

ANOVA-One Way Analysis of Variance

One-Way Analysis of Variance (ANOVA) is an extension of hypothesis testing for two population means using the t-distribution. The ANOVA allows us to compare more than two populations means, if the following two conditions are satisfied.

1. The populations are normally distributed.
2. The populations' variances are all equal ($\sigma_1^2 = \sigma_2^2 = \sigma_3^2 = \dots = \sigma_n^2$).

When you do your project on ANOVA you will have to use Minitab to check condition 1 and the rule of thumb for the equality of variance to check condition 2.

The hypothesis testing for the equality of the means is given below.

- Step 1. $H_0 : \mu_1 = \mu_2 = \mu_3 = \dots = \mu_n$
 $H_a : \text{At least one mean is different}$
- Step 2. Test statistic: F (Note: This value comes from the ANOVA table)
- Step 3. Reject H_0 if $F > F_{v_1, v_2; \alpha}$.
 OR If the p-value $< \alpha$. (Note: we are going to use the p-value)
- Step 4. Conclusion.

Note: If we fail to reject H_0 we conclude that all the means are equal.
 If we reject H_0 we have to find out which mean or means are different. We have to do pair-wise comparison on the means. This work will be done in Minitab.

Example: We would like to compare the average time that it takes a fire station to respond (the time it takes the fire truck to leave the station) to a phone call. There are four different fire stations in town. The following data was provided over a week's period. Is there a significant difference among the average response time of these four fire stations? Test it at $\alpha = 0.05$.

Station 1	Station 2	Station 3	Station 4
12 min	14 min	19 min	24 min
18 min	12 min	17 min	34 min
	13 min	21 min	

Use Minitab to do the Hypothesis Testing.

Worksheet 1 ***

	C1	C2	C3	C4	C5	C6	C7	C8	C9
	Factor	Response							
1	1	12							
2	1	18							
3	2	14							
4	2	12							
5	2	13							
6	3	19							
7	3	17							
8	3	21							
9	4	24							
10	4	34							
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Minitab - Untitled

File Edit Data Calc Stat Graph Editor Tools Window Help

Basic Statistics
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One-Way...
 One-Way (Unstacked)...
 Two-Way...
 Analysis of Means...
 Balanced ANOVA...
 General Linear Model...
 Fully Nested ANOVA...
 Balanced MANOVA...
 General MANOVA...
 Test for Equal Variances...
 Interval Plot...
 Main Effects Plot...
 Interactions Plot...

One-Way Analysis of Variance

C1	Factor
C2	Response

Response:

Factor:

Store residuals

Store fits

Confidence level:

Select Comparisons... Graphs...

Help OK Cancel

One-Way Multiple Comparisons

Tukey's, family error rate:

Fisher's, individual error rate:

Dunnett's, family error rate:

Control group level:

Hsu's MCB, family error rate:

Largest is best

Smallest is best

Help OK Cancel

One-way ANOVA: Response versus Factor

Source	DF	SS	MS	F	P
Factor	3	336.4	112.1	8.63	0.014
Error	6	78.0	13.0		
Total	9	414.4			

S = 3.606 R-Sq = 81.18% R-Sq(adj) = 71.77%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev
1	2	15.000	4.243
2	3	13.000	1.000
3	3	19.000	2.000
4	2	29.000	7.071

Pooled StDev = 3.606

Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Factor

Individual confidence level = 98.66%

Factor = 1 subtracted from:

Factor	Lower	Center	Upper
2	-13.404	-2.000	9.404
3	-7.404	4.000	15.404
4	1.507	14.000	26.493

Factor = 2 subtracted from:

Factor	Lower	Center	Upper
3	-4.200	6.000	16.200
4	4.596	16.000	27.404

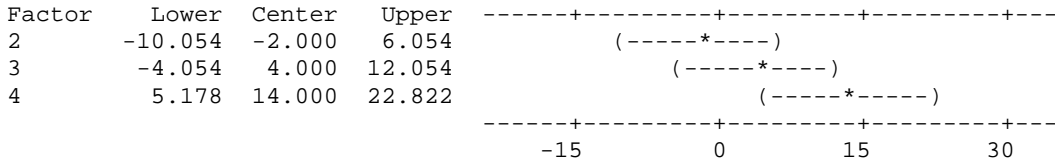
Factor = 3 subtracted from:

Factor	Lower	Center	Upper
4	-1.404	10.000	21.404

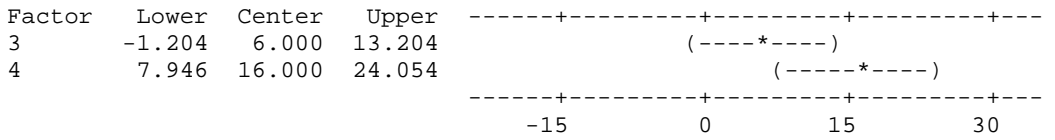
Fisher 95% Individual Confidence Intervals
 All Pairwise Comparisons among Levels of Factor

Simultaneous confidence level = 83.25%

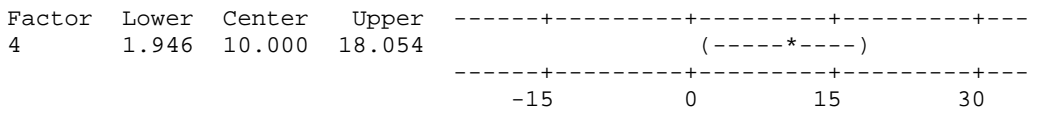
Factor = 1 subtracted from:



Factor = 2 subtracted from:



Factor = 3 subtracted from:



Homework: 12.35, 12.47, and 12.49 pages 661-665.

Note: Use Minitab to do Hypothesis testing and draw a conclusion only.