# MPSMD2RES Workshop 3: One-Way ANOVA

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## Contents



## 1 Overview

| | |
|---|---|
| *Data files required* | Activity after therapy, Driving errors after alcohol |
| *Booklet Version* | 1.1 |
| *Format* | large text PDF |

## 2 Objectives

This workshop introduces you to the Analysis of Variance (ANOVA), which is a statistical technique designed to help analyse designs with multiple groups.

- You'll begin by performing an ANOVA on group data where *different* people have contributed data to each group. This is known as a between-groups ANOVA analysis (sometimes a between-subjects analysis).
- You'll then carry out a second ANOVA using data where the *same* people have contributed data to each group. This is a within-groups ANOVA or a within-subjects ANOVA.

## 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 look at the differences between mean scores when there are more than two conditions. Basically, it compares the variance between the groups with the variance within the groups. The bigger the differences between the groups compared to within the groups, the more likely we are to get a significant result.

# 5 Between-Groups ANOVA

We'll begin with a one-way between-groups ANOVA in SPSS, and interpret the result.

- *One-way* means that the ANOVA has one 'factor', which translates as 'basis on which we have created groups'. Typically, it is the thing we have manipulated.
- This is a *between* or *independent* ANOVA because the people in the groups are different. In other words, the group data are not correlated.

Download the complete SPSS syntax

Download the complete SPSS output

## 5.1 Our Scenario

> A clinical psychologist was interested in the effect of 'sunshine therapy' on the activity levels of depressed patients. The therapy involved sitting in an empty room with artificial sunlight filtered through. She took a group of 300 depressed out-patients at a psychiatric hospital and split them into three sub-groups. She gave one sub-group a 3-hour session of sunshine therapy; the second sub-group received 3 hours of traditional Cognitive Behavioural Therapy (CBT); the third group received no therapy. After a series of sessions all the participants got together for an hour to socialise and support each other. During this

session, they were observed and the amount of time during which each patient engaged in social activities was recorded.

### 5.2 Step One: Obtain the Data

1. Open Activity after therapy.

Note that you have two columns. The first is 'group' and the second 'activity'. 'Group' represents type of therapy (no therapy, CBT, and sunshine). 'Activity' represents social activity level following the treatment.

### 5.3 Step Two: Run the Descriptive Statistics

Before we carry out the ANOVA (or any other statistical test) it is always good practice to get an idea of what is going on with the data. So, calculate the scores for the three groups. Whereas before you've used the *Descriptives* function, we need to tell SPSS that we'd like means for one variable ('activity') as classified by the value of another ('group').

2. Go to *Analyze > Compare means > Means*. Put the dependent variable in 'dependent' box and the independent variable into the 'independent' box. Now click *OK*.

1. What are the mean activity ratings for the three groups?

- *No therapy*: 1
- *CBT*: 2.8
- *Sunshine therapy*: 2.1

---

SPSS Syntax:

```
MEANS TABLES=activity BY group
  /CELLS=MEAN COUNT STDDEV.
```

### 5.4 Step Three: Get a Useful Picture of the Means

Box plots are very useful for getting a sense of what our grouped data *looks* like.

From Wikipedia:

> In descriptive statistics, a box plot or boxplot is a convenient way of graphically depicting groups of numerical data through their quartiles. Box plots may also have lines extending vertically from the boxes (whiskers) indicating variability outside the upper and lower quartiles, hence the terms box-and-whisker plot and box-and-whisker diagram.

Boxplots can be constructed by going to *Graphs* > *Legacy Dialogues* > *Boxplot*. For this kind of plot, make sure *Simple* and *Summaries for groups of cases* are selected, like Figure 1.

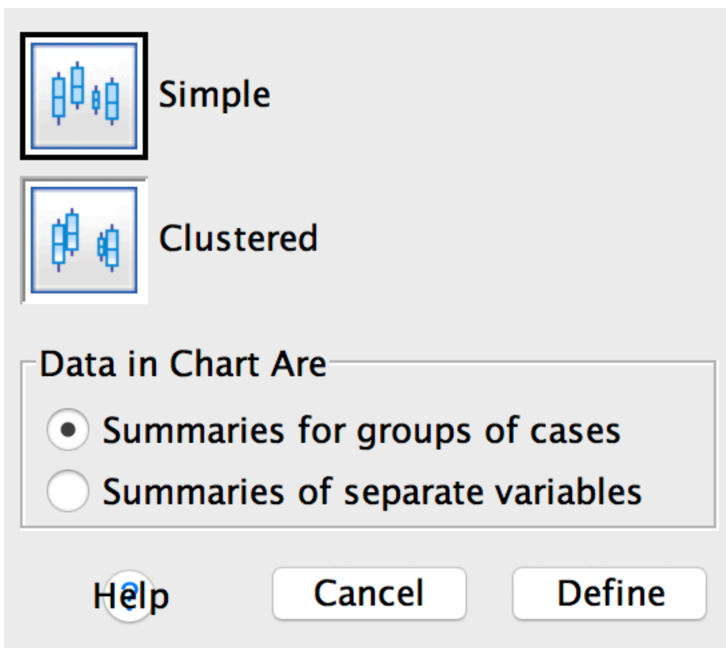


Figure 1: SPSS boxplot dialogue

When you've clicked *OK*, you can specify the dependent variable as *Variable* and the grouping variable as *Category Axis*, like Figure 2

3. Using the instructions above, create boxplots for the activity

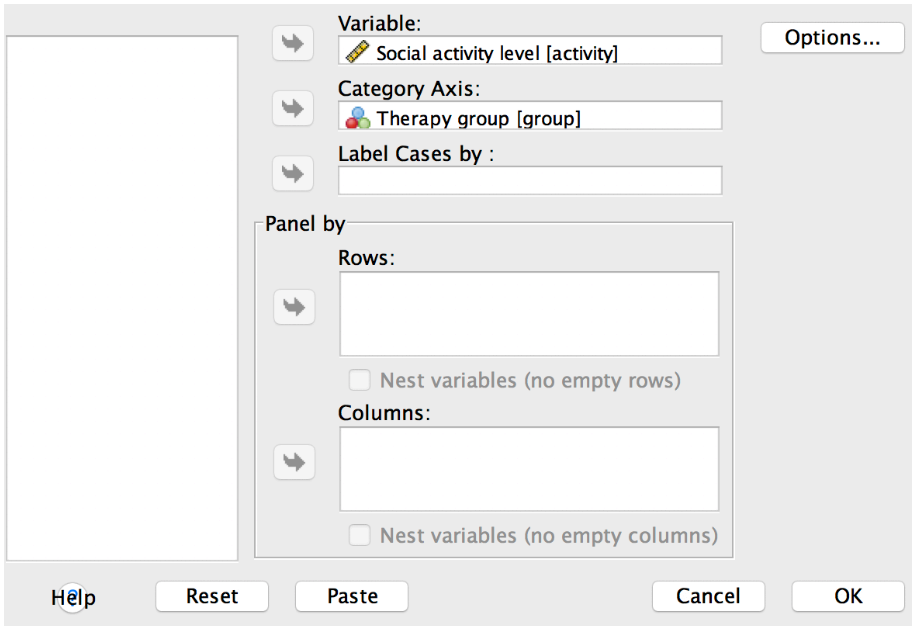


Figure 2: SPSS boxplot definition dialogue

ratings within each group by going to *Graphs* > *Legacy* > *Boxplot*. Make sure that your output looks like Figure 3.

SPSS syntax:

```
EXAMINE VARIABLES=activity BY group
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL.
```

### 5.5 Step Four: Set up the ANOVA

We can see that there are differences in activity between the groups. We're more interested in whether these differences are true. In other words, do the data better fit a null distribution (of no difference) or an alternative distribution (where the effect is true)? The Analysis of Variance can tell us this.

- Like any statistical test, the ANOVA requires certain condi-

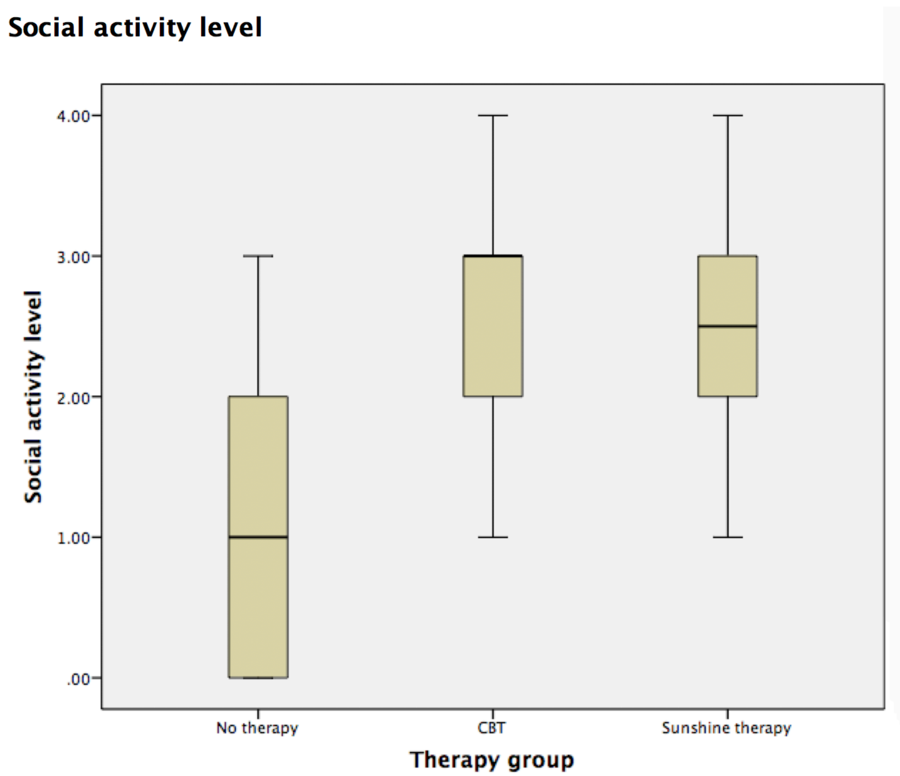


Figure 3: Social activity level by therapy group

tions to be in place. We'll talk more about these later. Right now, I want you to experience producing the ANOVA; we'll return again to the important skill of knowing whether or not an ANOVA is appropriate. So, for the time being, we'll focus on checking just one assumption: *the homogeneity of variance*.

- Similarly, to keep things simple, we won't talk about *effect size* for now.

Before you run the ANOVA, read through the following to get an overall sense of how you do it.

- First, you'll go to *Analyze > Compare means > One-way ANOVA*, then put the dependent variable into the 'dependent' box and the independent variable into the 'factor' box (Figure 4)

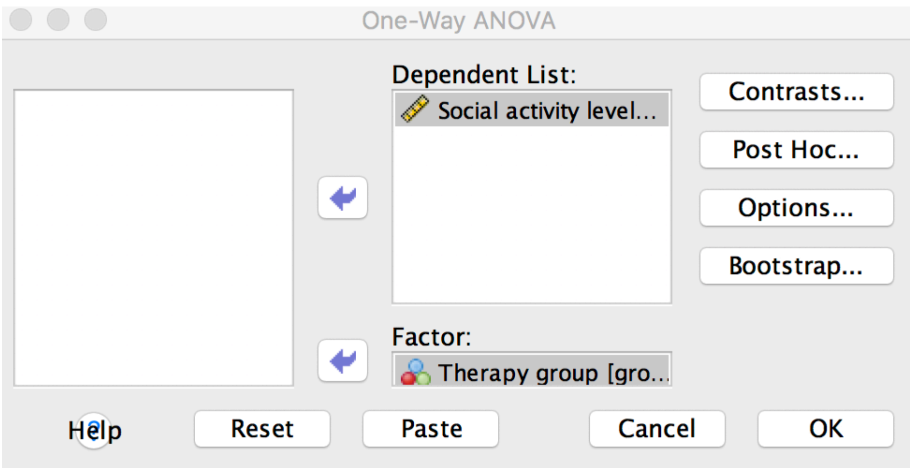


Figure 4: One-way ANOVA main dialogue

- To see exactly where the differences lie, if there are any, between the groups are you need to tell SPSS to carry out some *post hoc* tests. So you'll click on *post hoc* and select *Tukey* (Figure 5), then click *continue*.
- To ensure that we have satisfied the homogeneity of variance assumption, you'll click on *Options* and select *homogeneity of variance test* (Figure 6).
- Then you'll click on *continue* and *OK*.

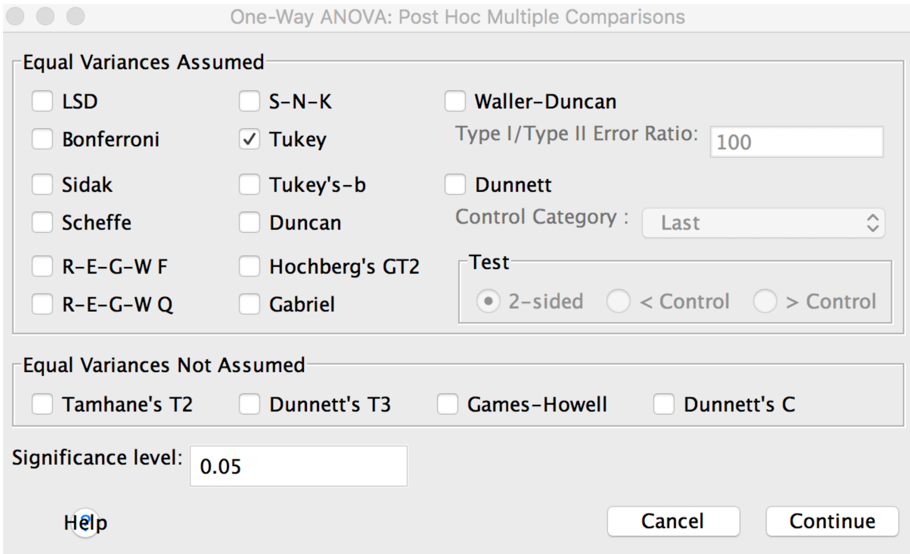


Figure 5: One-way ANOVA post hoc test dialogue

4. Run the ANOVA according to the instructions above.

That's a lot of clicking. Remember that you can click *paste* and have SPSS produce the 'syntax' for running the ANOVA as you've just configured it. If you want to run it again with different options or variables, this is often the more efficient way of making changes.

For completeness, the SPSS syntax is:

```
ONEWAY activity BY group
  /STATISTICS HOMOGENEITY
  /MISSING ANALYSIS
  /POSTHOC=TUKEY ALPHA(0.05).
```

## 5.6 Step Five: Interpret the Output

You should get the same output as I have below. Let's see first of all whether we have satisfied the assumption of homogeneity of variance. The first table in the output, Figure 7, compares the variance within each group against the others. If Levene's test is significant then, just like with T-tests, the assumption is violated and the result of

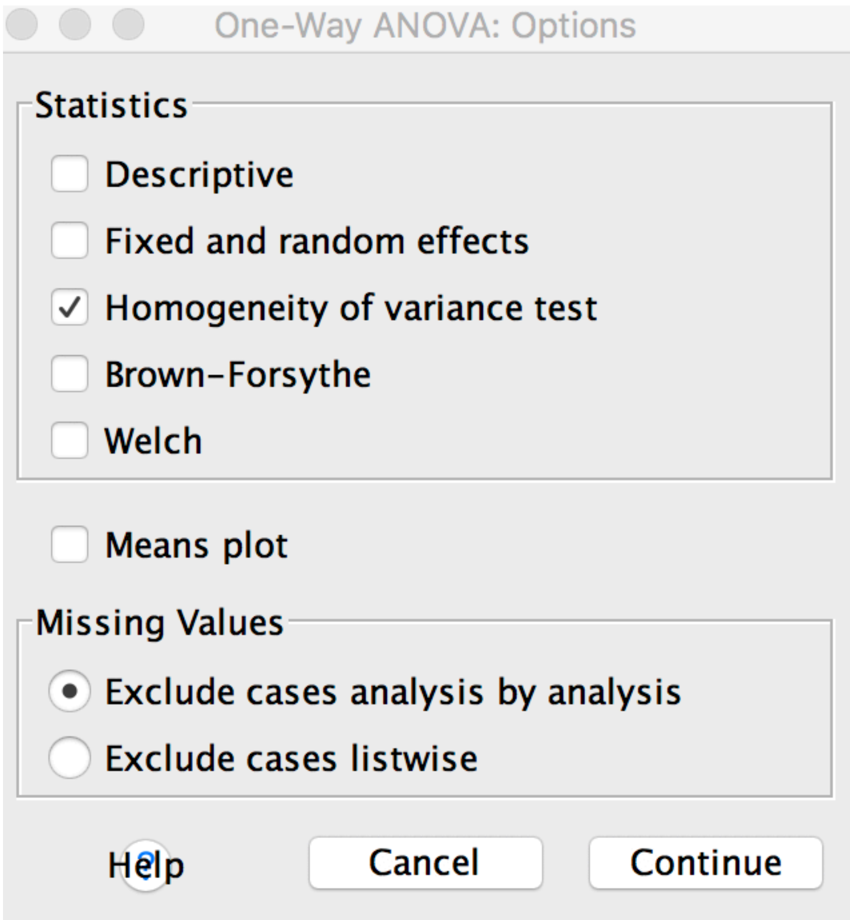


Figure 6: One-way ANOVA options dialogue

the ANOVA may not be reliable. If it is non-significant, then the assumption is met and the result of the ANOVA should be reliable.

**Test of Homogeneity of Variances**

Social activity level

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| .136 | 2 | 27 | .873 |

Figure 7: Output—Homogeneity of Variance

2. Have we met the homogeneity of variance assumption? Explain why or why not.

We have indeed met it because Levene's test returns a $p$ value of .873. This indicates that the variances do not differ significantly between groups.

The next table on the output, the 'ANOVA' table shows us whether the difference between the groups is statistically significant or not. Have a look at your own table (which should resemble Figure 8) and answer the next question in your Journal.

**ANOVA**

Social activity level

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 18.600 | 2 | 9.300 | 10.419 | .000 |
| Within Groups | 24.100 | 27 | .893 | | |
| Total | 42.700 | 29 | | | |

Figure 8: Output—ANOVA

3. Is there a significant effect of the type of therapy a person receives on their subsequent activity levels? Write out your interpretation in plain English and report the ANOVA results in APA style.

- Be sure to include the F ratio itself, degrees of freedom for between and within groups, mean squared error, and the significance.

Yes, there is a significant effect of group, $F(2,\ 27) = 10.419$, $MSE = 0.89$, $p < .001$.

### 5.7 Follow-up Comparisons

The final table in the output, the 'Multiple Comparisons' table (Figure 9), tells us the result of the *post hoc* comparisons.

Post hoc comparisons can help us determine which of the groups differ from one another. This is important because the ANOVA tells us only that there is a difference *somewhere* between the groups (i.e. between at least two). Post hoc paired comparisons look more deeply into the groups.

**Multiple Comparisons**

Dependent Variable: Social activity level
Tukey HSD

| (I) Therapy group | (J) Therapy group | Mean Difference (I–J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| No therapy | CBT | -1.80000* | .42251 | .001 | -2.8476 | -.7524 |
| | Sunshine therapy | -1.50000* | .42251 | .004 | -2.5476 | -.4524 |
| CBT | No therapy | 1.80000* | .42251 | .001 | .7524 | 2.8476 |
| | Sunshine therapy | .30000 | .42251 | .760 | -.7476 | 1.3476 |
| Sunshine therapy | No therapy | 1.50000* | .42251 | .004 | .4524 | 2.5476 |
| | CBT | -.30000 | .42251 | .760 | -1.3476 | .7476 |

*. The mean difference is significant at the 0.05 level.

Figure 9: Output—Post Hoc Comparisons

4. What conclusions can you draw from the *post hoc* tests?

- No therapy vs. CBT groups are significantly different at $p < .05$. Judging by the means, CBT leads to higher activity than no therapy.
- No therapy vs. Sunshine therapy groups are significantly different at $p < .05$. The means suggest, likewise, that Sunshine therapy leads to higher activity.
- CBT vs. Sunshine therapy are not, however, significantly different from one another. So our sample suggests these are equally effective in terms of their impact on social activity.

- Family-wise error is the problem of an increasing false positive rate as you perform multiple comparisons.

5. Why don't we need to make a family-wise error correction for the post-hoc tests?

Such tests are already conservative, i.e. have weaker statistical power, than planned comparisons, which means that they are corrected for the family-wise error rate.

# 6 Within-Groups ANOVA

We'll continue now with a one-way within-groups ANOVA using SPSS, and once again we will interpret the results.

- Remember, *one-way* means that the ANOVA has one 'factor', which translates as 'basis on which we have created groups'. Typically, it is the thing we have manipulated.
- This is a *within* or *repeated* ANOVA because the people in the groups are the same. In other words, the group data are not correlated. Because of this correlation, the ANOVA needs to account for the correlation by making an ajustment.

Download the complete SPSS syntax

Download the complete SPSS output

## 6.1 Our Scenario

> Does alcohol affect driving ability? A researcher interested in answering this question tested 10 people on a driving test under 3 conditions (no alcohol, one pint, and two pints) and counted up the number of errors they made.

## 6.2 Step One: Obtain the Data

Open Driving errors after alcohol. Note that you have three columns: 'control', 'onePint', and 'twoPints'.

- Why are the data now split across three columns? The answer lies with SPSS. It prefers to have people in rows. Earlier, in the between-groups example, each person was uniquely assigned to a group, so their score had a particular group code (no therapy, CBT, and sunshine). Now, in our within-groups example, each person has contributed to each group. In other words, they have been tested while sober, after one pint, and after two pints.

### 6.3 Step Two: Run the Descriptive Statistics

5. As before, we need to look at the means to get a sense of our data. Go to *Analyze > Descriptive Statistics > Descriptives...* and make sure all of the variables are transferred to the box marked *Variable(s)*. Click *OK*.
6. What are the mean number of driving errors made by participants in each of the three conditions?

- *No alcohol*: 1.40
- *One pint*: 6.50
- *Two pints*: 6.80

---

SPSS Syntax:

```
DESCRIPTIVES VARIABLES=control onePint twoPints
  /STATISTICS=MEAN STDDEV MIN MAX.
```

### 6.4 Step Three: Get a Useful Picture of the Means

For the data on therapy, we created boxplots that used a grouping variable (see Figure 1). Now we'll simply create boxplots for each variable (i.e. each condition).

You'll start by going to *Graphs > Legacy Dialogues > Boxplots*. Make sure that *Summaries of separate variables* are selected, like Figure 10.

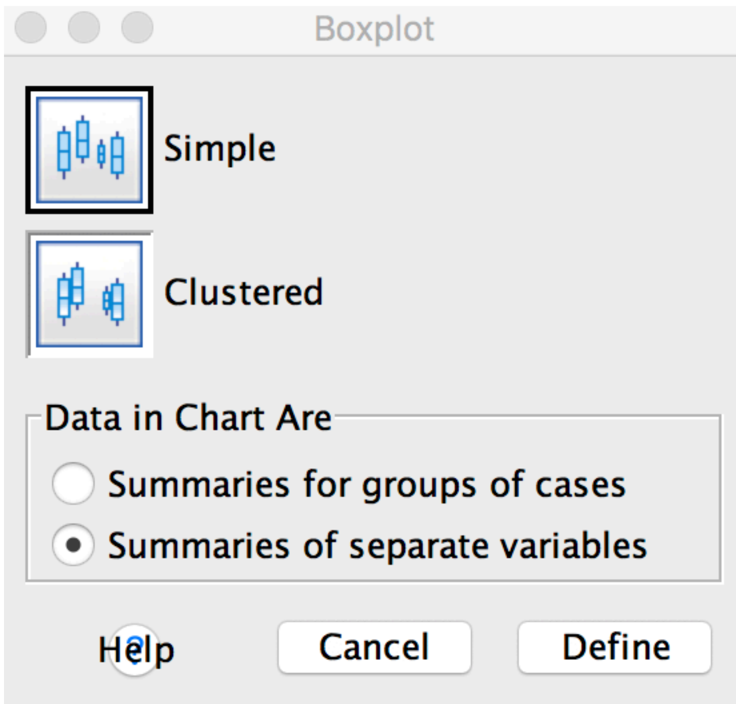

Figure 10: SPSS boxplot dialogue

When you've clicked *OK*, you can specify the variables of interest (all of them, in this case) in the *Boxes Represent* box. See Figure 11.

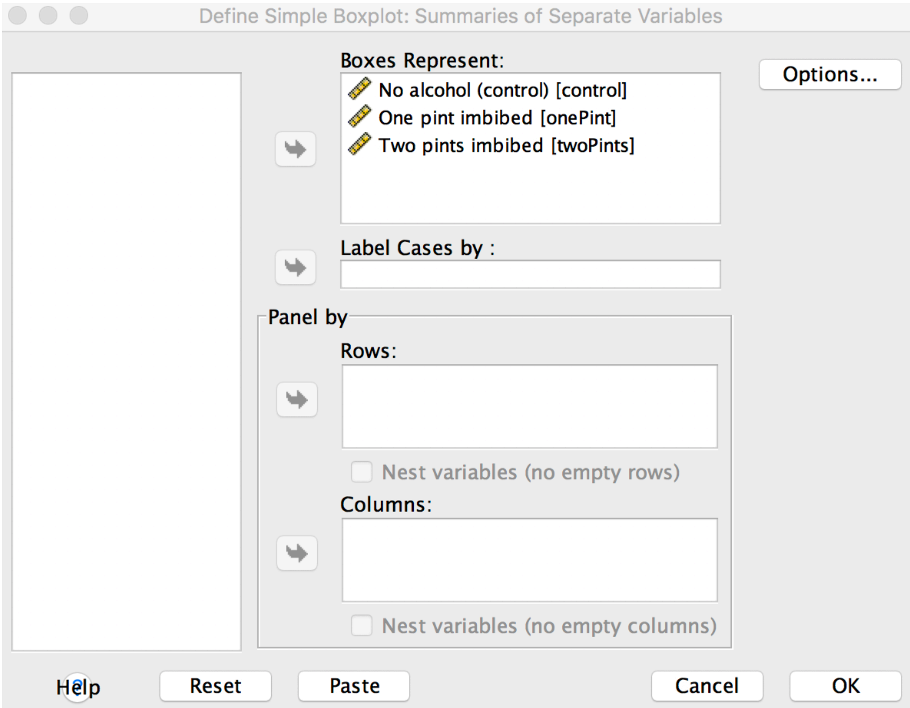


Figure 11: SPSS boxplot definition dialogue

6. Create boxplots for the groups (no alcohol, one pint and two pints) by going to *Graphs* > *Legacy* > *Boxplot*. Make sure that it looks like Figure 12.

SPSS syntax:

```
EXAMINE VARIABLES=control onePint twoPints
  /COMPARE VARIABLE
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL
  /MISSING=LISTWISE.
```

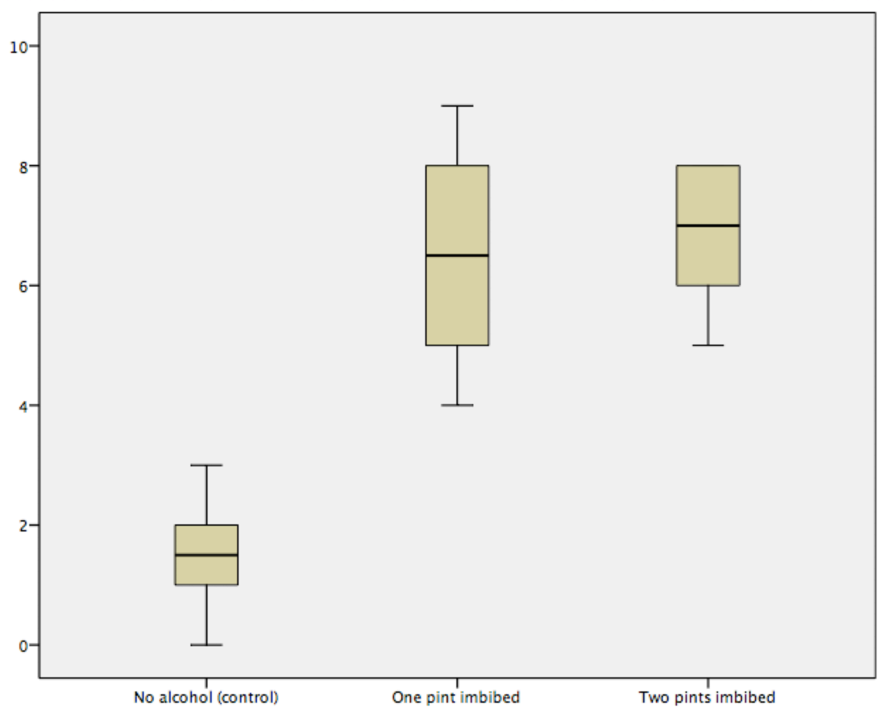


Figure 12: Number of errors by alcohol group

### 6.5 Step Four: Set up the ANOVA

As before, we can see that there are differences in activity between the groups, but these might superficial sample differences. We're more interested in whether these differences are true. In other words, do the data better fit a null distribution (of no difference) or an alternative distribution (where the effect is true)? The Analysis of Variance can tell us this.

- Again, we'll not concern ourselves with some of the prerequisites that need to be true before it is appropriate to run a repeated measures ANOVA, with the exception of one thing: the sphericity assumption.

Before you run the ANOVA, read through the following to get an overall sense of how you do it.

- First, you'll go to *Analyze > General Linear Model > Repeated Measures*.
- A box like Figure 13 will appear where you have to tell SPSS what the repeated measures factor is and how many levels (conditions) it contains. In this study there is only one factor, 'drink', and there are three levels (no alcohol, one pint, and two pints). So enter the factor name (such as 'group' in the *Within-Groups Factor Name* box, and enter its levels (3), in the *Number of Levels* box. Then click *add*.

Click the arrow to pass each of the conditions over into the middle box so that it looks like Figure 14

Then you'll click *continue* and *OK*.

7. Run the ANOVA according to the instructions above.

SPSS syntax:

```
GLM control onePint twoPints
  /WSFACTOR=group 3 Polynomial
  /METHOD=SSTYPE(3)
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=group.
```

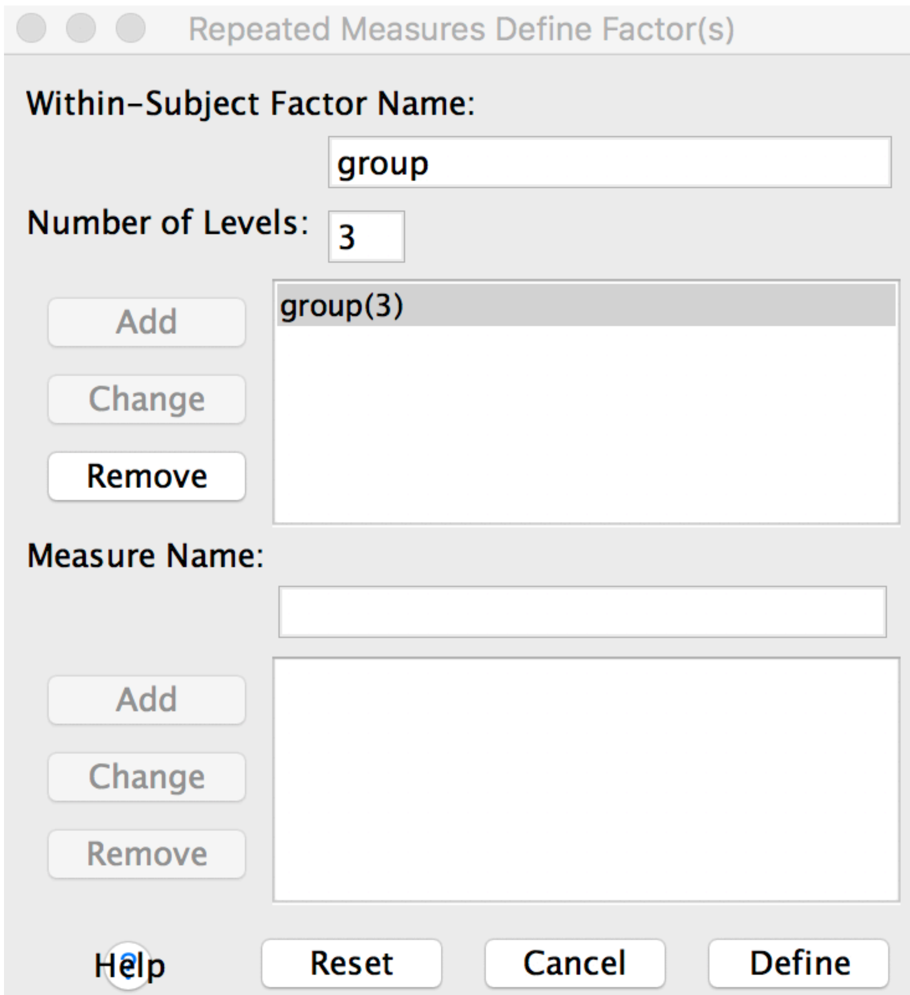


Figure 13: One-way within-groups ANOVA factor definitions

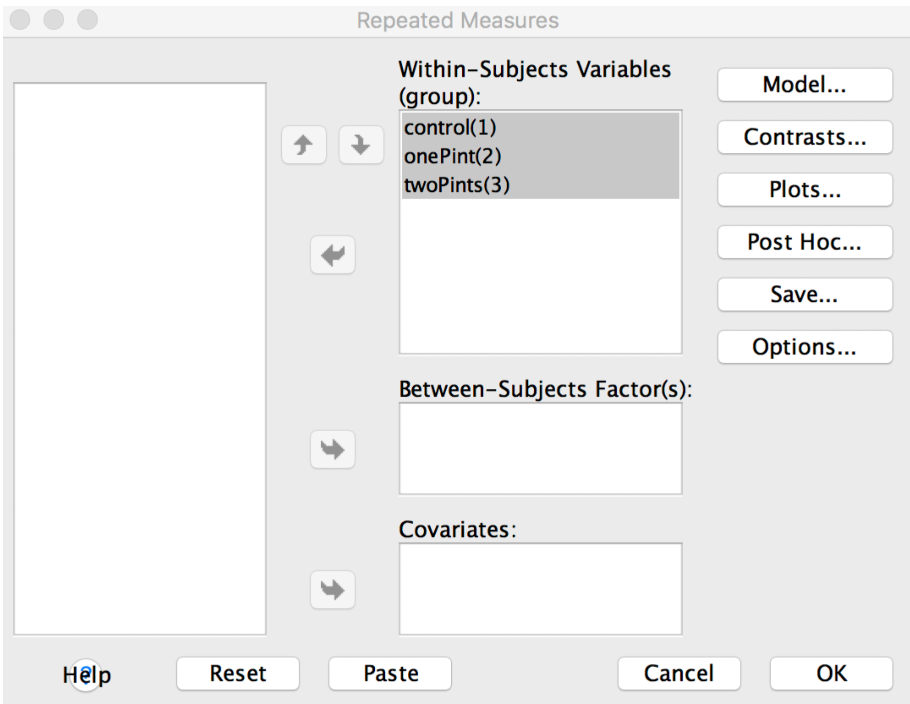


Figure 14: One-way within-groups ANOVA variables entered

## 6.6 Step Five: Interpret the Output

You should get the same output as I have here. Let's see what it tells us. We can ignore the *Multivariate Tests* table (Figure 15)

**Multivariate Tests[a]**

| Effect | | Value | F | Hypothesis df | Error df | Sig. |
|---|---|---|---|---|---|---|
| group | Pillai's Trace | .980 | 196.187[b] | 2.000 | 8.000 | .000 |
| | Wilks' Lambda | .020 | 196.187[b] | 2.000 | 8.000 | .000 |
| | Hotelling's Trace | 49.047 | 196.187[b] | 2.000 | 8.000 | .000 |
| | Roy's Largest Root | 49.047 | 196.187[b] | 2.000 | 8.000 | .000 |

a. Design: Intercept
Within Subjects Design: group

b. Exact statistic

Figure 15: Output—Multivariate Tests

The table in Figure 16, however, is much more important. *Mauchly's test of sphericity* is the repeated measures equivalent of Levene's test for homogeneity of variance. That means we will check to see if we have violated the assumption of equal variances of the differences between levels. See Field (2009).

8. Check the significance. If it *is* significant, then we have violated the assumption and may not to rely on the result of the ANOVA without adjustment.

**Mauchly's Test of Sphericity[a]**

Measure: MEASURE_1

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon[b] Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
|---|---|---|---|---|---|---|---|
| group | .497 | 5.590 | 2 | .061 | .665 | .737 | .500 |

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: group

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Figure 16: Output—Mauchley's Test

7. Have we met the sphericity assumption? Explain with regards to the statistic in the *Mauchly's Test of Sphericity* table.

Yes, we have met the assumption between Mauchly's test was not significant.

Depending on the result of Mauchly's test, we will decide which sub-row of data to look at on the next table, the *Tests of within-subjects effects* (Figure 17).

- If Mauchly's test was non-significant, we can assume sphericity, and we look at sub-row labelled 'Sphericity assumed'.
- If the test was significant, we cannot assume sphericity, and must look at one of the other rows. Each row is a corrected result based on a slightly different formula. There are lots of complicated discussions about which one to use, but if you do not want to go into all the complications, Girden (1992) recommends that when the estimate of sphericity is greater than .75 the Huynh-Feldt correction should be used; otherwise, the Greenhouse-Geisser correction should be used. For more information, see Field (2009).

**Tests of Within-Subjects Effects**

Measure: MEASURE_1

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| group | Sphericity Assumed | 184.200 | 2 | 92.100 | 109.546 | .000 |
| | Greenhouse-Geisser | 184.200 | 1.331 | 138.408 | 109.546 | .000 |
| | Huynh-Feldt | 184.200 | 1.475 | 124.921 | 109.546 | .000 |
| | Lower-bound | 184.200 | 1.000 | 184.200 | 109.546 | .000 |
| Error(group) | Sphericity Assumed | 15.133 | 18 | .841 | | |
| | Greenhouse-Geisser | 15.133 | 11.978 | 1.263 | | |
| | Huynh-Feldt | 15.133 | 13.271 | 1.140 | | |
| | Lower-bound | 15.133 | 9.000 | 1.681 | | |

Figure 17: Output—Tests of Within-Groups Effects

8. Is there a significant main effect of alcohol on driving ability? Write a sentence in this box to describe the finding and write out the result of the ANOVA in APA style.

The main effect of alcohol was significant, $F(2,18) = 109.55$, $MSE = .84$, $p < .001$. This means that the amount of errors participants made depended on how much alcohol they had drunk.

### 6.7 Follow-up Comparisons

Since the effect of alcohol on driving ability was significant, we need to do some follow-up analyses.

9. Do post-hoc tests on the data by carrying out three paired-samples T-tests comparing the three conditions (*Analyze > Compare Means > Paired Samples T-test*)

- T-test 1: no alcohol v one pint
- T-test 2: no alcohol v two pints
- T-test 3: one pint v two pints

SPSS syntax:

```
T-TEST PAIRS=control control onePint
  WITH onePint twoPints twoPints (PAIRED)
  /CRITERIA=CI(.9500)
  /MISSING=ANALYSIS.
```

9. What are the results of these T-tests? Report each in APA format and provide a verbal description of what the results mean.

- T-test 1: no alcohol v one pint: $t(9) = 9.70$, $p < .001$, 95% CI [-6.29, -3.91]
- T-test 2: no alcohol v two pints: $t(9) = 20.25$, $p < .001$, 95% CI [-6.00, -4.80]
- T-test 3: one pint v two pints: $t(9) = .76$, $p = .47$, 95% CI [-1.20, 0.60]

These results show that drinking one or two pints affected driving ability compared to the no alcohol condition. However, there was no difference in performance between the one versus two pint conditions.

As you know, when carrying out a number of t-tests, we need to control our family-wise error rate.

10. Applying Bonferroni's correction, what would the new significance cut-off be? Does it change the results of the T-test?

$.05 / 3 = .02$

- The new cut-off doesn't change the interpretation of our results. Drinking one or two pints affected driving ability compared to no alcohol but the amount of alcohol consumed did not impact performance.

# 7 Versions

This document is available in standard PDF, simplified layout PDF, standard dark theme PDF, PDF with Open Dyslexic font, large text PDF and spoken format. This document contains hyperlinks to sections within it, external webpages, and email addresses like ian.hocking@canterbury.ac.uk.

# 8 References

Field, A. (2009). *Discovering statistics using SPSS*. London: Sage Publications.