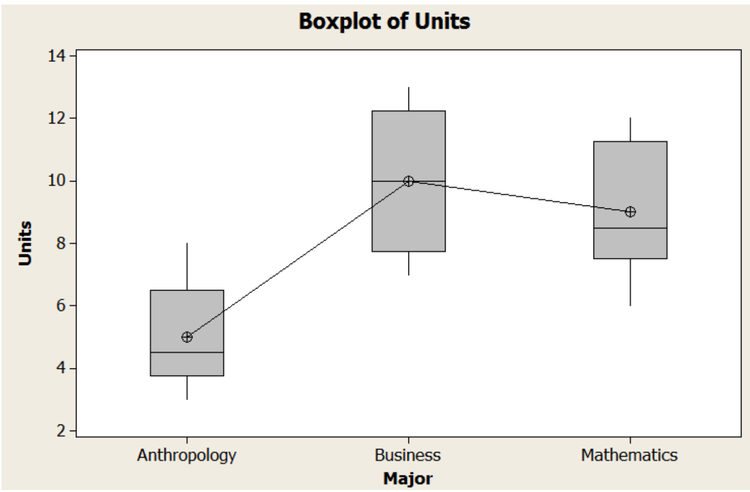
C1-T	C2
Major	Units
Anthropology	6
Anthropology	8
Anthropology	4
Anthropology	5
Anthropology	3
Anthropology	4
Mathematics	8
Mathematics	12
Mathematics	9
Mathematics	11
Mathematics	6
Mathematics	8
Business	13
Business	9
Business	11
Business	8
Business	7
Business	12

Minitab Procedure for One Factor ANOVA

1. Enter Factor in one column and Response in another column --->
2. Open the Procedure **Stat>ANOVA>One Way**
3. (Optional) Select any **Graphs** you want.
4. (Optional) Under **Comparisons**, select Tukey Test for valid pairwise comparisons of means.
5. Run the Test



One-way ANOVA: Units versus Major

```
Source  DF      SS     MS     F      P
Major    2   84.00  42.00  9.26  0.002
Error   15   68.00   4.53
Total   17  152.00

S = 2.129   R-Sq = 55.26%   R-Sq(adj) = 49.30%

                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level         N    Mean  StDev  -------+---------+---------+---------+--
Anthropology  6   5.000  1.789  (------*------)
Business      6  10.000  2.366                     (------*------)
Mathematics   6   9.000  2.191                 (------*------)
                                -------+---------+---------+---------+--
                                     5.0       7.5      10.0      12.5

Pooled StDev = 2.129

Grouping Information Using Tukey Method

Major         N    Mean  Grouping
Business      6  10.000  A
Mathematics   6   9.000  A
Anthropology  6   5.000    B

Means that do not share a letter are significantly different.
```

Post-hoc Analysis – Tukey's Honestly Significant Difference (HSD) Test[i].

When the Null Hypothesis is rejected in one factor ANOVA, the conclusion is that not all means are the same. This however leads to an obvious question: Which particular means are different? Seeking further information after the results of a test is called post-hoc analysis.

The problem of multiple tests

One attempt to answer this question is to conduct multiple pairwise independent same t-tests and determine which ones are significant. We would compare μ_1 to μ_2, μ_1 to μ_3, μ_2 to μ_3, μ_1 to μ_4, etc. There is a major flaw in this methodology in that each test would have a significance level of α, so making Type I error would be significantly more than the desired α. Furthermore, these pairwise tests would NOT be mutually independent. There were several statisticians who designed tests that effectively dealt with this problem of determining an "honest" significance level of a set of tests; we will cover the one developed by John Tukey, the Honestly Significant Difference (HSD) test.

The Tukey HSD test

Tests: $H_o : \mu_i = \mu_j$ $\quad H_a : \mu_i \neq \mu_j$ where the subscripts i and j represent two different populations

Overall significance level of α. This means that **all pairwise tests** can be run at the same time with an overall significance level of α.

Test Statistic: $HSD = q\sqrt{\frac{MSE}{n_c}}$

q = value from studentized range table

MSE = Mean Square Error from ANOVA table

n_c = number of replicates per treatment. An adjustment is made for unbalanced designs.

Decision: Reject Ho if $\left|\overline{X}_i - \overline{X}_j\right| > HSD$ critical value

Computer software, such as Minitab, will determine which pairs are significantly different.

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[i] Lowry, Richard. One Way ANOVA – Independent Samples. Vassar.edu, 2011