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The following resources are associated:

One-Way ANOVA worksheet and Kruskall-Wallis worksheet

One-Way ANOVA – Additional Material

Robustness

According to Glass et al. (1972) the equality of variances assumption must be met in order to run an ANOVA analysis. However, provided the total sample size is larger than 20, ANOVA is quite robust to non-normal skewness (provided the group sizes are equal - see Field, 2009, p. 360) but not to non-normal kurtosis. Thus, it should not be used when:



for any group. These values can be obtained using Analyze - Descriptive Statistics - Explore. For the example given in the main worksheet, select Strength for the Dependent List and Concentration for the Factor List and select Statistics as shown:

The kurtosis and standard error of kurtosis for each group are shown below (for details of example, see One Way ANOVA worksheet).

None of these ratios is higher than 2 and the sample size is 24 so, provided the Levene's test is negative, we could still have used the ANOVA test even if the normality assumptions had not been met.



Concentration	Kurtosis	Standard error	Ratio	Ratio > 2?
5%	1.19	0.85	1.40	No
10%	-0.22	0.85	0.26	No
15%	-0.94	0.85	1.11	No
20%	0.32	0.85	0.38	No



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Reviewer: Ellen Marshall University of Sheffield

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When assumptions and robust exceptions are not met

If the **equality of variances assumption is not met**, the **Brown-Forsythe** and **Welch** tests can be used. The Welch test is more powerful except where there is an extreme mean with a large variance when the Brown-Forsyth test is better. These tests are included within the ANOVA analysis in SPSS:

- Select Analyze Compare Means One Way ANOVA... and click on Options... button then select the **Brown-Forsythe** and **Welch** options
- If the result is significant, for post hoc testing, use the Games-Howell option

If normality assumptions and their robust exceptions are in doubt, use the Kruskal-Wallis or Jonckheere-Terpstra nonparametric tests. Kruskal-Wallis is appropriate where there is no

suspected order in the difference of means. If there is a suspected order (as in our example), use Jonckheere-Terpstra:

- Select Analyze Nonparametic Tests – Independent Samples...
- Select the Settings tabs, the Choose Test option from the Select an item list on the left and select Customise Tests
- Select one of these tests as shown on the right
- If the result is significant, for post hoc testing, use the automatic Model Viewer facility in SPSS – see the Kruskall-Wallis worksheet.

elect an item:							
Choose Tests	Automatically choose the tests based on the	ne data					
Test Options	Oustomize tests						
User-Missing Values	Compare Distributions across Groups						
		Kruskal-Wallis 1-way ANOVA (k samples)					
	mann-vvinuey 0 (2 samples)	Multiple comparisons:	All pairwise	-			
	Kolmogoro <u>v</u> -Smimov (2 samples)	Kolmogoro <u>v</u> -Smimov (2 samples) I					
	Test seguence for randomness	Hypothesis order:	Smallest to largest	-			
	 (Wald-Wolfowitz for 2 samples) 	Multiple comparisons:	All pairwise	-			
	Compare Ranges across Groups	Compare Medians acros	ss Groups				
	Moses extreme reaction (2 samples)	Median test (k samp	les)				
	Compute outliers from sample	Pooled sample m	ledian				
	© Custom number of outliers	Custom					
	Outliers: 1	Median: 0					
		Multiple comparisons	All pairwise	Ŧ			
	Estimate Confidence Interval across Groups						
	E Hedges Lohman estimate (0						

Comments

- Multiple t-tests should **not** be performed before a one-way ANOVA, although post-hoc tests are, in essence, t-tests
- It is possible to perform a one-way ANOVA with different sample sizes per group

References

- Field, A. (2009) *Discovering Statistics using SPSS (And sex and drugs and rock 'n' roll)*, 3rd ed., London: SAGE.
- Glass, G. V., Peckham, P. D. and Sanders, J. R. (1972) Consequences of failure to meet assumptions underlying the fixed effects analyses of variance and covariance, *Review of Educational Research*, 42(3), pp. 237-288.



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