

## 30. *Practical.* Analysis of counts and correlations

This lab focuses on applying the concepts from [Chapter 28](#) and [Chapter 29](#) in Jamovi ([The Jamovi Project, 2022](#)). Exercises in this practical will use the [Chi-squared goodness of fit](#) test, the [Chi-squared test of association](#), and the [correlation coefficient](#). For the chi-square tests, this practical will use a dataset inspired by the doctoral work of Dr Jessica Burrows ([Burrows et al., 2022](#)). This experimental work tested the effects of radiation on bumblebee nectar consumption, carbon dioxide output, and body mass in different bee colonies (Figure 30.1)<sup>1</sup>.



Figure 30.1.: This lab practical focuses on the effects of radiation on bumblebees.

The practical will use the [bumblebee.csv](#) dataset (right click and “Save Link As...”, then save it with the extension ‘.csv’). This dataset includes variables for the radiation level experienced by the bee (radiation), the colony from which the bee came (colony), whether or not the bee survived to the end of the 30 day experiment (survived), the mass of the bee in grams at the beginning of the experiment (mass), the output of carbon dioxide put out by the bee (CO<sub>2</sub>) in micromoles per minute, and the daily volume of nectar consumed by the be in ml (nectar).

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<sup>1</sup>This figure was released into the public domain by [Marco Almbauer](#) on 4 May 2018. Please note that the data in this practical are for educational purposes only. They are not the data that were actually collected by [Burrows et al. \(2022\)](#).

### 30.1. Survival goodness of fit

Suppose that we want to run a simple goodness of fit test to determine whether or not bees are equally likely to survive versus die in the experiment. If this is the case, then we would expect to see the same number of living and dead bees in the dataset. We can use a Chi-square goodness of fit test to answer this question. What are the null and alternative hypotheses for this  $\chi^2$  goodness of fit test?

- $H_0$ : \_\_\_\_\_
- $H_A$ : \_\_\_\_\_

What is the sample size (N) of the dataset?

N: \_\_\_\_\_

Based on this sample size, what are the expected counts for bees that survived and died?

Survived ( $E_{surv}$ ): \_\_\_\_\_

Died ( $E_{died}$ ): \_\_\_\_\_

Next, we can find the observed counts of bees that survived and died. To do this, we need to use the Frequency tables option in Jamovi. We did this once in [Chapter 16](#) for calculating probabilities. As a reminder, to find the counts of bumblebees that survived (Yes) or did not survive (No), we need to go to the Exploration toolbar in Jamovi, then choose 'Descriptives'. Place 'Survival' in the Variables box, then check the box for 'Frequency tables' below. A Frequencies table will appear in the panel on the right. Write down the observed counts of bees that survived and died.

Survived ( $O_{surv}$ ): \_\_\_\_\_

Died ( $O_{died}$ ): \_\_\_\_\_

Try to use the formula in [Chapter 28.2](#) to calculate the  $\chi^2$  test statistic. Here is what it should look like for the two counts in this dataset,

$$\chi^2 = \frac{(O_{surv} - E_{surv})^2}{E_{surv}} + \frac{(O_{died} - E_{died})^2}{E_{died}}.$$

What is the  $\chi^2$  value?

$\chi^2$ : \_\_\_\_\_

There are 2 categories for the survival category (Yes and No). How many degrees of freedom are there?

df: \_\_\_\_\_

Using the  $\chi^2$  and df values, find the approximate p-value using this [interactive application](#).

P: \_\_\_\_\_

Now we can try to use Jamovi to replicate the analysis above. In Jamovi Analyses tab, select 'Frequencies' from the toolbar, then select 'N outcomes'. A new window will open up (Figure 30.2).

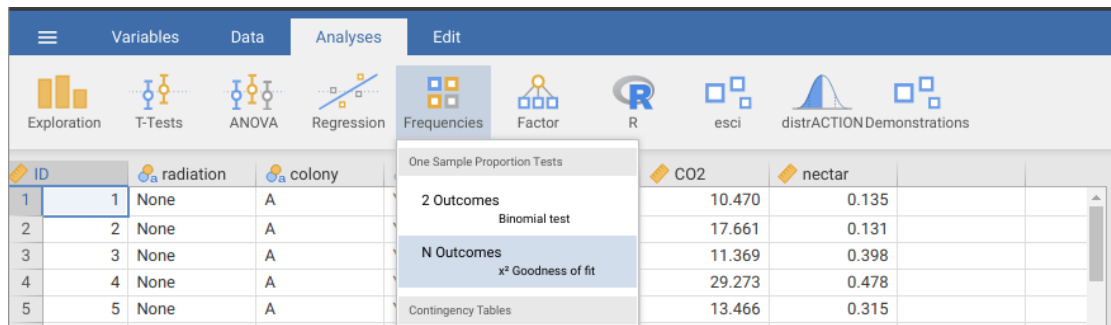


Figure 30.2.: Jamovi toolbar showing the location of the Frequencies options, with the Chi-square goodness of fit test available under a choice called 'N Outcomes' in the pulldown menu.

After selecting the option 'N Outcomes:  $\chi^2$  Goodness of fit', a new window will appear called 'Proportion Test (N Outcomes)'. To run a  $\chi^2$  goodness of fit test on bee survival, move the 'survived' variable in to the 'Variable' box. Leave the Counts box empty (Figure 30.3).

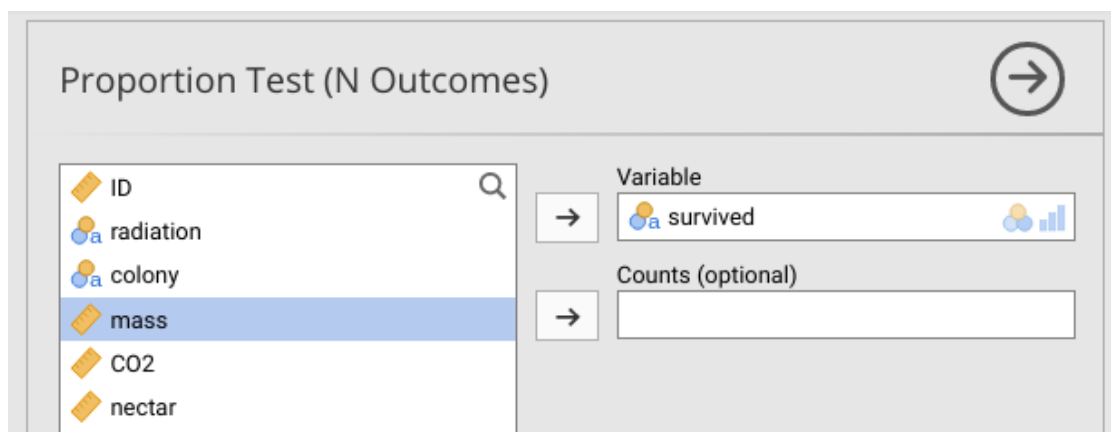


Figure 30.3.: Jamovi interface for running a Chi-square goodness of fit test on bumblebee survival in a dataset.

The  $\chi^2$  Goodness of Fit table will appear in the panel to the right. From this table, we can see the  $\chi^2$  test statistic, degrees of freedom (df), and the p-value (p). Do these values

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match the values that you calculated by hand and with the [interactive application](#)?

Next, we will try another goodness of fit test, but this time to test whether or not bees were taken from all colonies with the same probability.

## 30.2. Colony goodness of fit

Next, suppose that we want to know if bees were sampled from the colonies with the same expected frequency. What are the null and alternative hypotheses in this scenario?

- $H_0$ : \_\_\_\_\_
- $H_A$ : \_\_\_\_\_

How many colonies are there in this dataset?

Colonies: \_\_\_\_\_

Run the  $\chi^2$  goodness of fit test using the same procedure in Jamovi that you used in the previous exercise. What is the output from the Goodness of Fit table?

$\chi^2$ : \_\_\_\_\_

df: \_\_\_\_\_

p: \_\_\_\_\_

From this output, what can you conclude about how bees were taken from the colonies?

Note that the distrACTION module in Jamovi includes a  $\chi^2$  distribution (called ‘x2-Distribution’), which you can use to compute probabilities and quantiles in the same way as we did for previous distributions in the module. Next, we will move on to a  $\chi^2$  test of association between

### 30.3. Chi-Square test of association

Suppose we want to know if there is an association between bee colony and bee survival. We can use a  $\chi^2$  test of association to investigate this question. What are the null and alternative hypotheses for this test of association?

- $H_0$ : \_\_\_\_\_
- $H_A$ : \_\_\_\_\_

To run the  $\chi^2$  test of association, choose ‘Frequencies’ from the Jamovi toolbar (Figure 30.2), but this time select ‘Independent Samples:  $\chi^2$  test of association’ from the pull-down menu. To test for an association between bee colony and survival, place ‘colony’ in the ‘Rows’ box and ‘survived’ in the ‘Columns’ box. Leave the rest of the boxes blank (Figure 30.4).

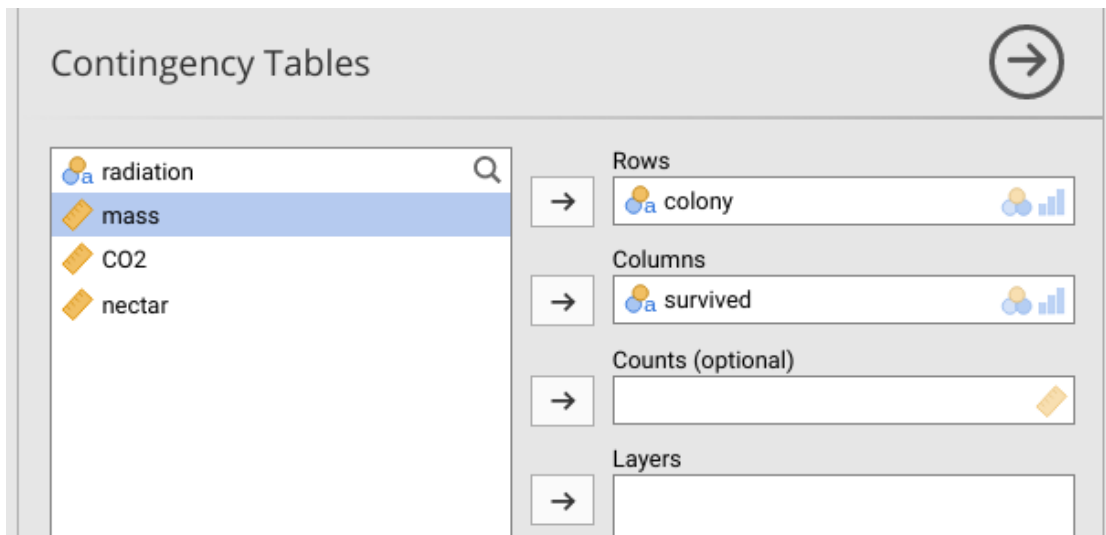


Figure 30.4.: Jamovi interface for running a Chi-square test of association on bumblebee survival versus colony in a dataset.

There is a pulldown called ‘Statistics’ below the Contingency Tables input. Make sure that the  $\chi^2$  checkbox is selected. Output from the  $\chi^2$  test of association will appear in the panel to the right. Report the key statistics in the output table below.

$\chi^2$ : \_\_\_\_\_

df: \_\_\_\_\_

p: \_\_\_\_\_

From these statistics, should you reject or not reject the null hypothesis?

$H_0$ : \_\_\_\_\_

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Note that scrolling down further in the left panel (Contingency Tables) reveals an option for plotting. Have a look at this and create a barplot by checking ‘Bar Plot’ under **Plots**. Note that there are various options for changing bar types (side by side or stacked), y-axis limits (counts versus percentages), and bar groupings (by rows or columns).

Now try running a  $\chi^2$  test of association to see if there is an association between radiation and bee survival (hint, you just need to swap ‘colony’ for ‘radiation’ in the Rows box). What can you conclude from this test? Explain your conclusion as if were reporting the results of the test to someone who was unfamiliar with statistical hypothesis testing.

Lastly, did the order which you placed the two variables matter? What if you switched Rows and Columns? In other words, put ‘survived’ in the Rows box and ‘radiation’ in the columns box. Does this give you the same answer?

Next, we will look at correlations between variables.

#### 30.4. Pearson product moment correlation test

Suppose that we want to test if bumblebee mass at the start of the experiment (mass) is associated with the amount of nectar consumed (nectar). Specifically, we want to know if more massive bees also output less carbon dioxide ( $CO_2$ ). Before running any test, it is a good idea to plot the two variables using a scatterplot. To do this, select the ‘Exploration’ button from the toolbar in Jamovi, but instead of choosing ‘Descriptives’ as usual from the pulldown menu, select ‘Scatterplot’. A new window will open up that allows you to build a scatterplot by selecting the variables that you place on the x-axis and the y-axis. Put mass on the x-axis and nectar on the y-axis, as shown in Figure 30.5.

Notice that the scatterplot appears in the panel on the right. Each point in the scatterplot is a different bee (i.e., row). Just looking at the scatterplot, does it appear as though bee mass and  $CO_2$  output are correlated? Why or why not?

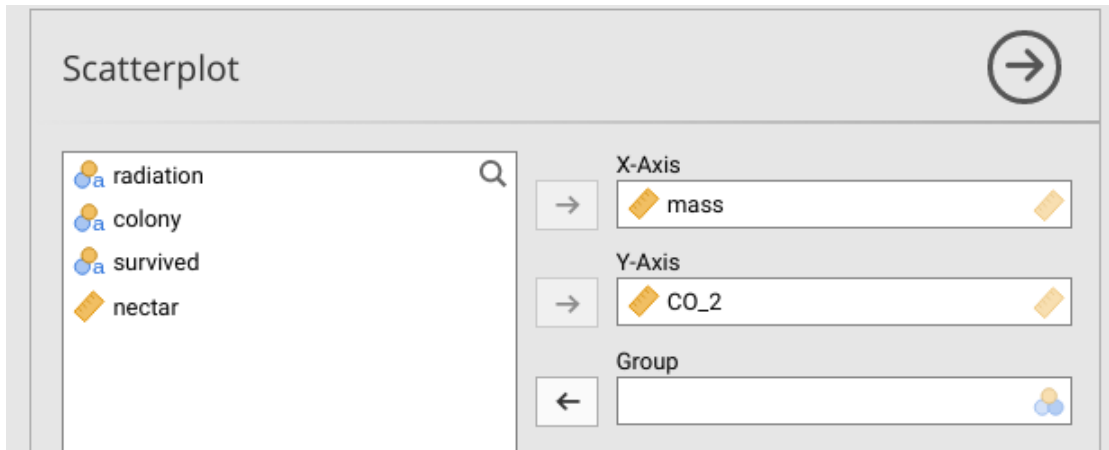


Figure 30.5.: Jamovi interface for building a scatterplot with bumblebee mass on the x-axis and nectar consumption on the y-axis

Note that it is possible to separate points in the scatterplot by group., Try placing ‘survived’ in the box ‘Group’.

Now we can test whether or not bee mass and  $CO_2$  output are negatively correlated. What are the null and alternative hypotheses of this test?

- $H_0$ : \_\_\_\_\_
- $H_A$ : \_\_\_\_\_

Before we test whether or not the correlation coefficient ( $r$ ) is significant, we need to know which correlation coefficient to use. Remember from [Chapter 29.3](#) that a test of the Pearson product moment correlation assumes that the sample  $r$  is normally distributed around the true correlation coefficient. If both of our variables (mass and  $CO_2$ ) are normally distributed, then we can be confident that this assumption will not be violated. But if one or both variables are not normally distributed, then we should consider using the Spearman rank correlation coefficient instead. To test if mass and  $CO_2$  are normally distributed, navigate to the Descriptives panel in Jamovi (where we usually find the summary statistics of variables). Place mass and  $CO_2$  in the ‘Variables’ box, then scroll down and notice that there is a checkbox under **Normality** for ‘Shapiro-Wilk’. Check this box, then find the p-values for the Shapiro-Wilk test of normality in the panel to the right. Write these p-values down below.

Mass P: \_\_\_\_\_

$CO_2$  P: \_\_\_\_\_

Based on these p-values, which type of correlation coefficient should we use to test  $H_0$ , and why?

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To run the correlation coefficient test, choose the button in the Jamovi toolbar called 'Regression', then select the first option 'Correlation Matrix' from the pulldown menu (Figure 30.6).

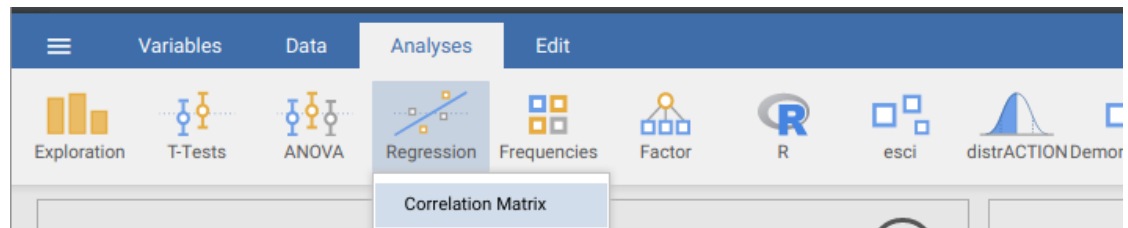


Figure 30.6.: Jamovi toolbar showing the location of the Regression options, with the Correlation Matrix option available in the pulldown menu.

The Correlation Matrix option will pull up a new window in Jamovi (Figure 30.7).

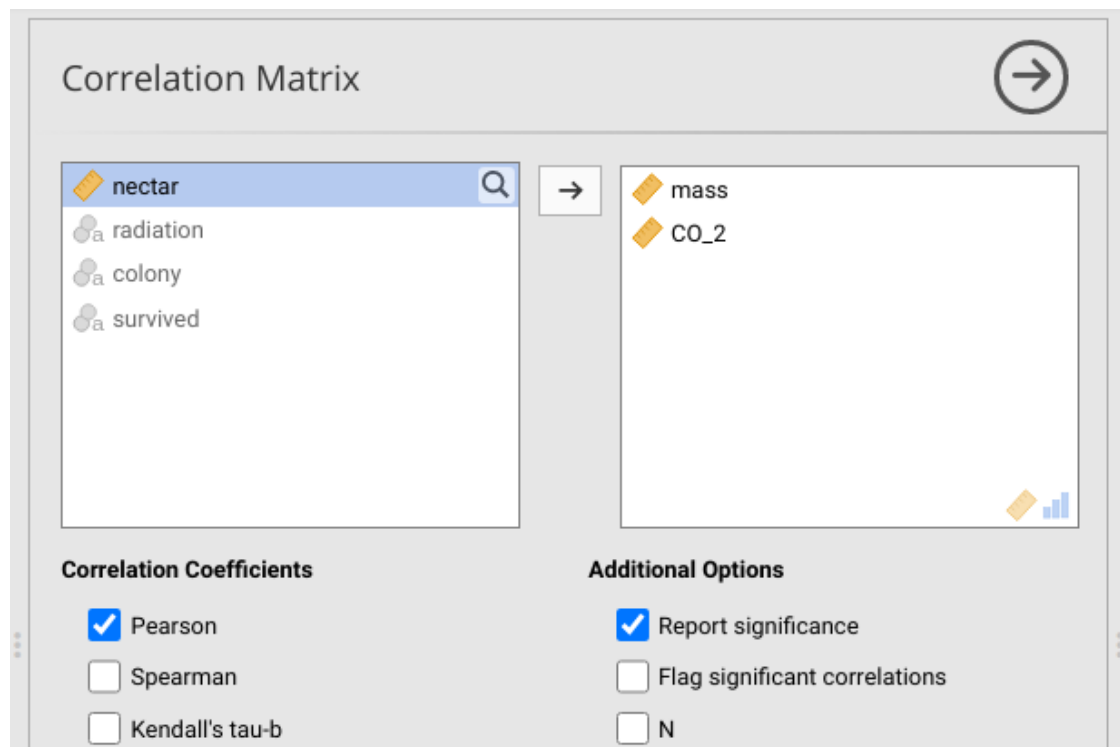


Figure 30.7.: Jamovi interface for testing correlation coefficients.

Notice that the Pearson product moment correlation is selected in the checkbox of Figure 30.7 ('Pearson'). Immediately below this checkbox is a box called 'Spearman', which



would report the Spearman rank correlation coefficient test. Below the **Correlation Coefficients** options, there are options for **Hypothesis**. Remember that we are interested in the alternative hypothesis that mass and  $CO_2$  are negatively correlated, so we should select the radio button ‘Correlated negatively’.

The output of the correlation test appears in the panel on the right in the form of a table called ‘Correlation Matrix’. This table reports both the correlation coefficient (here called “Pearson’s  $r$ ”) and the p-value. Write these values below.

$r$ : \_\_\_\_\_

$P$ : \_\_\_\_\_

Based on this output what should we conclude about the association between bumblebee mass and carbon dioxide output?

Next, we will test the whether or not bee mass is associated with nectar consumption.

## 30.5. Spearman rank correlation test

Next, we will test whether or not bee mass and nectar consumption are correlated. What are the null and alternative hypotheses of this test?

- $H_0$ : \_\_\_\_\_
- $H_A$ : \_\_\_\_\_

Run a Shapiro-Wilk test of normality on each of the two variables, as was done in the previous exercise. Based on the output of these tests, what kind of correlation coefficient should we use for testing the null hypothesis?

Correlation coefficient: \_\_\_\_\_

Test whether or not bee mass and nectar consumption are correlated. What is the correlation coefficient and p-value from this test?

$r$ : \_\_\_\_\_

$P$ : \_\_\_\_\_

Based on these results, do should we reject or not reject the null hypothesis?

$H_0$ : \_\_\_\_\_

Suppose that we had used the Pearson product moment correlation coefficient instead of the Spearman rank correlation coefficient. Would we have made the same conclusion

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about the correlation (or lack thereof) between bee mass and  $CO_2$  output? Why or why not?

If you have sufficient time, move on to the final exercise, which will demonstrate an additional way to run Chi-square tests.

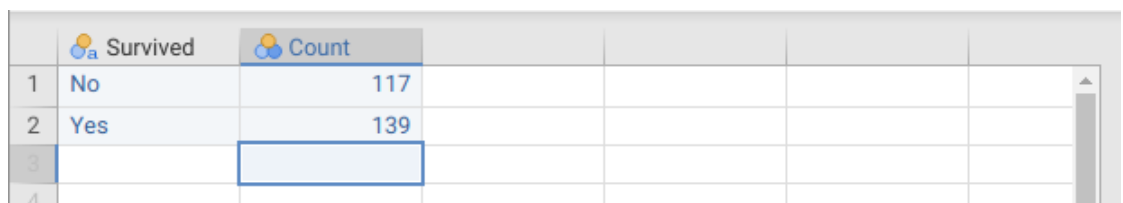
## 30.6. Untidy goodness of fit

In Exercise 30.1, we ran a  $\chi^2$  test using data in a tidy format, in which each row corresponded to a single observation and categorical data were listed over  $N = 256$  rows. For the ‘survived’ variable, this meant 256 rows of ‘Yes’ or ‘No’. But there is a shortcut in Jamovi if we do not have a full tidy dataset. If you know that the dataset included 139 ‘Yes’ counts and 117 ‘No’ counts, you could set up the data as a table of counts (Table 30.1).

Table 30.1.: Counts of bees that did not survive (No) or did survive (Yes) in an experiment involving radiation.

Survived	Count
No	117
Yes	139

Open a new data frame in Jamovi, then recreate the small dataset in Table 30.1. Column names should be ‘Survived’ and ‘Count’, as shown in Figure 30.8.



	Survived	Count				
1	No	117				
2	Yes	139				
3						
4						

Figure 30.8.: Jamovi data frame with a simple organisation of count data.

Next, navigate to the ‘Analyses’ tab and choose ‘N Outcomes’ to do a goodness of fit test. Place ‘Survived’ in the Variable box, then place ‘Count’ in the Counts (optional) box. Notice that you will get the same  $\chi^2$ , df, and p values in the output table as you did in Exercise 30.1

We could do the same for a  $\chi^2$  test of association, although it would be a bit more complicated. To test for an association between radiation and survival, as we did at the end of Exercise 30.3, we would need 3 columns and 8 rows of data (Table 30.2).

Table 30.2.: Counts of bees that did not survive (No) or did survive (Yes) for different levels of radiation.

Survived	Radiation	Count
No	None	12
Yes	Low	52
No	Medium	29
Yes	High	35
No	None	39
Yes	Low	25
No	Medium	37
Yes	High	27

If we put Table 30.2 into Jamovi, we can run a  $\chi^2$  test of association by navigating to the ‘Frequencies’ button in the Jamovi toolbar and selecting ‘Independent Samples:  $\chi^2$  test of association’ from the pulldown. In the Contingency Tables input panel, we can put ‘Survived’ in the Rows box, ‘Radiation’ in the Columns box, then place ‘Count’ in the Counts (optional) box. The panel on the right will give us the output of the  $\chi^2$  test of association.