MPSMD2RES Workshop 4: Two-Way Between Groups ANOVA

Dr Ian Hocking, Psychology Programme

Contents

1 Overview

Data files required	Example 1 SPSS data
Booklet Version	1.0
Format	PDF with Open Dyslexic font

2 Objectives

This workshop extends your knowledge of Analysis of Variance (ANOVA) to factorial designs. Remember that ANOVA uses the ratio between explained and unexplained variance to tell you whether the means are difference between levels (groups) of a factor (the thing you are manipulating, or your independent variable). Having looked at the simple case of one-way (i.e. one factor) ANOVA last week, in both independent and repeated forms, this week you'll look at the two-way ANOVA in its independent form.

- In the first example, you'll examine the effects of traffic noise and age on learning;

- In the second example, you'll examine the effects of music and alcohol on driving behaviour;
  - You'll also learn how to set up your SPSS data file.

Remember, this booklet will focus on between-groups analysis. That is, for a given factor, there will be different people in each level. This means that the observations will be independent.

3 About this document

This document is available in different formats for students who may have accessibility requirements. See Versions. The system is still being piloted and I'd be interested in your feedback.

3.1 Tasks and Your Research Journal

Use this booklet in conjunction with your own Research Journal, where you will record your workings, thoughts, and other comments related to the exercises. Your Research Journal can take any form, but a Word document might be best; you can copy and paste output from SPSS alongside your notes.

(If you're looking at a non-standard, accessible version of this document, some of the formatting below will be simplified.)

- When I ask you to complete a task, like calculate a mean, it will be formatted like this.
- This is what a Research Journal reminder looks like. I'll use these when asking you to make a note.

3.2 Other Aspects of this Booklet

- This formatting will be used to highlight something important.

Here I'll provide answers to questions. Note that this version of the document won't be available until after your workshop.

3.3 Mathematics and Statistics Help

If you're not confident in your algebra, which is important for dealing with equations, try this Introduction to Algebra.

3.4 Answers

You'll be provided with a second version of this document, containing answers, a few days after your seminar. I'll include **SPSS** Syntax and possibly **SPSS** Data files to help you reproduce the correct answers quickly.

When you use menus and dialogue boxes within **SPSS** to do analyses, **SPSS** is actually building up a complex command in its native language, syntax, and then running this command. It is feasible for you to access these complex commands yourself. In any dialogue box, the paste button will produce the appropriate syntax to do a particular analysis. You can save this syntax as text and run it again at a later date to get the same output. If you want to repeat an analysis quickly, changing bits like variables or type of test, editing syntax is often the best way.

Paste the syntax into an **SPSS** syntax window using File > New > Syntax. Highlight the syntax and click the green arrow to make **SPSS** run the syntax, producing the appropriate output.

It would be a good idea to get used to **SPSS** Syntax, though I'm not expecting you to use it instead of the graphical, 'point and click' interface.

4 Workshop

Analysis of variance or 'ANOVA' is a statistical technique that allows us to examine the differences between mean scores when there are more than two conditions. Basically, it compares the variance between the conditions with the variance within the conditions. The bigger the differences between the conditions and the smaller the individual differences within a condition, the more likely we are to get a significant result. In this booklet we will carry out the analysis required for a design with two independent variables (i.e. two factors). Both of them are between-subjects (i.e. there are different people in each group or condition).

The ANOVA will tell us three things:

1. Is there a main effect of factor one on the dependent variable (DV)?
2. Is there a main effect of factor two on the DV?
3. Is there an interaction effect of the two factors on the DV?

All data and syntax for this booklet:

- Example 1 SPSS data
- Example 1 SPSS syntax
- Eaxmple 2 SPSS data
- Example 2 SPSS syntax

5 Example 1: Traffic noise and Learning

> The conditions under which words are remembered are thought to affect the amount of subsequent recall. In particular, road traffic noise at the time of learning has been shown to affect subsequent recall and it seems to be most damaging for children. To look at this phenomenon, participants in the current experiment were randomly assigned to one of two noise conditions: loud (with road traffic) or quiet (no audible road traffic) and asked to read a 1000 word story. There were 20 children (aged 11 - 14) and 20 adults (aged 30 - 35). One week later they came back into the lab and were asked a series of 20 questions about the story. Recall (the dependent variable) was measured as the number of correct answers.

5.1 Step One: Load the data into SPSS

The full data set is available for download here: Example 1 SPSS data

1. Open the data file and familiarise yourself with its contents. Use the paragraph above you help you.

1. What is the design of this study?

This is a 2 x 2 between-groups factorial design. Factor 1 is Age (child; adult) and factor 2 is Noise Condition (loud; quiet).

5.2 Step Two: Run descriptive statistics

Before we carry out the ANOVA, we should get an idea of what is going on with the data.

2. Calculate the mean scores for the four conditions by going to Analyze > Compare means > Means. As shown in Figure 1, put the DV (recall) into the Dependent List and 'ageGroup' into the Independent List. Now click on Next and 'ageGroup' should disappear. You are now specifying the second layer of your comparison (note where it says Layer 2 of 2). Click on 'noise' and put this into the Independent List and click OK.

- Your means per condition should be the same as mine in Figure 2.

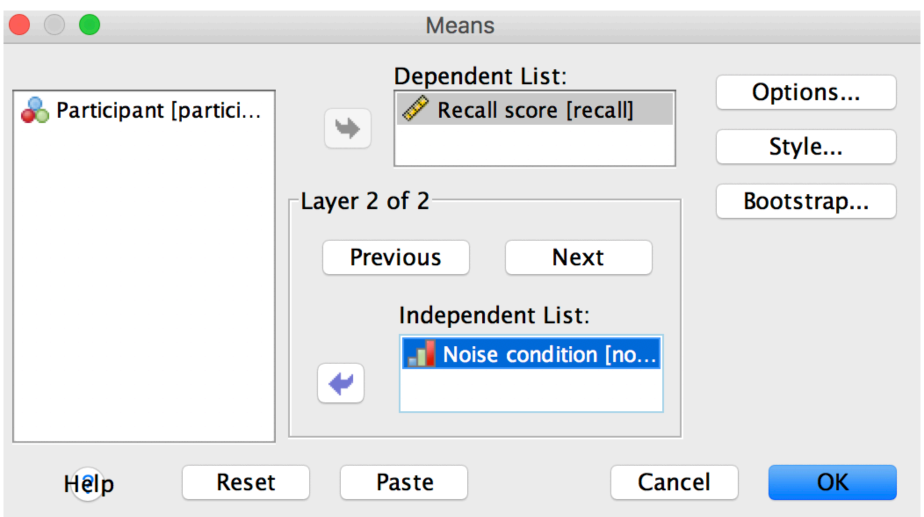

Figure 1: SPSS compare means dialogue

2. What do the descriptives tell you?

Report

Recall score

Age group	Noise condition	Mean	N	Std. Deviation
Child	Loud	6.1000	10	1.37032
	Quiet	8.8000	10	2.85968
	Total	7.4500	20	2.58488
Adult	Loud	11.4000	10	1.71270
	Quiet	13.6000	10	3.37310
	Total	12.5000	20	2.83772
Total	Loud	8.7500	20	3.10983
	Quiet	11.2000	20	3.91488
	Total	9.9750	40	3.70369

Figure 2: Output—compare means output

In our sample:

- Children had lower recall than adults.
- Quiet noise conditions resulted in better recall than louder conditions.
- The difference between quiet and load conditions in children was be greater than for adults, so noise impaired children's recall more than adults'.

SPSS Syntax:

```
MEANS TABLES=recall BY ageGroup BY noise
  /CELLS=MEAN COUNT STDDEV.
```

5.3 Step Three: Set up the ANOVA

By looking at the descriptive statistics, we have some inkling of group differences. Now let's see whether those differences are significant or not.

Read through the instructions below before doing them yourself.

1. Remember that all the SPSS statistical analyses are under the Analyze menu, so go there, select General Linear Model, then Univariate.

2. As I've done in Figure 3, put the dependent variable into the Dependent Variable box and the independent variables into the Fixed Factors box.

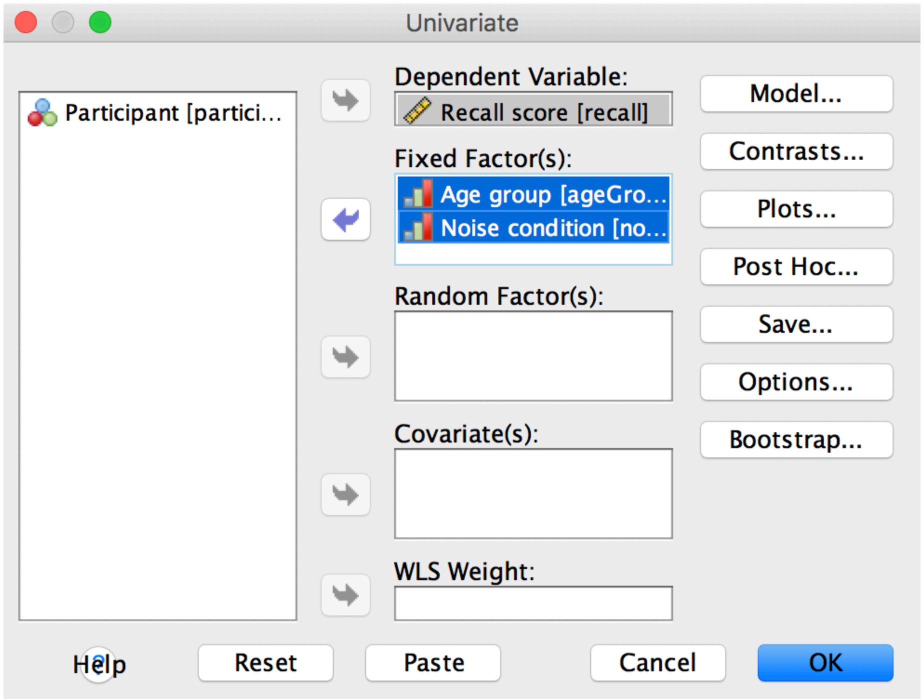

Figure 3: SPSS Univariate ANOVA dialogue

3. Click on Options and make sure you have selected the factors and interactions that are included in Figure 4.

4. Now click Continue. We know that graphs aid the understanding of patterns in our data, so click Plots and ask SPSS to produce a graph with 'ageGroup' on the horizontal axis and 'noise' as separate lines, just as you see in Figure 5.

5. Click on Add and Continue. Then click OK.

By the end of the above process, you will have set up and run your first two-way between-subjects ANOVA.

3. Go ahead and run the ANOVA described above.

SPSS syntax for the ANOVA:

```
* Run the first ANOVA on recall with age and noise
* as between participants factors.
```

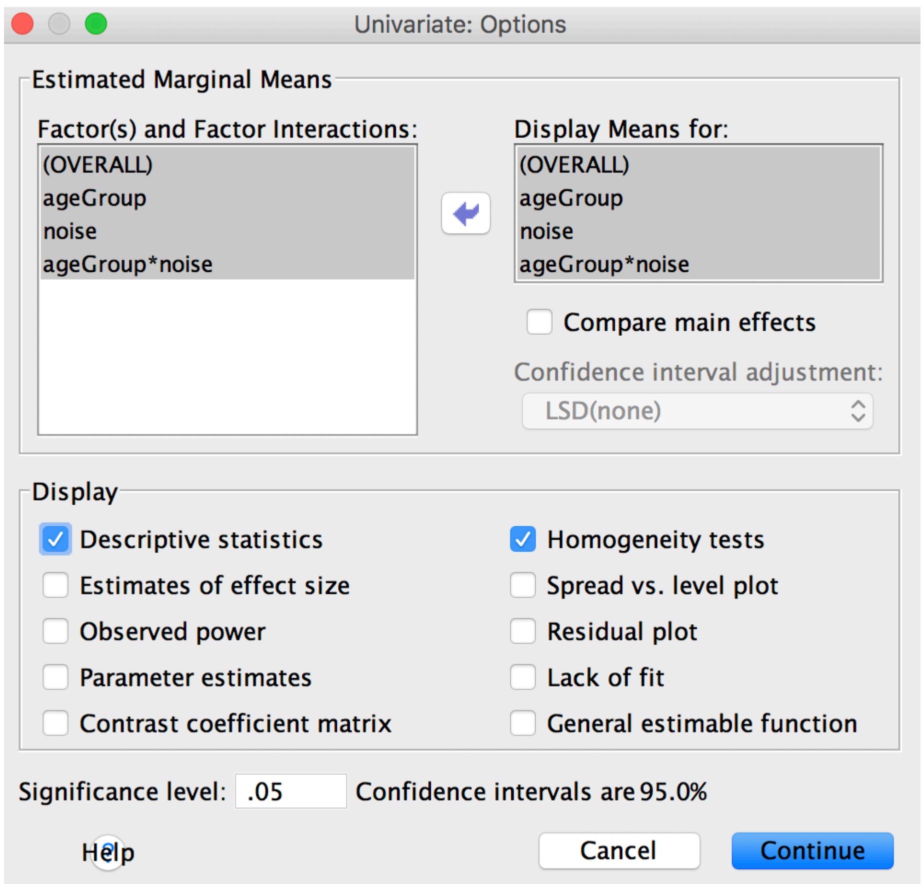

Figure 4: SPSS Univariate ANOVA dialogue, Options

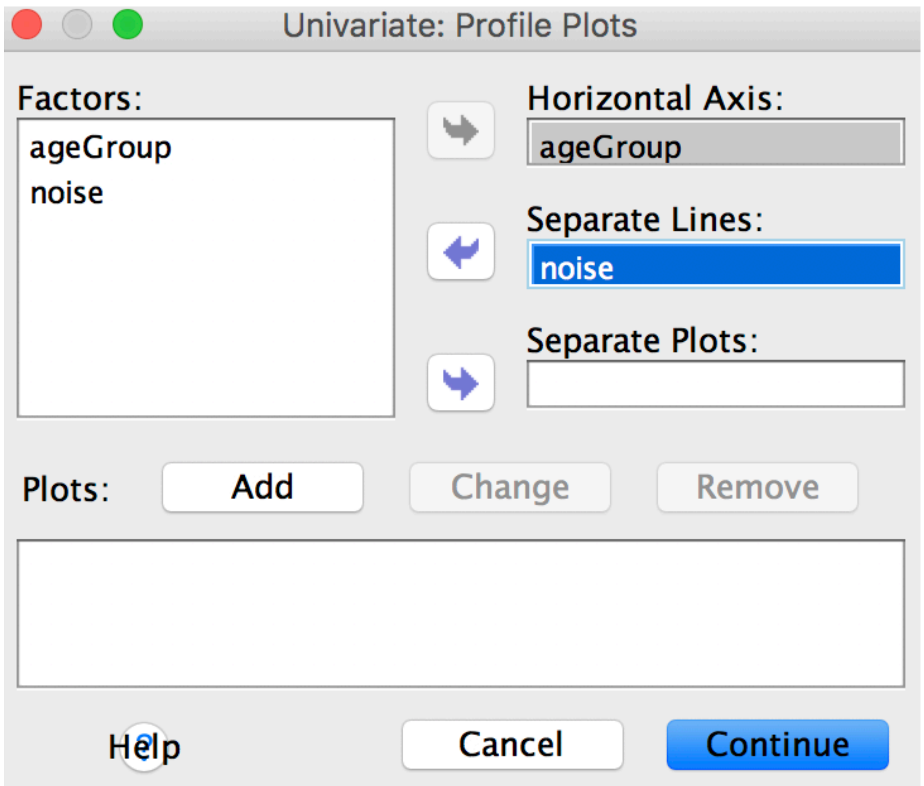

Figure 5: SPSS Univariate ANOVA dialogue, Profile Plots

```
UNIANOVA recall BY ageGroup noise
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /PLOT=PROFILE(ageGroup*noise)
  /EMMEANS=TABLES(OVERALL)
  /EMMEANS=TABLES(ageGroup)
  /EMMEANS=TABLES(noise)
  /EMMEANS=TABLES(ageGroup*noise)
  /PRINT=HOMOGENEITY DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /DESIGN=ageGroup noise ageGroup*noise.
```

5.4 Step Four: Interpret the output

We are now ready to answer the important question. Are those differences significant or not?

The first box tells us how many people we have under each condition—nothing new here. The second box gives us the descriptive statistics that we should already have looked at in Step Two. The first new bit of information comes with Levene's Test of the assumption of homogeneity of variance. Remember that we want the variances to be equal (not different), so this needs to be non-significant.

3. Look at the homogeneity of variance statistic in Figure 6. Has the homogeneity of variance assumption been met? Include the statistics to back that up.

Yes, Levene's test is nonsignificant, $F(3,26) = 1.93$, $p = .142$.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Recall score

F	df1	df2	Sig.
1.934	3	36	.142

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + ageGroup + noise + ageGroup * noise

Figure 6: Output—Homogeneity of Variance

Take a look at the ANOVA table (Tests of Between-Subjects Effects), which should resemble Figure 7.

Tests of Between-Subjects Effects

Dependent Variable: Recall score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	315.675[a]	3	105.225	17.274	.000
Intercept	3980.025	1	3980.025	653.356	.000
ageGroup	255.025	1	255.025	41.865	.000
noise	60.025	1	60.025	9.854	.003
ageGroup * noise	.625	1	.625	.103	.751
Error	219.300	36	6.092		
Total	4515.000	40			
Corrected Total	534.975	39			

a. R Squared = .590 (Adjusted R Squared = .556)

Figure 7: Output—ANOVA

3. Use Figure 7 to answer the following questions, providing the statistics to back up your answers.

3.1 Is there a main effect of factor one on the DV?

3.2 Is there a main effect of factor two on the DV?

3.3 Is there an interaction effect of the two factors on the DV?

3.1. Yes, there is a main effect of noise on recall: $F(1,36) = 9.85$, $MSE = 6.09$, $p = .003$.

3.2. Yes, there is a main effect of age on recall: $F(1,36) = 41.87$, $MSE = 6.09$, $p < 0.01$.

3.3. There was no interaction: $F(1,36) = .10$, $MSE = 6.09$, $p < .75$.

Providing charts in APA style is an important skill. SPSS charts need some work to make them conform. Figure 8 is a spruced up version of the plot that SPSS original produced. Editing charts is achieved by double-clicking on them in the output window. This exposes a toolbox with which can change visual properties.

4. See if you can get your plot to look like Figure 8.

4. What do the significant effects reported in Figure 7, together with the plot in Figure 8, tell us?

The effect of age was significant, and adult participants had better recall than younger ones. The effect of noise was significant, and quiet conditions led to better recall than loud conditions. The interaction was not significant,

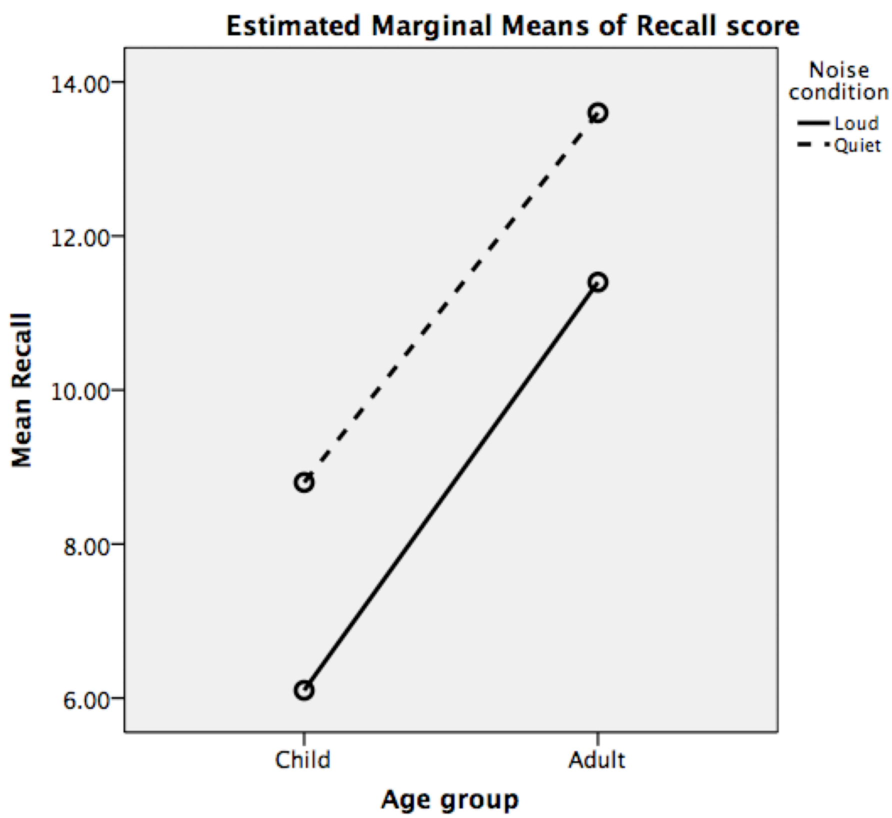

Figure 8: Output—Profile Plots

so the effect of noise was the same for both adults and children (the differences observed in the descriptive statistics failed to reach significance).

6 Example 2: Alcohol and Music on Driving Ability

In the lecture, I described an experiment investigating the effects of alcohol and music on driving behaviour. Below you will find the raw data. Participants were allocated to one of four groups, depending on whether or not they had some alcohol before getting in the car and whether or not they had music whilst driving. Alcohol and Music are the two factors, both between-subjects. The DV is driving ability, measured as the number of errors committed whilst driving.

Table 2: The effects of alchohol and music on driving ability.

participant	music	alcohol	errors
1	1	1	8
2	1	1	10
3	1	1	7
4	1	2	0
5	1	2	2
6	1	2	1
7	2	1	5
8	2	1	4
9	2	1	3
10	2	2	2
11	2	2	0
12	2	2	1

5. Type these data into SPSS, which will give you more practice with setting up data files correctly. Make sure:

- You enter the above data correctly in the Data view;
- In the Variable view, give each variable an appropriate label and name (I've called my variables participant, music, alcohol, errors—use the same for now, so that you don't have any problems running the syntax below);
- Also in the Variable view, use the Values column to assign values to your grouping numbers (without these, your output will be more difficult to interpret);
- Finally, in the Variable view, set the Measure view correctly for each

variable (without this, SPSS may not perform the correct analyses).

- My values for music are 1 = Music, 2 = No music; values for alcohol are 1 = Alcohol, 2 = No alcohol
- participant is nominal, music is ordinal, alcohol is ordinal, errors is scale

5. Report the design of the study

This is a 2 x 2 between-groups factorial design. Factor one is music (no music; music) and factor two is alcohol (no alcohol; alcohol).

6. As usual, get an overview of your data by looking at the means. Go to Analyse > Compare Means and compute them for each group. You should get something like Figure 9.

Report

Errors

Music condition	Alcohol condition	Mean	N	Std. Deviation
Music	Alcohol	8.3333	3	1.52753
	No alcohol	1.0000	3	1.00000
	Total	4.6667	6	4.17931
No music	Alcohol	4.0000	3	1.00000
	No alcohol	1.0000	3	1.00000
	Total	2.5000	6	1.87083
Total	Alcohol	6.1667	6	2.63944
	No alcohol	1.0000	6	.89443
	Total	3.5833	12	3.28795

Figure 9: Output—Descriptives for error by alcohol group and music group

6. Describe what you see in the means.

Participants produced more errors when they heard music (mean 4.67) versus not hearing music (2.50). With alcohol, their errors increased markedly (from 1.00 to 6.2).

7. Now set up the ANOVA as you did in Example 1's Step Three. Remember:

- to ask that SPSS produce a table of descriptives as well marginal means for all our effects;
- to test the homogeneity of variance;
- to produce a plot depicting the results (ask for alcohol as separate

lines and music on the horizontal axis, so that you get the same plot as mine).

SPSS Syntax:

```
UNIANOVA errors BY music alcohol
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /PLOT=PROFILE(music*alcohol)
  /EMMEANS=TABLES(OVERALL)
  /EMMEANS=TABLES(music)
  /EMMEANS=TABLES(alcohol)
  /EMMEANS=TABLES(music*alcohol)
  /PRINT=HOMOGENEITY DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /DESIGN=music alcohol music*alcohol.
```

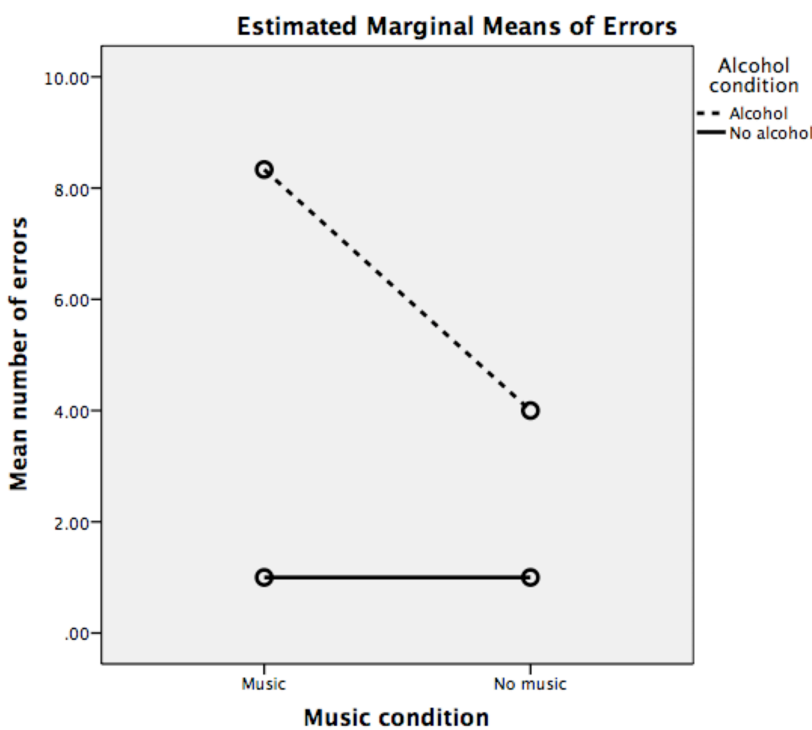

Figure 10: Output—Estimated Marginal Means

8. Before you check anything else, have a look at your plot to see the familiar data pattern. Edit it to make it look like Figure 10.

7. What does the graph tell us about our results? On the basis of the graph, would you expect a main effect of music? A main effect of alcohol? An interaction? Explain your answer to each of those questions.

- Yes, you might expect a main effect of music. When collapsed across alcohol condition, the means will be different.
- You might expect a main effect of alcohol because, again, when collapsing across the other factor (music), the means will be different.
- Since the lines are not parallel, we might expect an interaction.

Now let's have a look at the results and find out what the statistics are telling us.

7. Have we met the homogeneity of variance assumption? Report the statistics from Figure 11 to back up your answer.

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Errors

F	df1	df2	Sig.
.400	3	8	.757

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + music + alcohol + music * alcohol

Figure 11: Output—Levene's Test of Equality of Variances

Yes, Levene's test is nonsignificant: $F(3,8) = 0.40$, $p = .76$. A non significant result means that the variances are likely to be equal.

8. Report all main and interaction effects. In plain English, what does each effect mean in terms of group differences? Which of these effects need post hoc tests and why?

We have:

- A significant main effect of music on driving ability, $F(1, 8) = 10.56$, $MSE = 1.33$, $p = .012$. Driving ability differed depending on music group (with music, performance was worse).

- A significant main effect of alcohol on driving ability, $F(1, 8) = 60.06$, $MSE = 1.33$, $p < .001$. Driving ability differed depending on alcohol group (with alcohol, performance was worse).

- A significant interaction of music and alcohol on driving ability, $F(1, 8) = 10.56$, $MSE = 1.33$, $p = .012$

We should carry out simple main effects analyses for the interaction. No post hoc testing is required to follow up the significant main effects because both factors have only two conditions; because of this, there's nothing more we can learn from post hoc pairwise comparisons.

The (spoiler alert) significant interaction effect needs to be followed up with simple main effects analyses. Remember that in order to carry out **SME** analyses, we need to access the **SPSS** Syntax Editor.

9. Go to Analyse > General Linear Model > Univariate.

- If you haven't exited **SPSS**, you'll find that the settings for your last **ANOVA** will still be present in the dialogue box. In this case, simply click paste and the syntax for the **ANOVA** will appear in a new syntax window. (The window might be somewhere in the background.)

- If you have exited **SPSS**, you'll have to re-enter the settings for your last **ANOVA** before clicking paste.

10. Ensure your syntax looks like Figure 12.

```
UNIANOVA errors BY music alcohol
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /PLOT=PROFILE(music*alcohol)
  /EMMEANS=TABLES(OVERALL)
  /EMMEANS=TABLES(music)
  /EMMEANS=TABLES(alcohol)
  /EMMEANS=TABLES(music*alcohol)
  /PRINT=HOMOGENEITY DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /DESIGN=music alcohol music*alcohol.
```

Figure 12: Syntax—Univariate ANOVA, without SME analyses

- Syntax is a programming language, and these need attention to detail. Even a misplaced comma will stop a program running correctly.
- In **SPSS** Syntax, variables are black and all other text colour-coded. If you find that you've typed a command but **SPSS** has not coloured-coded it, then this suggests that **SPSS** has not recognised the command; have you spelled it correctly?

In Figure 12, look at the line reading:

```
/EMMEANS=TABLES(music*alcohol)
```

We're going to extend this line so that it asks **SPSS** to calculate the simple main effects within music of alcohol[1], while making a Bonferroni adjustment to control for familywise error:

```
/EMMEANS=TABLES(music*alcohol) compare (music) ADJ(BONFERRONI)
```

Additionally, beneath it, we will include the following, which produces the simple main effects within alcohol of music[2] (while making the same familywise error adjustment):

```
/EMMEANS=TABLES(music*alcohol) compare (alcohol) ADJ(BONFERRONI)
```

Your syntax should now look like Figure 13.

```
UNIANOVA errors BY music alcohol
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /PLOT=PROFILE(music*alcohol)
  /EMMEANS=TABLES(OVERALL)
  /EMMEANS=TABLES(music)
  /EMMEANS=TABLES(alcohol)
  /EMMEANS=TABLES(music*alcohol) compare (music)  ADJ(BONFERRONI)
  /EMMEANS=TABLES(music*alcohol) compare (alcohol) ADJ(BONFERRONI)
  /PRINT=HOMOGENEITY DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /DESIGN=music alcohol music*alcohol.
```

Figure 13: Syntax—Univariate **ANOVA**, including **SME** analyses

10. Run the syntax.

[1]These **SME**s will tell us (i) whether listening to music affected driving ability in the group that had alcohol and (ii) whether listening to music affected driving in the group that had no alcohol.

[2]These **SME**s will tell us (i) whether drinking alcohol affected driving ability in the group that had music in the car and (ii) whether alchohol affected driving in the group that did have music.

- Make sure the syntax window has focus and the syntax you wish to run is currently under cursor selection.
- Then click on the menu bar Run followed by Selection.
- Check that your two new Univariate Tests tables look like Figure 14 and Figure 15. If they don't, something might be wrong with your syntax, so go back and see if you can spot your error.

Univariate Tests

Dependent Variable: Errors

Alcohol condition		Sum of Squares	df	Mean Square	F	Sig.
Alcohol	Contrast	28.167	1	28.167	21.125	.002
	Error	10.667	8	1.333		
No alcohol	Contrast	.000	1	.000	.000	1.000
	Error	10.667	8	1.333		

Each F tests the simple effects of Music condition within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

Figure 14: Output—Univariate Tests, Simple Main Effects of Music within Alcohol

Univariate Tests

Dependent Variable: Errors

Music condition		Sum of Squares	df	Mean Square	F	Sig.
Music	Contrast	80.667	1	80.667	60.500	.000
	Error	10.667	8	1.333		
No music	Contrast	13.500	1	13.500	10.125	.013
	Error	10.667	8	1.333		

Each F tests the simple effects of Alcohol condition within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

Figure 15: Output—Univariate Tests, Simple Main Effects of Alcohol within Music

9. Were the simple main effects of music within alcohol significant (Figure 14)? Report the statistics to back up your answer.

The SME of music was significant within the alcohol condition, $F(1,8) = 21.13$, $MSE = 1.33$, $p = .002$, but it wasn't significant within the no alcohol condition, $F(1,8) = .001$, $MSE = 1.33$, $p > .99$.

10. Were the simple main effects of alcohol within music significant (Figure 15)? Report the statistics to back up your answer.

The SME of Alcohol was significant within the no music condition, $F(1,8) = 60.50$, $MSE = 1.33$, $p < .001$, and it was also significant within the music condition, $F(1,8) = 10.13$, $MSE = 1.33$, $p = .013$.

11. Based on the results of the **ANOVA** and post hoc analyses, what can we conclude?

- Both music and alcohol had an effect on driving ability independently (which we have determined by observing the main effect of each factor). The presence of music made their performance worse, as did the presence of alcohol.

There was a significant interaction. Follow up analyses indicated:

- When participants had alcohol, music made their performance worse. When participants had no alcohol, music didn't have an effect on their performance. (This is concluded from the **SME** of music within alcohol.)
- Participants were made worse by alcohol no matter whether they heard music or not. (This is concluded from the **SME** of alcohol within music.)

7 Versions

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