UNIVERSITY OF SAN FRANCISCO
CHANGE THE WORLD FROM HERE

Tutorial 23: Contrasts for Two Way ANOVA

Description

In this tutorial we will learn how to conduct planned contrasts and post-hoc contrasts with Two Way ANOVAs. Contrasts are comparisons of two means. Typically, when conducting an ANOVA we tend to compare more than two means. A Two Way ANOVA tests three hypotheses at the same time:

1) Effects of Factor A (or Independent Variable A)
   H_0: All μ 's for categories of A are equal
   H_a: At least one μ is not equal
   (note: the alternative hypothesis H_a can also be denoted as H_1)
2) Effects of Factor B (or Independent Variable B)
   H_0: All μ 's for categories of B are equal
   H_a: At least one μ is not equal
3) An interaction effect for Factor A by Factor B (whether mean differences in Factor A depend on mean differences in Factor B)
   H_0: There is no interaction between Factor A and Factor B
   H_a: There is an interaction between Factor A and Factor B

Let's say the Two Way ANOVA indicated an effect for a Factor that had more than 2 levels, then we can conclude that the factor has an effect on the dependent variable but do not know which mean difference is contributing to that effect. Contrasts can also help us learn more about interaction effects (3rd hypothesis test). If we found an interaction effect the Two Way ANOVA table will tell us that there is an effect and will tell us how big of an effect it is but will not tell us anything about how the means in one factor change as a function of the other factor. Contrasts can help us figure that out.

For this tutorial we will learn how to conduct contrasts/post-hoc tests to clarify factor effects and interaction effects. We will use the Two Way ANOVA conducted in Tutorial #22 as a demonstration. The Two Way ANOVA in Tutorial #22 examined whether the type of apology (No Apology, Half Apology, Full Apology) given by Kathy who perpetrated a discriminatory act toward Maria and whether those who reported English as their native language or not (Eng = Yes, Eng = No) effect the extent to which participants agree that Kathy should be fined for disruption of peace (**k_fine**).

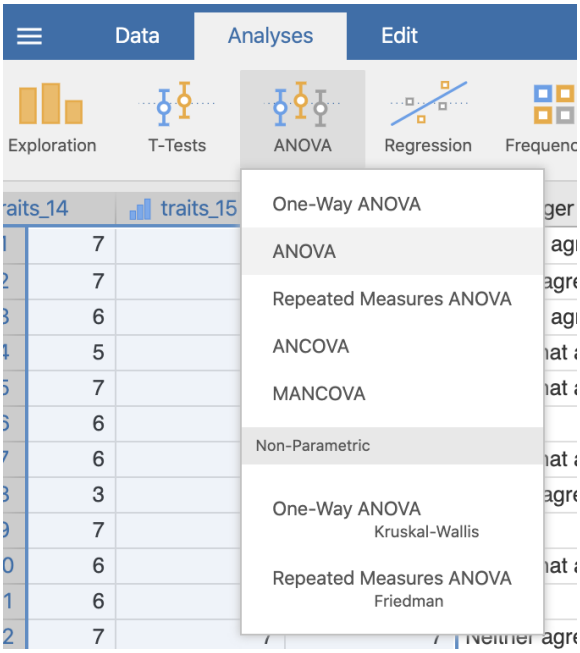
Note: we are using the datafile ARMF2020_wave1andwave2.omv

Content

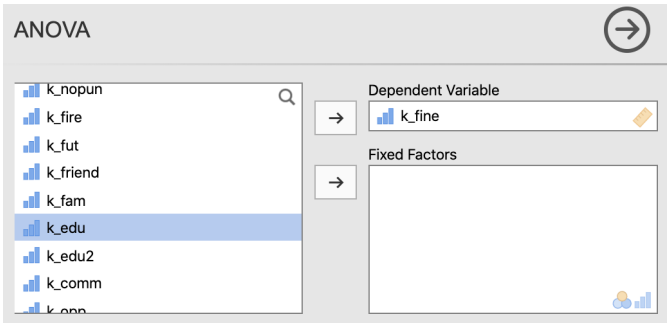
1. **Conduct a Two Way ANOVA**
2. **Selecting contrast analysis**
3. **Interpreting the results**
4. **APA Format describing the findings**

STEPS

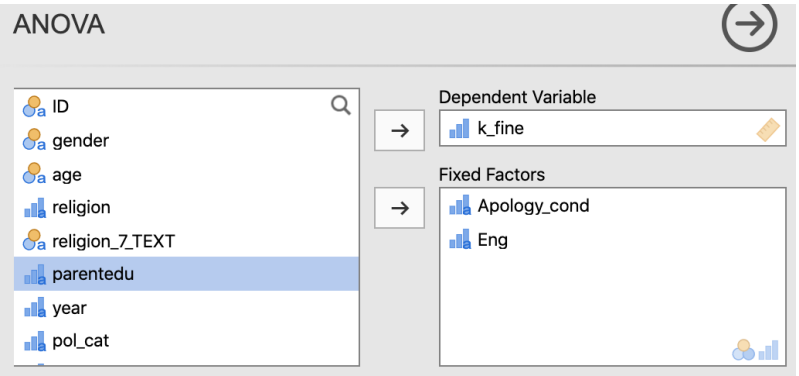
1. **Conduct a Two Way ANOVA**
   a. Open Jamovi datafile for this dataset.
   b. Go to the 'Analyses' tab.
   c. Click on ANOVA and select 'ANOVA'.



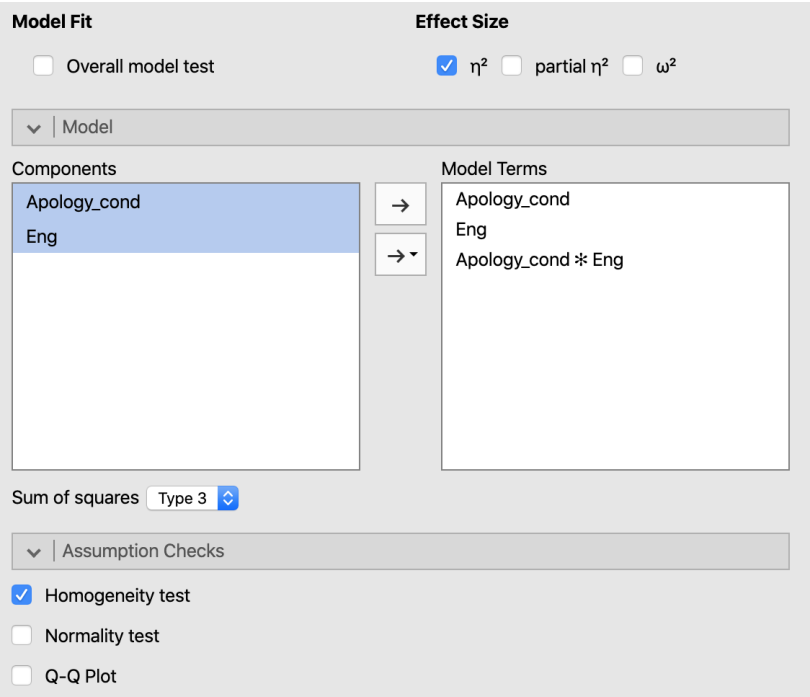
   d. Select the variable 'k_fine' and move it into the 'Dependent variable window.



   e. Select the variables 'Apology_cond' and 'Eng' move them into the 'Fixed Factors' window:



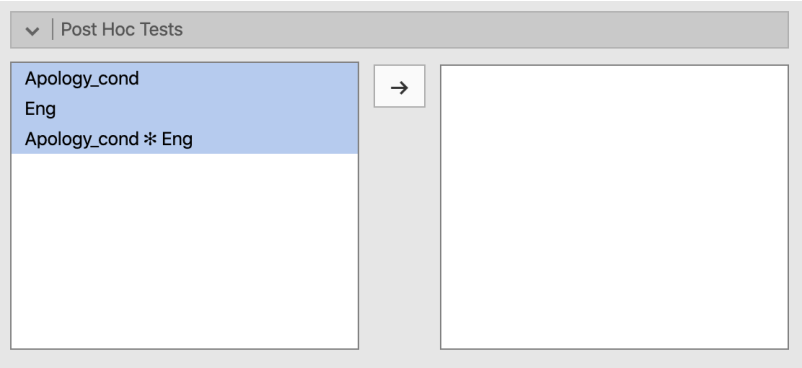
f. Below the variable windows you may specify the statistics you would like Jamovi to carry out.
g. First select the **effect size** by clicking on the check box next to η^2
h. Then define your model by opening the Model section (click on the arrow next to word 'Model'):
    i. Select the two factors from the components window and move them into the 'Model Terms' window.
i. Then open the 'Assumption Checks' section by clicking on the arrow next to the words 'Assumption Checks'.
    i. Select "Homogeneity test', this tests whether the variance of the six groups are similar or not.



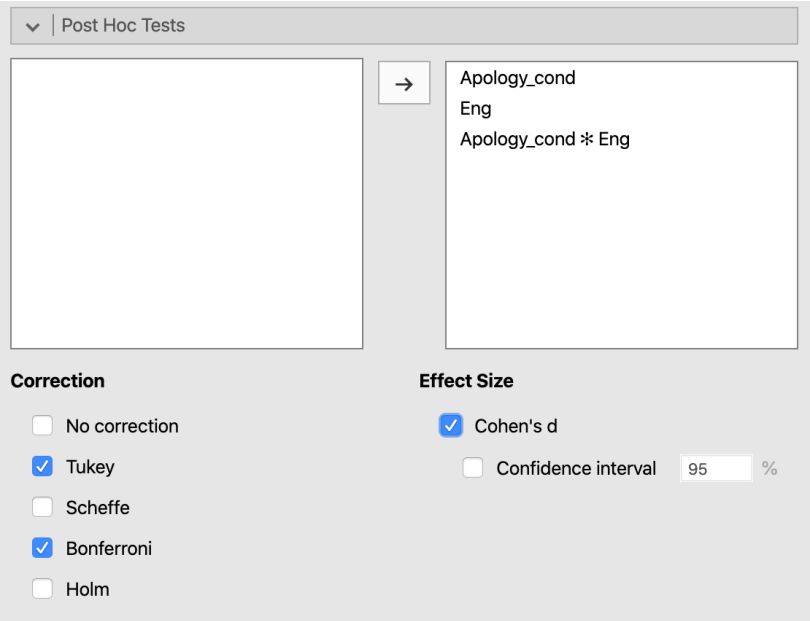
2. Selecting the contrast analysis

a. Open the 'Post Hoc Tests' section by clicking on the arrow next to the words 'Post Hoc Tests'.
b. Select the factors and the interaction term (Apology_cond*Eng) in the window

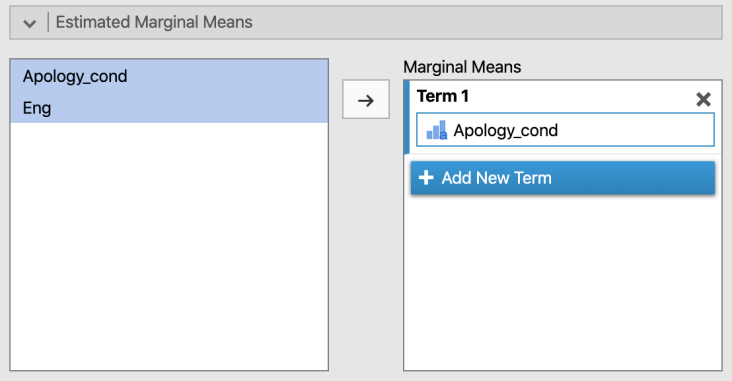
on the left:



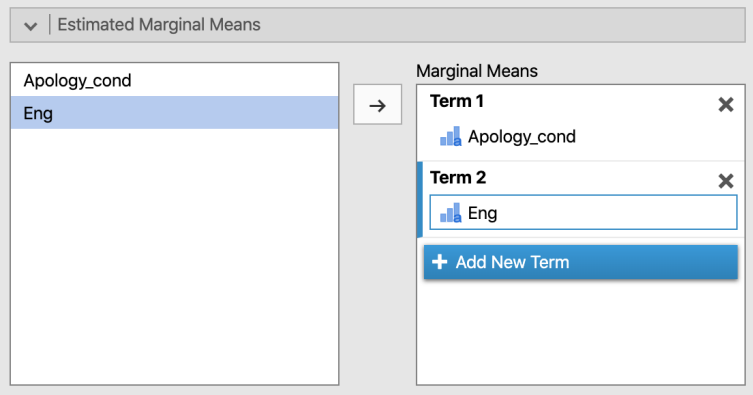
c. Drag the factors and the interaction term to the window on the right or click the arrow in the middle to move them over to the window on the right.
d. Select the type of correction test to be conducted under 'Correction', the most commonly used correction tests are 'Tukey' and 'Bonferroni'. Select one or the other.
e. Finally, under 'Effect Size' select Cohen's d to get a measure of effect size for each contrast calculated.



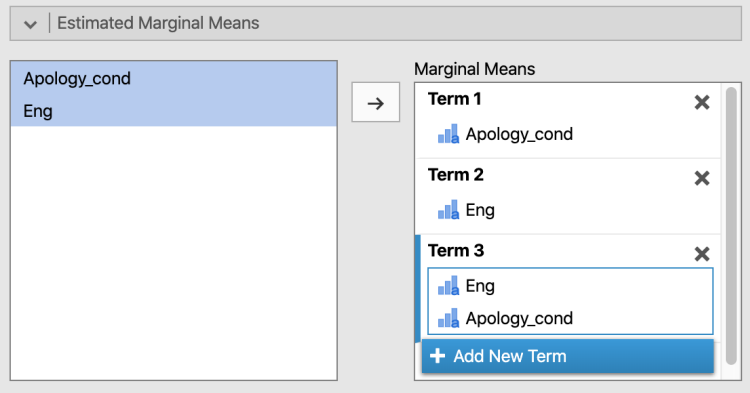
f. To report descriptive statistics open the Estimated Marginal Means section by clicking on the arrow next to the words 'Estimated Marginal Means'.
   i. Select the first factor 'Apology_Cond' and drag into the box below Term 1.



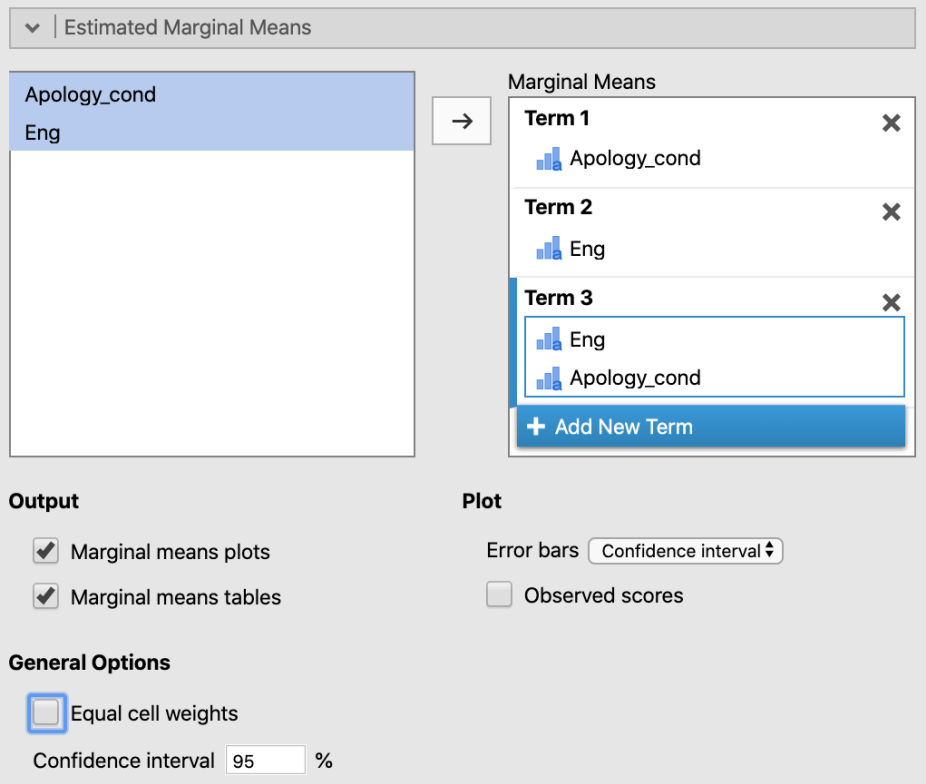
ii. Then click on “Add New Term” to create another term.
iii. Select the second factor ‘Eng’ and drag into the box below Term 2.



iv. Click on “Add New Term” again to create a third term for the interaction.
v. Select both factors and drag them both into the box below Term 3.



vi. Select “Marginal means plots”.
vii. Select “Marginal means tables”.
viii. Unselect everything else.



3. Interpreting the results

a. This is the Jamovi output that is produced for the ANOVA test - this table has been explained in tutorial #22 but essentially demonstrates NO main effect for Apology_cond (p = .581), a main effect for Eng (p<.01) on the dependent variable k_sincere, and an interaction effect between the two factors Eng and Apology_cond (p = .028).

ANOVA

ANOVA - k_fine

	Sum of Squares	df	Mean Square	F	p	η²
Apology_cond	2.50	2	1.25	0.544	0.581	0.006
Eng	16.41	1	16.41	7.134	0.008	0.038
Apology_cond ✻ Eng	16.73	2	8.37	3.638	0.028	0.039
Residuals	397.83	173	2.30			

[3]

Assumption Checks

Homogeneity of Variances Test (Levene's)

F	df1	df2	p
1.51	5	173	0.188

[3]

b. Interpreting the Post Hoc tests for each factor

Post Hoc Tests

Post Hoc Comparisons - Apology_cond

Comparison			Mean Difference	SE	df	t	p_{tukey}	$p_{bonferroni}$	Cohen's d
Apology 1	-	Apology 2	–0.2946	0.337	173	–0.8737	0.658	1.000	–0.1943
	-	Apology 3	–0.3212	0.341	173	–0.9416	0.615	1.000	–0.2118
Apology 2	-	Apology 3	–0.0265	0.332	173	–0.0798	0.996	1.000	–0.0175

Note. Comparisons are based on estimated marginal means

Post Hoc Comparisons - Eng

Comparison			Mean Difference	SE	df	t	p_{tukey}	$p_{bonferroni}$	Cohen's d
Yes	-	No	0.735	0.275	173	2.67	0.008	0.008	0.484

Note. Comparisons are based on estimated marginal means

i. Table titled Post Hoc Comparisons - Apology_cond:
   1. Reports all possible mean comparisons between three different means (Apology 1 vs. Apology 2, Apology 1 vs. Apology 3, and Apology 2 vs. Apology 3)
   2. There was no main effect for Apology_cond so we would expect not to find any differences in means of k_fine for each apology condition and as we can see by examining both p_{tukey} and $p_{bonferroni}$ the values are all greater than .05 so there are no statistically significant differences between means.
   3. Note the means that are being compared can be found in the Estimated Marginal Means table.

Estimated Marginal Means - Apology_cond

			95% Confidence Interval	
Apology_cond	Mean	SE	Lower	Upper
Apology 1	4.52	0.196	4.13	4.90
Apology 2	4.31	0.197	3.92	4.69
Apology 3	4.38	0.196	4.00	4.77

ii. Table titles Post Hoc Comparisons - Eng
   1. Since Eng only has two levels there is only one test and this test indicated a statistically significant difference between mean perceived sincerity of those who reported english as their native language (Yes) and those who did not (No). Both p_{tukey} and $p_{bonferroni}$ are <.05.
   2. Note the actual means can be found in the Estimated Marginal Means table. This difference is between M_{Yes} = 4.56 and M_{No} = 3.85.

Estimated Marginal Means - Eng

Eng	Mean	SE	95% Confidence Interval Lower	95% Confidence Interval Upper
Yes	4.56	0.128	4.30	4.81
No	3.85	0.243	3.37	4.33

c. Interpreting the Post Hoc tests for an interaction effect

i. There was an interaction effect between the two factors, Apology_cond and Eng, to understand how these factors depend on each other we need to examine both the Post-Hoc Comparisons - Apology_cond*Eng and the Estimated Marginal Plots (for visualizing the interaction).

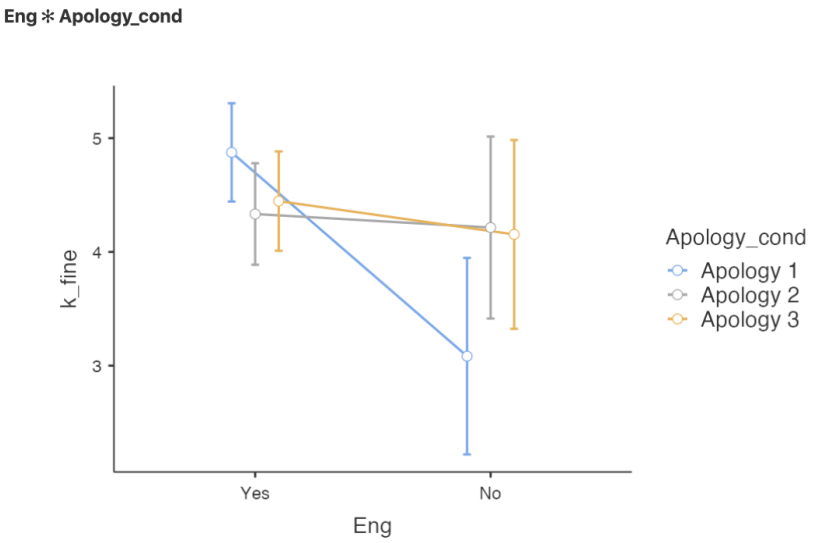
ii. Examining both p_{tukey} and $p_{bonferroni}$ was notice that the only comparison that is significant is the comparison of Apology 1/Yes and Apology 1/No groups (p_{tukey} =.004, $p_{bonferroni}$ = .005).

Post Hoc Comparisons - Apology_cond ✻ Eng

Comparison					Mean Difference	SE	df	t	p_{tukey}	$p_{bonferroni}$	Cohen's d
Apology_cond	Eng		Apology_cond	Eng							
Apology 1	Yes	-	Apology 1	No	1.7917	0.489	173	3.661	0.004	0.005	1.1815
		-	Apology 2	Yes	0.5417	0.315	173	1.721	0.520	1.000	0.3572
		-	Apology 2	No	0.6607	0.461	173	1.434	0.706	1.000	0.4357
		-	Apology 3	Yes	0.4282	0.311	173	1.376	0.741	1.000	0.2824
		-	Apology 3	No	0.7212	0.474	173	1.521	0.651	1.000	0.4756
	No	-	Apology 2	Yes	−1.2500	0.493	173	−2.537	0.119	0.181	0.8243
		-	Apology 2	No	−1.1310	0.597	173	−1.896	0.408	0.895	−0.7458
		-	Apology 3	Yes	−1.3635	0.490	173	−2.780	0.066	0.091	0.8991
		-	Apology 3	No	−1.0705	0.607	173	−1.763	0.492	1.000	−0.7059
Apology 2	Yes	-	Apology 2	No	0.1190	0.464	173	0.257	1.000	1.000	0.0785
		-	Apology 3	Yes	−0.1135	0.316	173	−0.359	0.999	1.000	−0.0748
		-	Apology 3	No	0.1795	0.477	173	0.376	0.999	1.000	0.1184
	No	-	Apology 3	Yes	−0.2325	0.462	173	−0.504	0.996	1.000	0.1533
		-	Apology 3	No	0.0604	0.584	173	0.103	1.000	1.000	0.0399
Apology 3	Yes	-	Apology 3	No	0.2930	0.475	173	0.616	0.990	1.000	0.1932

Note. Comparisons are based on estimated marginal means

iii. Examining the Estimated Marginal Means Plots for the interaction helps us visualize the interaction between Apology_cond and Eng and shows us that the biggest difference in means is in fact only appearing for Apology 1 (no apology) between the English Native speaker and non-native speakers **(blue line).** **One conclusion we can draw from this interaction is that the effect found for differences between english native speaker and non-native speakers appears only in the no apology condition so effect Eng depends on the apology condition.**



iv. Examining the Estimated Marginal Means Tables tells us what are the estimated means that are showing the significant difference, you can then report these means when describing the findings.

Estimated Marginal Means - Eng ✻ Apology_cond

				95% Confidence Interval	
Apology_cond	Eng	Mean	SE	Lower	Upper
Apology 1	Yes	4.88	0.219	4.44	5.31
	No	3.08	0.438	2.22	3.95
Apology 2	Yes	4.33	0.226	3.89	4.78
	No	4.21	0.405	3.41	5.01
Apology 3	Yes	4.45	0.221	4.01	4.88
	No	4.15	0.421	3.32	4.98

d. **APA format describing the findings:**

In addition to describing the findings from the two-way ANOVA reported in Tutorial #22 it is important to report means differences found for both main effects and interaction effects (additions highlighted in yellow):

A two-way anova was conducted to examine the effects of the apology type and participants native language on the extent participants agree that Kathy should be fined for her actions. No effect of the type of apology was found. An effect for one's native language was also found $F(1, 173) = 7.13$, $p<.01$, $\eta^2 = .03$. Additionally, an interaction effect was found, such that $F(2, 173) = 3.64$, $p<.05$, $\eta^2 = .03$.

The main effect for one's native language indicated that those with English as their native language endorsed fining Kathy more so than those who were non-native English speakers ($M_{yes} = 4.56$, $S.E._{yes} = 0.13$; $M_{no} = 3.85$, $S.E._{yes} = 0.24$). Additionally, post-hoc

analyses indicated that this difference was driven by those in the no apology condition (p <.01, M_{yes} = 4.88, $S.E._{yes}$ = 0.22; M_{no} = 3.08, $S.E._{yes}$ = 0.48), while no mean differences between native and non-native English speakers were found in the other apology conditions.

----------END TUTORIAL----------

This Jamovi tutorial is a companion to a video tutorial and these materials were developed by:

Aline Hitti, Ph.D., University of San Francisco
Saera Khan, Ph.D., University of San Francisco
Sage Stefanick, University of San Francisco
Erica Divinagracia, University of San Francisco
Adolfo Barrales, University of San Francisco

This tutorial was made possible by an Open Education Resource grant awarded to the first two authors by Gleeson Library, University of San Francisco.

UNIVERSITY OF SAN FRANCISCO

CHANGE THE WORLD FROM HERE