University of Colorado
Boulder

Human-Robot Interaction

Choosing a Test, Contingency Analysis, & Correlations

Professor **Dan Szafir**

Computer Science & ATLAS Institute
University of Colorado Boulder

Choosing a Statistical Test

Things to consider

What do you want to do?

- Look for differences between conditions (i.e., test hypotheses)
- Compare frequency (counts)
- Correlate variables
- Reduce data

Things to consider

How many factors and levels (conditions)

How many dependent variables

What type of variables are they?

- E.g., nominal, ordinal, ratio, etc.

Things to consider

Paired or unpaired data?

- Independent samples – *unpaired*
  - Used in most controlled laboratory experiments
- Dependent samples – *paired*
  - Used in observational studies, field experiments, in the presence of confounding factors, etc.

Example:

- Unpaired data: weight loss between two populations, one given new drug and the other given a placebo
- Paired data: Weight before and after drug in one population

Paired or Matched Data

Variable	Test
Nominal	McNemar's Test
Ordinal (ordered categories)	Wilcoxon
Quantitative (discrete or non-normal)	Wilcoxon
Quantitative (normal)	Paired t-test

Some Summaries

www.maths.dur.ac.uk/mathlab/resources/whichtest.html

Choosing a statistical test

What do you want to do?	Number of variables and conditions	Design	Parametric/ Nonparametric	Statistical Test
Look for differences between conditions	One independent variable: two conditions. One dependent variable	Independent measures (unrelated)	Parametric	Independent t test
		Independent measures (unrelated)	Nonparametric	Mann–Whitney U test
		Repeated measures (related)	Parametric	Related t test
		Repeated measures (related)	Nonparametric	Wilcoxon signed-ranks test
	One independent variable: more than two conditions. One dependent variable	Independent measures	Parametric	One factor independent measures ANOVA
		Independent measures	Nonparametric	Kruskal–Wallis test
		Repeated measures	Parametric	One factor repeated measures ANOVA
		Repeated measures	Nonparametric	Friedman test
	Two independent variables. One dependent variable	Independent measures on both variables	Parametric	Two factor independent measures ANOVA
		Repeated measures on both variables	Parametric	Two factor repeated measures ANOVA
		One independent measures factor and one repeated measures factor	Parametric	Two factor mixed design ANOVA
	One independent variable. More than one dependent variable	Independent measures. Multivariate design	Parametric	One factor independent measures MANOVA
Compare frequency counts (in categories)	One or more variables	Association	Nonparametric	Chi-square test
Correlate variables	Two variables	Correlational	Parametric	Pearson's r
	Two variables	Correlational	Nonparametric	Spearman's r_s
	More than two variables	Correlational	Parametric	Multiple correlation
Reduce data	Many variables	Correlational	Parametric	Factor analysis

Summary Table of Statistical Tests

Level of Measurement	Sample Characteristics					Correlation
	1 Sample	2 Sample		K Sample (i.e., >2)		
		Independent	Dependent	Independent	Dependent	
Categorical or Nominal	X^2 or bi-nomial	X^2	Macnarmar's X^2	X^2	Cochran's Q	
Rank or Ordinal		Mann Whitney U	Wilcoxin Matched Pairs Signed Ranks	Kruskal Wallis H	Friendman's ANOVA	Spearman's rho
Parametric (Interval & Ratio)	z test or t test	t test between groups	t test within groups	1 way ANOVA between groups	1 way ANOVA (within or repeated measure)	Pearson's r
		Factorial (2 way) ANOVA				

(Plonskey, 2001)

Output Variable

Input Variable

	Nominal	Categorical (>2 categories)	Ordinal	Quantitative Discrete	Quantitative Non-Normal	Quantitative Normal
Nominal	X^2 or Fisher's	X^2	X^2 trend or Mann-Whitney	Mann-Whitney	Mann-Whitney or log-rank (a)	Student's t-test
Categorical (>2 categories)	X^2	X^2	Kruskal-Wallis (b)	Kruskal-Wallis (b)	Kruskal-Wallis (b)	Analysis of variance (c)
Ordinal	X^2 trend or Mann-Whitney	(e)	Spearman rank	Spearman rank	Spearman rank	Spearman rank or linear regression (d)
Quantitative Discrete	Logistic regression	(e)	(e)	Spearman rank	Spearman rank	Spearman rank or linear regression (d)
Quantitative Non-Normal	Logistic regression	(e)	(e)	(e)	Plot data and Pearson or Spearman rank	Plot data and Pearson or Spearman rank and linear regression
Quantitative Normal	Logistic regression	(e)	(e)	(e)	Linear regression (d)	Pearson and linear regression

Contingency Analysis

Comparing Frequencies (counts)

Example

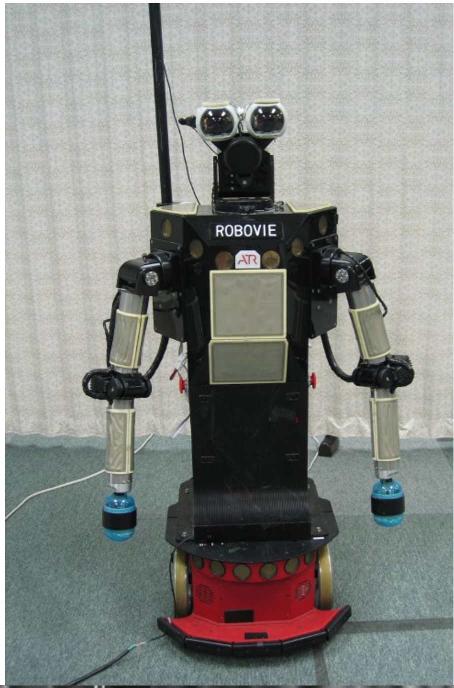
RQ: Does robot morphology affect user perceptions of gaze cues?

Measure: number of people who report a gaze cue from a Gemenoid and from a Robovie

Question: is the number of people who reported a gaze cue different when the cue comes from a Gemenoid or Robovie?

What are my IVs, DVs, factors, and levels?

What type of variables are they?



Contingency Table

Displays the multivariate frequency distributions of variables in a matrix format

Also called “cross-tabulation”

	Reported Gaze Cue	Did Not Report Gaze Cue	*Totals*
Geminoid	10	4	14
Robovie	3	11	14
Totals	13	15	28

Output Variable

Input Variable

	Nominal	Categorical (>2 categories)	Ordinal	Quantitative Discrete	Quantitative Non-Normal	Quantitative Normal
Nominal	**X^2 or Fisher's**	**X^2**	**X^2 trend or Mann-Whitney**	Mann-Whitney	Mann-Whitney or log-rank (a)	Student's t-test
Categorical (>2 categories)	**X^2**	**X^2**	Kruskal-Wallis (b)	Kruskal-Wallis (b)	Kruskal-Wallis (b)	Analysis of variance (c)
Ordinal	X^2 trend or Mann-Whitney	(e)	Spearman rank	Spearman rank	Spearman rank	Spearman rank or linear regression (d)
Quantitative Discrete	Logistic regression	(e)	(e)	Spearman rank	Spearman rank	Spearman rank or linear regression (d)
Quantitative Non-Normal	Logistic regression	(e)	(e)	(e)	Plot data and Pearson or Spearman rank	Plot data and Pearson or Spearman rank and linear regression
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IV: Categorical | DV: Categorical

Compare the frequency distributions across categorical variables

Pearson's Chi-squared Test

Number of cells in table

Observed Frequency

$$X^2 = \sum_{i=1}^{n} \frac{(0_i - E_i)^2}{E_i}$$

Pearson's Test Statistic

Expected Frequency

Pearson's Chi-squared Test

To calculate expected values:
(RowTotal*ColTotal/GridTotal)

	Reported Gaze Cue	Did Not Report Gaze Cue	*Totals*
Geminoid	10 (14*13/29 = **6.28**)	4 (7.72)	14
Robovie	3 (6.72)	12 (8.28)	15
Totals	13	16	29

Pearson's Chi-squared Test

$$X^2 = \sum_{i=1}^{n} \frac{(0_i - E_i)^2}{E_i} = \frac{(10 - 6.28)^2}{6.28} + \frac{(3 - 6.72)^2}{6.72} + \frac{(4 - 7.72)^2}{7.72} + \frac{(12 - 8.28)^2}{8.28}$$

$$X^2 = 7.73$$

	Reported Gaze Cue	Did Not Report Gaze Cue	*Totals*
Geminoid	10 (14*13/29 = **6.28**)	4 (7.72)	14
Robovie	3 (6.72)	12 (8.28)	15
Totals	13	16	29

Degrees of Freedom

df = (Number of rows – 1) * (Number of columns – 1)

df = (2 – 1) * (2 – 1) = 1

	Reported Gaze Cue	Did Not Report Gaze Cue	*Totals*
Geminoid	10 (14*13/29 = **6.28**)	4 (7.72)	14
Robovie	3 (6.72)	12 (8.28)	15
Totals	13	16	29

What are degrees of freedom?

Number of values in the final calculation that are "free to vary"

Example: estimate mean from dataset X with 5 values

- If I tell you $\mu_x = 3.5$ what values can x_1, x_2, x_3, x_4, x_5 take?
- What if I tell you $x_1 = 7$?
- And if I tell you $x_2 = 2.5$?
- …
- How many values x_1 … x_5 can take on any value given the mean?
- General: for mean estimation with n values, we have $(n-1)$ degrees of freedom

Degrees of Freedom

df = (Number of rows – 1) * (Number of columns – 1)

df = (2 – 1) * (2 – 1) = 1

	Reported Gaze Cue	Did Not Report Gaze Cue	*Totals*
Geminoid	10 (14*13/29 = **6.28**)	4 (7.72)	14
Robovie	3 (6.72)	12 (8.28)	15
Totals	13	16	29

Pearson’s Chi-squared Test

$X^2 = 7.73$

df = (2 – 1) * (2 – 1) = 1

.005 < p < .0025

	Reported Gaze Cue	Did Not Report Gaze Cue	*Totals*
Geminoid	10 (14*13/29 = **6.28**)	4 (7.72)	14
Robovie	3 (6.72)	12 (8.28)	15
Totals	13	16	29

χ^2 CRITICAL VALUES

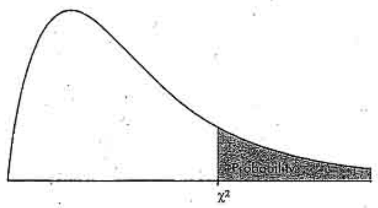


TABLE C: χ^2 CRITICAL VALUES

	Tail probability p										
df	.25	.20	.15	.10	.05	.025	.02	.01	.005	.0025	.001
1	1.32	1.64	2.07	2.71	3.84	5.02	5.41	6.63	7.88	9.14	10.83
2	2.77	3.22	3.79	4.61	5.99	7.38	7.82	9.21	10.60	[illegible]	13.82
3	4.11	4.64	5.32	6.25	7.81	9.35	9.84	11.34	12.84	14.32	16.27
4	5.39	5.99	6.74	7.78	9.49	11.14	11.67	13.28	14.86	16.42	18.47
5	6.63	7.29	8.12	9.24	11.07	12.83	13.39	15.09	16.75	18.39	20.51
6	7.84	8.56	9.45	10.64	12.59	14.45	15.03	16.81	18.55	20.25	22.46
7	9.04	9.80	10.75	12.02	14.07	16.01	16.62	18.48	20.28	22.04	24.32
8	10.22	11.03	12.03	13.36	15.51	17.53	18.17	20.09	21.95	23.77	26.12
9	11.39	12.24	13.29	14.68	16.92	19.02	19.68	21.67	23.59	25.46	27.88
10	12.55	13.44	14.53	15.99	18.31	20.48	21.16	23.21	25.19	27.11	29.59
11	13.70	14.63	15.77	17.28	19.68	21.92	22.62	24.72	26.76	28.73	31.26
12	14.85	15.81	16.99	18.55	21.03	23.34	24.05	26.22	28.30	30.32	32.91
13	15.98	16.98	18.20	19.81	22.36	24.74	25.47	27.69	29.82	31.88	34.53
14	17.12	18.15	19.41	21.06	23.68	26.12	26.87	29.14	31.32	33.43	36.12
15	18.25	19.31	20.60	22.31	25.00	27.49	28.26	30.58	32.80	34.95	37.70
16	19.37	20.47	21.79	23.54	26.30	28.85	29.63	32.00	34.27	36.46	39.25
17	20.49	21.61	22.98	24.77	27.59	30.19	31.00	33.41	35.72	37.95	40.79
18	21.60	22.76	24.16	25.99	28.87	31.53	32.35	34.81	37.16	39.42	42.31
19	22.72	23.90	25.33	27.20	30.14	32.85	33.69	36.19	38.58	40.88	43.82
20	23.83	25.04	26.50	28.41	31.41	34.17	35.02	37.57	40.00	42.34	45.31
21	24.93	26.17	27.66	29.62	32.67	35.48	36.34	38.93	41.40	43.78	46.80
22	26.04	27.30	28.82	30.81	33.92	36.78	37.66	40.29	42.80	45.20	48.27
23	27.14	28.43	29.98	32.01	35.17	38.08	38.97	41.64	44.18	46.62	49.73
24	28.24	29.55	31.13	33.20	36.42	39.36	40.27	42.98	45.56	48.03	51.18
25	29.34	30.68	32.28	34.38	37.65	40.65	41.57	44.31	46.93	49.44	52.62
26	30.43	31.79	33.43	35.56	38.89	41.92	42.86	45.64	48.29	50.83	54.05
27	31.53	32.91	34.57	36.74	40.11	43.19	44.14	46.96	49.64	52.22	55.48
28	32.62	34.03	35.71	37.92	41.34	44.46	45.42	48.28	50.99	53.59	56.89
29	33.71	35.14	36.85	39.09	42.56	45.72	46.69	49.59	52.34	54.97	58.30
30	34.80	36.25	37.99	40.26	43.77	46.98	47.96	50.89	53.67	56.33	59.70
40	45.62	47.27	49.24	51.81	55.76	59.34	60.44	63.69	66.77	69.70	73.40
50	56.33	58.16	60.35	63.17	67.50	71.42	72.61	76.15	79.49	82.66	86.66
60	66.98	68.97	71.34	74.40	79.08	83.30	84.58	88.38	91.95	95.34	99.61
80	88.13	90.41	93.11	96.58	101.9	106.6	108.1	112.3	116.3	120.1	124.8
100	109.1	111.7	114.7	118.5	124.3	129.6	131.1	135.8	140.2	144.3	149.4

Pearson's Chi-square in R

Between-participants comparisons

E.g., Participants interacted with two robots and measurements taken of whether they reported seeing a gaze cue that the robot exhibited

```
> setwd("C:\\Users\\Dan\\OneDrive\\Teaching\\HRI Spring 2016\\Lecture 21")
> gaze <- read.table('RobotGaze.csv', sep=",", header=TRUE)
> gaze
```

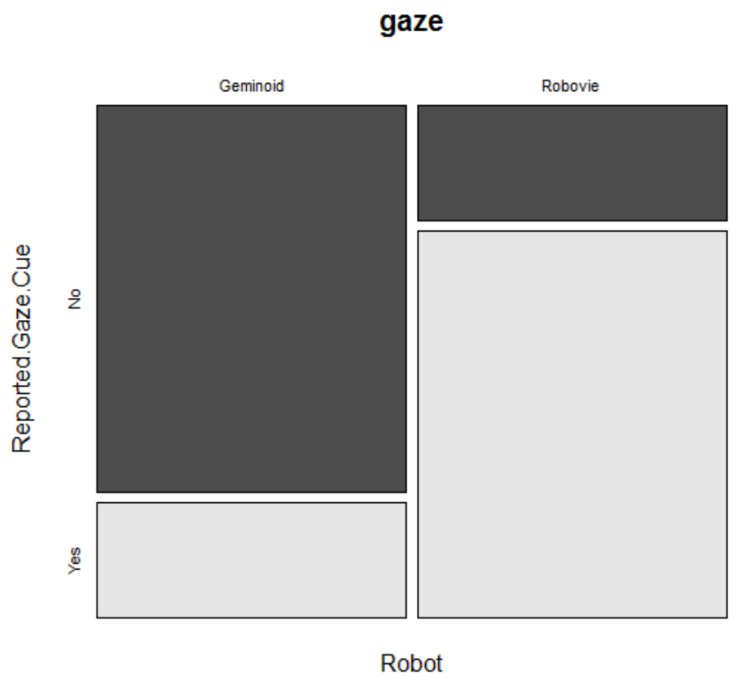
```
     Robot Reported.Gaze.Cue
1  Robovie               Yes
2 Geminoid               Yes
3  Robovie               Yes
4 Geminoid                No
5  Robovie               Yes
6 Geminoid                No
7 Geminoid                No
8  Robovie                No
```

Pearson’s Chi-square in R

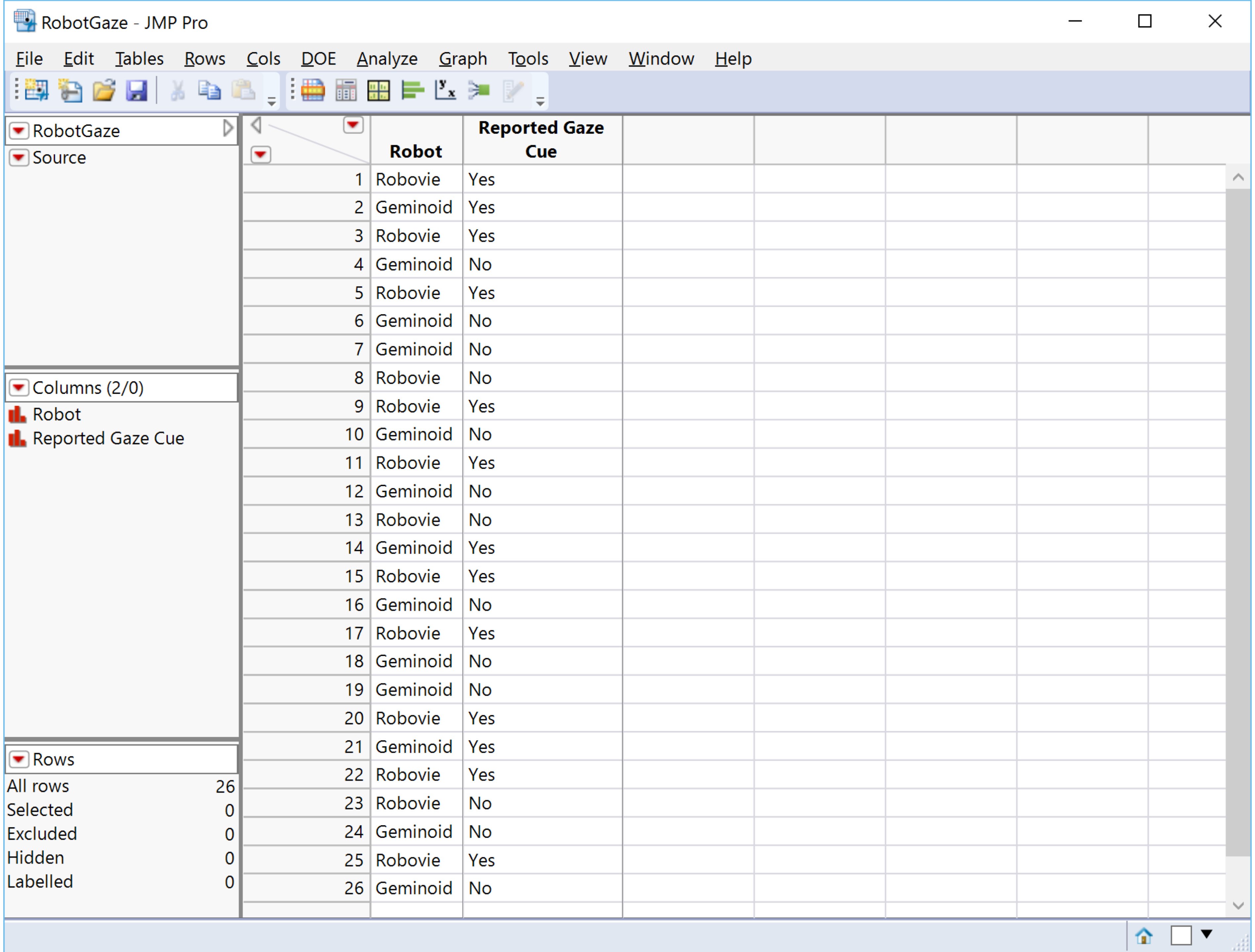
```
> table(gaze)
          Reported.Gaze.Cue
Robot       No Yes
  Geminoid 10   3
  Robovie   3  10
> chisq.test(table(gaze))
Pearson's Chi-squared test with Yates' continuity correction
data:  table(gaze)
X-squared = 5.5385, df = 1, p-value = 0.0186
```

Pearson’s Chi-square in R

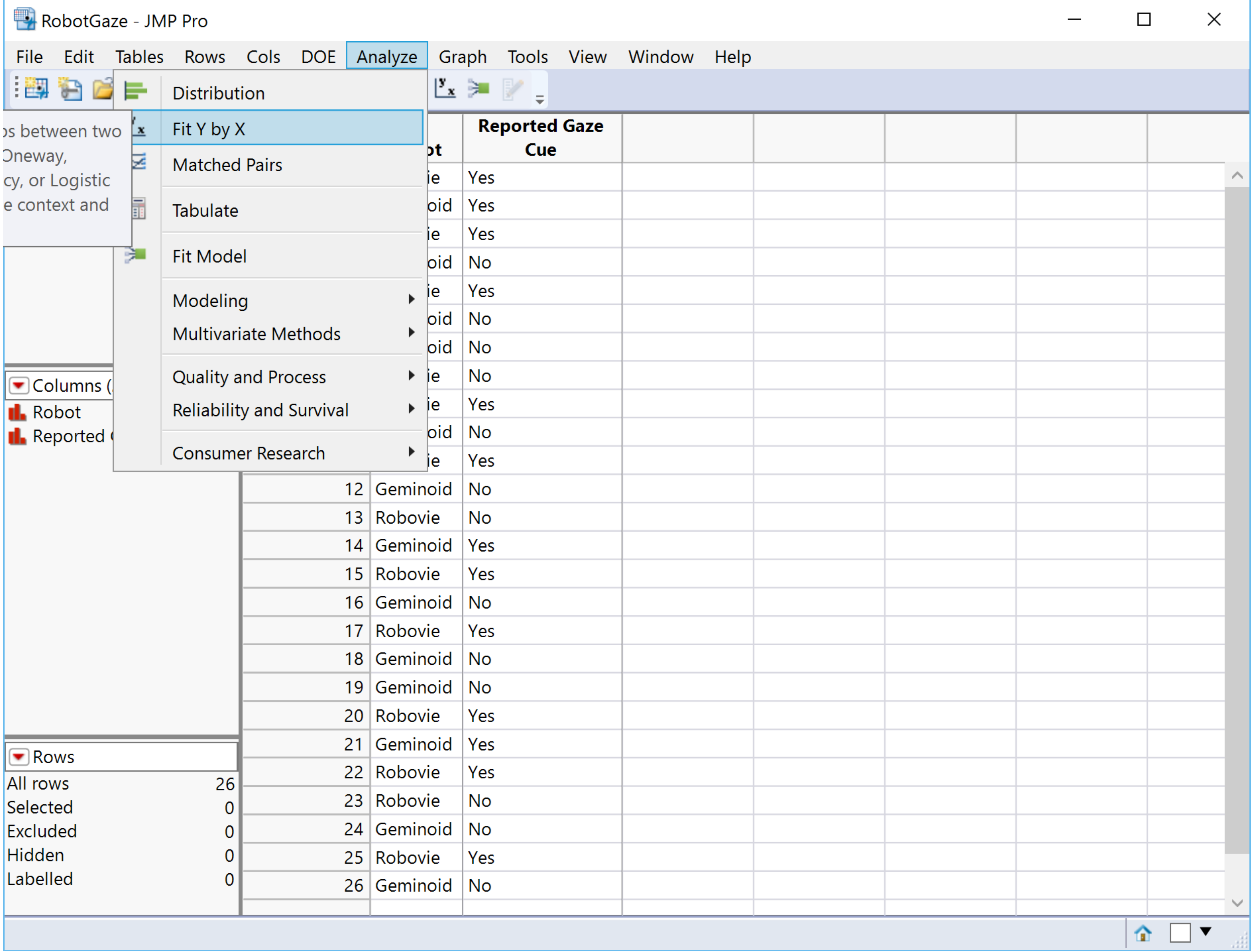
```
> require(stats)
> mosaicplot(~ Robot + Reported.Gaze.Cue, data =
gaze, color = TRUE)
```



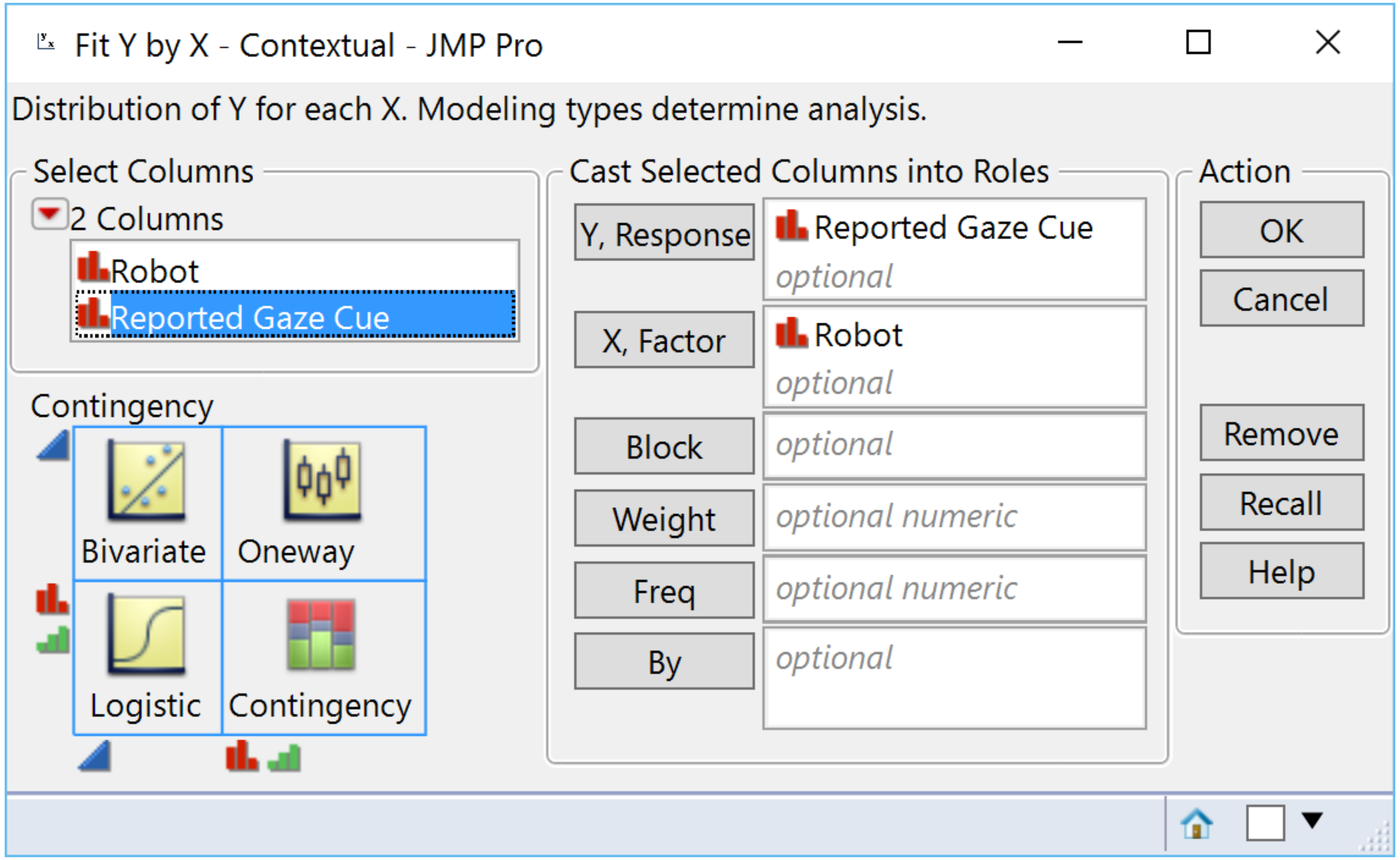
Chi-square in JMP



	Robot	Reported Gaze Cue
1	Robovie	Yes
2	Geminoid	Yes
3	Robovie	Yes
4	Geminoid	No
5	Robovie	Yes
6	Geminoid	No
7	Geminoid	No
8	Robovie	No
9	Robovie	Yes
10	Geminoid	No
11	Robovie	Yes
12	Geminoid	No
13	Robovie	No
14	Geminoid	Yes
15	Robovie	Yes
16	Geminoid	No
17	Robovie	Yes
18	Geminoid	No
19	Geminoid	No
20	Robovie	Yes
21	Geminoid	Yes
22	Robovie	Yes
23	Robovie	No
24	Geminoid	No
25	Robovie	Yes
26	Geminoid	No


RobotGaze - JMP Pro
File
Edit
Tables
Rows
Cols
DOE
Analyze
Graph
Tools
View
Window
Help
Distribution
Fit Y by X
Matched Pairs
Tabulate
Fit Model
Modeling
Multivariate Methods
Quality and Process
Reliability and Survival
Consumer Research
ps between two
Oneway,
cy, or Logistic
e context and
Columns (
Robot
Reported
Reported Gaze Cue
12 Geminoid No
13 Robovie No
14 Geminoid Yes
15 Robovie Yes
16 Geminoid No
17 Robovie Yes
18 Geminoid No
19 Geminoid No
20 Robovie Yes
21 Geminoid Yes
22 Robovie Yes
23 Robovie No
24 Geminoid No
25 Robovie Yes
26 Geminoid No
Rows
All rows 26
Selected 0
Excluded 0
Hidden 0
Labelled 0

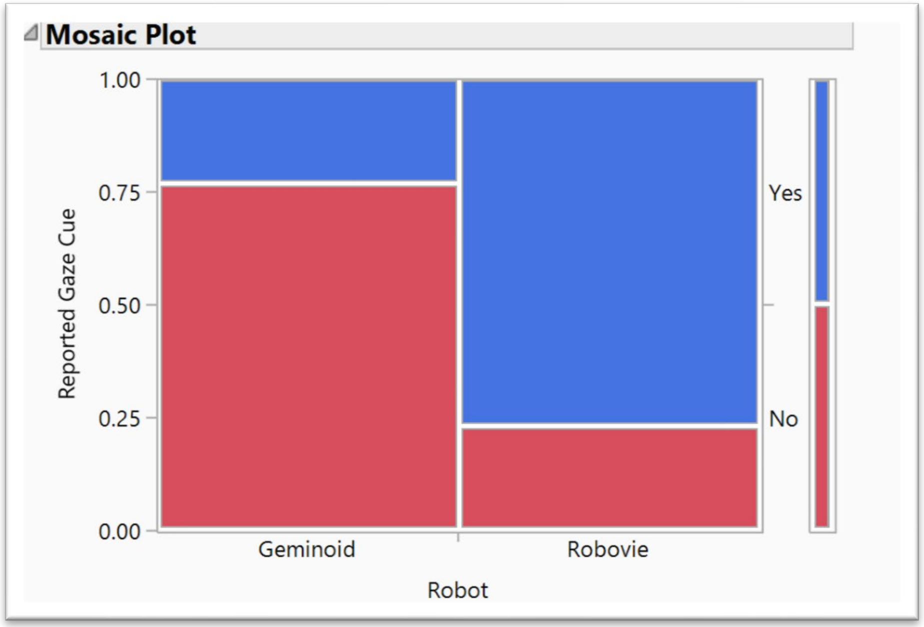
Chi-square in JMP



Chi-square in JMP

Count / Total % / Col % / Row %	No	Yes	Total
Geminoid	10	3	13
	38.46	11.54	50.00
	76.92	23.08	
	76.92	23.08	
Robovie	3	10	13
	11.54	38.46	50.00
	23.08	76.92	
	23.08	76.92	
Total	13	13	26
	50.00	50.00	

N	DF	-LogLike	RSquare (U)
26	1	3.9765190	0.2207



Tests

N	DF	-LogLike	RSquare (U)
26	1	3.9765190	0.2207

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	7.953	0.0048*
Pearson	7.538	0.0060*

Fisher's Exact Test	Prob	Alternative Hypothesis
Left	0.9994	Prob(Reported Gaze Cue=Yes) is greater for Robot=Geminoid than Robovie
Right	0.0085*	Prob(Reported Gaze Cue=Yes) is greater for Robot=Robovie than Geminoid
2-Tail	0.0169*	Prob(Reported Gaze Cue=Yes) is different across Robot

Pearson's Chi-squared vs Fisher's Exact Test

- Chi-square can be used with large samples
  - But with small samples or when data is very unequally distributed among table cells, sampling distribution of test statistic may be poor approximation of theoretical chi-squared distribution
    - In other words, Chi-squared test may not be appropriate in these cases
- Rule of thumb: Only use Chi-square when expected values in all cells are >= 5
  - If any expected value is < 5, use Fisher's exact test

Contingency Table

Reported Gaze Cue

Robot	Count / Total % / Col % / Row %	No	Yes	Total
	Geminoid	10	3	13
		38.46	11.54	50.00
		76.92	23.08	
		76.92	23.08	
	Robovie	3	10	13
		11.54	38.46	50.00
		23.08	76.92	
		23.08	76.92	
	Total	13	13	26
		50.00	50.00	

Tests

N	DF	-LogLike	RSquare (U)
26	1	3.9765190	0.2207

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	7.953	0.0048*
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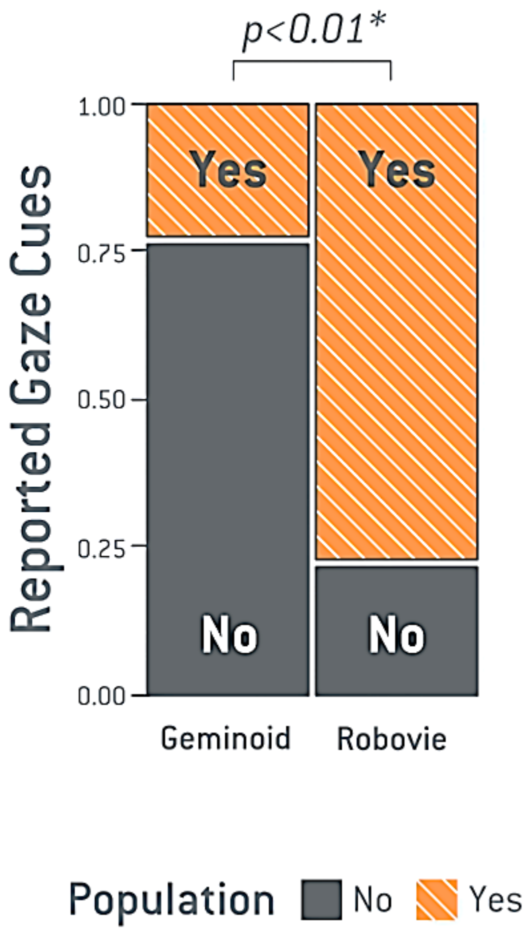
2-Tail	0.0169*	Prob(Reported Gaze Cue=Yes) is different across Robot

Reporting Results

"A contingency analysis for the manipulation check showed that significantly fewer participants reported identifying the gaze cue in Geminoid's behavior than in Robovie's ($X^2(1,26) = 7.54$, $p < .01$)."



Questions?

Correlation / Regression

Correlation

Measure of relation between two variables

Used mostly for *interval* or *ratio* scales

Range from -1 to 1

- -1 is negative correlation
- 1 is positive correlation
- 0 is no correlation

Output Variable

Input Variable

	Nominal	Categorical (>2 categories)	Ordinal	Quantitative Discrete	Quantitative Non-Normal	Quantitative Normal
Nominal	X^2 or Fisher's	X^2	X^2 trend or Mann-Whitney	Mann-Whitney	Mann-Whitney or log-rank (a)	Student's t-test
Categorical (>2 categories)	X^2	X^2	Kruskal-Wallis (b)	Kruskal-Wallis (b)	Kruskal-Wallis (b)	Analysis of variance (c)
Ordinal	X^2 trend or Mann-Whitney	(e)	Spearman rank	Spearman rank	Spearman rank	Spearman rank or linear regression (d)
Quantitative Discrete	Logistic regression	(e)	(e)	Spearman rank	Spearman rank	Spearman rank or linear regression (d)
Quantitative Non-Normal	Logistic regression	(e)	(e)	(e)	Plot data and Pearson or Spearman rank	Plot data and Pearson or Spearman rank and linear regression
Quantitative Normal	Logistic regression	(e)	(e)	(e)	Linear regression (d)	**Pearson and linear regression**

IV: Continuous | DV: Continuous

Correlation: measure the relation between two variables

Pearson's r

- Simple linear correlation
- To what extent are two variables *proportional* or *linearly related* to each other

r value denotes the strength of the linear relationship [-1,1]

R^2 is the coefficient of determination = percent of variation in one variable that is related to the variation in the other

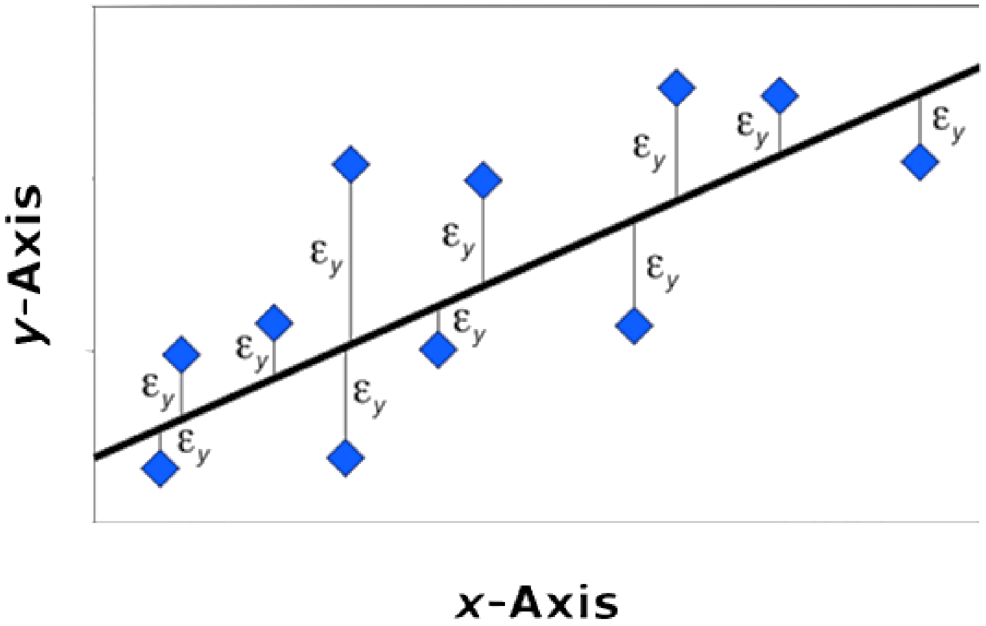
- E.g., $r = 0.7$ means $R^2 = .49$, thus 49% of the variance is related

The proportion can be summarized by a simple line

- The *regression* or *least squares* line
- Determined by minimizing the sum of squared distances

Regression Line

$$Y = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \epsilon_i$$



Correlational Significance

The extent to which a result would not be obtained by chance

E.g., a p-value of 0.05 indicates that there is a 5% probability that the relation between the variables found in our sample is a fluke

Lower p-value indicates higher reliability of result

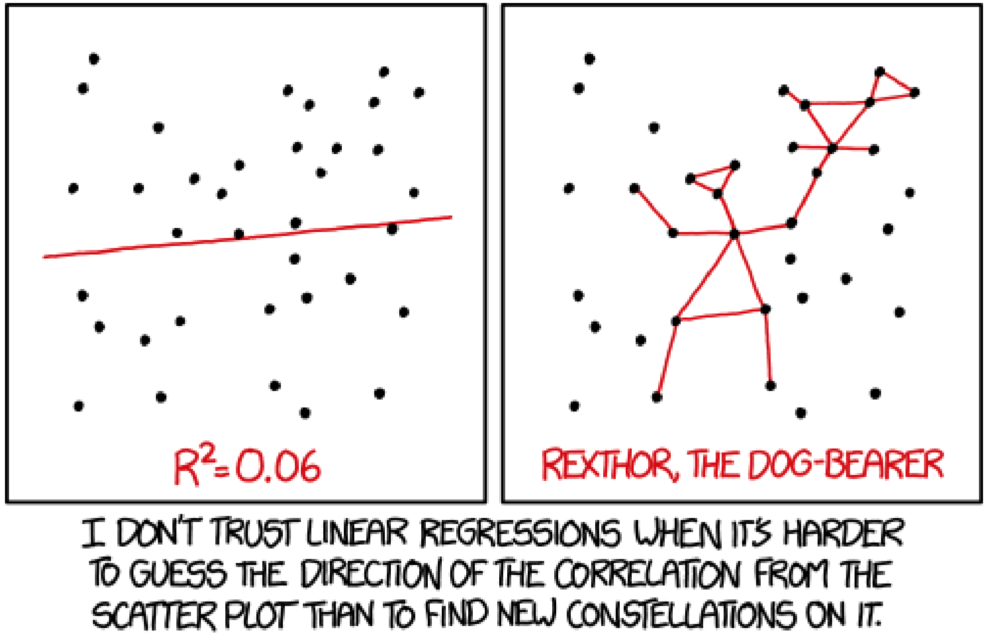
Sample Size

Significance level is primary source of information about the reliability of the correlation

Significance of a correlation depends on sample size

Rule of thumb

- Sample size above 50 is good
- Sample size above 100 is safe



Calculating Correlations in R

Create correlation matrices

```
cor(q, use="complete.obs", method="pearson")
```

Decide how to deal with missing data

- Assume that data is complete (`all.obs`)
- Use complete data (`complete.obs`)
- Use all complete pairs (`pairwise.complete.obs`)

Choose a method

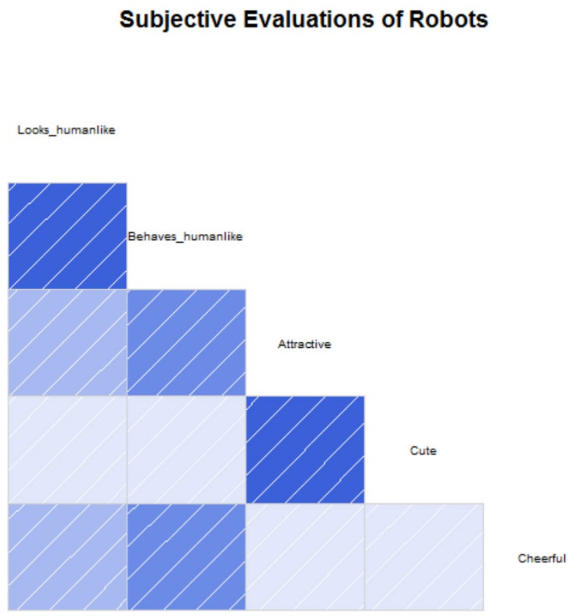
- **Pearson**, Spearman, Kendall

```
> setwd("C:\\Users\\Dan\\OneDrive\\Teaching\\HRI Spring 2016\\Lecture 19")
> qdata <- read.csv("FactorAnalysis_Data.csv")
> q <- qdata[,3:21]
> cor(q, use="complete.obs", method="pearson")
                  Looks_humanlike Behaves_humanlike  Attractive         Cute    Cheerful    Friendly  Optimistic        Warm
Looks_humanlike       1.000000000        0.44603356  0.15798337 0.1271830043  0.26959127  0.21529524 -0.18416606  0.03128560
Behaves_humanlike     0.446033560        1.00000000  0.41192484 0.0645465708  0.41996172 -0.02102620 -0.02615191  0.18662954
Attractive            0.157983372        0.41192484  1.00000000 0.4530741634  0.07724687  0.08522856  0.02830693  0.26893092
Cute                  0.127183004        0.06454657  0.45307416 1.0000000000  0.05919710  0.07899856 -0.06829162  0.23219653
Cheerful              0.269591275        0.41996172  0.07724687 0.0591970984  1.00000000  0.54851122 -0.17711632  0.40384792
Friendly              0.215295243       -0.02102620  0.08522856 0.0789985554  0.54851122  1.00000000  0.04838903  0.64688143
Optimistic           -0.184166063       -0.02615191  0.02830693 -0.0682916214 -0.17711632  0.04838903  1.00000000  0.31447681
Warm                  0.031285597        0.18662954  0.26893092 0.2321965330  0.40384792  0.64688143  0.31447681  1.00000000
Happy                 0.217179525        0.02898437 -0.06506949 0.0842958167  0.32716571  0.64424695  0.28240538  0.55431834
Knowledgeable         0.362102228        0.20109834  0.16462753 -0.1461526859  0.27862653  0.39205549  0.29599271  0.32010781
Responsible           0.003858589       -0.07080370  0.30971012 0.1404354062 -0.14008590  0.21638481  0.33652380  0.42348767
Intelligent           0.429512593        0.29846334  0.12306964 0.0006549498  0.24063946  0.30570895 -0.01861615  0.39542917
Sensible              0.441047628        0.26769554  0.28256988 0.1600671199  0.11096477  0.11333561  0.24578385  0.40563392
Loyal                 0.074197414       -0.09136711  0.39709652 0.0743198341  0.02460031  0.19154632  0.15325031 -0.10876876
Honest               -0.089310583       -0.10009483  0.25984151 -0.1116312737 -0.08313890  0.13453646  0.26065396  0.11674230
Cooperative          -0.114363909       -0.11119388  0.30733932 -0.0285485284 -0.02913668  0.09919735  0.39861045 -0.05680518
Attentive             0.264076764        0.23008907 -0.07310180 -0.2289964169  0.05416551 -0.12863120 -0.18525566 -0.08297274
You_like_the_robot    0.180465620        0.38270700  0.66483516 0.6283679198  0.27971546  0.15736110 -0.15243746  0.34757695
Robot_likes_you       0.077527181       -0.07114104  0.23090165 0.1776676828  0.07928510  0.30075565 -0.05703160  0.21714118
                        Happy Knowledgeable  Responsible  Intelligent   Sensible       Loyal      Honest  Cooperative
Looks_humanlike    0.21717952    0.36210223  0.003858589 0.4295125934 0.44104763  0.07419741 -0.08931058 -0.114363909
Behaves_humanlike  0.02898437    0.20109834 -0.070803702 0.2984633429 0.26769554 -0.09136711 -0.10009483 -0.111193875
Attractive        -0.06506949    0.16462753  0.309710117 0.1230696411 0.28256988  0.39709652  0.25984151  0.307339316
Cute               0.08429582   -0.14615269  0.140435406 0.0006549498 0.16006712  0.07431983 -0.11163127 -0.028548528
Cheerful           0.32716571    0.27862653 -0.140085903 0.2406394570 0.11096477  0.02460031 -0.08313890 -0.029136680
Friendly           0.64424695    0.39205549  0.216384813 0.3057089466 0.11333561  0.19154632  0.13453646  0.099197354
Optimistic         0.28240538    0.29599271  0.336523795 -0.0186161459 0.24578385  0.15325031  0.26065396  0.398610449
Warm               0.55431834    0.32010781  0.423487672 0.3954291700 0.40563392 -0.10876876  0.11674230 -0.056805183
Happy              1.00000000    0.32385994  0.441806745 0.3670399283 0.23100943  0.20574245  0.20676318 -0.111322334
Knowledgeable      0.32385994    1.00000000  0.167220231 0.6692242683 0.46754583  0.26815566  0.21494520  0.173053650
Responsible        0.44180674    0.16722023  1.000000000 0.1821125508 0.15365926  0.42462989  0.38018745  0.089139224
Intelligent        0.36703993    0.66922427  0.182112551 1.0000000000 0.57014444  0.12166221  0.11957908 -0.202122744
```

Visualizing Correlations

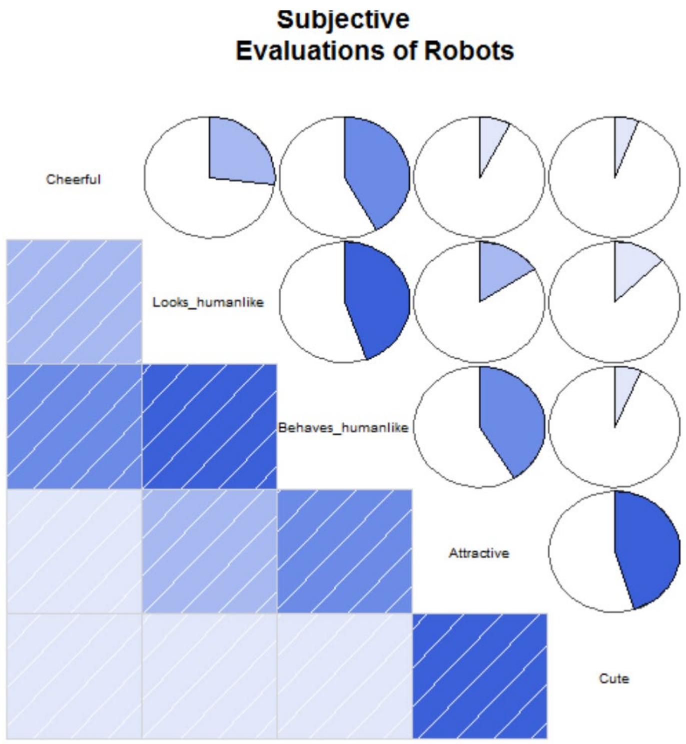
Create correlation matrices

```
> library(corrgram)
> corrgram(q[,1:5], order=NULL, lower.panel=panel.shade,
upper.panel=NULL, text.panel=panel.txt, main="Subjective
Evaluations of Robots")
```



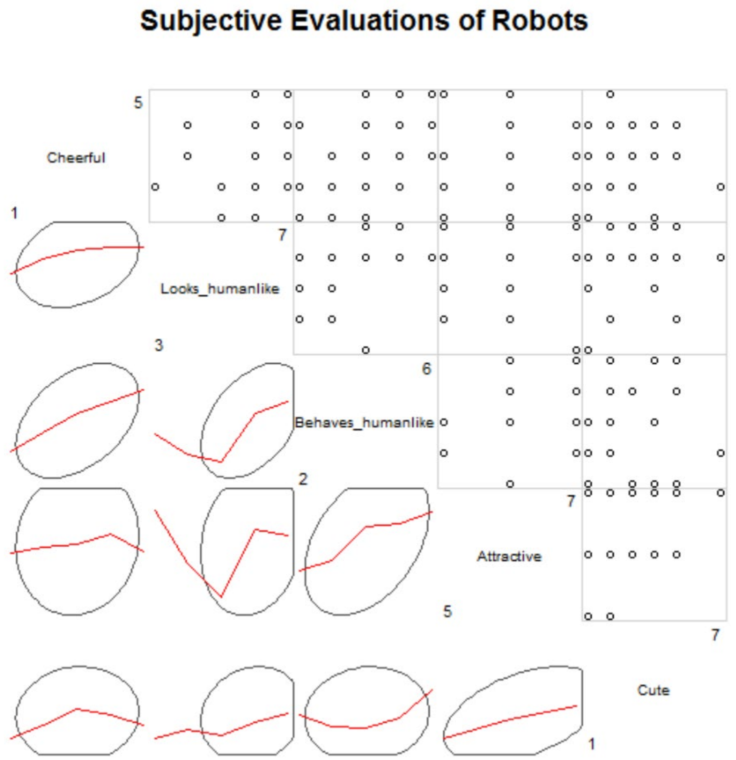
Visualizing Correlations

```
> corrgram(q[,1:5], order=TRUE, lower.panel=panel.shade,
upper.panel=panel.pie, text.panel=panel.txt, main="Subjective
Evaluations of Robots")
```



Visualizing Correlations

```
> corrgram(q[,1:5], order=TRUE, lower.panel=panel.ellipse,
upper.panel=panel.pts, text.panel=panel.txt,
diag.panel=panel.minmax, main="Subjective Evaluations of Robots")
```



Correlational Significance Test

```
> library(Hmisc)
> rcorr(as.matrix(q), type="pearson")
```

r

	Looks_humanlike	Behaves_humanlike	Attractive	Cute	Cheerful
Looks_humanlike	1.00	**0.45**	0.16	0.13	0.27
Behaves_humanlike	0.45	1.00	**0.41**	0.06	**0.42**
Attractive	0.16	**0.41**	1.00	**0.45**	0.08
Cute	0.13	0.06	**0.45**	1.00	0.06
Cheerful	0.27	**0.42**	0.08	0.06	1.00

p

	Looks_humanlike	Behaves_humanlike	Attractive	Cute	Cheerful
Looks_humanlike		**0.0153**	0.4131	0.5109	0.1573
Behaves_humanlike	**0.0153**		**0.0264**	0.7394	**0.0233**
Attractive	0.4131	**0.0264**		**0.0136**	0.6904
Cute	0.5109	0.7394	**0.0136**		0.7603
Cheerful	0.1573	**0.0233**	0.6904	0.7603	

Significant — based on .05 confidence level

Correlations in JMP

FactorAnalysis_Data - JMP Pro

File Edit Tables Rows Cols DOE Analyze Graph Tools View Window Help

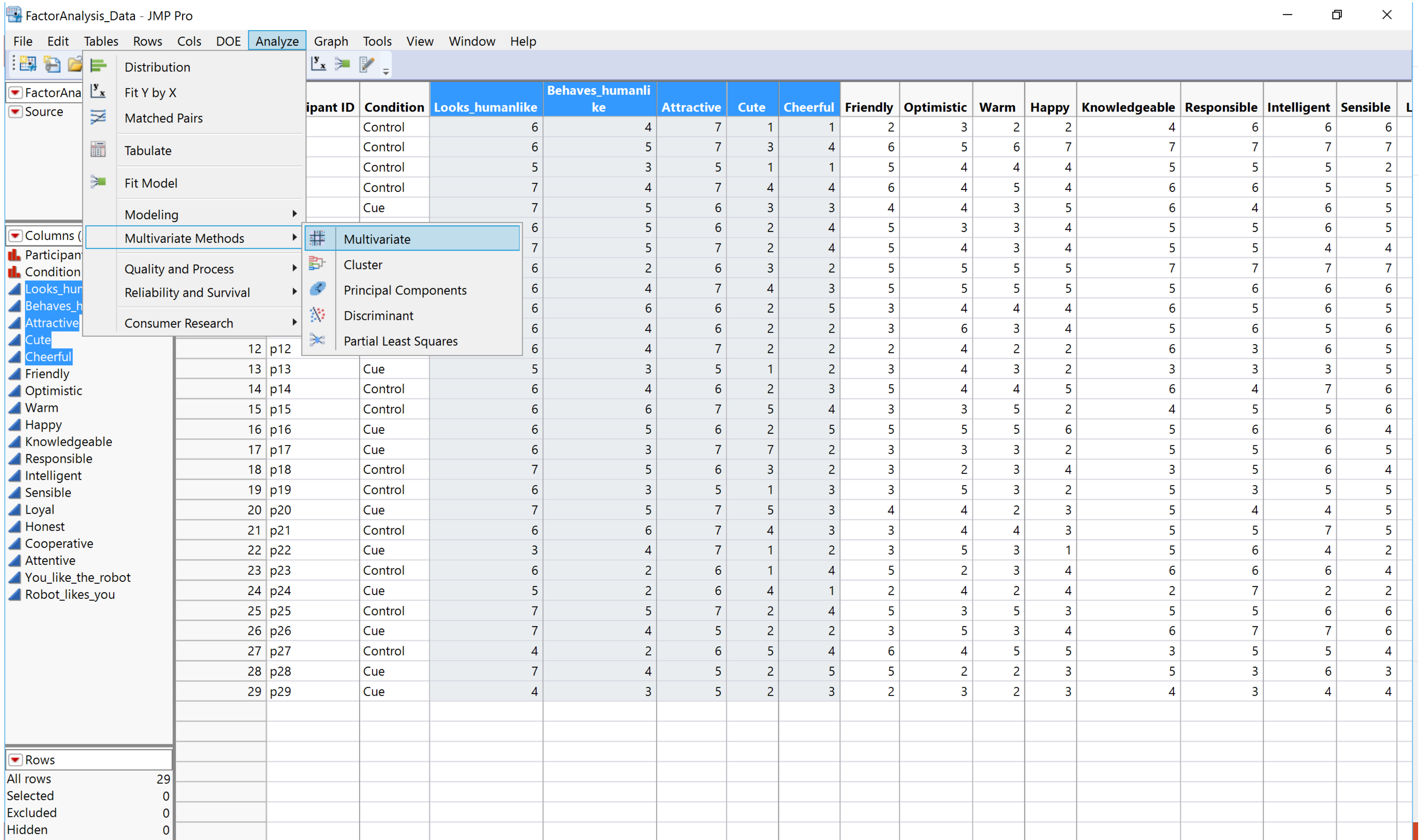
FactorAnalysis_Data
Source

Columns (21/5)
Participant ID
Condition
Looks_humanlike
Behaves_humanlike
Attractive
Cute
Cheerful
Friendly
Optimistic
Warm
Happy
Knowledgeable
Responsible
Intelligent
Sensible
Loyal
Honest
Cooperative
Attentive
You_like_the_robot
Robot_likes_you

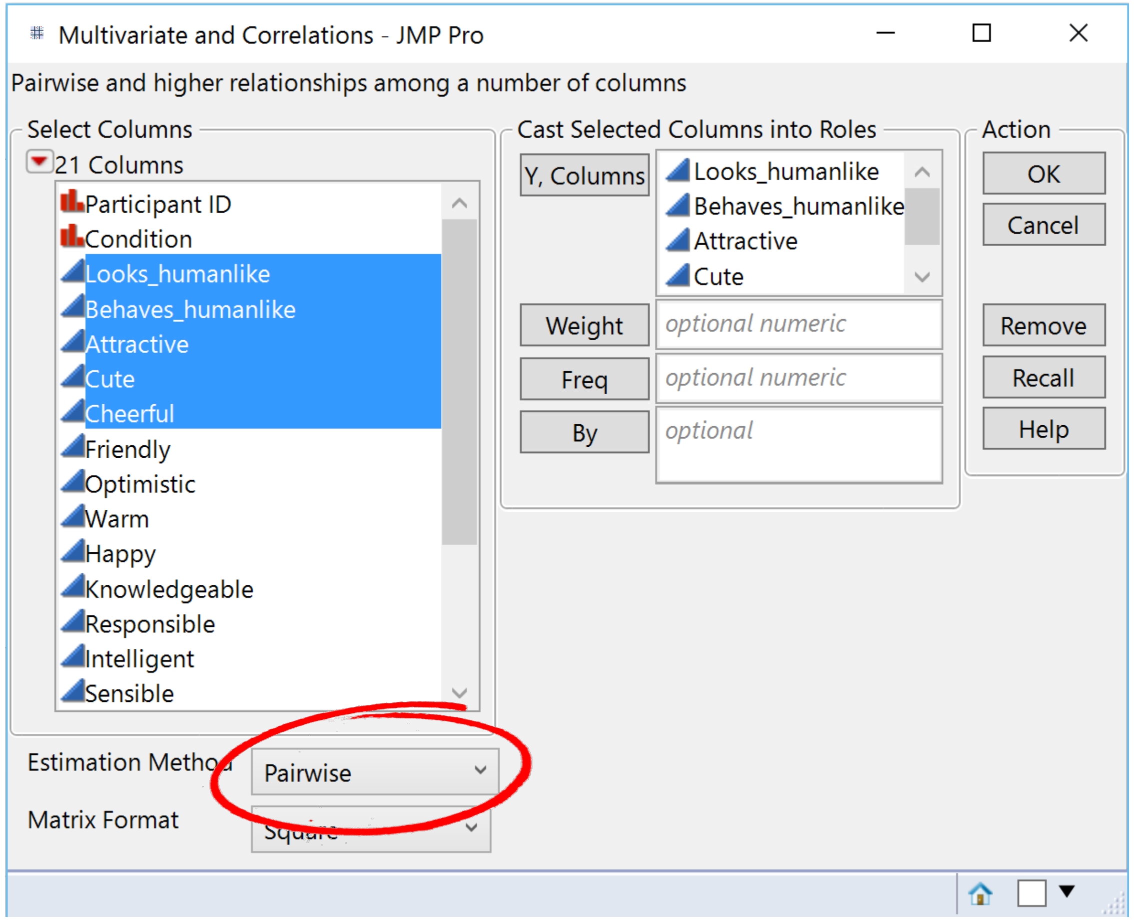
Rows
All rows 29
Selected 0
Excluded 0
Hidden 0

	Participant ID	Condition	Looks_humanlike	Behaves_humanlike	Attractive	Cute	Cheerful	Friendly	Optimistic	Warm	Happy	Knowledgeable	Responsible	Intelligent	Sensible
1	p01	Control	6	4	7	1	1	2	3	2	2	4	6	6	6
2	p02	Control	6	5	7	3	4	6	5	6	7	7	7	7	7
3	p03	Control	5	3	5	1	1	5	4	4	4	5	5	5	2
4	p04	Control	7	4	7	4	4	6	4	5	4	6	6	5	5
5	p05	Cue	7	5	6	3	3	4	4	3	5	6	4	6	5
6	p06	Cue	6	5	6	2	4	5	3	3	4	5	5	6	5
7	p07	Cue	7	5	7	2	4	5	4	3	4	5	5	4	4
8	p08	Cue	6	2	6	3	2	5	5	5	5	7	7	7	7
9	p09	Cue	6	4	7	4	3	5	5	5	5	5	6	6	6
10	p10	Control	6	6	6	2	5	3	4	4	4	6	5	6	5
11	p11	Control	6	4	6	2	2	3	6	3	4	5	6	5	6
12	p12	Cue	6	4	7	2	2	2	4	2	2	6	3	6	5
13	p13	Cue	5	3	5	1	2	3	4	3	2	3	3	3	5
14	p14	Control	6	4	6	2	3	5	4	4	5	6	4	7	6
15	p15	Control	6	6	7	5	4	3	3	5	2	4	5	5	6
16	p16	Cue	6	5	6	2	5	5	5	5	6	5	6	6	4
17	p17	Cue	6	3	7	7	2	3	3	3	2	5	5	6	5
18	p18	Control	7	5	6	3	2	3	2	3	4	3	5	6	4
19	p19	Control	6	3	5	1	3	3	5	3	2	5	3	5	5
20	p20	Cue	7	5	7	5	3	4	4	2	3	5	4	4	5
21	p21	Control	6	6	7	4	3	3	4	4	3	5	5	7	5
22	p22	Cue	3	4	7	1	2	3	5	3	1	5	6	4	2
23	p23	Control	6	2	6	1	4	5	2	3	4	6	6	6	4
24	p24	Cue	5	2	6	4	1	2	4	2	4	2	7	2	2
25	p25	Control	7	5	7	2	4	5	3	5	3	5	5	6	6
26	p26	Cue	7	4	5	2	2	3	5	3	4	6	7	7	6
27	p27	Control	4	2	6	5	4	6	4	5	5	3	5	5	4
28	p28	Cue	7	4	5	2	5	5	2	2	3	5	3	6	3
29	p29	Cue	4	3	5	2	3	2	3	2	3	4	3	4	4

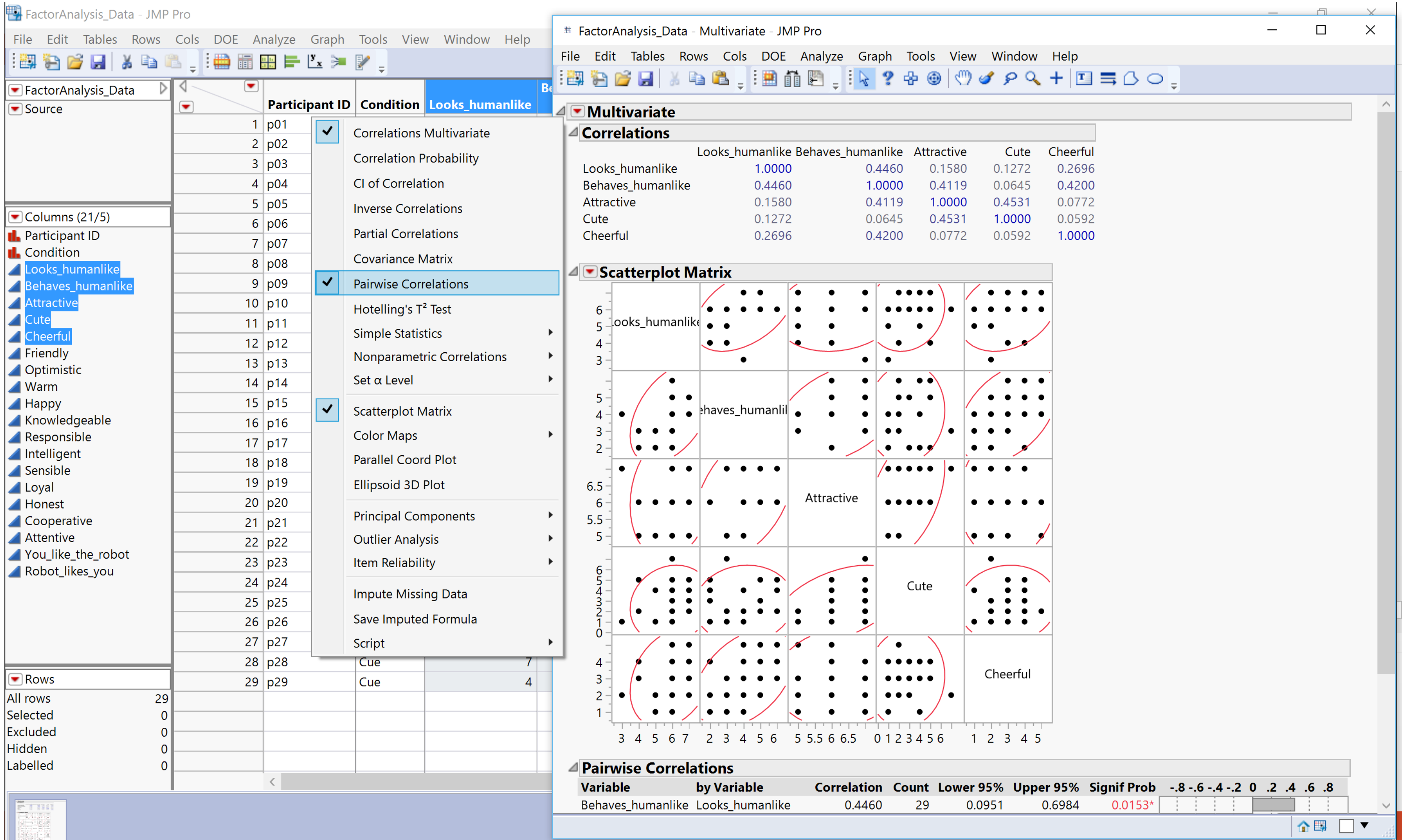
Correlations in JMP



Correlations in JMP

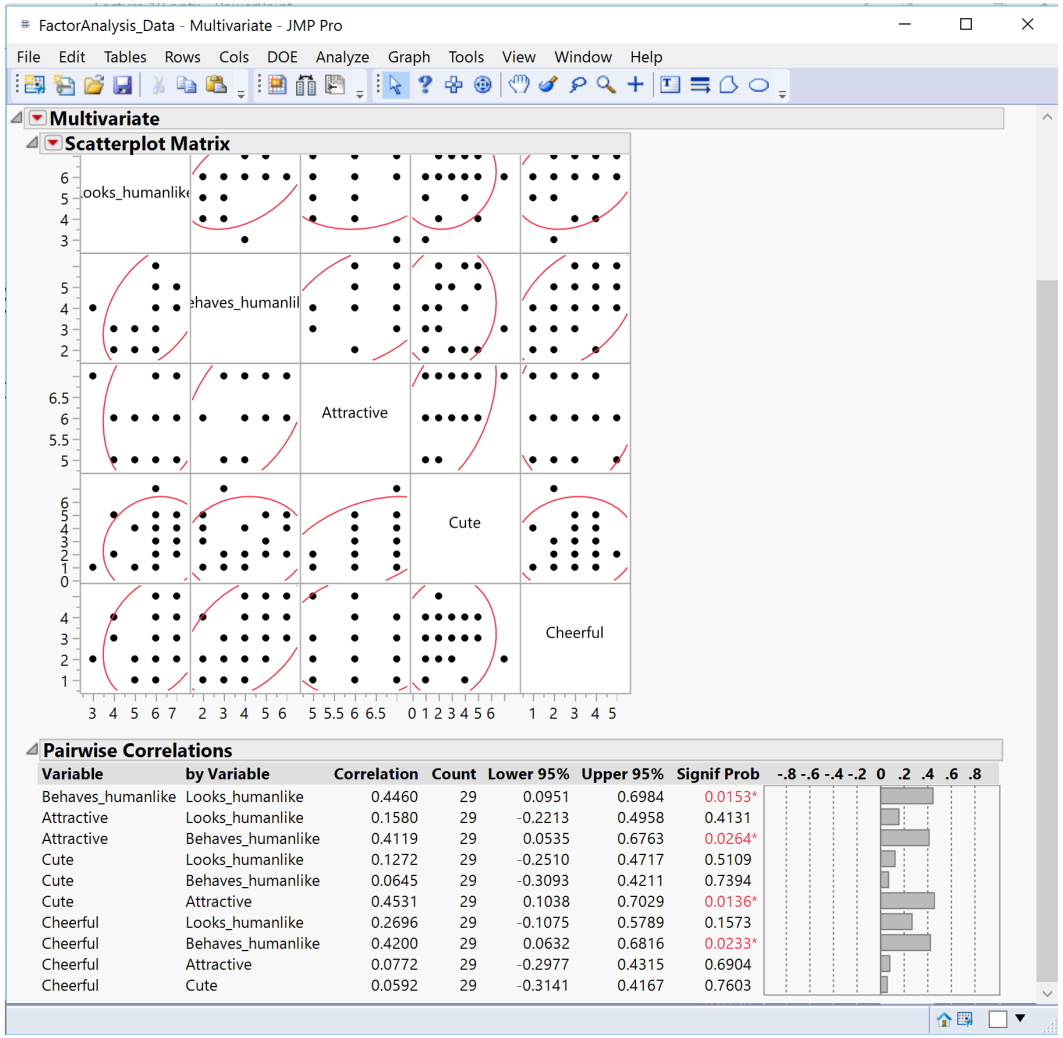


Correlations in JMP



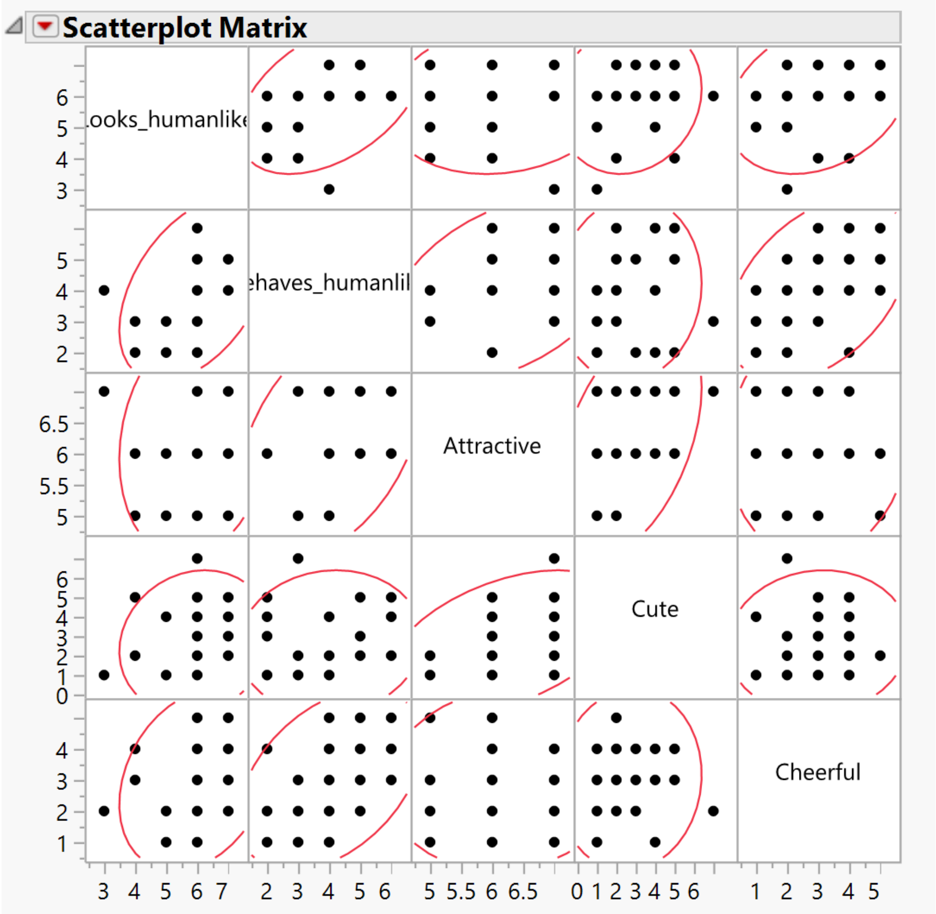
	Looks_humanlike	Behaves_humanlike	Attractive	Cute	Cheerful
Looks_humanlike	1.0000	0.4460	0.1580	0.1272	0.2696
Behaves_humanlike	0.4460	1.0000	0.4119	0.0645	0.4200
Attractive	0.1580	0.4119	1.0000	0.4531	0.0772
Cute	0.1272	0.0645	0.4531	1.0000	0.0592
Cheerful	0.2696	0.4200	0.0772	0.0592	1.0000

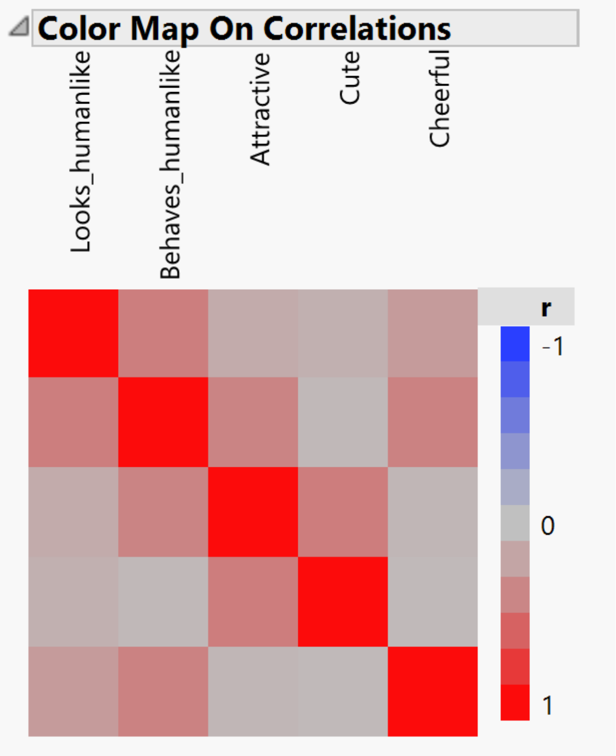
Correlations in JMP

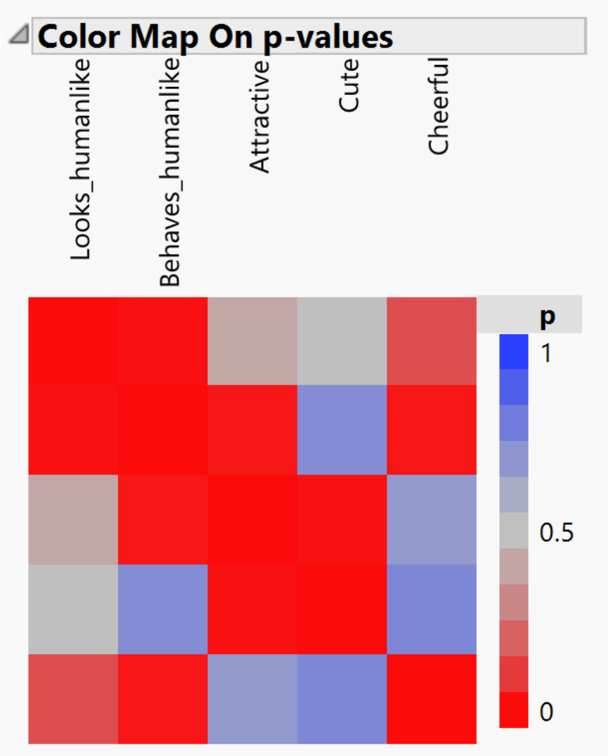


Variable	by Variable	Correlation	Count	Lower 95%	Upper 95%	Signif Prob
Behaves_humanlike	Looks_humanlike	0.4460	29	0.0951	0.6984	0.0153*
Attractive	Looks_humanlike	0.1580	29	-0.2213	0.4958	0.4131
Attractive	Behaves_humanlike	0.4119	29	0.0535	0.6763	0.0264*
Cute	Looks_humanlike	0.1272	29	-0.2510	0.4717	0.5109
Cute	Behaves_humanlike	0.0645	29	-0.3093	0.4211	0.7394
Cute	Attractive	0.4531	29	0.1038	0.7029	0.0136*
Cheerful	Looks_humanlike	0.2696	29	-0.1075	0.5789	0.1573
Cheerful	Behaves_humanlike	0.4200	29	0.0632	0.6816	0.0233*
Cheerful	Attractive	0.0772	29	-0.2977	0.4315	0.6904
Cheerful	Cute	0.0592	29	-0.3141	0.4167	0.7603

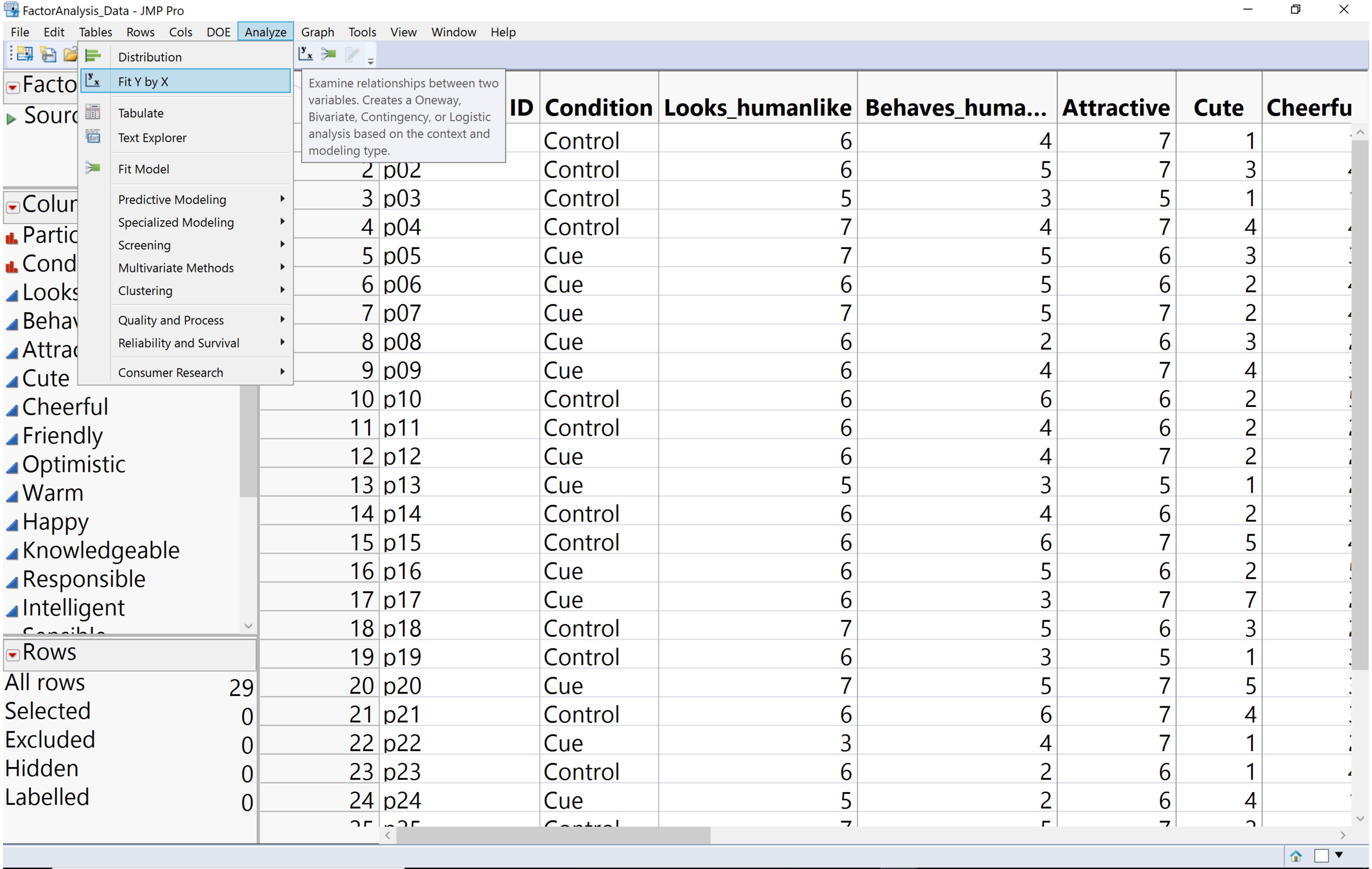
Visualization



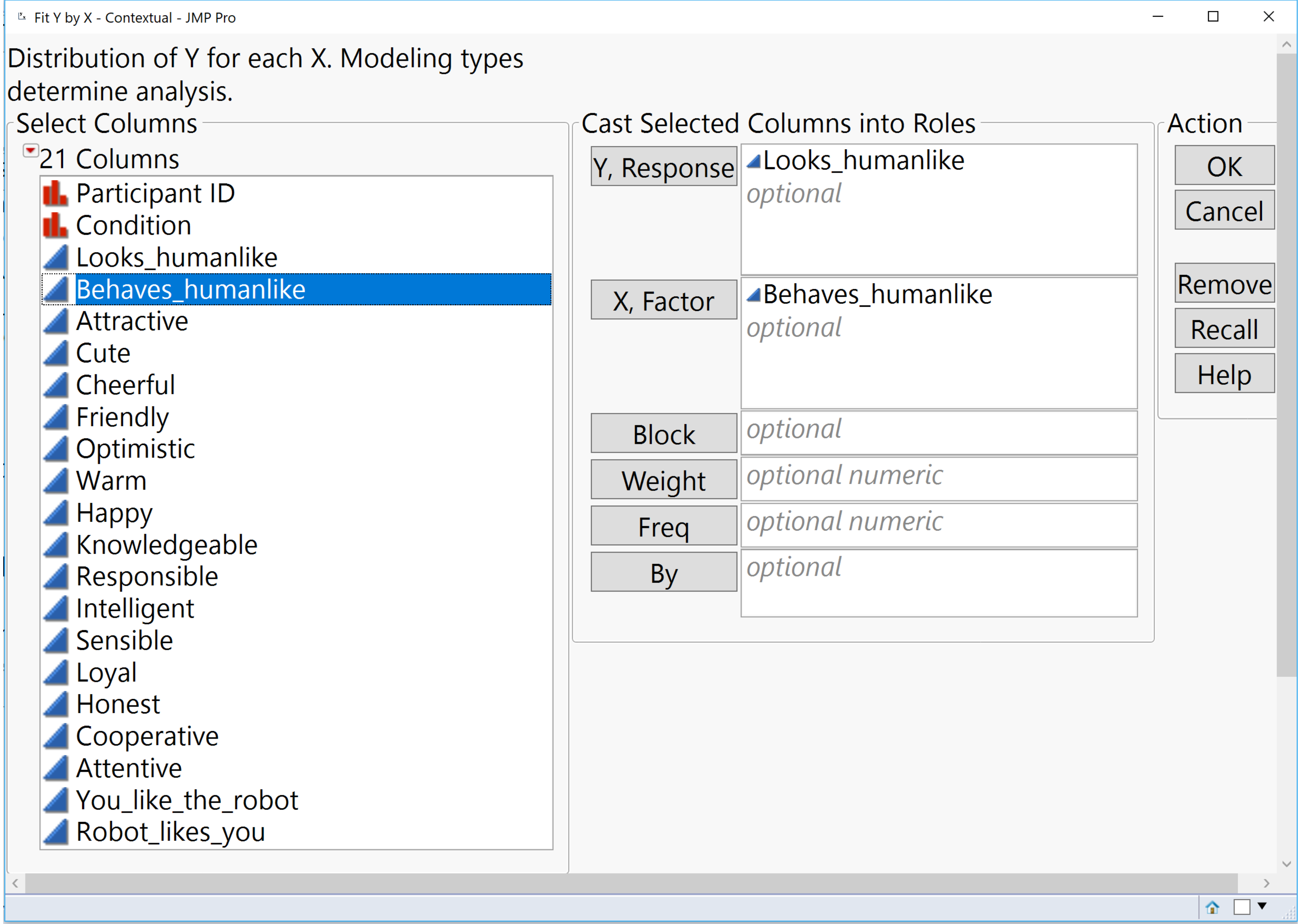


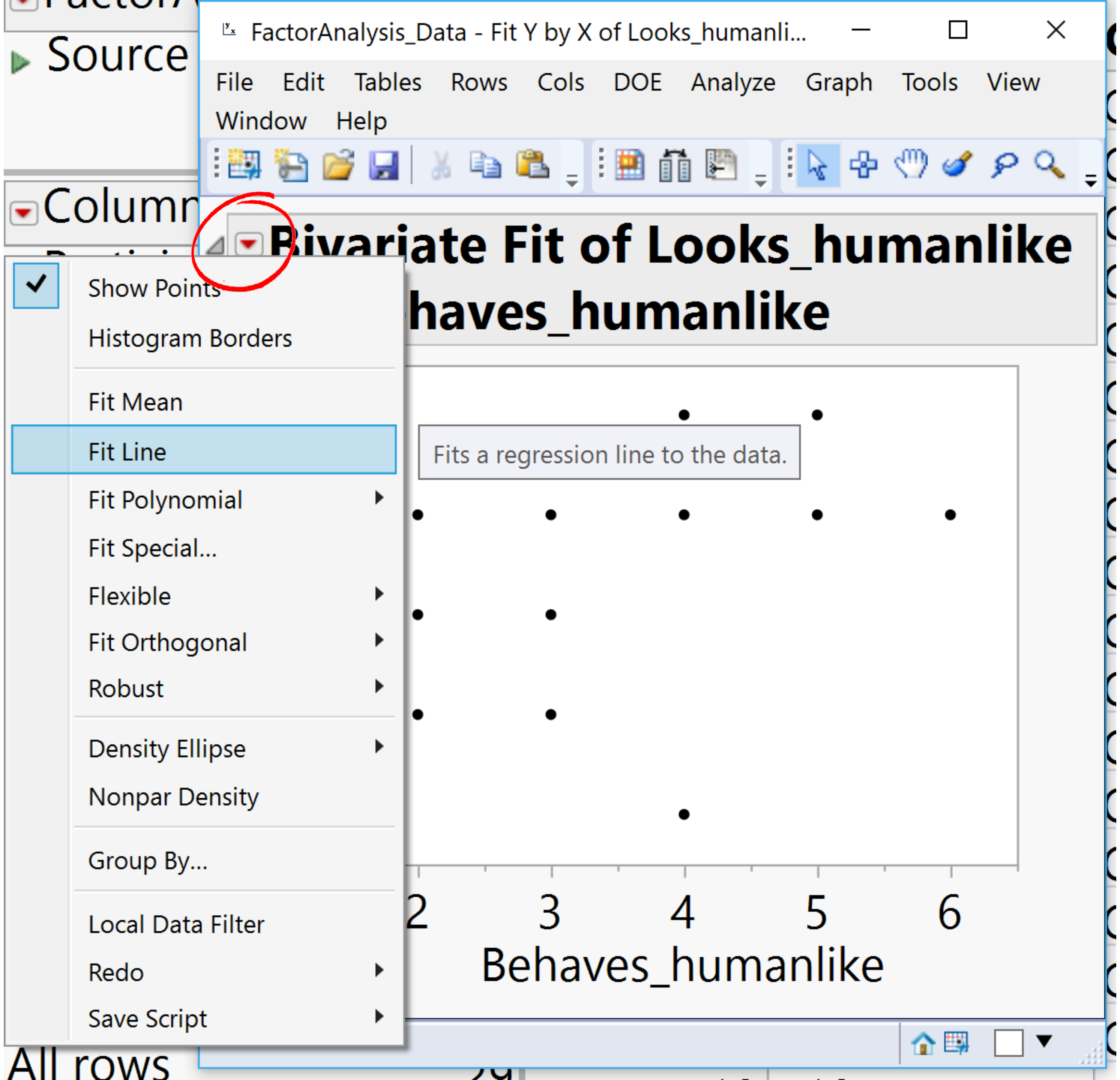


Regression in JMP

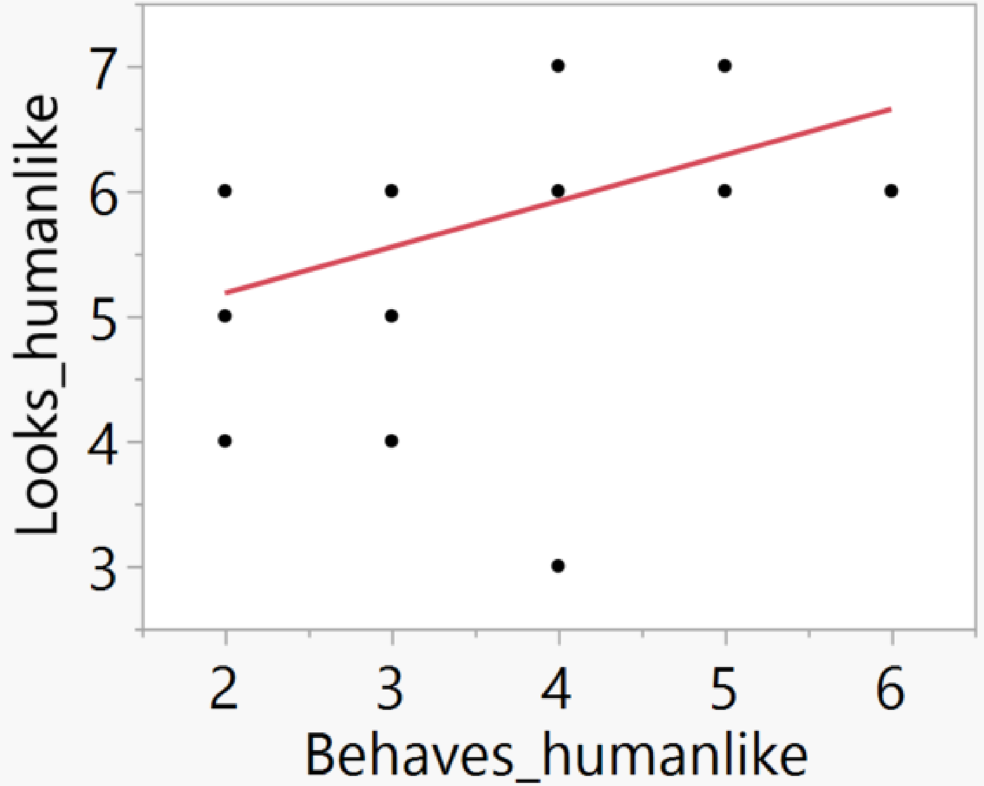


	ID	Condition	Looks_humanlike	Behaves_huma...	Attractive	Cute
		Control	6	4	7	1
2	p02	Control	6	5	7	3
3	p03	Control	5	3	5	1
4	p04	Control	7	4	7	4
5	p05	Cue	7	5	6	3
6	p06	Cue	6	5	6	2
7	p07	Cue	7	5	7	2
8	p08	Cue	6	2	6	3
9	p09	Cue	6	4	7	4
10	p10	Control	6	6	6	2
11	p11	Control	6	4	6	2
12	p12	Cue	6	4	7	2
13	p13	Cue	5	3	5	1
14	p14	Control	6	4	6	2
15	p15	Control	6	6	7	5
16	p16	Cue	6	5	6	2
17	p17	Cue	6	3	7	7
18	p18	Control	7	5	6	3
19	p19	Control	6	3	5	1
20	p20	Cue	7	5	7	5
21	p21	Control	6	6	7	4
22	p22	Cue	3	4	7	1
23	p23	Control	6	2	6	1
24	p24	Cue	5	2	6	4


Fit Y by X - Contextual - JMP Pro
Distribution of Y for each X. Modeling types determine analysis.
Select Columns
21 Columns
Participant ID
Condition
Looks_humanlike
Behaves_humanlike
Attractive
Cute
Cheerful
Friendly
Optimistic
Warm
Happy
Knowledgeable
Responsible
Intelligent
Sensible
Loyal
Honest
Cooperative
Attentive
You_like_the_robot
Robot_likes_you
Cast Selected Columns into Roles
Y, Response
Looks_humanlike
optional
X, Factor
Behaves_humanlike
optional
Block
optional
Weight
optional numeric
Freq
optional numeric
By
optional
Action
OK
Cancel
Remove
Recall
Help


Source
Column
FactorAnalysis_Data - Fit Y by X of Looks_humanli...
File
Edit
Tables
Rows
Cols
DOE
Analyze
Graph
Tools
View
Window
Help
Bivariate Fit of Looks_humanlike
haves_humanlike
Show Points
Histogram Borders
Fit Mean
Fit Line
Fit Polynomial
Fit Special...
Flexible
Fit Orthogonal
Robust
Density Ellipse
Nonpar Density
Group By...
Local Data Filter
Redo
Save Script
Fits a regression line to the data.
2
3
4
5
6
Behaves_humanlike
All rows

Bivariate Fit of Looks_humanlike By Behaves_humanlike



Linear Fit

Linear Fit

Looks_humanlike = 4.4469697 + 0.3678451*Behaves_humanlike

Summary of Fit

RSquare	0.198946
RSquare Adj	0.169277
Root Mean Square Error	0.909192
Mean of Response	5.931034
Observations (or Sum Wgts)	29

Lack Of Fit

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	5.543045	5.54305	6.7056
Error	27	22.319024	0.82663	Prob > F
C. Total	28	27.862069		0.0153*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	4.4469697	0.597456	7.44	<.0001*
Behaves_humanlike	0.3678451	0.142052	2.59	0.0153*

Reporting

Correlations

- DF = N - 2
- If reporting on strength and direction of linear relationship report r
  - Results of the Pearson correlation indicated that there was a significant linear relationship between [var1] and [var2], r(df) = .[value], p = .[value]
- Report R^2 if discussing proportion of explained variance
  - [Var1] accounted for [value]% of the variation in [var2]
  - Or just include as r(df) = .[value], p = .[value], with R^2 = [value]

Regression

- We will come back to if we have time

> predictor and response variables to obtain linearity. For students in the no review condition, EEG-monitored attention levels accounted for 25.19% of the variance in student recall abilities and served as a marginal predictor of recall scores, $\beta = .187, t(10) = 2.17, p = .055$, providing partial support for our premise.

Questions?

University of Colorado
Boulder

THANKS!

Professor **Dan Szafir**

Computer Science & ATLAS Institute
University of Colorado Boulder