Statistics with jamovi – Overarching handout

Each inferential statistic that we learn about in this course has the same basic process for testing hypotheses: (1) look at your data, (2) check assumptions, (3) perform the test, and (4) interpret results. There is some test-specific information you need to know (e.g., the dependent t-test doesn't have the assumption of homogeneity of variance) but otherwise *the steps and processes are always the same.*

This handout summarizes everything covered in this course. It also aligns with both (a) how each of the inferential statistics chapters of the textbook is written and (b) the practice activities and homework assignments.

STEP 1: LOOK AT THE DATA

Always check to make sure you understand what the independent variable (IV) and dependent variable (DV) are in your research question! You should only examine those variables in your analysis. You should also understand whether the design is a between- or within-subjects design and whether the variables are continuous or categorical. All of those decisions determine which inferential statistic you'll perform (see Chapter 6: Inferential Statistics).

PROVIDE DESCRIPTIVE STATISTICS

Regardless of what statistical test we are performing, we want to look at the data. This includes visual examinations of the data and descriptive statistics. See the table below for how you should describe your data depending on the variables of your dataset.

Variable(s)	Example tests	Visualization	Descriptive statistics
Continuous	Correlation, regression	Histogram with a density curve OR the boxplot with the violin curve and data	Mean, median, mode, skew, kurtosis, Shapiro-Wilk's test, etc.
Categorical	Chi-square	Bar plot	Frequency table
Continuous split by categorical	t-tests, ANOVAs	Boxplot with the violin curve and data	Mean, median, mode, skew, kurtosis, etc. split by categorical

You are looking to make sure you understand the central tendency (i.e., mean, median, mode) and dispersion (i.e., range, variance, standard deviation). We partly use this to understand whether we meet the assumption of normality for parametric statistics, but also to determine that our data isn't messed up (e.g., an accidently "99" on a 1-10 point scale). You look at this data to make sure you understand it and that it's prepared for data analysis.

Read Chapter 2: Statistics Foundations to learn more about descriptive statistics. Read Chapter 3: Overview of jamovi for how to get descriptive statistics and how to clean data.

DESCRIBE YOUR HYPOTHESES

When we do inferential statistics, we are performing *null hypothesis significance testing (NHST)*. Therefore, we have to setup both our null and alternative hypotheses.

Null vs alternative: The null hypothesis is almost always that there is no effect. The alternative is always that there is some effect, but it might be a directional hypothesis. Both the null and alternative must be mutually exclusive (i.e., any potential result only supports only the null OR the alternative) and exhaustive (i.e., all possible results are captured in the hypotheses).

Directional hypotheses: The alternative hypothesis can be directional meaning it's one-tailed (e.g., one group is bigger than another) or non-directional meaning it's two-tailed (e.g., you think there is a difference but you're not sure which group may be bigger).

Be specific! Your hypotheses must include the variable(s) in the hypotheses. For example, in the independent t-test it must be clear what is your dependent variable and what is your independent variable that you are analyzing.

STEP 2: CHECK ASSUMPTIONS

Note that sometimes you need to perform the test in jamovi (step 3) to check assumptions (step 2). Yes, this is quite confusing! However, the reason why I have you do this first is because you need to know which assumptions you meet to determine which version of the test you perform.

Most inferential statistics we cover in this course require your dependent variable to be continuous and the data to be independent. This requires understanding your data and research design.

Otherwise, there are two assumptions that we are typically checking for: normality and homogeneity of variance.

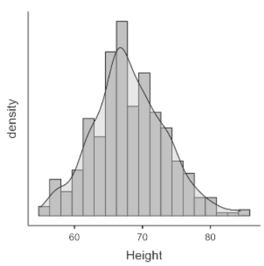
ASSUMPTION OF NORMAL DISTRIBUTION

Parametric statistics are called that because they require a parametric (i.e., normal) distribution. There are four ways to test for whether the DV is normally distributed. Unless in special circumstances you should test normality using all four methods below!

Note that you are only testing if the DV is normally distributed. Do not split by IV!!!

1. Visualize the distribution

Exploration → Descriptives. Select Histogram & Density under Plots. If the line looks like a bell-shaped curve (like in the example), then you meet the assumption of normality.



2. Skew & kurtosis z-scores

Exploration → Descriptives. Select Skewness and Kurtosis under Statistics. Divide the values by their Std. errors (e.g., skew z-score is .23/.12 = 1.92, kurtosis z-score is .11/.24 = .46). If the z-scores > |1.96| then you do not meet the assumption of normality; If the z-scores < |1.96| then you do meet the assumption of normality. In the example, we meet normality via both the skew and kurtosis.

	Height
Skewness	0.23
Std. error skewness	0.12
Kurtosis	0.11
Std. error kurtosis	0.24

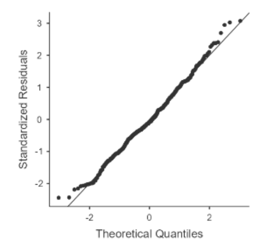
3. Shapiro-Wilk's test

Exploration → Descriptives. Select Shapiro-Wilk under Statistics **OR** In the inferential statistic select Normality test. Significant p-value ($p < .05$) means you do not meet the assumption of normality; a non-significant p-value ($p > .05$, like in the example) means you do meet the assumption of normality.

	Height
N	408
Shapiro-Wilk W	0.99
Shapiro-Wilk p	0.070

4. Q-Q plot

Exploration → Descriptives. Select Q-Q under Plots **OR** In the inferential statistic select Q-Q plot. If the dots significantly deviate from the line then you do not meet the assumption. If the dots seem to fall along the diagonal line (like in the example to the right) then you do meet the assumption of normality



HOW TESTING NORMALITY VARIES ACROSS TESTS

Statistic	How to test	If normality is violated
Independent t-test	Test the normality of the continuous DV	Perform the Mann-Whitney U
Dependent t-test	Calculate the difference score between the paired measurements of the DV and then test normality of that difference score variable.	Perform the Wilcoxon rank test
One-way ANOVA	Test the normality of the continuous DV	Perform the Kruskal-Wallis test
Repeated measures ANOVA	Currently you can only test this in jamovi using the Q-Q plot in the repeated measures ANOVA analysis.	Perform Friedman's test
Correlation	Test the normality of both continuous variables	Perform Spearman's rank correlation
Regression	Technically you are testing the normality of the residuals, so you need to test this using the linear regression analysis in jamovi using the "Normality test" and "Q-Q plot of residuals" assumption checks.	*In this class, just proceed with the regression & note failing to meet the assumption in your write-up.*

The chi-square is not included because it's not a parametric test and therefore does not have the assumption of normality.

Statistics with jamovi – Overarching handout

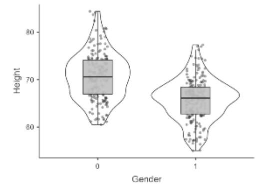
ASSUMPTION OF HOMOGENEITY OF VARIANCE

If you have a categorical IV with a continuous DV then you also have the assumption of homogeneity of variance (i.e., the variances between groups are equal). There are three ways to test for homogeneity of variance (note: one is a special case only used in the repeated measures ANOVA).

In this case, you are looking at the continuous DV split by the categorical IV because you want to see if the variance in the DV is different among the groups of the IV!

1 & 2. Examine variance between groups

Exploration → Descriptives. Select Box plot, Violin, Data (Jittered) under Plots. Also, select Variance under Statistics to get the actual variances between groups. Look at the range of the plots from top to bottom and compare between groups; also compare the variance values. If they are roughly the same, then you meet the assumption of homogeneity of variance.



3. Levene's test

In the independent t-test and one-way ANOVA inferential statistics in jamovi select Homogeneity test. A significant p-value ($p < .05$) means you do not meet the assumption of homogeneity of variance whereas a non-significant p-value ($p > .05$) means you do meet the assumption of homogeneity of variance.

Homogeneity of Variances Test (Levene's)

	F	df	df2	p
Height	3.26	1	397	0.072

Repeated Measures ANOVA. Mauchly's test of sphericity*

This is only performed with a repeated measures ANOVA (or any factorial design with a repeated measures component). In the repeated measures ANOVA inferential statistic in jamovi select Sphericity tests. Significant p-value ($p < .05$) means you do not meet the assumption of sphericity; a non-significant p-value ($p > .05$) means you do meet the assumption of sphericity.

Tests of Sphericity

	Mauchly's W	p	Greenhouse-Geisser ε	Huynh-Feldt ε
RM Factor 1	0.95	< .001	0.95	0.95

* Mauchly's test of sphericity is only used for testing homogeneity of variance in the repeated measures ANOVA and its variants.

HOW TESTING HOMOGENEITY OF VARIANCE VARIES ACROSS TESTS

Statistic	How to test	If homogeneity is violated*
Independent t-test	Examine variances & Levene's test	Perform Welch's t-test
Dependent t-test	N/A	N/A
One-way ANOVA	Examine variances & Levene's test	Perform Welch's F-test
Repeated measures ANOVA	Mauchly's test of sphericity	Perform Greenhouse-Geisser correction if that value is > .75; otherwise, Huynh-Feldt correction

The chi-square, correlation, and regression are not included here because they do not have both a categorical IV and continuous DV.

** Note that if you do not meet normality then no matter what you use the test indicated under the "If normality is violated" box above.*

OTHER ASSUMPTIONS ACROSS TESTS

Chi-square goodness of fit test: You must have expected frequencies greater than 5. Select the "Expected counts" box and examine the data of expected counts in your output. If you fail to meet this assumption, you probably don't have enough data for the analysis.

Chi-square test of independence:

1. You must have expected frequencies greater than 5. Select the "Expected counts" box and examine the data of expected counts in your output. If you fail to meet this assumption, perform Fisher's exact test.
2. Data must be independent, meaning it's a between-subjects design. If you fail to meet this assumption, perform McNemar's test.

Correlation: There is an added assumption that the relationship among the continuous variables is linear. This requires examining the scatterplot and looking to see whether the dots seem to fall generally in a line. If you fail to meet this assumption, perform Spearman's test.

Factorial ANOVA: For the independent factorial ANOVA test it like you would the one-way ANOVA. For the repeated measures factorial ANOVA or mixed factorial ANOVA test assumptions like you would the repeated measures ANOVA.

Regression:
In this class, if you violate any of these assumptions just mention you violated this assumption in your write-up and proceed anyway. The book briefly discusses what to do if you violate some of the assumptions, but we won't do them.

1. No outliers: There shouldn't be any multivariate outliers. Perform Cook's distance. Max values greater than 1 indicate a multivariate outlier.
2. Normality of the residuals: This is like normality from above, but only with our residuals and not the raw data. It is tested and interpreted using Shapiro-Wilk's test and the Q-Q plot like you did with other statistics.
3. Linearity and homoscedasticity: Examine the first residuals plot. It should look like a random blob of points. If the points curve, you violate linearity; if the points seem to "funnel," then you violate homoscedasticity.
4. Independence of residuals: It's not independence of data per se but independence of residuals. This is tested using Durbin-Watson test for autocorrelation. You want the DW statistic to be close to 2 and not statistically significant to meet this assumption.
5. No multicollinearity: You don't want multiple variables to be highly correlated. This is tested using collinearity statistics. To meet the assumption you want VIF values 10 or lower and tolerance values .2 or greater.

STEP 3: PERFORM THE TEST

This is where the textbook is most helpful to know which boxes to check and how to setup jamovi to get all the relevant output you need to be able to do the next step. Go to the textbook for the inferential statistic you are performing and go to the Perform the test section and follow the steps. *Note that you perform the test based on which assumptions were met and, in some cases, based on whether you have a directional alternative hypothesis.*

STEP 4: INTERPRET THE RESULTS

This is also where the textbook is most helpful to know what exactly to examine for each inferential statistic. Go to the textbook for the inferential statistic you are performing and go to the Interpret results section and follow the steps. Look at the overall statistic p-value for the *t*, *F*, *r*, or χ^2 to determine whether the results are statistically significant

What is your p-value	Significant?	Null hypothesis?	Type of error?
p < α (typically p < .05)	Statistically significant	Reject the null	Type 1 (false positive)
p > α (typically p > .05)	Not statistically significant	Fail to reject the null	Type 2 (false negative)

WRITING RESULTS IN APA FORMAT

When writing up the results of a statistical test, we should always include the following information:

1. Description of your research question and/or hypotheses.
2. Description of your data (e.g., *M* and *SD* for your groups). If you fail to meet assumptions, you should specify that and describe what test you chose to perform as a result.
3. The results of the inferential test, including (a) what test was performed, (b) the test value, (c) degrees of freedom, (d) p-value, and (e) effect size. Italicize all the statistical letters (e.g., M, SD, p, t, r, etc.). Round everything to 2 decimals except the p-value which is rounded to 3 decimals.
4. Interpretation of the results or whether the hypothesis was supported or not, including any other information as needed. Overall, it should be clear what you did and what your results were! Read for clarity!

In addition, follow the guidance in the textbook for how to best visualize the results of the test (Visualize the results)