# Homework #7: one-way ANOVA.
# Due: In lab, March 18-22

**DIRECTIONS:** For this homework, please turn in hard copies in class on Wed, Feb 13. This homework counts double. Write answers out in a separate Microsoft Word document (note that some questions may not require an answer – so you can skip these or just say "completed" – but we'll try to put what the actual question to be answered, or what you need to do to get credit, by placing that in **bold** in the question). We encourage you to work in groups for R-related material, but make sure to do the work yourself too and *always* come up with independent answers. Homeworks that have identical answers will receive F's.

**Q1)** The big-5 agreeableness scale is a scale of empathy, and it was measured on the first lab session along with a question about your favorite color. There is a hypothesis that a person's favorite color is associated with their personality. In particular, people who choose 'warm colors like red, pink, or orange are thought to be more spontaneous, less organized, and less systematic than people who choose 'cooler' colors (like blue or purple) or neutral colors (like green). We first need to create a new variable in survey2013 that codes whether the participants (i.e., you all!) chose warm, cool, or neutral colors. To do this, run the entire set of commands below:

```
load(url("http://www.matthewckeller.com/Stats3101/Stat3101.Datasets-2013.RData"))
col <- survey2013$fav.color
warmth <- rep('neutral',nrow(survey2013))
warmth[col=='blue' | col=='purple'] <- 'cool'
warmth[col=='pink' | col=='red' | col=='orange'] <- 'warm'
survey2013$col.warmth <- as.factor(warmth)
```

The above commands created a new variable in survey2013 called "col.warmth," which takes the values 'cool', 'warm', or 'neutral.' Now we need to run an Analysis of Variance (ANOVA) to test the hypothesis that favorite color type (the quasi-IV, which has 3 levels) is associated with conscientiousness, measured as the personality construct, conscientious (the DV).

A) **What is your alternative and null hypotheses?**

B) **Run an ANOVA using R.** To do this through the Menu, first make sure suvey2013 is the active dataset (but run the commands above before making it the active dataset), then go to Statistics -> Means -> One-way ANOVA. Choose "conscientious" as the "Response Variable" (i.e., the dependent variable) and choose "col.warmth" as your "Groups" (i.e., your predictor or quasi-IV). To run the ANOVA in script, do the following:

```
summary(aov(conscientious ~ col.warmth,data=survey2013))
```

And to get the three means (to see whether the data is consistent with your experimental hypothesis), do this:

```
numSummary(survey2013$conscientious,groups=survey2013$col.warmth,statistics=c('mean','sd'))
```

**Create an ANOVA summary table of your results.**

C) **What is your F-value and p-value? What do you conclude?**

D) A low p-value (a significant finding) merely indicates that a result was unlikely to have arisen by chance. It doesn't tell us how "large" or "important" an effect is (e.g., very small mean differences between groups – i.e., a small effect – can nevertheless be significant if the sample size is very large). Provide an estimate of the "effect size" (an $r^2$) for the effect you found above. You should be able to figure this out from the "Sum Sq" (the sums of squares) in the R output, using the formula for $r^2$ showed in class or the book. **How much variation in agreeableness is "explained" by a person's favorite color?**

E) **Write a four sentence summary of your findings.** Make sure to include an estimate of the "effect size" (i.e., $r^2$) of the effect you found, and include a side-by-side boxplot of agreeableness as a function of favorite color below your 4-sentence summary. To get a boxplot, do this:
boxplot(survey2013$conscientious ~ survey2013$col.warmth)

F) **Was this an experiment or not? Can we make causal inference based on this study (this is a hypothetical, so answer irrespective of whether or not your results were significant)?**

G) **If you collected data on <u>fewer</u> students (the exact number is kept intentionally vague), but your effect size estimate ($r^2$ estimate) stayed the same, what would happen to your p-value? Explain, intuitively, why this occurs.**

**Q2) <u>Do this problem by hand and show your work.</u>** You may use the formulas below to answer these questions, or may choose to use the ones from your book.

There are $k$ groups, and there are $n_j$ individuals within each group and $N$ individuals total. The subscript $j$ indexes group, so $j$=1 for group 1, $j$=2 for group 2, and so forth. $\bar{\bar{X}}$ stands for the "grand mean," or the mean of all the data points. Note that these formulas are equivalent but different—and more intuitive and easier in my opinion—than those in your book. You can choose to memorize the formulas below or the ones that are in your book – it's up to you. These are the only formulas you'll need to know for one-way ANOVA:

$$SS_{between} = \sum_{j=1}^{k} n_j(\bar{X}_j - \bar{\bar{X}})^2 \qquad df_{between} = k-1 \qquad MS_{between} = SS_{between} / df_{between} \qquad F = MS_{between} / MS_{within}$$

$$SS_{within} = \sum_{j=1}^{k} SS_j = \sum_{j=1}^{k}\sum_{i=1}^{n_j}(X_i - \bar{X}_j)^2 \qquad df_{within} = N-k \qquad MS_{within} = SS_{within} / df_{within}$$

$$SS_{Total} = SS_{between} + SS_{within} = \sum_{i}^{N}(X_i - \bar{\bar{X}})^2 \qquad df_{Total} = df_{between} + df_{within} = N-1$$

Here are the scores on a statistical reasoning test from people who had taken a stats class at CU:
GROUP1: 10, 15, 17, 18
Here are the scores on a statistical reasoning test from people who had taken a stats class at CSU:
GROUP2: 6, 8, 10, 12

Here are the scores on a statistical reasoning test from people who had taken a class at NU:
GROUP3: 10, 12, 12, 14

We are interested in whether statistical reasoning test scores are different depending on where the statistics class was taken

A) **What is the null and alternative hypothesis?**

B) **What is your alpha level? Give an intuitive explanation behind what this number means.**

C) **What is the mean of Group 1? Of Group 2? Of Group 3?**

D) **Fill out an ANOVA summary table for the above data.**

E) **Based on the F-test value and df for the test above, what is your conclusion? Do you reject the null hypothesis or not?** You can use Table B4 in the back of your book to understand whether to reject the null hypothesis or not.

F) **What is your estimate of effect size ($r^2$)?**

G) **Explain what would happen to your estimate of *F*, *p*, and $r^2$ under the following scenarios:**

i) The differences between the means get larger, but the variation within the groups remains the same.

ii) The variation within the groups gets larger, but the differences between the means remain the same.

iii) The differences between the means stay the same, the variation within the groups remains the same, but the sample size for each group gets larger.