Problem Set Example

A central question in modern paleoanthropology relates to the evolutionary relationship between *Homo sapiens neandertalis* and *H. sapiens sapiens*. While this debate involves many different morphological and genetic characteristics, cranial capacity is a particularly interesting hominid feature as we can assume this trait reflects something about brain function, and cranial capacity is also a feature that is under constant selective pressure given the prominence of ever-increasing brain size in the evolutionary history of the hominids.

From a multi-year excavation of an early Upper Paleolithic cave site in the Ardeche Valley in France we have two samples of hominid skeletons from the same stratigraphic layer; a sample of *H. sapiens sapiens* (n = 65) and a sample of *H. sapiens neandertalis* (n = 40). We are interested in establishing whether there is any significant difference between the cranial capacities of these two hominid species from this cave site. This question is of interest because of the contemporaneous nature of the samples involved: 1) If the cranial capacity of the modern human sample were larger than the Neanderthal sample, this would fit with the general trend of increasing brain size in hominid evolution and allow for the possible inclusion of Neanderthals in the modern human lineage; 2) If there were no difference between the samples, this would indicate that there could be an evolutionary relationship between the two species, but this relationship does not involve a change in brain size; or 3) if the Neanderthal cranial capacity was larger than modern humans, then this would suggest that if there were was a direct evolutionary relationship, selection must have favored a smaller brain size over some period, which would seem to be a reverse in the overall evolutionary trajectory. Notice that in this example we are not interested in establishing whether or not there was a direct evolutionary relationship between the two hominid species, but what the difference in cranial capacities would imply for the selection pressure on this feature through time.

Let $\overline{Y}_{HS}$ = the sample mean of cranial capacities (cm^3) for the *H. sapiens* specimens, and $\overline{Y}_N$ = the sample mean of the cranial capacities (cc) for the *H. sapiens neandertalis* specimens.

Our null hypothesis states that at the a = 0.05 level (95%):

$$H_O : \overline{Y}_{HS} - \overline{Y}_N = 0$$
$$H_A : \overline{Y}_{HS} - \overline{Y}_N \neq 0$$

The data is presented below.

Sample 1 (*H. sapiens*)

1515.76	1449.28	1562.24	1554.26	1557.96	1510.08
1543.60	1544.76	1601.12	1451.81	1426.20	1483.16
1514.12	1642.25	1615.58	1341.99	1528.13	1493.79
1487.02	1544.99	1666.85	1385.76	1450.12	1704.03
1486.32	1383.82	1592.90	1593.60	1490.65	1436.54
1657.99	1431.63	1498.54	1493.67	1610.25	1469.66
1376.44	1524.47	1525.90	1570.23	1455.96	1496.65
1379.01	1478.99	1555.18	1356.47	1501.22	1467.37
1451.92	1443.61	1439.34	1581.18	1551.29	1583.46
1493.35	1629.15	1579.33	1512.91	1583.87	1435.96
1614.69	1512.78	1509.27	1602.42	1513.34	

Sample 2 (*H. sapiens neandertalis*)

1484.87	1513.47	1585.60	1629.96	1556.09
1611.27	1431.65	1631.36	1452.82	1574.92
1603.14	1480.14	1512.62	1644.48	1515.71
1512.63	1619.96	1538.36	1493.08	1438.90
1618.47	1596.34	1558.54	1628.90	1707.60
1598.62	1466.86	1385.80	1501.70	1569.05
1679.39	1518.82	1622.09	1579.56	1659.30
1535.89	1605.96	1525.57	1495.84	1452.51

In order to establish the normality of the data at hand and choose the appropriate statistical test we need to look at the descriptive data.

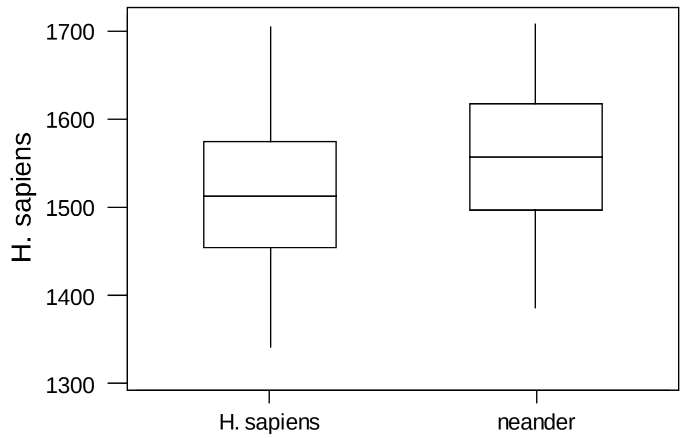
The descriptive output and boxplots from MINITAB are:

Descriptive Statistics

```
Variable          N      Mean    Median  Tr Mean     StDev  SE Mean
H. sapie         65    1514.6    1512.8   1514.3      78.4      9.7
neander          40    1553.4    1557.3   1553.7      74.7     11.8

Variable        Min       Max        Q1       Q3
H. sapie     1342.0    1704.0    1453.9   1574.8
neander      1385.8    1707.6    1497.3   1616.7
```

Boxplots of the data are given to visually characterize the distributions.



Looking at the means and medians for both samples, we see that they are pretty similar, suggesting symmetry. The boxplot shows that the medians fall roughly in the middle of the body of the data, and the tails seem to be equivalent. We conclude that these data are close enough to being normally distributed to go ahead with a *t*-test. We note that the sample sizes are unequal, but the standard deviations are similar enough to assume equal variances. This is also clear on the boxplot output, as the range of both distributions is roughly equivalent. It is also interesting that the Neanderthal average cranial capacity seems to be larger than the modern human cranial capacity.

Given the above observations, I choose to test the null hypothesis of no difference using a 2 sample 2 tailed *t*-test, correcting for different sample sizes, and using the Pooled method to account for the two sample variances.

To begin, we can pool our standard errors, using the equation:

$$se_p = s_p \sqrt{\left(\frac{1}{n_1} + \frac{1}{n_2}\right)},$$

So, in our case:

$$s_p = \frac{s_1 + s_2}{2} = \frac{78.4 + 74.7}{2} = 76.55,$$

And:

$$se_p = 76.55\sqrt{\left(\frac{1}{65}+\frac{1}{40}\right)} = 76.55(0.20093) = 15.38$$

As we have assumed our variances are equal, to calculate our degrees of freedom (v) we can use the familiar equation $v = n_1 + n_2 - 2 = 103$. So, our t_{CRIT} ($v = 103$, $a = 0.05$) = 1.98.

To calculate our confidence limits at the 95% level we use the standard equations relating to a 2 sample test:

$$L_L = \left(\overline{Y}_{HS} - \overline{Y}_N\right) - t_{CRIT}\left(se_P\right)$$
$$L_U = \left(\overline{Y}_{HS} - \overline{Y}_N\right) + t_{CRIT}\left(se_P\right)$$

So, in our case, substituting the appropriate numbers:

$$L_L = \left(\overline{Y}_{HS} - \overline{Y}_N\right) - 1.98(15.38) = -38.8 - 30.45 = -69.25$$
$$L_U = \left(\overline{Y}_{HS} - \overline{Y}_N\right) + 1.98(15.38) = -38.8 + 30.45 = -8.35$$

To calculate our actual *t*-test:

$$t_{STAT} = \frac{\overline{Y}_{HS} - \overline{Y}_{NS}}{se_p} = \frac{38.8}{15.38} = 2.52$$

To run this test in MINITAB the following procedures were used:

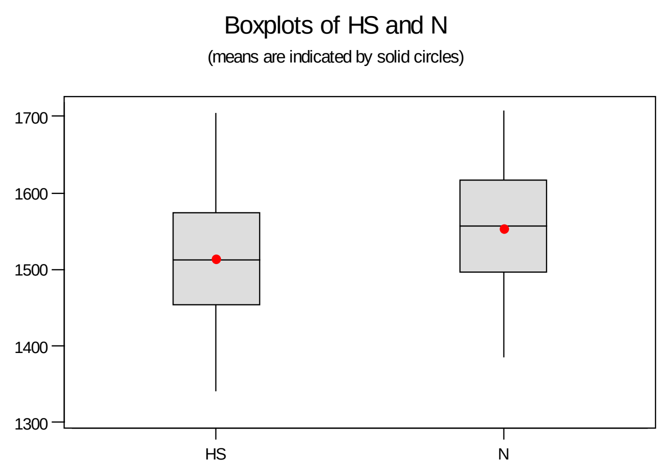
>STAT
>BASIC STATISTICS
>2 SAMPLE t
>Click SAMPLES IN DIFFERENT COLUMNS
>ALTERNATIVE is NOT EQUAL
>Click ASSUME EQUAL VARIANCE
>GRAPHS: Boxplot
>OKAY

And the resulting output is:

Two Sample T-Test and Confidence Interval

```
Two sample T for H. sapiens vs neander
            N      Mean     StDev   SE Mean
H. sapie   65    1514.6      78.4       9.7
neander    40    1553.4      74.7        12

95% CI for mu H. sapie - mu neander: ( -69.6,  -8)
T-Test mu H. sapie = mu neander (vs not =): T= -2.51  P=0.014  DF=  103
Both use Pooled StDev = 77.0
```



The results indicate that confidence limits do not encompass our null hypothesis of a mean difference of zero, and that the *p* = 0.014, which is less than our stated significance level of *a* = 0.05. As such, we conclude that at the *a* = 0.05 level, we have enough evidence to reject the null hypothesis of no difference in favor of the alternative. That is to say that within the constraints of the data at hand there is a statistically significant difference in the average cranial capacities of a sample of *H. sapiens sapiens* and *H. sapiens neandertalis*. Even though we chose a 2 tailed test, the fact that both confidence limits are negative indicates that not only is there a significant difference, but that the average of the modern human sample is statistically less than the average of the Neanderthal sample.

This result has interesting implications for our question at hand. While this test does not directly address the evolutionary relationship between Neanderthals and modern humans, it has interesting implications for the nature of selective pressures on cranial size that must have occurred in order for us to include Neanderthals in the hominid lineage that led to modern humans. In order for Neanderthals to be evolutionarily a part of the direct lineage of modern humans, then the results of this test would seem to indicate that at some stage selection must have favored *smaller* cranial capacities, a situation which seems counter to everything we know about the evolutionary trajectory of the hominid lineage. This also has interesting implications for brain function. Does it follow then that Neanderthals must have had greater cognitive capacity than modern humans given that their cranial capacity was on average larger? Possibly, but unlikely as we know that Neanderthals had a less complex material culture, and less personal ornamentation. What is going on then? Another way to look at this scenario is that cranial capacity is known to scale with body size in primates. It is also known that Neanderthals had a larger body size than modern humans, probably due to simple biogeographic and ecological principles such as Allen's and Bergman's rules. Therefore, maybe the larger cranial capacity is simply a function of a larger body size, and that selection favored a smaller body size due to basic economics, which led to a consequent proportional decrease in cranial capacity. In that case, I would suggest running the same test, but this time controlling for body size to see whether there is a significant difference in *proportional* cranial capacity between the two samples.