# Extra sum of squares: testing equality in a subset of groups

Example dataset: case 0502.jmp

**Question:** whether the sixe other judges (not Spock's) have the same mean percentage of women on their venires?

H<sub>0</sub>:  $\mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7$ H<sub>1</sub>: at least one "≠"

group	1	2	3	4	5	6	7
Full model	$\mu_1$	$\mu_2$	$\mu_3$	$\mu_4$	$\mu_5$	$\mu_6$	$\mu_7$
Reduced model	$\mu_1$	$\mu_0$	$\mu_0$	$\mu_0$	$\mu_0$	$\mu_0$	$\mu_0$

Steps:

- 1) generate a new column (group ids) for the reduced model
- 2) run ANOVA for the full model ->[fit y by x]
- 3) run ANOVA for the reduced model->->[fit y by x]
- 4) calculate the difference between error sum of squares, and find the p-value for the F statistic.

# Linear Combinations and Multiple Comparisons of Means

# 1. Using JMP to specify and solve linear combinations: dataset: feed.jmp

Launch *Fit Model* platform, specify the appropriate variables for the ANOVA, including the response variable *Y* (mass) and explanatory effects *X* (feed type).

Running the model generates the *F*-statistic that test the null hypothesis of equal means which we reject.

To examine the more specific questions with linear combinations, click the triangle next to the effect of interest and select *LS Means Contrast…* which yields a "Contrast Specification" dialog box where you click + or - to specify the contrast of interest. The appropriate orthogonal coefficients are generated automatically.

Contrast								
(	Contrast Specification							
Fe	Feed Grp							
1	0	+	-					
2	0	+	-					
3	0	+	-					
4	0	+	-					
Click on + or - to make contrast values.								

Contrast								
Test Detail								
1	1	0		0				
2	0	1		0				
3	0	0		1				
4	-1	-1		-1				
Estimate	-25.62	-16.94	14	.11				
Std Error	1.85	1.85	1.9	623				
t Ratio	-13.85	-9.157	7.1	907				
Prob> t	6e-10	1.6e-7	3.1	e-6				
SS	1641	717.41	442	.43				
Sum of Squ	ares 42	226.3478	947					
Numerator I	DF		3					
Denominato	or DF		15					
F Ratio	64.64152	297						
Prob > F	1	1.061311e-11						

#### 2. Using JMP for Unplanned Comparisons

Choose the *Fit Y to X* platform, the appropriate *Y* and *X* variables, then *Compare Means*. JMP offers:

• **Compare Each Pair:** LSD procedure; computes pairwise comparisons among means using Student's *t* test. This procedure does <u>not</u> control the familywise error rate;

• **Compare All Pairs:** Tukey or Tukey-Kramer HSD procedure; controls the familywise error rate; exact test if sample sizes are the same; conservative if sample sizes differ.

• **Compare with Best:** Hsu MCB procedure; tests whether means are < the unknown maximum or >the unknown minimum.

• **Compare with Control:** Dunnett's procedure; tests whether means are different from the mean of a control group.

You can adjust the  $\alpha$ -level used by these procedures (default is 5%) if you choose Set Alpha Level from the menu within the Fit Y by X platform.

LSD and Tukey are also available in the Fit Model Platform.

## Example of the Each Pair, Student's t Test

This example uses the Big Class.jmp sample data table. It shows a one-way layout of weight by age, and shows the group comparison using comparison circles that illustrate all possible ttests.

- 1.Open the Big Class.jmp sample data table.
- 2.Select Analyze > Fit Y by X.
- 3.Select weight and click Y, Response.
- 4.Select age and click X, Factor.
- 5.Click OK.

From the red triangle menu, select Compare Means > Each Pair, Student's t.

Example of Each Pair, Student's t Comparison Circles



The means comparison method can be thought of as seeing if the actual difference in the means is greater than the difference that would be significant. This difference is called the LSD (least significant difference). The LSD term is used for Student's t intervals and in context with intervals for other tests. In the comparison circles graph, the distance between the circles' centers represent the actual difference. The LSD is what the distance would be if the circles intersected at right angles.

Means Comparisons   Comparisons for each pair using Student's t   Confidence Quantile   t   Loss to the state of the state	mple	of M	leans Con	npariso	ns Repo	ort for E	Each Pair, Student's t
Comparisons for each pair using Student's t   Confidence Quantile   t Alpha   2.03224 0.05   LSD Threshold Matrix   Abs(Dif)-LSD 17 16 15 14 12 13   17 -33.140 -10.807 4.373 13.634 14.189 17.944   16 -10.807 -43.73 13.634 14.189 17.944   15 -4.373 -17.961 -8.699 -8.145 -4.324   14 13.634 -8.699 -11.851 -16.570 -16.692 -13.184   12 14.189 -8.145 -11.720 -16.692 -20.294 -16.720   13 17.944 -4.389 -8.124 -13.184 -16.720 -21.695   Positive values show pairs of means that are significantly different. Connecting Letters Report Level Mean   17 A 140.66667 16 A B 118.33333 12 B 9.00000 13 B 94.71429   Level Mean 17 13 45.95238 13.78194 1	eans C	ompa	arisons				
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List Threshold Matrix   Abs(Dif)-LSD 17 16 15 14 12 13   17 -33.140 -10.807 4.373 13.634 14.189 17.944   16 -10.807 -33.140 -17.961 -8.699 -8.145 -4.389   15 4.373 -17.961 -21.695 -11.851 -11.720 -8.124   14 13.634 -8.699 -11.851 -16.570 -21.695   Positive values show pairs of means that are significantly different.   Connecting Letters Report   Level Mean   17 A 140.66667   16 A B 118.33333   12 B 99.0000   13 B 94.71429   Level Mean   17 13 45.95238 13.78194 17.9666 0.0021*   17 13 45.95238 13.78194 17.9441 73.96066 0.0021*   17 12 41.66667 14.386 60.03268 0.0041*   17 13 45.9	2.032	t 24	Alpha 0.05				
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12 14.189 -8.145 -11.720 -16.692 -20.294 -16.720   13 17.944 -4.389 -8.124 -13.184 -16.720 -21.695   Positive values show pairs of means that are significantly different.   Connecting Letters Report   Level Mean   17 A 140.66667   16 A B 118.3333   15 B 108.32871   14 B 100.83333   12 B 99.00000   13 B 94.71429   Levels not connected by same letter are significantly different. <b>Ordered Difference Std Err Dif Lower CL Upper CL p-Value</b> 17 13 45.95238 13.78194 17.9441 73.96066 0.0021*   17 12 41.66667 13.52106 14.1886 69.14477 0.0041*   17 14 39.83333 12.89183 13.6340 66.03268 0.0047*   17 14 39.83333 12.89184 -4.3892 51.62733 0.0927*   16 13 23.3195	14	12 624	-9.600	11 951 -1	6 570 -16	602 -12	2 1 9 4
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Positive values show pairs of means that are significantly different.	13	17 044	-4 389	-8 124 -1	3 184 -16	720 -21	605
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Level   - Level   Difference   Std Err Dif   Lower CL   Upper CL   p-Value     17   13   45.95238   13.78194   17.9441   73.96066   0.0021*     17   12   41.66667   13.52106   14.1886   69.14477   0.0041*     17   14   39.83333   12.89183   13.6340   66.03268   0.0040*     17   15   32.38095   13.78194   4.3727   60.38923   0.0247*     16   13   23.61905   13.78194   -4.3892   51.62733   0.0957     17   16   22.33333   16.30702   -10.8065   55.47318   0.1798     16   12   19.33333   13.52106   -8.1448   46.81144   0.1619     16   14   17.50000   12.89183   -8.6993   43.69935   0.1836     15   13   13.57143   10.67545   -8.1237   35.26655   0.2123     16   15   10.04762   13.78194   -17.9607   38.05590	Orde	red D	lifferences R	leport			
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15 14 7.45238 9.49855 -11.8510 26.75576 0.4381   14 13 6.11905 9.49855 -13.1843 25.42242 0.5238	15	12	0.29571	10 2264	-17.900/ 5 .11.7204	58.0009	0.2752
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14 12 183232 011500 16 6024 20 25007 0 9419	14	12	1 92222	0 1150	-16.602	20.2519	7 08418

In Example of Means Comparisons Report for Each Pair, Student's t, the LSD threshold table shows the difference between the absolute difference in the means and the LSD (least significant difference). If the values are positive, the difference in the two means is larger than the LSD, and the two groups are significantly different.

#### Example of the All Pairs, Tukey HSD Test

1.Open the Big Class.jmp sample data table.

- 2.Select Analyze > Fit Y by X.
- 3.Select weight and click Y, Response.
- 4.Select age and click X, Factor.
- 5.Click OK.

From the red triangle menu, select Compare Means > All Pairs, Tukey HSD.



Example of All Pairs, Tukey HSD Comparison Circles

#### Example of Means Comparisons Report for All Pairs, Tukey HSD

Means Comparisons								
⊿ <b>⊂</b> Corr	npariso	ns for all p	airs using	Tukey-K	ramer HS	SD		
⊿ Conf	fidence	Quantile						
	q* A	lpha						
3.018	825	0.05						
⊿ LSD	Thresh	old Matrix						
Abs(Di	if)-HSD							
	17	16	15	14	12	13		
17	-49.219	-26.885	-9.216 0	.923 0.8	357 4.3	55		
16	-26.885	-49.219 -	31.550 -21	.411 -21.4	477 -17.9	78		
15	-9.216	-31.550 -	32.221 -21	.217 -21.9	912 -18.6	50		
14	0.923	-21.411 -	21.217 -24	.609 -25.0	581 -22.5	50		
12	0.857	-21.477 -	21.912 -25	.681 -30.1	L40 -26.9	12		
13	4.355	-17.978 -	18.650 -22	.550 -26.9	912 -32.2	21		
Positiv	e valuer i	show pairs of	means that a	re significar	thy different	+		
/ Com	e values :	Letters De	mort	re significat	itiy unreren			
- Com	necting	Letters Re	port					
Level		Mean						
1/	A I	40.00007						
10		10.0000						
14	A D 1	00.20371						
17	D 1	00.000.00						
13	B	94 71429						
Levels	not conn	ected by sam	e letter are sid	unificantly o	lifferent.			
4 Orde	ared Di	fforoncos P	enort	, initiality c				
oruc		incremees is	cepore					
Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value		
17	13	43,93238	13,78194	4.3001	87.54968	0.0235		
17	14	41.00007	12 90192	0.8008	82.47037 79.74404	0.0422*		
17	15	33 28002	13 79104	-0 2162	73 07225	0.2029		
16	13	23 61005	13 78104	-17 9783	65 21625	0.5325		
17	16	22,33333	16.30702	-26,8853	71,55192	0.7443		
16	12	19,33333	13,52106	-21.4766	60.14323	0.7091		
16	14	17,50000	12,89183	-21,4107	56,41071	0.7512		
15	13	13,57143	10.67545	-18.6497	45,79256	0.7982		
16	15	10.04762	13.78194	-31.5497	51.64492	0.9769		
15	12	9.28571	10.33646	-21.9123	40.48369	0.9442		
15	14	7.45238	9.49855	-21.2166	36.12134	0.9683		
14	13	6.11905	9.49855	-22.5499	34.78801	0.9867		
12	13	4.28571	10.33646	-26.9123	35.48369	0.9983 (:::)		
14	12	1.83333	9.11590	-25.6807	29.34736	1.0000		

In Example of Means Comparisons Report for All Pairs, Tukey <u>HSD</u>, the Tukey-Kramer HSD Threshold matrix shows the actual absolute difference in the means minus the HSD, which is the difference that would be significant. Pairs with a positive value are significantly different. The q\* (appearing above the HSD Threshold Matrix table) is the quantile that is used to scale the HSDs. It has a computational role comparable to a Student's t.

#### Example of the With Best, Hsu MCB Test

1.Open the Big Class.jmp sample data table. 2.Select Analyze > Fit Y by X.

- 3.Select weight and click Y, Response.
- 4.Select age and click X, Factor.
- 5.Click OK.

From the red triangle menu, select Compare Means > With Best, Hsu MCB.

Examples of With Best, Hsu MCB Comparison Circles



Example of Means Comparisons Report for With Best, Hsu MCB

Comparisons with the best using Hsu's MCB										
△ Confidence Quantile										
d Alpha 2.23157 0.05 2.23157 2.34056 2.38159 2.35278 2.34056										
⊿ Com	parison	vs. Min/	Max							
Level 17 16 15 14 12 13	vs. Max   vs. Min     Level   p-Value   p-Value     17   .   0.0039*     16   0.2162   0.1268     15   0.0441*   0.2978     14   0.0075*   0.6416     12   0.0080*   0.7071     13   0.0036*   0.9365									
⊿ LSD	Thresho	ld Matri	x							
Mean[i	i]-Mean[j]-	LSD								
	17	16	15	14	12	13				
17	-36.390	-14.057	0.124	9.130	9.855	13.695				
16	-58./24	-36.390	-22.210	-13.203	-12.4/9	-8.638				
15	-03.130	-40.803	-24.987	-15.109	-15.034	-11.415				
14	-08.002	40.209	-29.084	-19,418	-19.014	-10.113				
12	-76.708	-49.307 -54.374	-33.479	-23.544 -28.741	-23,495	-24.987				
If a column has any positive values, the mean is significantly less than the max. Mean[i]-Mean[i]+  SD										
incarij.	17	16	15	14	12	13				
17	36.390	58.724	64.638	70.536	73.479	78.210				
16	14.057	36.390	42.305	48.203	51.145	55.876				
15	-1.626	20.708	24.987	30.074	33.605	38.558				
14	-11.064	11.269	14.780	19.418	23.281	28.351				
12	-11.493	10.840	14.907	19.877	23,495	28.479				
12	15 107	7 1 7 6	11 415	16 500	20.024	24.007				

The Comparison vs. Min/Max report compares each level to the minimum and the maximum level. For example, level 17 is the only level that is significantly different from the minimum level.

## Example of the With Control, Dunnett's Test

- 1.Open the Big Class.jmp sample data table.
- 2.Select Analyze > Fit Y by X.
- 3.Select weight and click Y, Response.
- 4.Select age and click X, Factor.
- 5.Click OK.

From the red triangle menu, select Compare Means > With Control, Dunnett's.

Select the group to use as the control group. In this example, select age 12.



# Example of With Control, Dunnett's Comparison Circles

Using the comparison circles in <u>Example of With Control,</u> <u>Dunnett's Comparison Circles</u>, you can conclude that level 17 is the only level that is significantly different from the control level of 12.

## **Example Contrasting All of the Compare Means Tests**

- 1.Open the Big Class.jmp sample data table.
- 2.Select Analyze > Fit Y by X.
- 3.Select weight and click Y, Response.
- 4.Select age and click X, Factor.
- 5.Click OK.
- 6. From the red triangle menu, select each one of the Compare Means options.

Although the four methods all test differences between group means, different results can occur. <u>Comparison Circles for Four</u>

<u>Multiple Comparison Tests</u> shows the comparison circles for all four tests, with the age 17 group as the control group.





From <u>Comparison Circles for Four Multiple Comparison Tests</u>, notice that for the Student's t and Hsu methods, age group 15 (the third circle from the top) is significantly different from the control group and appears gray. But, for the Tukey and Dunnett method, age group 15 is not significantly different, and appears red.