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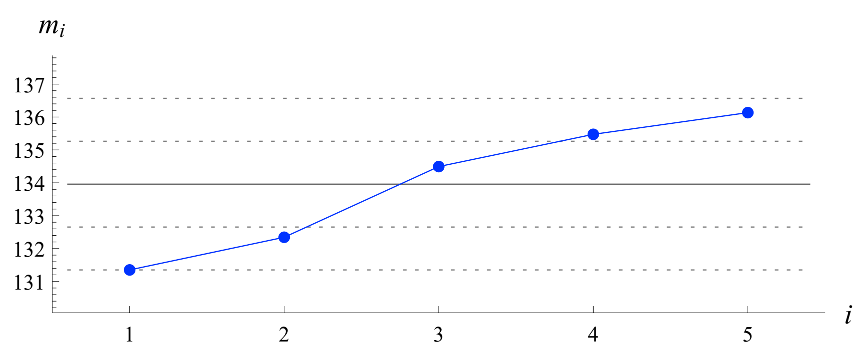
HW7 Problem 6(a): Headbreadths Analyses

Headbreadths	*Epoch 1*	*Epoch 2*	*Epoch 3*	*Epoch 4*	*Epoch 5*	*Pooled over epochs*
Sample Size	30	30	30	30	30	150
Sample Mean	131.35	132.34	134.49	135.47	136.13	133.96
Sample SD	5.16	4.80	3.40	3.94	5.35	4.89

The ratio of the maximum to the minimum standard deviation for epochs equals (5.35/3.40)=1.57.

```
AnovaOneWay[headbreadths]
```



	DF	SumOfSq	MeanSq	FRatio	PValue
Group	4	501.711	125.428	5.94625	0.000185
Error	145	3058.57	21.0936		
Total	149	3560.28			

Because we observe a P-value of 0.000185, we can safely reject the null hypothesis that each Epoch has the same mean headbreadth measurement at the 5% level.

```
α = .05;
BonferroniOneWay[headbreadths, α]
```

Number of Comparisons:	Rejection Region:	Sampling Distribution:
10	$\lvert T \rvert \geq 2.85063$	StudentT (df=145)

Significant mean differences:

$\hat{\mu}_1-\hat{\mu}_4=-4.12$ $\hat{\mu}_1-\hat{\mu}_5=-4.78$ $\hat{\mu}_2-\hat{\mu}_5=-3.79$

According to the Bonferroni comparisons, we can safely conclude that the Epoch pairings of (1,4), (1,5), and (2,5) all have significantly different mean headbreadth measurements at the 5% level.

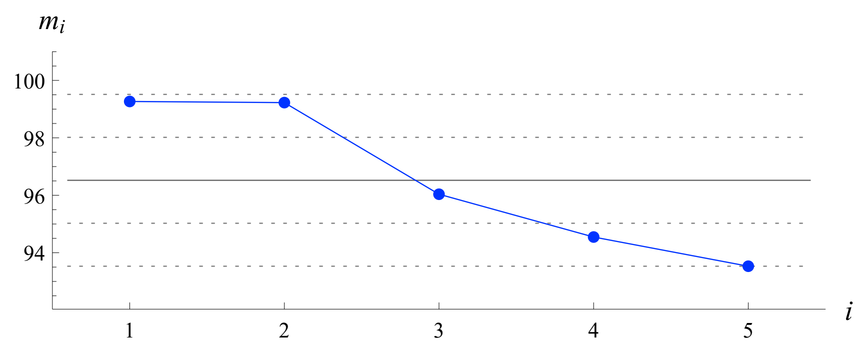
HW7 Problem 6(b): Basialveolar Lengths Analyses

bllengths is a list of 5 sample lists.

Basialveolar Lengths	*Epoch 1*	*Epoch 2*	*Epoch 3*	*Epoch 4*	*Epoch 5*	*Pooled over epochs*
Sample Size	30	30	30	30	30	150
Sample Mean	99.27	99.23	96.04	94.55	93.53	96.52
Sample SD	5.96	4.26	4.55	4.64	5.02	5.40

The ratio of the maximum to the minimum standard deviation equals (5.96/4.26)=1.399.

```
AnovaOneWay[bllengths]
```



	DF	SumOfSq	MeanSq	FRatio	PValue
Group	4	838.139	209.535	8.64911	2.74×10^{-6}
Error	145	3512.79	24.2262		
Total	149	4350.93			

Because we observe a P-value of 0.000002, we can safely reject the null hypothesis that each Epoch has the same mean basialveolar measurement at the 5% level.

```
α = .05;
BonferroniOneWay[bllengths, α]
```

Number of Comparisons:	Rejection Region:	Sampling Distribution:
10	$\lvert T\rvert \geq 2.85063$	StudentT (df=145)

Significant mean differences:

$\hat{\mu}_1-\hat{\mu}_4=4.72$ $\hat{\mu}_1-\hat{\mu}_5=5.74$ $\hat{\mu}_2-\hat{\mu}_4=4.68$
$\hat{\mu}_2-\hat{\mu}_5=5.7$

According to the Bonferroni comparisons, we can safely conclude that the Epoch pairings of (1,4), (1,5), (2,4), and (2,5) all have significantly different mean basialveolar measurements at the 5% level.

HW7 Problem 6(c): Discussion

From the results of the ANOVA and Bonferroni tests, I think that we definitely have enough evidence to conclude that the dimensions of male Egyptian skulls varied significantly between 4000 BC and 150 BC. Firstly, I believe that our results are valid because of the parametric approaches that we used. As we saw in the lab notebook, the measurements for headbreadths and basialveolar lengths had very few outlier (two for headbreadths and one for basialveolar length). This implies that using a non-parametric approach wouldn't really make much of a difference because such approaches have the greatest impact when we observe a large number of outliers. However, my one area of concern would be with the variation among standard deviations for the skull measurements. For the headbreadth and basioveolar length measurements, we saw ratios of standard deviations of roughly 1.57 and 1.4 for each measurement, respectively. This may not completely ruin out analyses, but the Bonferroni approach does assume that the standard deviations are equal for each paired comparison. In the future, larger sample sizes would be nice to help with this, but it may not be easy to come across ~6000 year old skulls.

In terms of our results, it appears that we observed a gradual change in the dimensions of male Egyptian skulls over time. For each measurement, we could safely reject the null hypothesis that they had the same mean measurements across time at the 5% level. Furthermore, we saw significant differences between Epoch groupings of (1,4), (1,5), and (2,5) for headbreadth measurements and (1,4), (1,5), (2,4), and (2,5) for basialveolar measurements. These results suggest gradual changes in the Egyptian male skulls as we see the most significant changes in measurements from Epochs 1 and 2 until Epochs 2 and 5. As we see from the ANOVA graphs, it appears that headbreadths gradually increased in length while basialveolar lengths gradually decreased.

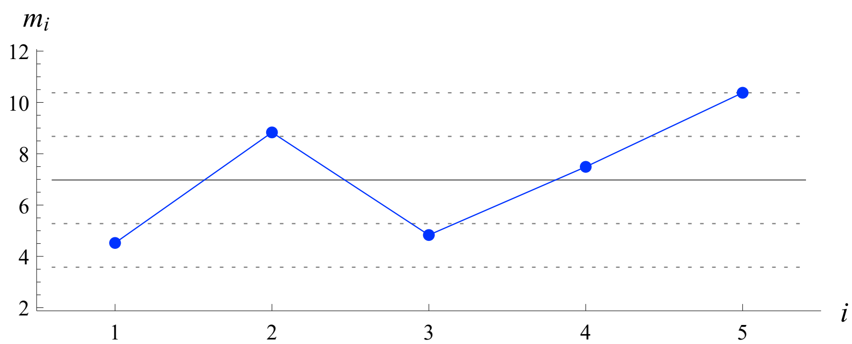
HW7 Problem 7: Clothing Manufacturing Study

Percentages of Material Wasted	*Supplier 1*	*Supplier 2*	*Supplier 3*	*Supplier 4*	*Supplier 5*	*Pooled over suppliers*
Sample Size	22	22	19	19	13	95
Sample Mean	4.52	8.83	4.83	7.49	10.38	6.977
Sample SD	10.03	15.35	4.40	3.66	9.55	9.893

The ratio of the maximum to the minimum standard deviation equals (15.35/3.66)=4.193.

HW7 Problem 7(b): Parametric Analysis

```
AnovaOneWay[percentages]
```



	DF	SumOfSq	MeanSq	FRatio	PValue
Group	4	450.921	112.73	1.15963	0.334
Error	90	8749.09	97.2121		
Total	94	9200.01			

Because we observe a P-value of 0.334, we can not reject the null hypothesis that each supplier wasted the same percentage of cloth in our sample.

```
α = .05;
BonferroniOneWay[percentages, α]
```

Number of Comparisons:	Rejection Region:	Sampling Distribution:
10	$\lvert T \rvert \geq 2.87788$	StudentT (df=90)

There are no significant differences.

Additionally, the Bonferroni test also concludes that there are no significant differences between the means for each particular group.

HW7 Problem 7(c): Non-Parametric Analysis

```
ranks = N[Ranks[percentages]];
KruskalWallisTest[samples]
```

Statistic:	PValue:	Distribution:
10.2536	0.00594	ChiSquare(df=2)

Because we observe a P-value of 0.0059, we can conclude from the Kruskal-Wallis test that not all suppliers had the mean percentage of wasted cloth.

```
RankSumTest[percentages[[4]], percentages[[5]],
 TwoSided → True,
 ExactDistribution → True]
```

Rank Sum Statistic:	TwoSided P Value:	Sampling Distribution:
272.	0.114426	Exact

PValues for 2 Sided Tests	*Supplier 2*	*Supplier 3*	*Supplier 4*	*Supplier 5*
Supplier 1	0.0087	0.0786	0.0008	0.0211
Supplier 2	**	0.4563	0.5515	0.1367
Supplier 3	**	**	0.0643	0.0302
Supplier 4	**	**	**	0.1144

According to the rank sum tests, supplier 1 differs from suppliers 2, 4, and 5 at the 5% level and supplier 3 differs from supplier 5 at the 5% level.

HW7 Problem 7(d): Discussion

From the results of our non-parametric analyses, I believe that we have sufficient evidence to con clude that not all cloth suppliers waste the same percentages of materials. Although the parametric analyses did not reveal any compelling evidence to suggest any differences, we should note the significant difference in standard deviations that we saw between the cloth suppliers. Because we saw a ratio of about 4.2 for the maximum-to-minimum standard deviations, this suggests that parametric analyses may be mis leading because we need to assume that each group has the same standard deviation, but we saw a significant difference. This may not persist if we are able to get similarly large samples for each supplier, but suppliers 1 and 2 have largest samples and the only outliers (4 for each), so it appears that non-parametric analysis would be the most fruitful approach for this comparison.

From the results of our non-parametric analyses, it appears that not all suppliers wasted the same percentage of cloth. From our Kruskal-Wallis test, we observe a P-value of 0.0059, which means that we can safely reject the null hypothesis that each supplier wastes the same amount of cloth at the 5% level. Furthermore, from our individual rank sum tests, it appears that supplier 1 varied significantly in its waste suppliers 2, 4, and 5, and supplier 3 varied from supplier 5 (all comparisons being at the 5% level of significance). From the graph attached to our ANOVA analysis, it appears that supplier 1 and supplier 3 had far lower percentages of waste than the other suppliers. However, because of the large degree of variation in the variances between samples, parametric analysis could not reach this conclusion.