Topic 2: ANOVA follow-up tests: single factor designs

On the following pages are a series of mock exam questions. For each of these the exam task is to look at the ANOVA table and identify whether suitable follow-up tests can/should be applied. The instructions for the exam task are as follows:

When a single-factor Analysis of Variance is performed, it is sometimes the case that the main summary ANOVA table gives insufficient information about the pattern of results and further follow-up tests are required. Each of the ANOVA summary tables below is from a single-factor fully between-subjects design.

For each table, suggest a suitable follow-up test in order fully to understand the outcome of the analysis. Explain your choice of test(s). If you believe that no follow-up tests are necessary, then also explain why. Assume that no planned comparisons are intended.

YOUR CLASSROOM/HOMEWORK TASK

For each question there is an example of an example of an answer that contains at least one error, along with the mark that would have been awarded for the answer in the exam.

Your task is to identify which aspects of the answer are inaccurate and explain why. For bonus marks, give corrected sentence(s) so that full marks can be obtained.

The exam marking scheme was as follows:

Correctly identified whether effect is significant or not: 1/2 mark
Correctly identified size of the experiment: 1/2 mark
Named a valid follow-up test for these data: 1 mark
Valid explanation for use of follow-up test: 1 mark

Total for each fully correct answer: 3 marks

1)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	Significance
A BETWEEN-GROUP	100	1	100	10	$p < .05$
S/A WITHIN-GROUP	80	8	10		
TOTAL	180	9			

This is a single factor between-subjects Anova with two levels in the factor.

There is a no significant effect.

No further analyses are possible because the ***F*** value has supplied all the information, the two means do not differ significantly.

1 mark /3

2)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	Significance
A BETWEEN-GROUP	400	4	10	1	$p > .05$
S/A WITHIN-GROUP	240	24	10		
TOTAL	640	29			

This is a single factor between-subjects Anova with four levels in the factor.

There is no significant effect.

Although the ***F*** value is non-significant, it is permissible to perform up to six pairwise follow-up comparisons using the Bonferroni adjustment, i.e. dividing the significance level by the number of comparisons made. This is because the Bonferroni adjustment is an unprotected test: it fully corrects familywise Type I Error and therefore an overall significant ***F*** value is not needed.

2.5 marks /3

3)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	Significance
A BETWEEN-GROUP	200	2	10	1	$p > .05$
S/A WITHIN-GROUP	120	12	10		
TOTAL	320	14			

This is a single factor between-subjects Anova with three levels in the factor.

There is no significant effect.

However, collecting data in a large experiment is time consuming and experimenters should guard against Type II Errors. Therefore the experimenter should now formulate and perform two planned comparisons in order to ensure that the data are not wasted.

1 mark /3

4)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	Significance
A BETWEEN-GROUP	100	1	100	10	$p < .05$
S/A WITHIN-GROUP	80	8	10		
TOTAL	180	9			

This is a single factor between-subjects Anova with two levels in the factor.

There is a significant effect.

No further analyses are necessary because the ***F*** value has supplied all the information, the two means differ significantly. However, if the researcher is cautious about making a Type I Error then the Scheffé test can be applied to ensure that there really is a significant difference between the means.

2 marks /3

5)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	Significance
A BETWEEN-GROUP	200	2	100	10	$p < .05$
S/A WITHIN-GROUP	120	12	10		
TOTAL	320	14			

This is a single factor between-subjects Anova with three levels in the factor.

There is a significant effect.

In this situation follow-up tests must be performed because the significant ***F*** value is ambiguous, it does not pinpoint which means differ from each other. The Tukey test can be used to compare all means with all other means. However, because the Tukey test does not make a stringent correction, any significant differences should be verified with pairwise comparisons using the Bonferroni adjustment to the significance level which fully corrects for familywise Type I Error.

2 marks /3

6)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	Significance
A BETWEEN-GROUP	200	2	10	1	$p > .05$
S/A WITHIN-GROUP	120	12	10		
TOTAL	320	14			

This is a single factor between-subjects Anova with three levels in the factor.

There is no significant effect.

Because there are three levels in the factor, the significant ***F*** value is ambiguous. The researcher should now perform the Tukey test, which corrects the significance level for multiple comparisons ensuring that familywise Type I Error is kept under control.

1.5 marks /3

7)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	Significance
A BETWEEN-GROUP	400	4	100	10	$p < .05$
S/A WITHIN-GROUP	240	24	10		
TOTAL	640	29			

This is a single factor between-subjects Anova with four levels in the factor.

There is no significant effect.

Researchers should always plan in advance to maximise statistical power by intending to make planned comparisons. Even when the results of an experiment are non-significant they can still apply their planned comparisons to these data. In this instance, up to three pairwise comparisons are possible for this design without correcting the significance level.

0 marks /3

8)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	Significance
A BETWEEN-GROUP	400	4	10	1	$p > .05$
S/A WITHIN-GROUP	240	24	10		
TOTAL	640	29			

This is a single factor between-subjects Anova with five levels in the factor.

There is no significant effect.

No follow-up tests are necessary because the ***F*** value is clearly non-significant.

2 marks /3

9)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	Significance
A BETWEEN-GROUP	10	1	10	1	$p > .05$
S/A WITHIN-GROUP	80	8	10		
TOTAL	90	9			

This is a single factor between-subjects Anova with two levels in the factor.

There is a no significant effect.

Although the ***F*** value is non-significant ANOVA is a parametric test and it is possible that one of the assumptions of ANOVA was violated leading to a Type II error or else the design might be unbalanced, therefore the test should be repeated with a more robust test such as the ***t***-test, which is less sensitive to unbalanced designs.

1 mark /3

10)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	Significance
A BETWEEN-GROUP	200	2	10	1	$p > .05$
S/A WITHIN-GROUP	120	12	10		
TOTAL	320	14			

This is a single factor between-subjects Anova with three levels in the factor.

There is no significant effect.

Although the ***F*** value is non-significant, it is permissible to perform up to two of the three possible follow-up pairwise comparisons (a–1) using the Bonferroni adjustment, i.e. dividing the significance level by the number of comparisons made. This is because the Bonferroni adjustment is an unprotected test: it fully corrects familywise Type I Error and therefor an overall significant ***F*** value is not needed.

2.5 marks /3