**CPaT Stats Week 4: t-tests and ANOVA**

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Due Week 5, hardcopy in Lab next week (Tuesday).

Please delete everything except the questions (**Q1-18**) with your answers inserted in **BOLD** prior to handing in your final assignment as a hardcopy. Bring this completed lab assignment to class next week to hand in. Please be sure your name(s) is (are) on your document.

Upload the associated Excel file to the fileshare:

cpt/Workspace/\_StatsLabReports/Week\_4/

CushingSkomraWeiss\_Wk4statsLab.xlsx (or .xls)

where you type your last name(s) in place of “CushingSkomraWeiss”

**Part 1: Hypothesis Testing**

In a well-designed statistical study, the null hypothesis (H0) is either true or false in the “real world.” Since we cannot know this reality for sure, we sample the population and statistically analyze the resulting data to determine our “best guess” for the pattern occurring in the real world, and as a result either accept or reject the null hypothesis. We are either correct or not.

**Q1**. Please fill out the following table. Read and understand the table’s labeled rows and columns, prior to filling in the table (Hint – they are not exactly like the book!!):

Please fill in the blanks with “correct” or “error”, showing when we would be making a correct decision and when we would be making an error. For extra credit: if “error” denote which type of error we are making (Type I or Type II).

Table 1. A table outlining the outcomes of any experiment –

a description of the world of hypothesis testing.

|  |  |  |
| --- | --- | --- |
| **Your Decision** | **Truth value of H0 in the “real world”** | |
| **Null Hypothesis is false** | **Null Hypothesis is true** |
| Fail to Reject H0 |  |  |
| Reject Ho |  |  |

**Q2**. Using your own words, describe what is meant by a p-value:

**Q3**. Using your own words, describe what is meant by the power of an experiment:

**Part 2: t-tests**

**Data for the rest of the lab are in the spreadsheet: wk4\_1kcsStemMap.**

**Data for Part 2 is in the worksheet: PSME-T-test**

Our text does not cover t-tests, saying (correctly) that ANOVA can be used whenever you want to compare two samples to determine if one is different. We are including t-tests because they are probably the most commonly used statistic for comparing two groups (samples). Last week we compared two groups (heights of males and females in an Evergreen class) by computing the absolute value of the means, and then used resampling stats to compare the heights of the two groups to see if the difference we saw was statistically significant.

A t-test can be used to compare the means of two groups directly. It can help you determine if two samples are different when you have an independent categorical variable and a dependent continuous variable. We ask “what is the probability of two different samples being drawn from a common population of measurements? With what frequency can we expect samples with means as different as those in our sample if they come from a common population?”[[1]](#footnote-1)

We will use a dataset from the 1kcs study conducted by Nadkarni, VanPelt, McIntosh/Fiala (for the NSF funded Canopy Database Project[[2]](#footnote-2) that took place here at Evergreen. We will compare tree heights (or DBH) of plots from two different (forest) age classes. The research question is: “Do tree heights differ for the two forest age classes?”

We’ll do t-test using both Excel and JMP, and compare the differences.

**Q4:** Use Excel to calculate the difference in the means of the two groups, and report Excel results here.

To see how to do the JMP t-test,

see cpt/Handouts/Stats judysResamplingCheatSheet

**Q5:** report JMP t-test results here

**Part 3: ANOVA – Comparing 2 means**

**Use the same data for Part 3 as you did for Part 2: PSME-T-test**

Since the book hints that ANOVA can be used to compare n samples (where n can be 2), run an ANOVA on the dataset above.

To see how to run an ANOVA in JMP, consult the JMP documentation, or Judy’s JMPCheatSheet in Handouts\Stats. For Parts 3 and 4 of this lab, assume that the data we give you meet the assumptions of ANOVA.

**Q6**: report results of the ANOVA test on the 2 means:

**Part 4: ANOVA – Comparing many means**

**Use the worksheet ANOVA-PSME-2-3-5-JMP for this part of the lab.**

What if we want to compare more than two samples? You could compare then two by two, but this could get tedious.

During this lab we will start with one-way ANOVA, next week we will move into two-way and maybe three-way ANOVAs.

To explore these topics, we will again use data from a collaborative research project. For that project, we conducted fieldwork on forest structure and function for eight sites in a 1000-year chronosequence (50- to 950- years old) in the western Cascades of Washington State. For a full description of the 1kcs research study, see <http://acdrupal.evergreen.edu/studycenter/1kcs>.

For this part of the lab, we will compare tree heights (or DBH) of plots from 3 different (forest) age classes, all in the 1kcs study. The research question is the same as for Parts 2 and 3, “Does forest age class influence tree height?”, but we will have more samples (more age classes).

We will use one dataset for all ANOVA tests in this week’s lab. The data set includes the following variables (a subset of the full study):

* Site\_num (really, an age class)
* Site\_ID
* Plote\_id
* Stem\_tag
* Species\_ID
* DBH
* Height

In JMP, copy the data and paste with column names into a new data file. Make sure JMP appropriately classified your variables as either categorical (red histogram symbol) or continuous (blue ramp symbol). The first Y-variable you will work with will be tree height.

To test for assumptions of a parametric ANOVA, we will check the data for normality and equal variances. If the data do not pass these tests (Shaprio Wilks and Levene’s, respectively), then we cannot trust the results of a parametric ANOVA and will need to run a Monte Carlo (resampling) analysis.

For practice, however, we will run a parametric ANOVA even if these data do not meet those assumptions.

**Q7:** In your own words, say how parametric analysis and resampling analysis differ:

First let’s test our data for the 2 assumptions of ANOVA – normality and equality of variances.

To run a Shapiro-Wilks test in JMP, see JudysJMPcheatSheet.

**Q8**. Run Shapiro-Wilks tests for each age class. Which age classes are likely taken from normal populations and which are not? Fill out the table below (go back to Lab #3 if you forget how to run these tests):

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Site** | **W value** | **P value\*\*\*** | **Normal?** |
| **Group1** | 1. **MC** |  |  |  |
| **Group2** | 1. **PC** |  |  |  |
| **Group3** | 1. **TC** |  |  |  |

\*\*\*rather exceptionally, for Shaprio-Wilks a p-value > .05 indicates normality.   
If the p-value > .05 we reject H0 that the data are not normal. We’ll say why next Monday!

**Q9**. Now also check if the samples have equal variances. **To run a Levene’s test in JMP:** See JudysJMPcheatSheet

* What is the Levene’s F statistic? \_\_\_\_\_\_\_\_\_\_
* What is the p-value\*\*\*? \_\_\_\_\_\_\_\_\_\_
* Do the three samples have equal variances? \_\_\_\_\_\_\_\_\_\_

\*\*\*again, rather exceptionally, for Levene’s a p-value > .05 indicates equal variances.   
If the p-value > .05 we say the data have equal variances.

As you hopefully see above, technically we probably should not run a parametric ANOVA. Instead we will run a parametric ANOVA for practice and then compare the results to a resampling ANOVA.

**Parametric ANOVA:**

Now, for comparison (and to practice using JMP for ANOVA), in JMP use the Fit Y by X function to run a one-way ANOVA to test the null hypothesis that age class does not influence tree height (hint: Ask yourself which variable is dependent (Y)? Which variable is independent (X)?).

**Q10. What are your null and alternative hypotheses?**

**Q11.** Report your ANOVA results by filling in the blanks in the table below:

**ANOVA Summary of Fit**

|  |  |
| --- | --- |
| Rsquare |  |

**Analysis of Variance**

| **Source** | **DF** | **Sum of Squares** | **Mean Square** | **F Ratio** | **Prob > F** |
| --- | --- | --- | --- | --- | --- |
| Age Class |  |  |  |  |  |
| Error |  |  |  |  |  |
| C. Total |  |  |  |  |  |

**Q12.** In your own words, what do you think these results mean?

**Q13.** Create a vertical bar graph of mean tree height +/- 1 standard error by height class. Insert your graph below.

**Q14.** For which (if any) plots (age classes) does it appear that heights differ?

**Q15** (optional): in JMP run a Tukey’s HSD test to determine which age classes are significantly different from the others. You will want to report your F(x,x) = X.XX, p = X.XXXX (an F with x,x degrees of freedom = X.XX, p = X.XXX) and Tukey’s lowercase letters on the graph you will make in Q10 below.

**Q16 (optional)**. Please interpret your results as you would in a scientific paper.

**Part 5: Resampling ANOVA (Not all of you will get to this part this week).**

**You will be using the same data for Part 5 as you did for Part 4, but I have formatted it to make it easier for you to do a resampling ANOVA: PSME-2-3-5-Excel**

To analyze these data using Resampling Stats you will first need to calculate a few things. First, recall how many groups we have. # groups is *a* (below).

Then, recall how the sample size is for each group; this is *n*.

In Excel, please calculate the following:

1. *Number of groups (a)*
2. *sample size for each group/treatment (n)* (report ni’s for i = 1,a if sample sizes are not all the same)
3. *overall mean* (*Ybar)*
4. *average for each group (Ybari where i=1,a)*
5. *Total Sum of Squares (SStotal)*
6. *SS Among (SSamong)*

To calculate Total Sum of Squares, use the following algorithm:

* SStotal = 0
* For i = 1, a
  + For j = 1,n
    - SStotal = SStotal + (Yij – Ybar)2

To calculate SSamong, use the following algorithm: (Ybari is average for I’th group

* SSamong = 0
* For i= 1,a
  + For j = 1,n
    - SSamong = SSamong + (Ybari - Ybar)2

**Q17. Fill in the following table with your calculations:**

What is your (actual) SSamong? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |
| --- | --- |
| *Number of groups (a)* |  |
| *sample size for each group (n* |  |
| *overall mean* (*Ybar)* |  |
| *average for each group (Ybari where i=1,a)* | |  | | --- | | Group 1: | | Group 2: | | Group 3: | |  | |
| *Total Sum of Squares (SStotal)* |  |
| *SS Among (SSamong)* |  |
|  |  |

Using Resampling Stats, shuffle all data among treatments in Excel – recalculate SSamong and repeat and score the SSamong 1,000 times. Compare your actual SSamong to the null distribution of random SSamong values.

**Q17**. *What is your Resampling Stats p-value? Is it comparable to your ANOVA p-value from JMP? Speculate as to why or why not.*

1. This common sense explanation is drawn from Ch. 5 of Magnuson and Mourao’s *Statistics without Math*. [↑](#footnote-ref-1)
2. <http://acdrupal.evergreen.edu/canopy/> aka <http://canopy.evergreen.edu/canopydb> . Van Pelt, R., and N. M. Nadkarni. 2004. Development of canopy structure in Pseudotsuga menziesii forests in the southern Washington Cascades. *Forest Science* 50:326-341. Available at <http://acdrupal.evergreen.edu/files/canopy/vanpeltnadkarni_2004.pdf>. [↑](#footnote-ref-2)