Lecture 26
Linear Contrasts

STAT 8010 Statistical Methods I
October 23, 2019

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Notes

Facebook Friends Example Revisited

Too Much of a Good Thing? The Relationship Between Number of Friends and Interpersonal Impressions on Facebook

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A central feature of the online social networking system, Facebook, is the connection to and links among friends. The sum of the number of one's friends is a feature displayed on users' profiles as a vestige of the friend connections a user has accrued. In contrast to offline social networks, individuals in online network systems frequently accrue friends numbering several hundred. The uncertain meaning of friend status in these systems raises questions about whether and how sociometric popularity conveys attractiveness in non-traditional, non-linear ways. An experiment examined the relationship between the number of friends a Facebook profile featured and observers' ratings of attractiveness and extraversion. A curvilinear effect of sociometric popularity and social attractiveness emerged, as did a quartic relationship between friend count and perceived extraversion. These results suggest that an overabundance of friend connections raises doubts about Facebook users' popularity and desirability.

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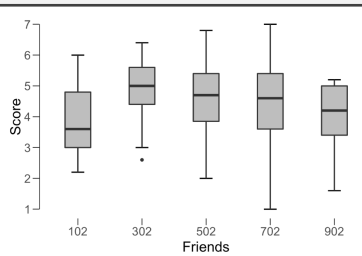
Facebook Friends Example

There are 5 "treatment groups" in this study:

> *Participants examined one of five stimuli, each containing a Facebook profile mockup. Elements of these stimuli (e.g. photographs, wall posts, etc.) remained constant over the five versions, with the exception of the number of friends which appeared on the profile as 102, 302, 502, 702, or 902....* – Tong et al., 2008



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Facebook Friends Example: Descriptive Statistics

	Score				
	102	302	502	702	902
Valid	24	33	26	30	21
Missing	0	0	0	0	0
Mean	3.817	4.879	4.562	4.407	3.990
Std. Deviation	0.999	0.851	1.070	1.428	1.023
Minimum	2.200	2.600	2.000	1.000	1.600
Maximum	6.000	6.400	6.800	7.000	5.200

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Facebook Friends: Overall F-Test

Question: Are Facebook attractiveness affected by # of friends?

$H_0 : \mu_1 = \mu_2 = \cdots = \mu_5$
H_a: At least one group mean is different from others

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Analysis of Variance Table

Response: Score
           Df Sum Sq Mean Sq F value
Friends     4  19.89  4.9726   4.142
Residuals 129 154.87  1.2005
           Pr(>F)
Friends   0.00344 **
Residuals
```


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Facebook Friends Example: Fisher's LSD

We conclude that μ_i and μ_j differ at α level if $|\bar{X}_i - \bar{X}_j| > LSD$, where

$$LSD = t_{\alpha/2, df=N-J}\sqrt{\text{MSE}\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}$$

```
> LSD_none$groups    > LSD_bon$groups
       Score groups         Score groups
302 4.878788      a  302 4.878788      a
502 4.561538     ab  502 4.561538     ab
702 4.406667    abc  702 4.406667     ab
902 3.990476     bc  902 3.990476      b
102 3.816667      c  102 3.816667      b
```


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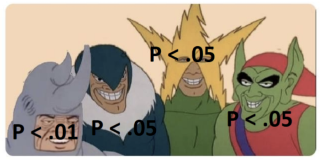
Me and the significant boys



Me and the significant boys after Bonferroni correction

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Facebook Friends Example: Tukey's HSD Test

We conclude that μ_i and μ_j differ at α level if $|\bar{X}_i - \bar{X}_j| > \omega$, where

$$\omega = q_{\alpha}(J, N-J)\sqrt{\frac{\text{MSE}}{n}},$$

$q_{\alpha}(J, N-J)$ can be obtained from the studentized range table

Critical Values of Studentized Range Distribution(q) for Familywise ALPHA = .05.

Denominator DF	Number of Groups (a.k.a. Treatments) 3	4	5	6	7	8	9	10
51	3.414	3.756	3.999	4.187	4.340	4.469	4.580	4.677
52	3.412	3.753	3.996	4.184	4.337	4.465	4.576	4.673
53	3.410	3.751	3.994	4.181	4.334	4.462	4.572	4.669
54	3.408	3.749	3.991	4.178	4.331	4.459	4.569	4.666
55	3.406	3.747	3.989	4.176	4.328	4.455	4.566	4.662
56	3.405	3.745	3.986	4.173	4.325	4.452	4.562	4.659
57	3.403	3.743	3.984	4.170	4.322	4.449	4.559	4.656
58	3.402	3.741	3.982	4.168	4.319	4.447	4.556	4.652
59	3.400	3.739	3.979	4.165	4.317	4.444	4.553	4.649
60	3.399	3.737	3.977	4.163	4.314	4.441	4.550	4.646

Note: Here α is the FWER

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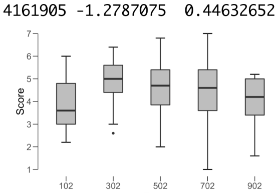
Facebook Example: Tukey's HSD Test

```
               diff        lwr         upr       p adj
302-102  1.0621212  0.2488644  1.87537798 0.003889635
502-102  0.7448718 -0.1132433  1.60298691 0.121456224
702-102  0.5900000 -0.2402014  1.42020143 0.288431585
902-102  0.1738095 -0.7320145  1.07963355 0.984016816
502-302 -0.3172494 -1.1121910  0.47769215 0.804080046
702-302 -0.4721212 -1.2368466  0.29260420 0.432633745
902-302 -0.8883117 -1.7345313 -0.04209203 0.034535577
702-502 -0.1548718 -0.9671402  0.65739661 0.984391504
902-502 -0.5710623 -1.4604793  0.31835479 0.391768065
902-702 -0.4161905 -1.2787075  0.44632652 0.669927748
```



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Linear Contrasts

Suppose we have J populations (e.g. response for J different treatments) of interest. We have seen how to perform multiple comparisons. For example, the comparison between μ_1 and μ_2 can be conducted using the test: $H_0: \mu_1 - \mu_2 = 0$ vs. $H_a: \mu_1 - \mu_2 \neq 0$. This comparison is actually a special case of linear contrasts

Linear Contrasts

Let $c_1, c_2, \cdots, c_J$ are constants where $\sum_{j=1}^J c_j = 0$, then $\sum_{j=1}^J c_j\mu_j$ is called a **linear contrast** of the population means.

Example: Suppose $J = 4$

1. $\mu_1 - \mu_3 : c_1 = 1, c_2 = 0, c_3 = -1, c_4 = 0$
2. $\mu_2 - \mu_4 : c_1 = 0, c_2 = 1, c_3 = 0, c_4 = -1$
3. $\mu_1 - \frac{1}{3}\mu_2 - \frac{1}{3}\mu_3 - \frac{1}{3}\mu_4 : c_1 = 1, c_2 = c_3 = c_4 = -\frac{1}{3}$

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Inferences for Linear Contrasts

If we want to make a inference about $L = \sum_{i=1}^J c_j\mu_j$. Then we use

$$\hat{L} = \sum_{j=1}^J c_j \bar{X}_j$$

as the point estimate. Furthermore, we can construct a $100(1-\alpha)\%$ CI for L:

$$(\hat{L} - t_{(\alpha/2, df=N-J)}\hat{se}_{\hat{L}}, \hat{L} + t_{(\alpha/2, df=N-J)}\hat{se}_{\hat{L}}),$$

where $\hat{se}_{\hat{L}} = \sqrt{\text{MSE}\left(\frac{c_1^2}{n_1} + \cdots + \frac{c_J^2}{n_J}\right)}$

To test whether L is significantly different from 0, we can conduct the following test:

$$H_0: \sum_{j=1}^J c_j\mu_j = 0 \text{ vs. } H_a: \sum_{j=1}^J c_j\mu_j \neq 0$$

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Hypothesis Testing for Linear Contrasts

1. Null and Alternative Hypotheses:

$$H_0: \sum_{j=1}^J c_j\mu_j = 0 \text{ vs. } H_a: \sum_{j=1}^J c_j\mu_j \neq 0$$

2. Test Statistic:

$$t_{obs} = \frac{\hat{L} - 0}{\hat{se}_{\hat{L}}} = \frac{\sum_{j=1}^J c_j\bar{X}_j}{\sqrt{\text{MSE}\left(\frac{c_1^2}{n_1} + \cdots + \frac{c_J^2}{n_J}\right)}}$$

3. Decision:

Reject H_0 if $|t_{obs}| > t_{\alpha/2, df=N-J}$ (or p-value $< \alpha$)

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Facebook Example: Linear Contrast

Suppose we'd like to compare μ_1 vs. $\frac{\mu_3+\mu_4}{2}$. Let $L = 1\mu_1 - \frac{1}{2}\mu_3 - \frac{1}{2}\mu_4$. Then the above comparison is equivalent to test whether L is different from 0

1. $H_0 : L = 0$ vs. $H_a : L \neq 0$
2. $t_{obs} = \frac{\hat{L}}{\hat{se}_{\hat{L}}} = \frac{1\times3.817-0.5\times4.562-0.5\times4.407}{\sqrt{1.2005\times(\frac{1^2}{24}+\frac{0.5^2}{26}+\frac{0.5^2}{30})}} = \frac{-0.6674}{0.2675} = -2.495$
3. Since $|t_{obs}| = |-2.495| = 2.495 > t_{0.025,df=129} = 1.9785$. We reject H_0 at 0.05 level

> **Note**: If we are performing several tests for different linear contrasts, we'll need to adjust α level accordingly to control the FWER

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