Topic 5: ANOVA follow-up tests: factorial 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 two-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 two-factor fully between-subjects design.

For each table, suggest suitable follow-up test(s) 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 which effects are significant (or not): 1 mark
Correctly identified size of each factor: 1 mark
Named a valid follow-up test for these data: 1 mark (2 marks for more difficult questions)
Valid explanation for use of follow-up test: 1 mark (2 marks for more difficult questions)

Total for each fully correct answer:
- 4 marks for straightforward question
- 6 marks for harder question.

1)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A	3	3	1	1	$p > .05$
B FACTOR B	1	1	1	1	$p > .05$
AxB INTERACTION	1	1	1	1	$p > .05$
S/AB WITHIN-GROUP	20	20	1		
TOTAL	25	25			

In this 4x2 fully between-subjects design, Factor A has four levels and Factor B has two levels.

There is a no significant Main Effect for either factor and the interaction is not significant.

Because there are no significant effects no further follow-up tests are possible. For each factor the non-significant Main Effect indicates that the level means do not differ. The lack of a significant interaction indicates that there is no need to investigate the Simple Main Effects.

3.5 marks /4

2)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A	1	1	1	1	$p > .05$
B FACTOR B	1	1	1	1	$p > .05$
AxB INTERACTION	20	1	20	20	$p < .01$
S/AB WITHIN-GROUP	20	20	1		
TOTAL	42	23			

In this 2x2 fully between-subjects design, Factor A and Factor B each has two levels.

There is a no significant Main Effect for either factor but the interaction is significant.

The significant interaction indicates that the Main Effects are not influencing the dependent variable independently. However, because neither Main Effect is significant it is unlikely that any of the Simple Main Effects will be significant, therefore no further tests are necessary.

2.5 marks /4

3)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A	3	3	1	1	$p > .05$
B FACTOR B	20	1	20	20	$p < .01$
AxB INTERACTION	1	1	1	1	$p > .05$
S/AB WITHIN-GROUP	20	20	1		
TOTAL	44	25			

In this 4x2 fully between-subjects design, Factor A has four levels and Factor B has two levels.

There is a significant Main Effect for Factor B but not Factor A and the interaction is not significant.

The lack of a significant interaction indicates that there is no need to investigate the Simple Main Effects. Instead, the significant difference for the pair of means for the Main Effect of Factor B can be interpreted directly. However, Factor A has four levels and therefore the results are ambiguous. The Tukey Test should be applied to this factor as a follow-up test to identify exactly which means differ significantly

2.5 marks /4

4)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A	60	3	20	20	$p < .01$
B FACTOR B	1	1	1	1	$p > .05$
AxB INTERACTION	20	1	20	20	$p < .01$
S/AB WITHIN-GROUP	20	20	1		
TOTAL	101	25			

In this 4x2 fully between-subjects design, Factor A has four levels and Factor B has two levels.

There is a significant Main Effect for Factor A but not Factor B and the interaction is significant.

In this situation the significances of the Main Effects cannot be interpreted by themselves because the two factors are not influencing the dependent variable independently. Therefore, it is necessary to use additional ***F*** tests to investigate the six Simple Main Effects to identify the source of the interaction.

4 marks /6

5)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A	20	1	20	20	$p < .01$
B FACTOR B	20	1	20	20	$p < .01$
AxB INTERACTION	1	1	1	1	$p > .05$
S/AB WITHIN-GROUP	20	20	1		
TOTAL	61	23			

In this 2x2 fully between-subjects design, Factor A and Factor B each has two levels

There is a significant Main Effect for both Factor A and Factor B but the interaction is not significant.

The lack of a significant interaction indicates that there is no need to investigate the Simple Main Effects because the two factors are influencing the dependent variable independently. However, because multiple comparisons have taken place, to control for Familywise Type I Error, the significance of each Main Effect should be confirmed using the Bonferroni adjustment, in other words dividing the significance level by three, the number of comparisons made on this table.

3 marks /4

6)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A	60	3	20	20	$p < .01$
B FACTOR B	20	1	20	20	$p < .01$
AxB INTERACTION	1	1	1	1	$p > .05$
S/AB WITHIN-GROUP	20	20	1		
TOTAL	101	25			

In this 4x2 fully between-subjects design, Factor A has four levels and Factor B has two levels.

There is a significant Main Effect for both Factor A and Factor B but the interaction is not significant.

No follow-up tests are necessary. The lack of a significant interaction indicates that there is no need to investigate the Simple Main Effects. The two factors are influencing the dependent variable independently. Therefore, the Main Effects can be interpreted directly.

4 marks /6

7)

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A	20	1	20	20	$p < .01$
B FACTOR B	20	1	20	20	$p < .01$
AxB INTERACTION	20	1	20	20	$p < .01$
S/AB WITHIN-GROUP	20	20	1		
TOTAL	80	23			

In this 2x2 fully between-subjects design, Factor A and Factor B each has two levels.

There is a significant Main Effect for both Factor A and Factor B and the interaction is also significant.

In this situation the significances of the Main Effects cannot be interpreted by themselves because the two factors are not independent. The Tukey Test can be used to make pairwise comparisons to investigate the four Simple Main Effects to identify the source of the interaction.

3 marks /4

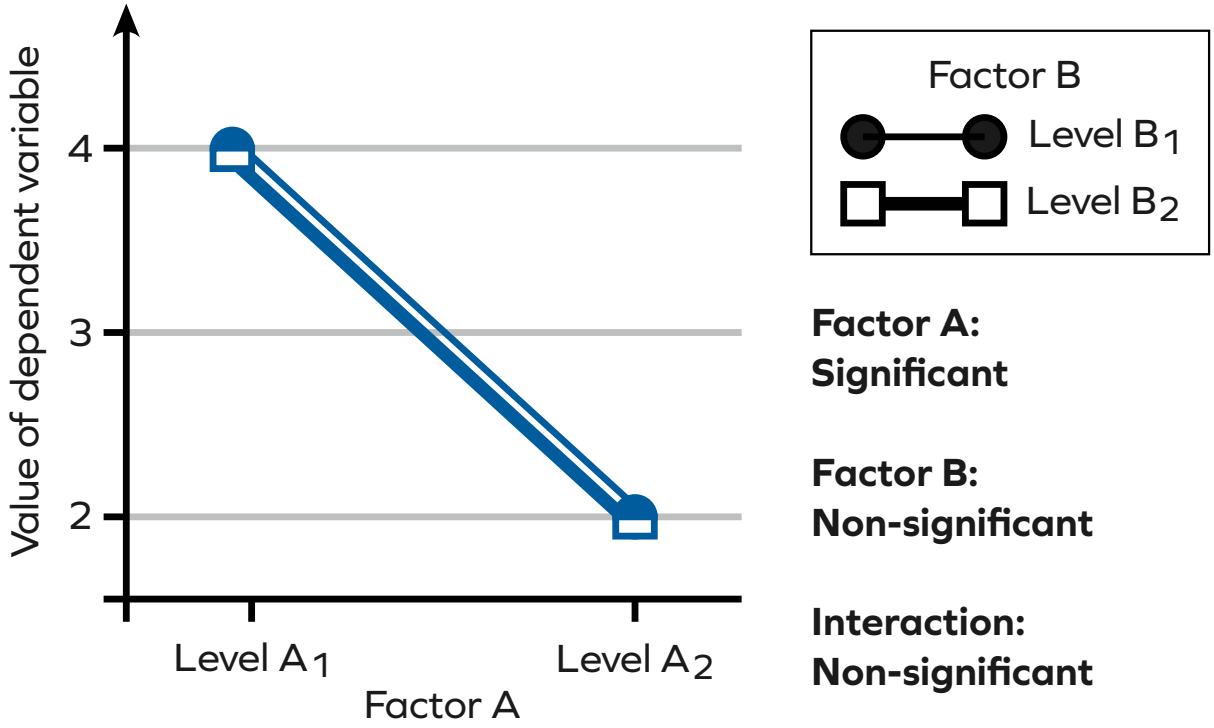
Topic 5: Analysing 2x2 Fully Between-Subjects ANOVA

On the next few pages are a series of exercises in which you will be creating data sets and analysing 2x2 interactions. This page is blank for convenience so that each exercise is on facing pages. The first exercise is completed for you so that you can see what is required for each one.

Creating and analysing a 2x2 fully between-subjects ANOVA (1)

Below is an empty graph suitable for plotting means. It represents a 2x2 factorial design. Right of each individual graph you are told which of Factor A, Factor B and the interaction should be significant.

a) On the graph you should plot, as clearly as possible, four cell means that will match the pattern of significances specified. *IMPORTANT: you may only choose from the following THREE values for the cell means: they may only be 2, 3, or 4.*



In this experimental design, there are only four scores in each cell, and the exact scores in each cell are determined by the cell means as follows:

For cells with a mean of **2**, the four scores must be **1, 2, 2, and 3**

For cells with a mean of **3**, the four scores must be **2, 3, 3, and 4**

For cells with a mean of **4**, the four scores must be **3, 4, 4, and 5**

b) In the table below, list the scores for each cell, corresponding with the cell means that you plotted on the graph

	Level A_1		Level A_2	
Level B_1	S_1	3	S_5	1
	S_2	4	S_6	2
	S_3	4	S_7	2
	S_4	5	S_8	3
Level B_2	S_9	3	S_{13}	1
	S_{10}	4	S_{14}	2
	S_{11}	4	S_{15}	2
	S_{12}	5	S_{16}	3

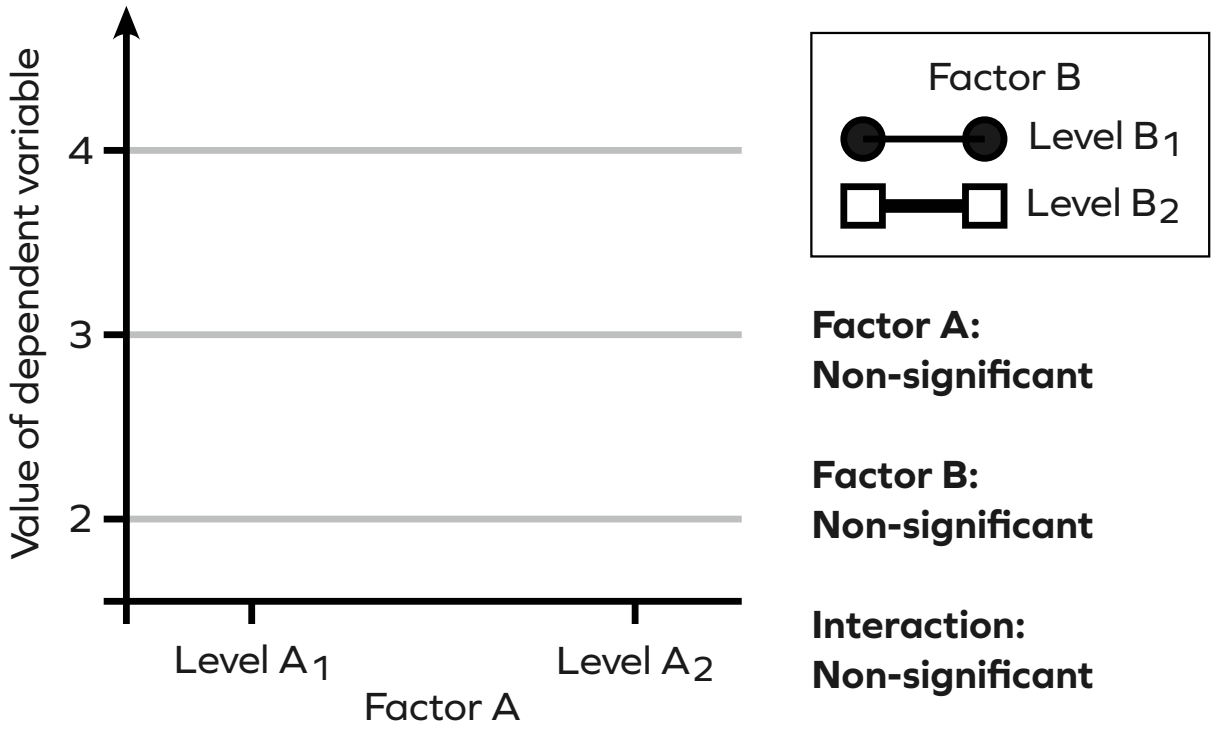
c) Finally, show that your choice of cell means was correct by performing an appropriate 2x2 fully between-subjects ANOVA on the data in the table

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A	16	1	16	24	$p < .01$
B FACTOR B	0	1	0	0	$p > .05$
AxB INTERACTION	0	1	0	0	$p > .05$
S/AB WITHIN-GROUP	8	12	$^2/_3$		
TOTAL	24	15			

Creating and analysing a 2x2 fully between-subjects ANOVA (2)

Below is an empty graph suitable for plotting means. It represents a 2x2 factorial design. Right of each individual graph you are told which of Factor A, Factor B and the interaction should be significant.

a) On the graph you should plot, as clearly as possible, four cell means that will match the pattern of significances specified. *IMPORTANT: you may only choose from the following THREE values for the cell means: they may only be 2, 3, or 4.*



In this experimental design, there are only four scores in each cell, and the exact scores in each cell are determined by the cell means as follows:

For cells with a mean of **2**, the four scores must be **1, 2, 2, and 3**

For cells with a mean of **3**, the four scores must be **2, 3, 3, and 4**

For cells with a mean of **4**, the four scores must be **3, 4, 4, and 5**

b) In the table below, list the scores for each cell, corresponding with the cell means that you plotted on the graph

	Level A_1	Level A_2
Level B_1	S_1	S_5
	S_2	S_6
	S_3	S_7
	S_4	S_8
Level B_2	S_9	S_{13}
	S_{10}	S_{14}
	S_{11}	S_{15}
	S_{12}	S_{16}

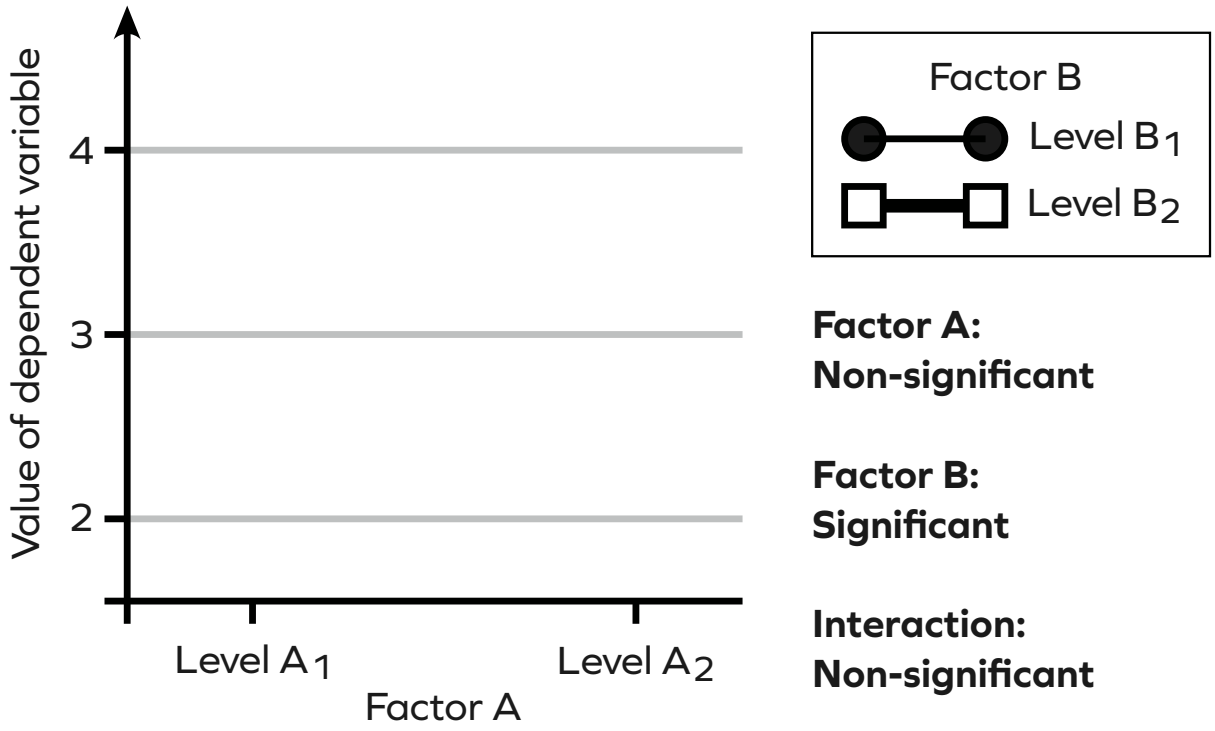
c) Finally, show that your choice of cell means was correct by performing an appropriate 2x2 fully between-subjects ANOVA on the data in the table

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A					
B FACTOR B					
AxB INTERACTION					
S/AB WITHIN-GROUP					
TOTAL					

Creating and analysing a 2x2 fully between-subjects ANOVA (3)

Below is an empty graph suitable for plotting means. It represents a 2x2 factorial design. Right of each individual graph you are told which of Factor A, Factor B and the interaction should be significant.

a) On the graph you should plot, as clearly as possible, four cell means that will match the pattern of significances specified. *IMPORTANT: you may only choose from the following THREE values for the cell means: they may only be 2, 3, or 4.*



In this experimental design, there are only four scores in each cell, and the exact scores in each cell are determined by the cell means as follows:

For cells with a mean of **2**, the four scores must be **1, 2, 2, and 3**

For cells with a mean of **3**, the four scores must be **2, 3, 3, and 4**

For cells with a mean of **4**, the four scores must be **3, 4, 4, and 5**

b) In the table below, list the scores for each cell, corresponding with the cell means that you plotted on the graph

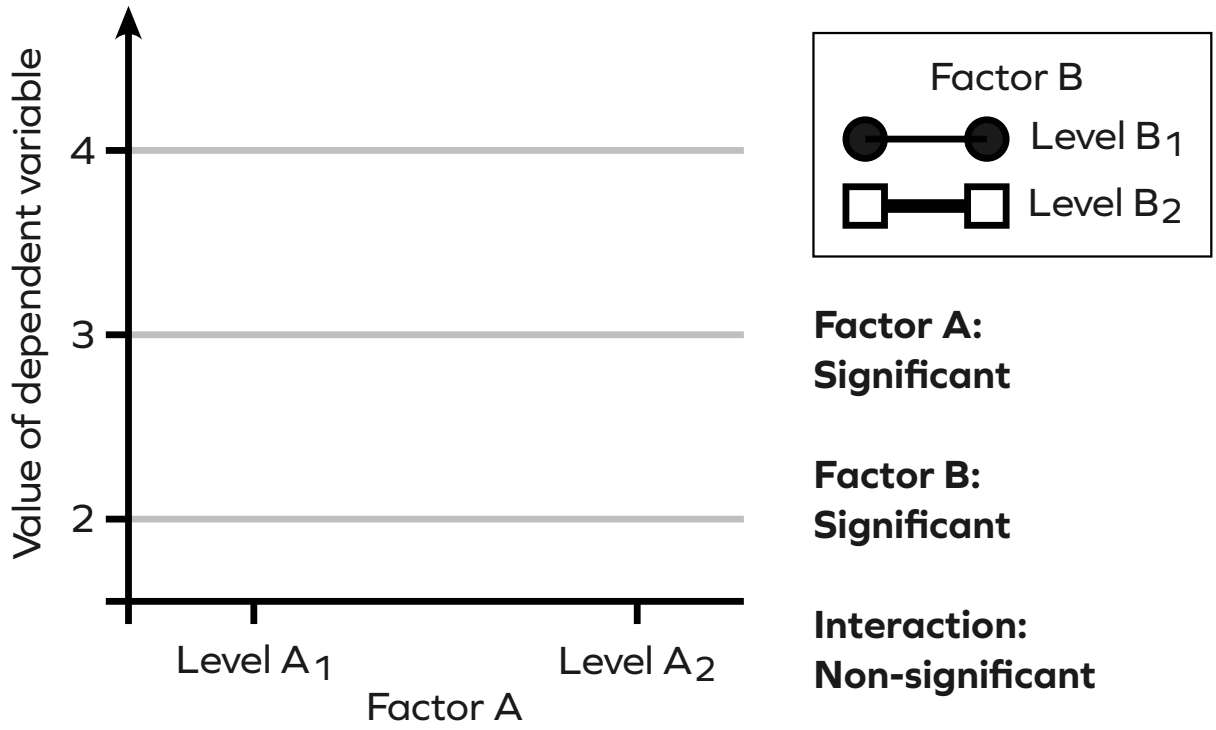
	Level A_1	Level A_2
Level B_1	S_1	S_5
	S_2	S_6
	S_3	S_7
	S_4	S_8
Level B_2	S_9	S_{13}
	S_{10}	S_{14}
	S_{11}	S_{15}
	S_{12}	S_{16}

c) Finally, show that your choice of cell means was correct by performing an appropriate 2x2 fully between-subjects ANOVA on the data in the table

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A					
B FACTOR B					
AxB INTERACTION					
S/AB WITHIN-GROUP					
TOTAL					

Creating and analysing a 2x2 fully between-subjects ANOVA (4)

Below is an empty graph suitable for plotting means. It represents a 2x2 factorial design. Right of each individual graph you are told which of Factor A, Factor B and the interaction



should be significant.

a) On the graph you should plot, as clearly as possible, four cell means that will match the pattern of significances specified. *IMPORTANT: you may only choose from the following THREE values for the cell means: they may only be 2, 3, or 4.*
In this experimental design, there are only four scores in each cell, and the exact scores in each cell are determined by the cell means as follows:

For cells with a mean of **2**, the four scores must be **1, 2, 2, and 3**

For cells with a mean of **3**, the four scores must be **2, 3, 3, and 4**

For cells with a mean of **4**, the four scores must be **3, 4, 4, and 5**

b) In the table below, list the scores for each cell, corresponding with the cell means that you plotted on the graph

	Level A_1	Level A_2
Level B_1	S_1	S_5
	S_2	S_6
	S_3	S_7
	S_4	S_8
Level B_2	S_9	S_{13}
	S_{10}	S_{14}
	S_{11}	S_{15}
	S_{12}	S_{16}

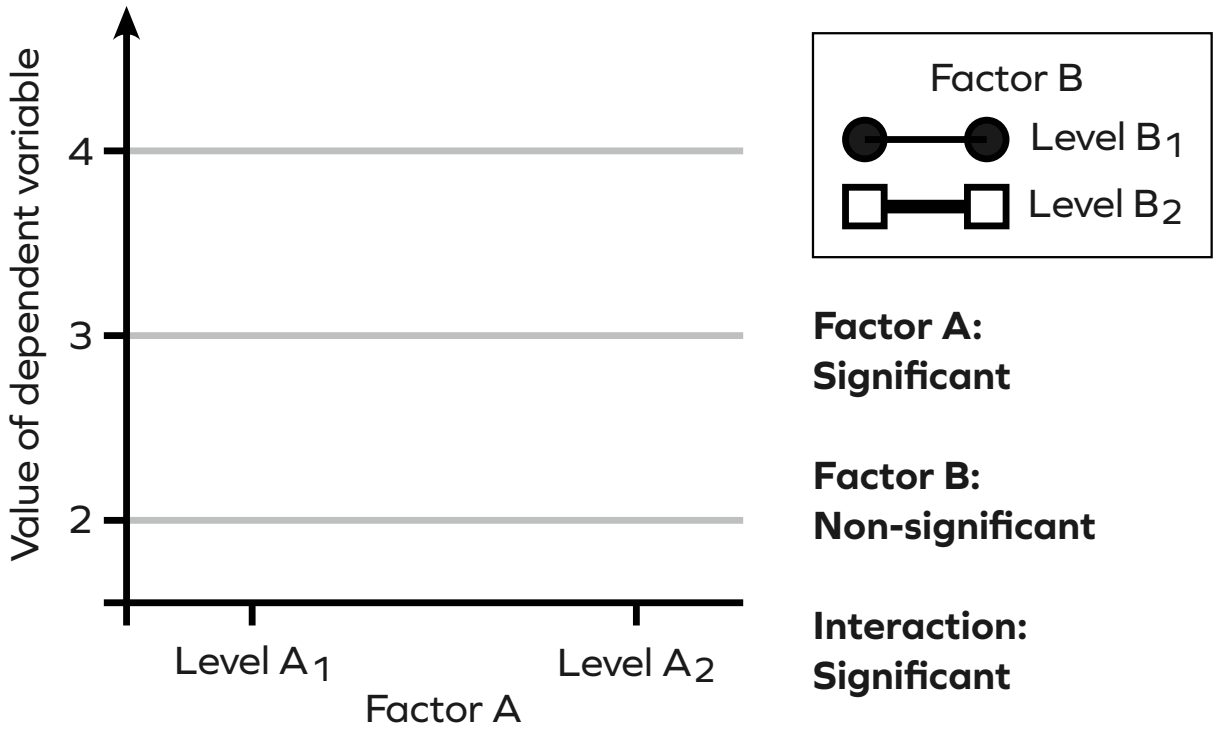
c) Finally, show that your choice of cell means was correct by performing an appropriate 2x2 fully between-subjects ANOVA on the data in the table

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A					
B FACTOR B					
AxB INTERACTION					
S/AB WITHIN-GROUP					
TOTAL					

Creating and analysing a 2x2 fully between-subjects ANOVA (5)

Below is an empty graph suitable for plotting means. It represents a 2x2 factorial design. Right of each individual graph you are told which of Factor A, Factor B and the interaction should be significant.

a) On the graph you should plot, as clearly as possible, four cell means that will match the pattern of significances specified. *IMPORTANT: you may only choose from the following THREE values for the cell means: they may only be 2, 3, or 4.*



In this experimental design, there are only four scores in each cell, and the exact scores in each cell are determined by the cell means as follows:

For cells with a mean of **2**, the four scores must be **1, 2, 2, and 3**

For cells with a mean of **3**, the four scores must be **2, 3, 3, and 4**

For cells with a mean of **4**, the four scores must be **3, 4, 4, and 5**

b) In the table below, list the scores for each cell, corresponding with the cell means that you plotted on the graph

	Level A_1	Level A_2
Level B_1	S_1	S_5
	S_2	S_6
	S_3	S_7
	S_4	S_8
Level B_2	S_9	S_{13}
	S_{10}	S_{14}
	S_{11}	S_{15}
	S_{12}	S_{16}

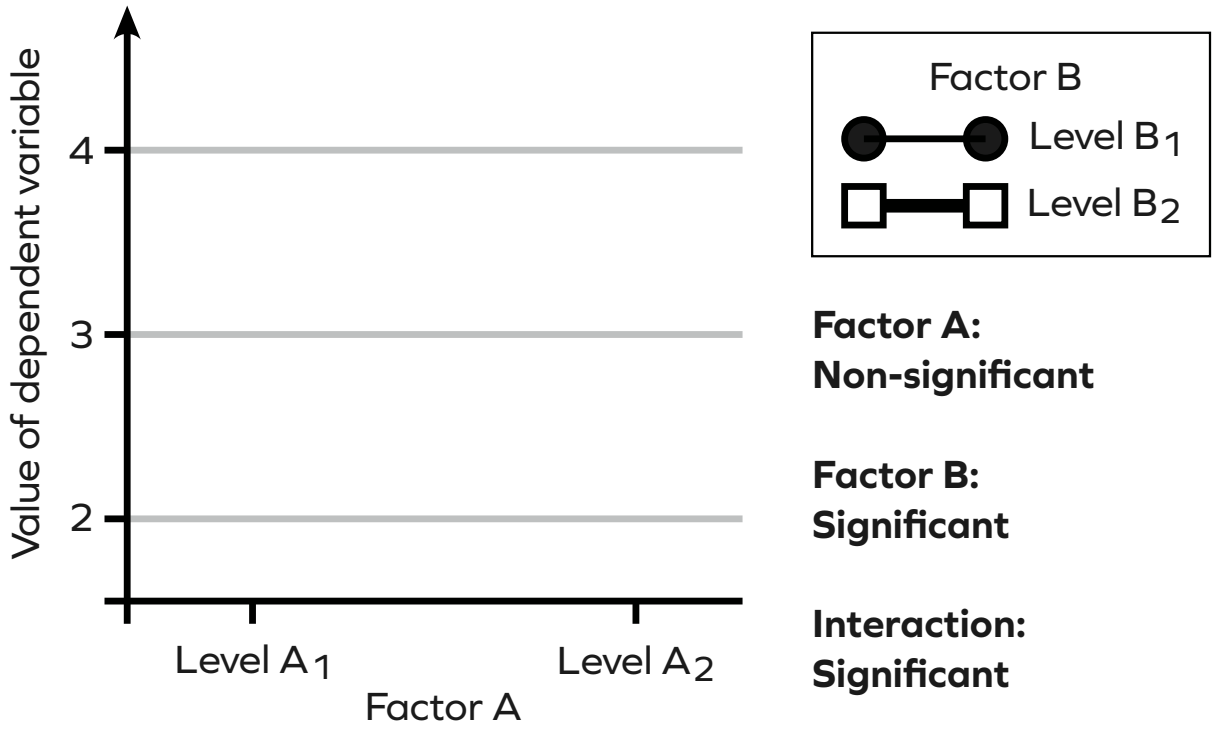
c) Finally, show that your choice of cell means was correct by performing an appropriate 2x2 fully between-subjects ANOVA on the data in the table

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A					
B FACTOR B					
AxB INTERACTION					
S/AB WITHIN-GROUP					
TOTAL					

Creating and analysing a 2x2 fully between-subjects ANOVA (6)

Below is an empty graph suitable for plotting means. It represents a 2x2 factorial design. Right of each individual graph you are told which of Factor A, Factor B and the interaction should be significant.

a) On the graph you should plot, as clearly as possible, four cell means that will match the pattern of significances specified. *IMPORTANT: you may only choose from the following THREE values for the cell means: they may only be 2, 3, or 4.*



In this experimental design, there are only four scores in each cell, and the exact scores in each cell are determined by the cell means as follows:

For cells with a mean of **2**, the four scores must be **1, 2, 2, and 3**

For cells with a mean of **3**, the four scores must be **2, 3, 3, and 4**

For cells with a mean of **4**, the four scores must be **3, 4, 4, and 5**

b) In the table below, list the scores for each cell, corresponding with the cell means that you plotted on the graph

	Level A_1	Level A_2
Level B_1	S_1	S_5
	S_2	S_6
	S_3	S_7
	S_4	S_8
Level B_2	S_9	S_{13}
	S_{10}	S_{14}
	S_{11}	S_{15}
	S_{12}	S_{16}

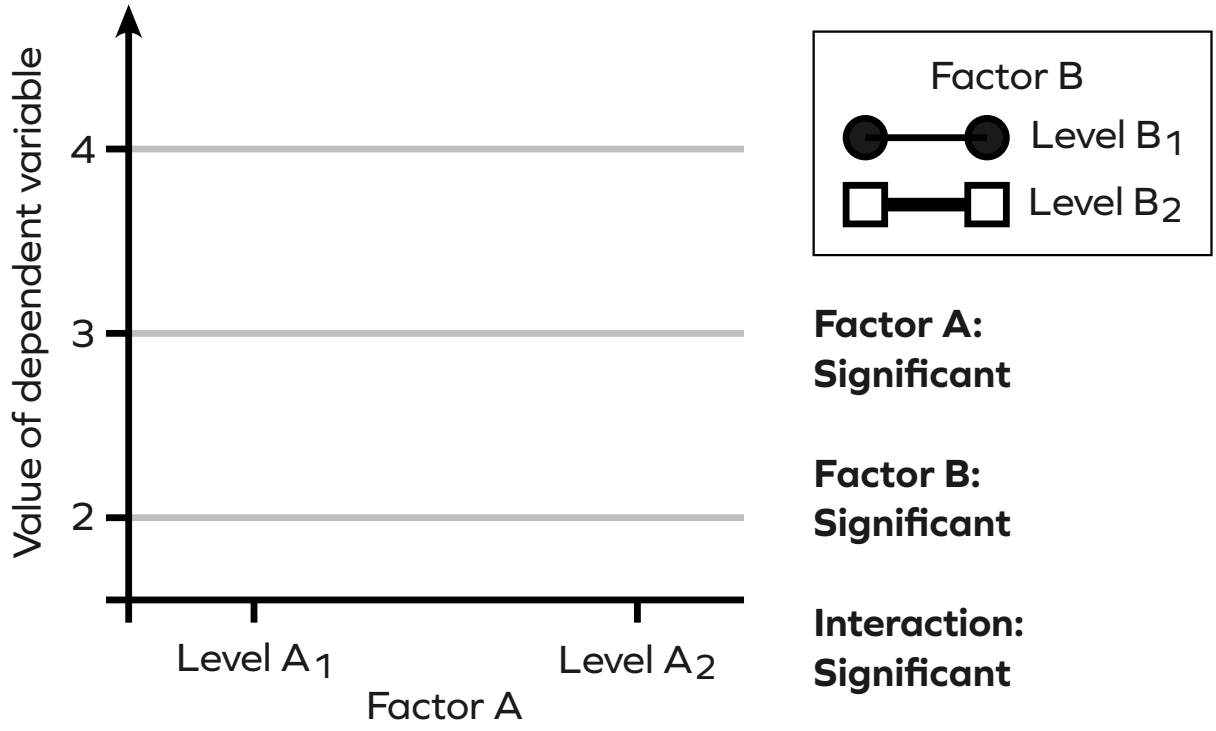
c) Finally, show that your choice of cell means was correct by performing an appropriate 2x2 fully between-subjects ANOVA on the data in the table

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A					
B FACTOR B					
AxB INTERACTION					
S/AB WITHIN-GROUP					
TOTAL					

Creating and analysing a 2x2 fully between-subjects ANOVA (7)

Below is an empty graph suitable for plotting means. It represents a 2x2 factorial design. Right of each individual graph you are told which of Factor A, Factor B and the interaction should be significant.

a) On the graph you should plot, as clearly as possible, four cell means that will match the pattern of significances specified. *IMPORTANT: you may only choose from the following THREE values for the cell means: they may only be 2, 3, or 4.*



In this experimental design, there are only four scores in each cell, and the exact scores in each cell are determined by the cell means as follows:

For cells with a mean of **2**, the four scores must be **1, 2, 2, and 3**

For cells with a mean of **3**, the four scores must be **2, 3, 3, and 4**

For cells with a mean of **4**, the four scores must be **3, 4, 4, and 5**

b) In the table below, list the scores for each cell, corresponding with the cell means that you plotted on the graph

	Level A_1	Level A_2
Level B_1	S_1	S_5
	S_2	S_6
	S_3	S_7
	S_4	S_8
Level B_2	S_9	S_{13}
	S_{10}	S_{14}
	S_{11}	S_{15}
	S_{12}	S_{16}

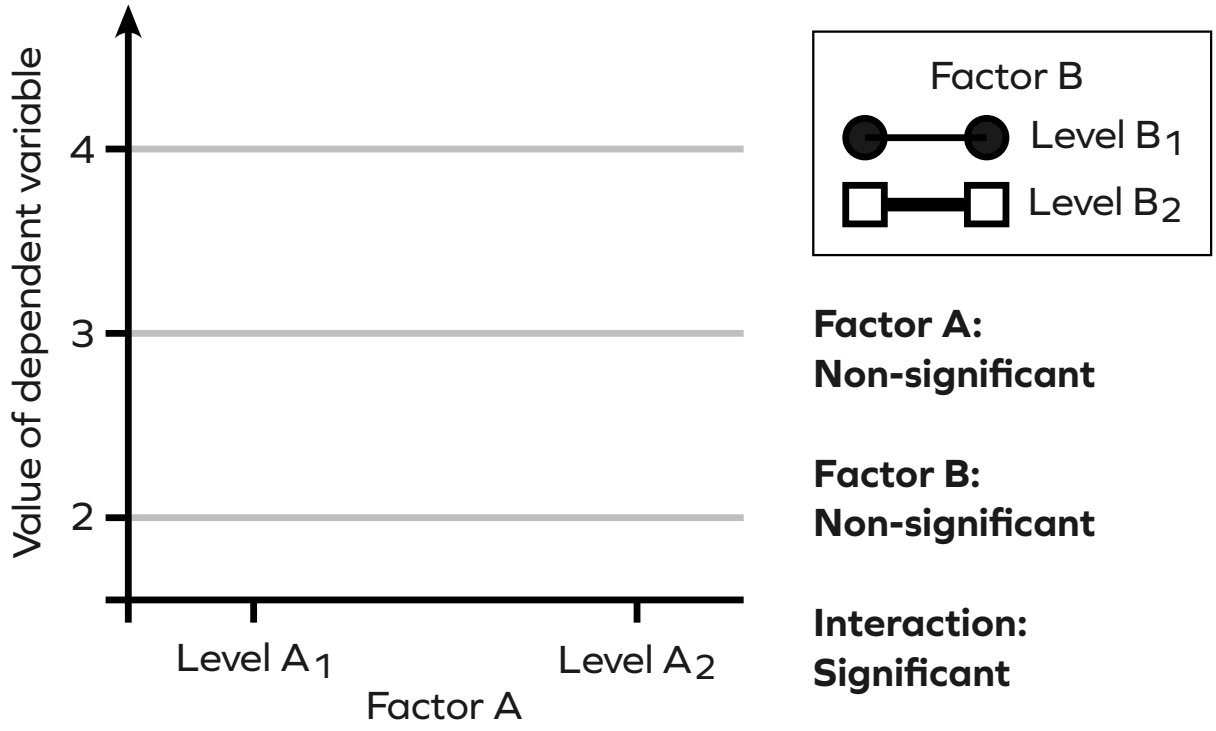
c) Finally, show that your choice of cell means was correct by performing an appropriate 2x2 fully between-subjects ANOVA on the data in the table

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A					
B FACTOR B					
AxB INTERACTION					
S/AB WITHIN-GROUP					
TOTAL					

Creating and analysing a 2x2 fully between-subjects ANOVA (8)

Below is an empty graph suitable for plotting means. It represents a 2x2 factorial design. Right of each individual graph you are told which of Factor A, Factor B and the interaction should be significant.

a) On the graph you should plot, as clearly as possible, four cell means that will match the pattern of significances specified. *IMPORTANT: you may only choose from the following THREE values for the cell means: they may only be 2, 3, or 4.*



In this experimental design, there are only four scores in each cell, and the exact scores in each cell are determined by the cell means as follows:

For cells with a mean of **2**, the four scores must be **1, 2, 2, and 3**

For cells with a mean of **3**, the four scores must be **2, 3, 3, and 4**

For cells with a mean of **4**, the four scores must be **3, 4, 4, and 5**

b) In the table below, list the scores for each cell, corresponding with the cell means that you plotted on the graph

	Level A_1	Level A_2
Level B_1	S_1	S_5
	S_2	S_6
	S_3	S_7
	S_4	S_8
Level B_2	S_9	S_{13}
	S_{10}	S_{14}
	S_{11}	S_{15}
	S_{12}	S_{16}

c) Finally, show that your choice of cell means was correct by performing an appropriate 2x2 fully between-subjects ANOVA on the data in the table

Source	Sum of Squares	Degrees of Freedom	Variance (Mean Square)	*F*-value	*p*-value (sig. level)
A FACTOR A					
B FACTOR B					
AxB INTERACTION					
S/AB WITHIN-GROUP					
TOTAL					