the start of the experiment

b. When specific hypotheses have not been generated prior to the start of the experiment

c. When homogeneity of variance is violated

d. When homogeneity of variance > .05

For the next problems, we will use the dataset called “3 Group One Way ANOVA” in Module 10. This dataset consists of data on **change** in elbow ROM following treatment for tendonitis in 45 patients. Fortunately, the study participants are equally divided among the 3 treatment groups (Ultrasound, Ice, and Control). This is a purely hypothetical study because we would never just provide a modality and we rarely have true controls that receive NO treatment. More commonly, our control consists of a group who receives the “standard of care” or “usual” treatment and this group is compared to newer interventions. In any case, that’s a design issue so let’s go with our hypothetical dataset to apply the ANOVA concepts. Each of the participants received the randomly assigned treatment for 10 days and the outcome measure was **change** in elbow ROM in degrees after 10 days of treatment. We wish to know which treatment gets the greatest change in ROM. Change scores are not always the best way to approach an analysis but researchers sometimes do this when they are not interested in testing within group differences for significance in each of the groups. They are only interested in differences *between* the groups. Here it provides a simple example of one-way ANOVA.

Null Hypothesis: There will be no significant difference in measures of elbow ROM **change** in participants who receive US, Ice or no treatment to their elbow.

Alternate Hypothesis: There will be significant difference in measures of elbow ROM **change** in participants who receive US, Ice or no treatment to their elbow.

Notice that we are going with a non-directional hypothesis. This is an important point because when comparing more than **two** group means, you CANNOT have a directional hypothesis. [See SPSS Tip 12.1 on p. 413].

We have ONE dependent variable (change in elbow ROM) and THREE group means (Ice, Ultrasound, Control) that are independent of each other. We wish to compare differences between the three group means, and elbow ROM is interval/ratio data so a one-way ANOVA is the appropriate statistical test to use. The alpha level that we select to test significance is .05.

Analysis: The first thing we need to do is to check our assumptions for running an ANOVA and check for outliers. Since ANOVA is a parametric analysis and we are interested in comparing independent groups, we need to check for normality and homogeneity of variance.

To test normality:

* Run descriptives by groups from the Explore menu including measures of kurtosis/skewness. Be sure to perform the K-S test to check normality. (You can also request histograms by group and Q-Q plots to get a visual of your data but I will not ask you to provide these for this homework.)
* While you are in the Explore menu, go ahead and get boxplots for each group to check for outliers.
* Test for HOV assumption in Explore menu as well.

NOTE: When you run normality tests and descriptives from the Explore menu, be sure to enter “group” as the “factor”. This will display all of your results by group. You can get some of the same information from the Frequencies or Descriptives menu (Both found under “Descriptive Statistics” in the Analyze menu) but in order to get outputs for separate groups, you will need to split your file. For this reason, my advice is to do your tests of assumptions in the Explore menu.

OK. Let’s see what you got. Please follow directions very closely. If instructions ask you to “Paste your Descriptives table for each of the 3 groups”, then that is the only thing that should be included for that item. The same for Questions 12-14. This tells me that you know what the various parts of your SPSS output are.

Questions 11-40 relate to the ROM dataset.

1. Please paste your Descriptive table for each of the 3 groups here (from the Explore menu). This is the table that includes a statistic for Skewness/Kurtosis among other things.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Descriptives** | | | | | |
|  | Treatment group | | | Statistic | Std. Error |
| Change in elbow ROM | Ultrasound | Mean | | 45.8000 | 2.52832 |
| 95% Confidence Interval for Mean | Lower Bound | 40.3773 |  |
| Upper Bound | 51.2227 |  |
| 5% Trimmed Mean | | 46.3889 |  |
| Median | | 48.0000 |  |
| Variance | | 95.886 |  |
| Std. Deviation | | 9.79213 |  |
| Minimum | | 23.00 |  |
| Maximum | | 58.00 |  |
| Range | | 35.00 |  |
| Interquartile Range | | 9.00 |  |
| Skewness | | -1.186 | .580 |
| Kurtosis | | .778 | 1.121 |
| Ice | Mean | | 40.4000 | 2.21209 |
| 95% Confidence Interval for Mean | Lower Bound | 35.6555 |  |
| Upper Bound | 45.1445 |  |
| 5% Trimmed Mean | | 40.1667 |  |
| Median | | 43.0000 |  |
| Variance | | 73.400 |  |
| Std. Deviation | | 8.56738 |  |
| Minimum | | 29.00 |  |
| Maximum | | 56.00 |  |
| Range | | 27.00 |  |
| Interquartile Range | | 14.00 |  |
| Skewness | | -.006 | .580 |
| Kurtosis | | -1.122 | 1.121 |
| Control | Mean | | 24.3333 | 2.04629 |
| 95% Confidence Interval for Mean | Lower Bound | 19.9445 |  |
| Upper Bound | 28.7222 |  |
| 5% Trimmed Mean | | 24.2037 |  |
| Median | | 22.0000 |  |
| Variance | | 62.810 |  |
| Std. Deviation | | 7.92525 |  |
| Minimum | | 14.00 |  |
| Maximum | | 37.00 |  |
| Range | | 23.00 |  |
| Interquartile Range | | 14.00 |  |
| Skewness | | .429 | .580 |
| Kurtosis | | -1.245 | 1.121 |

1. Please paste your Tests of Normality table here.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Tests of Normality** | | | | | | | |
|  | Treatment group | Kolmogorov-Smirnova | | | Shapiro-Wilk | | |
|  | Statistic | df | Sig. | Statistic | df | Sig. |
| Change in elbow ROM | Ultrasound | .203 | 15 | .096 | .873 | 15 | .037 |
| Ice | .174 | 15 | .200\* | .915 | 15 | .160 |
| Control | .174 | 15 | .200\* | .903 | 15 | .106 |
| \*. This is a lower bound of the true significance. | | | | | | | |
| a. Lilliefors Significance Correction | | | | | | | |

1. Please paste the 3 boxplots here.

Chart, box and whisker chart

Description automatically generated

1. Please paste your Test of HOV here.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Test of Homogeneity of Variance** | | | | | |
|  | | Levene Statistic | df1 | df2 | Sig. |
| Change in elbow ROM | Based on Mean | .088 | 2 | 42 | .916 |
| Based on Median | .057 | 2 | 42 | .945 |
| Based on Median and with adjusted df | .057 | 2 | 38.534 | .945 |
| Based on trimmed mean | .084 | 2 | 42 | .920 |

1. From your Descriptive table, do any of the test statistics for kurtosis/skewness appear to indicate any problems? \_\_\_\_\_ Why or why not? Yes, the kurtosis for the control and ice were found to be slightly less than -1 at -1.245 and -1.122, respectively, meaning they are a little flat. The skewness for ultrasounds was also slightly less than -1 at -1.186, meaning it is slightly skewed to the left.
2. Do your Boxplots indicate that there are any outliers or extreme scores?\_\_\_\_\_\_ Which case is it? Yes, the boxplots indicate there is an outlier or extreme score for the ultrasound group.
3. Is the score identified in #16 considered an outlier or an extreme score?

How do you know? (Hint. See page 145 -147). The score in question 16 is an outlier because it is denoted by a circle in SPSS, which is the symbol for an outlier, while an asterisk is the symbol for an extreme score.

At this point, you must make a decision to keep that case or delete it. (In this case, we will keep it because it appears to be a valid score and we prefer to maintain our equal sample size.

Note: you will often find these in datasets. My advice is to check to make sure that the score was entered correctly. If there is nothing to indicate that it was an entry error, then keep it. Our datasets in PT and OT are too small to toss out valid data and it is not unusual for patients to be true outliers.

1. Finally, from your Tests of Normality table, do any of the groups have an issue with normality? How do you know? The only group that had an issue with normality was the ultrasound group because its significance value is less than 0.05 at 0.037.

Note: If your tests of assumptions needed for the one-way ANOVA were violated, then you need to make a decision about whether to proceed with the one-way ANOVA or to go with the non-parametric Kruskal-Wallis test, which does not require meeting those same assumptions. In this case, we are choosing to continue with our one-way ANOVA.

Now, you are ready to run the one-way ANOVA on this dataset. Using what you learned from Dr. Field’s textbook as well as the video on one-way ANOVA in Module 10, go ahead and run the analysis. You will note that when you do the one-way ANOVA, SPSS asks you to select Post Hoc tests or Contrasts before you even know whether the overall ANOVA is significant. There is no need to run post hoc tests or contrasts if your overall ANOVA is not significant but go ahead and select the Tukey post hoc test because we have equal sample sizes and equal variances between groups and under those conditions, this test does a good job of preserving power while still adequately controlling for Type I error. Please review Cramming Sam’s Tips on Post hoc tests on page 407.

NOTE: REGWQ would be another option but we will go with the better known Tukey.

One other thing, when you conduct the overall ANOVA and you click on “Options” you have the option to select a test for HOV. We already ran a Levene’s test earlier and we know that HOV is not an issue with this dataset. However, had your earlier test been significant (HOV violated) you could select a different test here that would adjust the F-test to correct the problem. Typically you can select either the Brown-Forsythe *F* or the Welch’s *F*. [The Welch’s F does a better job of preserving power so that is the one I prefer when HOV is violated]. See Jane Superbrain 12.2 on p. 396. In our case, you don’t need to adjust the F because HOV was NOT violated (though Dr. Field is of the opinion that perhaps the Welch’s *F* should be the default test regardless of the results of the Levene’s test). In this case, you should select 3 different tests (Levene’s, Welch, and Brown-Forsythe). That way, if you find that the HOV assumption was violated, you would use the adjusted *F* provided by the Welch or Brown-Forsythe. Ok, go ahead and run the one-way ANOVA.

1. Please paste your ANOVA table here.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **ANOVA** | | | | | |
| Change in elbow ROM | | | | | |
|  | Sum of Squares | df | Mean Square | F | Sig. |
| Between Groups | 3740.578 | 2 | 1870.289 | 24.175 | .000 |
| Within Groups | 3249.333 | 42 | 77.365 |  |  |
| Total | 6989.911 | 44 |  |  |  |

1. What does the overall ANOVA table indicate? P < 0.001, so the ANOVA table indicates that there is a significant difference between measures of elbow ROM in participants who received various modalities for their elbow.
2. To calculate effect size for between group comparisons when there are more than 2 groups, we calculate omega. You can use the ANOVA table values to insert into the formula on page 419 to calculate this value. What is your calculated value for omega? ω 2 = 0.507

Bottom line though is that this calculation is not particularly useful. ☹ I just wanted to give you practice in extracting terms from the ANOVA table and understanding what they are. This calculation is not very useful for the following reasons:

* You could have SPSS give you Effect size for the overall ANOVA by running the ANOVA via the General Linear Model Univariate analysis rather than via the Compare Means, then One Way ANOVA function as described by Dr. Grande in the ANOVA video that I posted. The effect size provided by SPSS is eta squared (η2) which is a different type of effect size and about as useful as ω since it is still effect size of the overall ANOVA.
* We don’t care much about effect size for the overall ANOVA. What we really care about are effect sizes for the post hoc pairwise comparisons!

1. Please report the results of your overall ANOVA in reference to your null hypothesis. (see page 420 if you need to review) There was a significant effect of using different modalities on elbow ROM measurements, *F* = 24.175, *p* = < 0.001, ω2 = 0.507.
2. What is the F-statistic and p-value for the overall ANOVA if your Levene’s test had been significant and you had decided to use the Welch’s test to interpret you test? *F* = 25.038 and *p* = < 0.001
3. Please paste your table of Multiple Comparisons (post hoc tests) here.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Multiple Comparisons** | | | | | | |
| Dependent Variable: Change in elbow ROM | | | | | | |
| Tukey HSD | | | | | | |
| (I) Treatment group | (J) Treatment group | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
| Lower Bound | Upper Bound |
| Ultrasound | Ice | 5.40000 | 3.21175 | .224 | -2.4029 | 13.2029 |
| Control | 21.46667\* | 3.21175 | .000 | 13.6637 | 29.2696 |
| Ice | Ultrasound | -5.40000 | 3.21175 | .224 | -13.2029 | 2.4029 |
| Control | 16.06667\* | 3.21175 | .000 | 8.2637 | 23.8696 |
| Control | Ultrasound | -21.46667\* | 3.21175 | .000 | -29.2696 | -13.6637 |
| Ice | -16.06667\* | 3.21175 | .000 | -23.8696 | -8.2637 |
| \*. The mean difference is significant at the 0.05 level. | | | | | | |

1. Which of the 3 interventions produced the greatest change in ROM? What was the mean change for this group? Note: You will need to go back to your Descriptives table to look at mean change for each treatment group. What is shown in the Multiple Comparisons table is mean difference between the two groups compared. The intervention that produced the greatest change in ROM is the ultrasound group, and the mean change for this group was 45.80.
2. Which of the 3 interventions produced the least change in ROM? What was the mean change for this group? The intervention that produced the least change in ROM is the control group, and the mean change for this group was 24.33.

Well, you could have answered questions 25 and 26 by just looking at the descriptive table that you ran earlier. The post hoc tests however, tell us whether the differences between the groups are statistically significant. There are 3 possible comparisons.

For 27-29, list each of the 3 comparisons along with the mean difference and p-value for each comparison: (these are not in any particular order). State what the comparison is, followed by mean difference and p-value.

1. Comparison #1: Ultrasound and Ice Mean difference: 5.40 p-value: 0.224
2. Comparison #2: Ultrasound and Control Mean difference: 21.47 p-value: < 0.001
3. Comparison #3: Ice and Control Mean difference: 16.07 p-value: < 0.001
4. Here’s the fun part! Display your results using an **error bar chart**. You will need to do this using the Chart Builder. In Chart Builder, select simple bar and build your bar chart as you did before in Week 2 or 3. The only difference is that you click the box for “error bar chart” when building. [These are really useful because visually, you can see that the error bar for the control group does not overlap with the error bars for the US group or the Ice group. However, the error bar for the US group does overlap with the Ice group. So this visually supports what you found with your statistical tests of significance]. It’s not always this clear though. That’s why we need to do the statistical tests of significance.

Please paste your error bar chart here.

Chart, box and whisker chart

Description automatically generated

1. Let’s say that you had decided that all you are really interested in finding out from this dataset is whether each of your treatments (Ice and US) result in significantly greater changes in elbow ROM than the control. (You don’t care to know if Ice and US are different from each other.) In this case, you should select the Dunnett post hoc test. This is actually a planned comparison because you would have decided this ahead of time and your hypothesis would reflect this. You can select a 2-tailed test for a non-directional hypothesis or you have 2 options for a directional hypothesis. **(This is one of the rare times that SPSS allows you to select a one-tailed test and it will give you the p-value associated with the one-tailed test!)** I assume you believe that your interventions will yield a larger change in ROM than the control, so let’s go with directional and you would select “>Control”. Note: For “Control Category” you should enter “Last” because your control group is group number 3 in this dataset.

Go ahead and run that test now and paste your new multiple comparison table here.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Multiple Comparisons** | | | | | |
| Dependent Variable: Change in elbow ROM | | | | | |
| Dunnett t (>control)a | | | | | |
| (I) Treatment group | (J) Treatment group | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval |
| Lower Bound |
| Ultrasound | Control | 21.46667\* | 3.21175 | .000 | 15.1468 |
| Ice | Control | 16.06667\* | 3.21175 | .000 | 9.7468 |
| \*. The mean difference is significant at the 0.05 level. | | | | | |
| a. Dunnett t-tests treat one group as a control, and compare all other groups against it. | | | | | |

For 32 and 33, list each of the 2 Dunnett comparisons along with the mean difference and p-value for each comparison.

1. Comparison #1: Ultrasound and Control Mean difference: 21.47 p-value: < 0.001
2. Comparison #2: Ice and Control Mean difference: 16.07 p-value: < 0.001

You should see that these are the exact results that you got with the Tukey tests but you have only conducted TWO comparisons versus THREE. That’s a good option as long as it addresses your hypothesis and is the main reason for running planned comparisons versus post hoc tests.

NOTE: Had you selected “<Control” for the directional test, you would have gotten the very same numbers but the footnote at the bottom of the table would state “The mean difference is not-significant at the 0.05 level” because your intervention values were NOT significantly less than the control. That is, the differences were large enough to be significant but they were in the wrong direction so you must accept your null hypothesis that there would be no significant differences.

OK. We will now use the same dataset to look at planned contrasts. Let’s say you decided before you collected the data (also known as “a priori” or planned comparisons) that you wanted to compare the following:

Contrast 1: control vs. (Ice Group and US Group)

Contrast 2: Ice Group vs. US Group

There are statistical advantages to setting up contrasts ahead of time rather than waiting and just comparing everything.

The cake analogy that Field uses to describe contrasts is great. For an orthogonal contrast….after you use one slice of cake you can never use that piece again. Or in stats terms….after you divide up the variance from the model (SSM) you can’t reuse that variance again. The term “orthogonal” means that you have obeyed the rules when you set up your contrasts and the products add up to zero (see p.402, Table 12.4). If you don’t follow Field’s contrast rules and decide to re-use a piece of cake then the contrast would be called a non-orthogonal contrast. The rules for setting up contrasts in an orthogonal way are on page 401. We aren’t going to worry about non-orthogonal contrasts in this class but you should know that they are possible.

Let’s re-run the one-way ANOVA and but with the following selections:

Under the “contrasts” box you should select the polynomial box and quadratic (no need to look at more complicated trends since we only have three groups). Now SPSS will test for both linear and quadratic trends. A quadratic trend has one bend in the line that connects the means. You need at least three groups to see a quadratic trend).

You will, however need to enter coefficients for ANOVA to perform the analysis. . You can follow the instructions provided by Field for running a planned contrast on pages 408-410. Follow the instructions for entering contrast coefficients very closely, keeping in mind the group numbers that were assigned in the variable view. Contrast 1 and Contrast 2 coefficients will look exactly as shown in Figure 12.15 on page 409 EXCEPT that in our dataset, the control was group 3 (in Field’s, the control was group 1). The coefficients are entered in consecutive order of the groups, so Group 1, Group 2, then Group 3. That’s why your coefficients for groups 1 and 3 will be reversed from Contrasts 1 and 2 shown in Figure 12.15.

Your resulting ANOVA table should look like this:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **ANOVA** | | | | | | | |
| ROM | | | | | | | |
|  | | | Sum of Squares | df | Mean Square | F | Sig. |
| Between Groups | (Combined) | | 3740.578 | 2 | 1870.289 | 24.175 | .000 |
| Linear Term | Contrast | 3456.133 | 1 | 3456.133 | 44.673 | .000 |
| Deviation | 284.444 | 1 | 284.444 | 3.677 | .062 |
| Quadratic Term | Contrast | 284.444 | 1 | 284.444 | 3.677 | .062 |
| Within Groups | | | 3249.333 | 42 | 77.365 |  |  |
| Total | | | 6989.911 | 44 |  |  |  |

Since this is a little more complicated, I decided to show you what you SHOULD get and discuss what this means. We already knew that the overall ANOVA is significant from our previous analysis. The Between Groups (Combined) is the very same analysis we ran previously. Compare this F-statistic with the previous ANOVA table that you ran. The remaining statistics in this table check to see if there is a significant linear or quadratic trend in our outcomes. Keeping in mind that having a more advanced trend…(quadratic in this case) would be more important to report than if a lesser trend was significant (linear in this case). Here we see that only the linear trend is significant so that is the one we will report. That’s good because dealing with quadratic trends is beyond the scope of this course!

Now, let’s look at the results of the contrasts analysis. Here is what your table should look like:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Contrast Tests** | | | | | | | |
|  |  | Contrast | Value of Contrast | Std. Error | t | df | Sig. (2-tailed) |
| ROM | Assume equal variances | 1 | 37.5333 | 5.56292 | 6.747 | 42 | .000 |
| 2 | 5.4000 | 3.21175 | 1.681 | 42 | .100 |
| Does not assume equal variances | 1 | 37.5333 | 5.29480 | 7.089 | 31.862 | .000 |
| 2 | 5.4000 | 3.35942 | 1.607 | 27.515 | .119 |

Remember that we already checked for assumption of HOV and it was not violated, so we will use the statistics reported for “Assume equal variances.”

1. What does Contrast 1 tell you? (What is being compared and what does the test indicate? Contrast 1 tells us how the groups are being compared linearly between each other. The test indicates that this comparison is significant because p < 0.001.
2. What does Contrast 2 indicate? (What is being compared and what does the test indicate?) Contrast 2 tells us how the groups are being compared quadratically between each other. The test indicates that this comparison is not significant because p = 0.100.
3. How do the results of your planned contrasts compare to the results you got from your post hoc analysis? The results of the planned contrasts are pretty similar to the results from the post hoc analysis, as both found the comparison to be statistically significant.

For 37 and 38, compute the effect size for the contrasts using the *r* contrast formula on page 419. Just plug in the values needed in the formula from values in your ANOVA table.

1. *r* contrast 1= 0.721
2. *r* contrast 2= 0.251
3. Please report the results of your contrasts analysis. (see “Reporting results…” on page 420.

Planned contrasts revealed that using a modality significantly increased the measurements of elbow ROM compared to having a control, *t*(37.53) = 6.747, *p* = < 0.001, *r* = 0.721, but using an ultrasound did not significantly increase elbow ROM compared to using ice, *t*(5.40) = 1.681, *p* = 0.100, *r* = 0.251.

1. Table 12.6 on page 405 shows some standard contrasts that you could elect to have SPSS run without having to define the contrasts with dummy variable coding as we did to obtain our results above. Looking at the definition of the standard contrasts for Three Groups, which of the contrasts describes the analysis that we conducted above? Deviation last