Chapter 11 Statistical Foundations: Association, Prediction, & Chi-Square

Presented in this chapter is a discussion the zero order correlation (most widely used), the Pearson Product Moment Correlation, and simple linear prediction, which are used on at least interval level data. The Chi-square statistic which is applied to nominal level data is discussed.

I. Correlation (AKA the Zero Order Correlation)

A. Nature of the Correlation (See also Spatz, 2011, 89-96, 100-101.)

1. A correlation exists between two variables when one is related to the other. The more variance shared between the variables, the greater the association.
2. As the circles merge (See Figure 11.1) to increasingly overlap or become one, the more variance they share, the higher is the association between the variables represented by the circles.

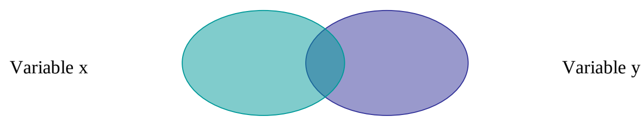


Figure 11.1 Association Between Variables

3. The portion of the two circles which overlap symbolize the degree of commonality or shared variance between the two circles which represent Variable "x" and Variable "y." We say that a specified percent or proportion of Variable "x" is explained, or accounted for, or predicted by Variable "y."

4. The nature and strength of an association or correlation between two variables can be inspected using a scatter plot or a statistic, called a correlation coefficient.

B. Inspecting the Association

1. Scatter Plots are used to visually inspect a suspected association between two variables.
   a. There are four general scatter plots: no relationship, Figure 11.2a; perfect positive relationship, Figure 11.2b; perfect negative relationship, Figure 11.2c; or curvilinear, Figure 11.2d.
   b. While less precise than a statistical correlation procedure, the scatter plot can be instructive. For example, a visual inspection reveals that in Figure 11.2a, the plots between the two variables are "all over the place," indicating no relationship. In this case, the application of a correlation procedure is most likely not necessary.

2. The correlation coefficient, *r*, quantifies the strength and nature (positive or negative) of an association.

a. *r* ranges between –1 and +1 or stated another way $-1 \leq r \leq 1$.
b. The value of *r* does not change if all of the values of either variable are converted to a different measurement scale.
c. The value of r is not affected by the choice of x or y for any data set.
d. *r* measures the strength of a linear relationship.
e. Correlation does not mean causation. Causality is logical not statistical.
f. Correlation coefficients should be tested for statistical significance. It is possible for an r = .06 to be significant, but that would most likely be due to a very large sample. Ignore such findings as they have no practical significance.
g. Salkind (2010, p. 129) provides guidance on interpreting *r*:
   (1) 0.8-1.0, very strong relationship
   (2) 0.6-0.79, strong relationship
   (3) 0.4-0.59, moderate relationship
   (4) 0.2-0.39, weak relationship
   (5) 0.0-0.19, very weak or no relationship

3. Coefficient of Determination (R^2)
a. The Coefficient of Determination is the correlation coefficient squared, *r* = .7 thus, .49 or 49% of the variance is shared between Variables "x" & "y."
b. The coefficient of determination represents the degree of shared variance between the two variables. The higher the squared value, the more the two variables have in common and the more accurate are predictions from one variable to the other.

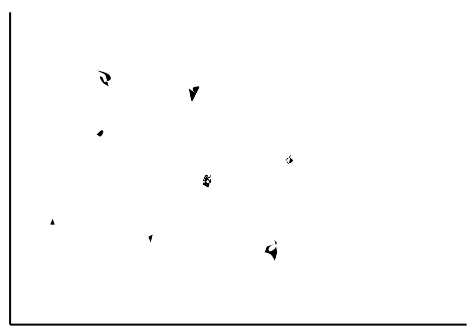


Figure 11.2a No Relationship

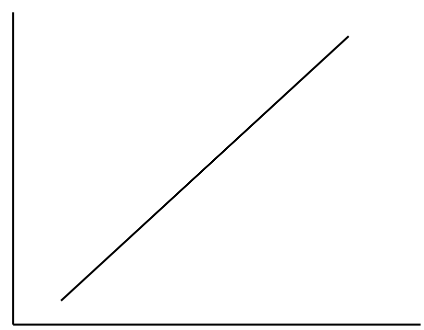


Figure 11.2b Positive Relationship

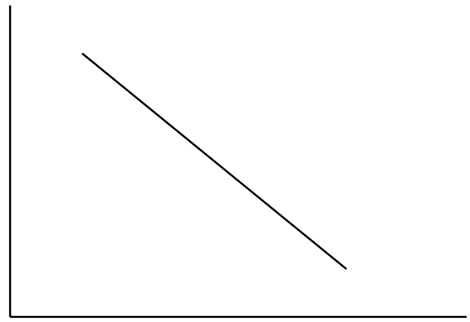


Figure 11.2c Negative Relationship

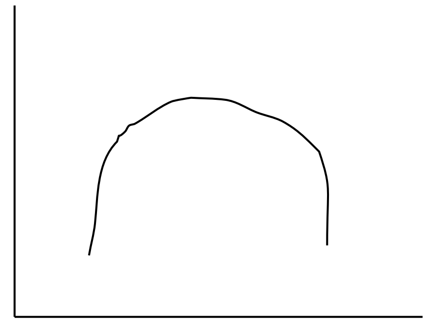


Figure 11.2d Curvilinear Relationship

C. Factors Affecting the Correlation Coefficient

1. Form of the relationship
   a. If the relationship between the two variables is not linear, low correlations are likely to result, even though there may be a robust curvilinear relationship.
   b. To test for a curvilinear relationship:
      (1) View the scatter plot, but with small samples this is not revealing.
      (2) The correlation ratio, eta (η), is used to assess or detect non-linear relationships.
         (a) If the obtained (i.e., linear) correlation coefficient and eta differ substantially from each other, then it is likely that the underlying relationship is curvilinear, i.e., quadratic, cubic, or quartic.
         (b) If the obtained correlation coefficient and eta are similar, then the relationship is probably linear.
   c. When eta is squared, the proportion of total variability in the dependent variable that can be accounted for by knowing the value of the independent variable is given. Neither a linear relationship nor dependent variable normality is required.

2. Outliers in the data
   a. Outliers can overstate or understate the relationship (i.e., size of correlation coefficient) due to "artificial" variance inflation or deflation.
   b. To assess outlier influence, if any, view the scatter plot; often outliers result from a recording or measurement error. If an outlier(s) is (are) truly present:
      (1) "Run" correlation procedures with and without the outliers.
      (2) If the resulting correlation coefficients are not terribly dissimilar, then retain the outliers; is they are then consider discarding the outliers, but be sure to report you did so and explain why.

3. Restriction of Range
   a. The homogeneity or heterogeneity of the sample will affect the size or the correlation coefficient.

b. For samples where there is little variance within "X" or "Y" or between "X" and
"Y", the size of the correlation will be restricted or reduced, due to reduced variance.

c. By applying the correction for restriction of range, the correlation coefficient can be estimated as if range was not restricted.

4. Skewed Distributions
   a. Since the assumption that "X" and "Y" are normally distributed is violated in skewed distributions, the skewed distribution(s) should be transformed into a normal or near normal distribution.
   b. If that is not possible, then use a non-parametric correlation coefficient.

5. Attenuation
   a. An observed correlation coefficient is lower than the "true" correlation.
   b. When a correlation coefficient is lowered due to the unreliability of the measure, attenuation occurs.
   c. The correction for attenuation can estimate the correlation coefficient as if the measures were perfectly reliable.

D. The Pearson Product Moment Correlation

1. Assumptions
   a. The selection of pairs is random and independent.
   b. The "x" and "y" variables are normally distributed.
   c. The linear regression line is straight.
   d. The variances of "y" for each "x" value are equal (homoscedasticity)
   e. Data are on at least an interval scale.

2. Formula 11.1 Pearson Product Moment Correlation (Spatz, 2011, p. 97; Triola, 1998, p. 479)

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum x)^2}\ \sqrt{n(\sum y^2) - (\sum y)^2}}$$

3. Effect Size Estimation
   a. For <u>correlations</u>, Cohen (1988 pp. 79-80) suggests r = 0.10 (small effect), r = 0.30 (medium effect) and r = 0.50 (large effect). The interpretation would be: A (small, medium, or large) percentage of the variance in the dependent (criterion or predicted) variable, usually 'y' is attributable, explained, or accounted for by the presence of the independent (predictor) variable, usually 'x'."
   b. Neither Cohen nor Stevens advanced a formula for computing ES for correlations.

4. Correlation Example
   a. **Case 11.1**: The manager of the company's motor pool has asked you to help her determine the relationship between vehicle weight and miles per gallon (mpg) for the company's fleet. She has given you the following information about vehicle weights, in 100's of pounds, and mpg for city and highway driving. Once the relationship was determined, she next asked you to predict the mpg based on the vehicle weight for two purchases at 4,200 and 3,700 pounds.

X Weight	29	35	28	44	25	34	30	33	28	24
Y mi/gal.	31	27	29	25	31	29	28	28	28	33

1. Is there a relationship between vehicle weight and miles per gallon of gas?
2. $\rho = 0$
3. $\rho \neq 0$
4. H_o: $\rho = 0$
5. H_1: $\rho \neq 0$
6. $\partial = .05$
7. Pearson Product Moment Correlation
8. Compute Test Statistic
   (a) Construct Data Table

On-Tail Tests	
Left-Tail	Right-Tail
Claim: -r	Claim: +r
H_o: $\rho \geq 0$	H_o: $\rho \leq 0$
H_1: $\rho < 0$	H_1: $\rho > 0$

Table 11.1
Pearson Product Correlation Case Data

X	Y	**X • Y**	**x^2**	**y^2**
29	31	899	841	961
35	27	945	1225	729
28	29	812	784	841
44	25	1,100	1,936	625
25	31	775	625	961
34	29	986	1,156	841
30	28	812	841	784
33	28	924	1,089	784
28	28	784	784	784
24	33	792	576	1,089
$\sum x = 309$	$\sum y = 289$	$\sum xy = 8,829$	$\sum x^2 = 9,857$	$\sum y^2 = 8,399$
$\bar{x} = 31$	$\bar{y} = 28.9$			

(b) Compute degrees of freedom (df = N-2) or 8
(c) Substitute into Formula 11.1 (Spatz, 2011, p. 97; Triola, 1998, p. 479)

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum x)^2}\ \sqrt{n(\sum y^2) - (\sum y)^2}}$$

$$r = \frac{10(8829) - (309)(289)}{\sqrt{10(9857) - (309)^2}\sqrt{10(8399) - (289)^2}} = -.8399$$

(d) Critical value = .632 at ∂ = .05 & *df* = N-2 or 8 for a two-tail test (Spatz, 2011, p. 385).

9. Apply Decision Rule: Since *r* = |-0.8399| ≥ .632, we reject H_o ρ = 0, as p < .05.
   (a) *GraphPad Software QuickCalcs*. (n.d.) computes an exact probability of 0.0024, which is less than the specified alpha (∂) = 0.05. The traditional hypothesis testing method is confirmed. We express this finding as *r* = 0.8399, *p* < 0.05.
   (b) A critical value table for *r* at alpha, levels 0.05 and 0.01 is located at <http://www.radford.edu/~jaspelme/statsbook/Chapter%20files/Table_of_Critical_Values_for_r.pdf>

10. There is sufficient evidence to conclude there is an association between vehicle weight and mpg. The more the vehicle weighs the lower the miles per gallon.

11. Effect Size Estimation: Applying Cohen's (1988, pp. 79-80) effect size criteria, *r* = |-0.8399| indicates a large effect. We conclude that "miles per gallon" is materially influenced by vehicle weight. For <u>correlations</u>, Cohen (1988, pp. 79-80) suggests r = .10 (small effect), r = .30 (medium effect) and r = .50 (large effect).

12. Spatz (2011, pp. 191-192) offers an alternative procedure, using the t-test, to test for statistically significant correlation.

5. **Coefficient of Determination (R^2)**
   a. The Coefficient of Determination is the correlation coefficient squared, r = 0.7 thus, .49 or 49% of the variance is shared between Variables A and B.
   b. The Coefficient of Determination represents the degree of shared variance between the two variables. The higher the squared value, the more the two variables have in common and the more accurate are predictions from one variable to the other. Spatz (2011, pp. 102-104) discusses R^2 or r^2.

II. Simple Linear Prediction

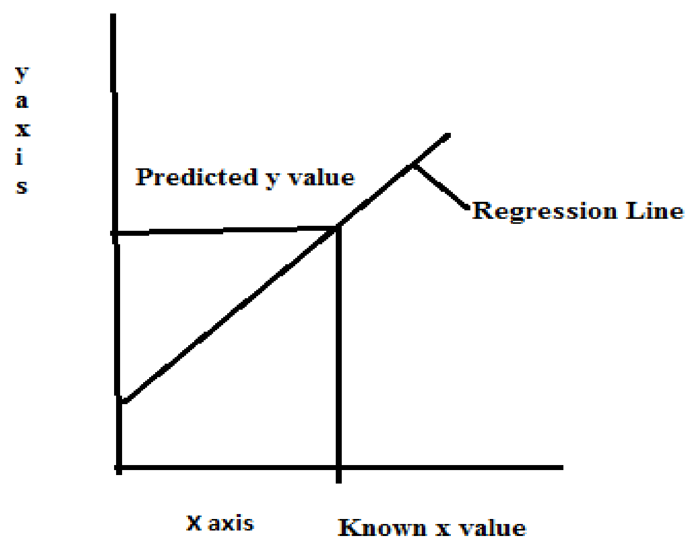
A. Introduction

1. There are times when an evaluator or researcher wants to predict the estimated value of one variable from his or her knowledge of another. A college admissions team may want to predict first semester GPA based on college placement (e.g., SAT or ACT) test score or if the price of gasoline is high, a potential buyer may want to predict her miles per gallon (MPG) based on the weight of the car. In making these predictions, we are assuming a liner

relationship between the predictor variable and the predicted (i.e., dependent or response) variable. See Figure 11.3.

a. The "y" axis is the predicted value scale (e.g., GPA, miles per gallon, etc.)
b. The "x" axis is the predictor value scale (e.g., SAT score, car weight, etc.)
c. In theory, we can predict from our knowledge of "x" using a regression equation, a predicted $\hat{y}$ value. We simply pick an "x" value and then go vertically up to the regression line and then horizontally to the "y" axis to find the predicted $\hat{y}$ value.
d. Often times, the scale of the figure (e.g., Figure 11.3) might give us a different predicted $\hat{y}$ value, depending on the particular graph we'd use. So, we compute a regression or prediction formula which lets us make predictions more accurately than using graph.

Figure 11.3 Regression Line



2. Constructing the Regression Line
   a. Terms & Symbols
      (1) Terms
         (a) "x" is the independent or predictor variable
         (b) "y" is the dependent or response variable
         (c) $\hat{y}$ is the predicted "y" value
         (d) "b_o" is the "y" intercept, the point on the "y" axis where the regression line meets it. See Figure 11.4.
         (e) "b_1" is the slope or steepness of the regression line; see Figure 11.4. If the slope of the regression line is 1.0, a 1.0 point increase in "x" results in a one point increase in "y." If the slope of the line is 0.05, a 1.0 increase in "x" results in 0.05 increase in "y."

(2) The Regression Equation (Triola, 1998, p. 495)

(a) Formula 11.2 Regression Equation: $\hat{y} = b_o + b_1 x$
Where: $\hat{y}$ = the predicted "y" value; b_o = the y-intercept of the regression line; b_1 the slope or steepness of the regression line: x = the predictor value

(b) Formula 11.3 $b_o = \bar{y} - b_1 \bar{x}$ (Triola, 1998, p. 496)

Where: $\bar{y}$ = mean of response (i.e., "y") variable; b_1 = slope of the regression line; and $\bar{x}$ = mean of the predictor (i.e., "x") variable

(c) Spatz (2011, p.114-119) presents somewhat different formula which produce an equivalent regression equation in terms of the predicted $\hat{y}$ value.

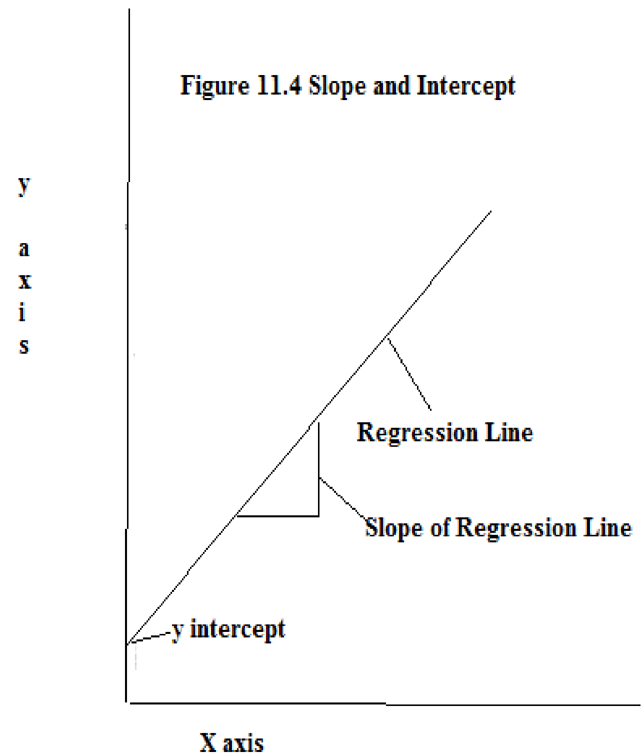


Figure 11.4 Slope and Intercept

2. Assumptions
   a. Only linear relationships are predicted.
   b. If the "x" and "y" variables lack a significant correlation, $\bar{y}$ (the mean of "y") is the best predicted y value. Unless there is a statistically significant correlation between "x" and "y," don't construct and use a regression equation.

c. If the x and y variables are significantly correlated, substitute the appropriate "x" value (e.g., SAT score) into the regression (or prediction) equation to obtain the best predicted "y" value (e.g., freshman 1st semester GPA),

3. Regression Equation Guidelines
   a. Don't use the linear regression formula to make predictions if there is not a statistically significant association between the variables.
   b. When making a prediction, don't over generalize or generalize to groups not represented in the population from which the sample is drawn. Don't go beyond the data.
   c. Make predictions only based upon current data.

B. MPG and Vehicle Weight Example Continued for Prediction

$\Sigma x = 309$ $\Sigma y = 289$ $\Sigma xy = 8{,}829$
$\Sigma x^2 = 9{,}857$ $\Sigma y^2 = 8{,}399$ $\bar{x} = 31$ $\bar{y} = 28.9$

1. Before computing Formulas 11.2 and 11.3, we must determine the slope of the line using Formula 11.4 Regression Line Slope (Triola, 1998, p. 496)

$$b_1 = \frac{n(\sum xy - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} = \frac{10(8829) - (309)(289)}{10(9857) - (309)^2} = -0.3273$$

2. Compute the y-intercept using Formula 11.3: $b_o = \bar{y} - b_1 \bar{x}$ or
   28.9 – (-.3273) (31) = 28.9 – (-10.1463) = 39.0463

3. Construct the Regression equation using Formula 11.2:
   $\hat{y} = 39.0463 + (-.3273)\,x$

4. Predict mpg for 2 cars of interest to a buyer.
   a. The predicted mpg for a 4200 pound care is 25.3 mpg
      ($\hat{y} = 39.0463 + (-.3273)(42)$ or $\hat{y} = 25.30$)

   b. The predicted mpg for a 3700 pound car is 26.94 mpg
      ($\hat{y} = 39.0463 + (-.3273)(37)$ or $\hat{y} = 26.94$)

III. Chi-Square (Analyzing Nominal Data)

A. Introduction

1. Nominal Data
   a. Nominal data consists of names, labels, or categories only. Data can't be arranged in an ordering scheme. Categories must be mutually exclusive.

Boy/Girl	European African Asian

b. What is actually analyzed are raw frequencies, i.e., the number of boys, girls or the number of Europeans, Africans, and Asians.

2. There are 3 commonly statistical procedures used analyze nominal data.
   a. <u>The Chi-Square Test for Goodness of Fit</u> assesses whether or not observed nominal data conforms to (or is statistically different from) some theoretical or expected distribution (Daniel, 1990, p. 306; Morehouse & Stull, 1975, p. 311).
   b. <u>The Chi-Square Test of Independence or Association</u> tests whether or not two variables from the same sample are related (Daniel, 1990, p. 181).
   c. <u>The Chi-Square Test of Homogeneity</u> (only briefly mentioned) assesses whether or not two or more samples, drawn from <u>different</u> populations, are homogenous (e.g., are similar or associated) on some characteristic of interest (Daniel, 1990, pp. 192-93).

B. Chi-Square Introduction

1. Chi-square has a distribution but is classified as a nonparametric statistical test by tradition (Daniel, 1990, pp. 178-179). Nonparametric tests are distribution-free statistics which are used when a population's (or a sample's) distribution is substantially non-normal and parametric tests are not suitable. See also Spatz (2011, pp. 300-304, 316-320).

2. The chi-square distribution approaches the normal distribution as *n* increases (Daniel, 1990, p. 180). When the sample size is $N \geq 30$, the chi-square is approximately normal (Morehouse & Stull, 1975, p. 313).

3. The null (or statistical) hypothesis (H_o) states that there is either "no differences between observed or expected frequencies" (Goodness of Fit) or "the variables or samples are not related, i.e., are independent" (Test for Independence) or are homogeneous (Test of Homogeneity).
   a. As normally applied, the X^2 is not directed at any specific alternative hypothesis (Reynolds, 1984, p. 22).
   b. Degrees of freedom, alpha, and power must be specified or determined. The applicable degrees of freedom (*df*) depends on the test applied. Alpha is specified, a priori, usually at the .05 or .01 level.

4. While a statistically significant X^2 establishes a relationship between two variables, it reveals little else (Reynolds, 1984, p. 20).
   a. A statistically significant chi-square is not a measure of the strength of an association (Daniel, 1990, p. 400; Reynolds, 1984, p. 30; Welkowitz, Ewen, & Cohen, 1991, p. 298; Udinsky, Osterlind, & Lynch, 1981, p. 214).

b. Hence, when a relationship has been established additional analysis must be conducted.
c. Subsequent analysis may be accomplished through partitioning X^2, which is a detailed, time intensive task (Reynolds, 1984, pp. 23-30) or applying measures of association (Reynolds, 1984, pp. 35-44; Welkowitz, Ewen, & Cohen, 1991, pp. 298-301; Siegel, 1956, pp. 196-202).

5. Assumptions
   a. The distribution is not symmetric.
   b. Chi-square values can be zero or positive but never negative.
   c. Chi-square distribution is different (i.e., different shape) for each degree of freedom. As the number of degrees of freedom increase, the distribution approaches the SNC.
   d. Degree of freedom (*df*) varies depending on the chi-square test being used.
   e. Measurements are independent of each other. Before-and-after frequency counts of the same subjects cannot be analyzed using χ^2.

6. Chi-Square Issues
   a. Expected frequency cell size
      (1) The greater the numerical difference between observed and expected frequencies within cells, the more likely is a statistically significant X^2. Cells with estimated frequencies (<5) may yield an inflated X^2.
      (2) There is considerable debate concerning small cell expected frequencies (Daniel, 1990, p. 185). Various authors have proposed guidelines depending on the specific test.
      (3) Welkowitz, Ewen, & Cohen (1991, p. 292) offer general advice:
      (a) for $df = 1$, all expected frequencies should be at least 5;
      (b) for $df = 2$, all expected frequencies should be at least 3; and
      (c) for $df = 3$, all but one expected frequency value should equal 5.
      (4) If cells are to be combined, then there should be a logical reason for the combination, otherwise interpretation is adversely affected. Morehouse and Stull (1975, pp. 320-321) advocate the use of Yates' Correction for Continuity when expected cell sizes are less than 5. However, Daniel (1990, p. 187) reported that there is a trend away from applying Yates' Correction. Spatz (2011, p. 317) advises against using the Yates correction.
   b. Percentages
      (a) There is some disagreement among authors as whether or not percentages may be included in chi-square computations.
      (b) Reynolds (1984, p. 36) argues for 2 X 2 contingency tables that "percentages permit one to detect patterns of departure from independence...and [that] percentages are particularly useful in 2 X 2 tables." However, Morehouse and Stull (1975, p. 320) disagree, "the direct numerical counts or raw data should always be used as a basis for the calculation of chi-square. Percentages and ratios are not

independent, and consequently, their use will result in errors in conclusions."

(c) Daniel (1990), Siegel (1956), Spatz (2011), Welkowitz, Ewen, & Cohen (1991), and Udinsky, Osterlind, & Lynch (1981) are silent on the subject, but none of their examples contain percentages.

C. Chi-Square Goodness of Fit Test

1. Theory and Formula
   a. The Chi Square Goodness of Fit Test is a one variable procedure. There is only one variable, often with several levels. Siegel (1956, pp. 42-47) refers to this type of test as "The χ^2 One Sample Test." See also Spatz (2011, pp. 310-316).
   b. In a goodness of fit test, there are observed and expected frequencies (Table 11.2).
      (1) Expected frequencies are derived from a theory, hypothesis, or commonly accepted standard.
      (2) The null hypothesis is that the collected data "fit the model." If the null is rejected, then the conclusion is that the data didn't fit the model, i.e., the expected frequencies (Welkowitz, Ewen, & Cohen, 1991, pp. 289-292). The alternative hypothesis, H_1, states the opposite.
      (3) In other words, if one is drawing a random sample from a population, it is expected that there will be a reasonable "fit" between the sample frequencies and those found in the population across some characteristic of interest (Daniel, 1990, p. 307; Reynolds, 1984, p. 17; Siegel, 1956, p. 43; Welkowitz, Ewen, & Cohen, 1991, pp. 289-291).

   c. Formula 11.5 Chi-Square Goodness of Fit (Spatz, 2011, p. 311)

$$\chi^2 = \sum\left[\frac{(O-E)^2}{E}\right]$$

   Where: χ^2 = chi-square value; O = observed frequencies; E = expected frequencies

   d. For Goodness of Fit test, there are no measures of association as it's a one variable test.
      (1) We are concerned only with whether or not the observed data "fit" the expected.
      (2) One reason the X^2 Goodness of Fit test is not used as a measure of association is that its magnitude depends on sample size (i.e., large sample equal large computed X^2 value and the larger the computed X^2, the greater the chances of rejecting the null hypothesis).

2. Index of Effect Size
   a. For the Goodness of Fit Test, we're comparing how an observed distribution "fits" an "expected" distribution; when **Cohen's w** = 0, there

is "perfect fit. As **w** increases the degree of departure from "a perfect fit" increases. Thus, we say when **w** = .1, there is a small effect or small departure from "fit".

b. Formula 11.6a Index of Effect Size Cohen (1988, pp. 216-218)

$$w = \sqrt{\sum_{i=1}^{m} \frac{(P_{1i} - P_{oi})^2}{P_{0i}}}$$

Where: P_{0i} = proportion in a cell, posited by the null hypothesis; P_{1i} = proportion in a cell posited by the alternative hypothesis; and m = # of cells.

Formula 11.6b is equivalent and easier to compute.

$$\sqrt{\sum \frac{(\text{Proportion}_{expected} - \text{Proportion}_{observed})^2}{\text{Proportion}_{expected}}}$$

Where: Proportion $_{\text{expected}}$ = expected proportion
Proportion $_{\text{observed}}$ = observed proportion

c. Formula 11.6a is quite complicated, tedious, and time consuming to compute by hand; use a statistical computer program, e.g., SPSS or SAS. For the Chi Square Test of Association or Heterogeneity, there are computationally convenient alternative effect size indices.
d. For interpreting **w**, Cohen (1988, pp. 224-225) recommends **w** = .10 (small effect), **w** = .30 (medium effect) and **w** = .50 (large effect).

4. **Case 11.2**: Oatmeal and Taste Preference
   a. Your company produces four types of microwave oatmeal products: Apple, Peach, Cherry, and Prune. The vice-president for sales has received marketing data that suggests the purchasing decision is not based on fruit taste preference. You have been asked to verify these data. At the $\alpha = .05$ level, test the claim that product purchase is unrelated to taste preference. You have randomly identified 88 customers and learned which oatmeal product they last purchased. The null states that purchasing decisions are the same for each taste preference.

   b. Apply Classical Hypothesis Testing Method
      (1) Are product purchases related to taste preference?
      (2) $\rho_1 = \rho_2 = \rho_3 = \rho_4$
      (3) $\rho_1 \neq \rho_2 \neq \rho_3 \neq \rho_4$
      (4) H_o: $\rho_1 = \rho_2 = \rho_3 = \rho_4$
      (5) H_1: $\rho_1 \neq \rho_2 \neq \rho_3 \neq \rho_4$

(6) $\alpha = 0.05$
(7) Chi-Square Goodness of Fit Test
(8) Compute the test statistic and select the relevant critical value(s).
(a) Data Table

Table 11.2a
Taste Preference Case Data

Taste	**0**	**E**	**O-E**	**(O-E)^2**	**(O-E)^2/E**
Apple	36	22	14	196	8.909
Peach	21	22	-1	1	0.045
Cherry	12	22	-10	100	4.545
Prune	19	22	-3	9	0.409
					χ^2 =13.908

(b) Compute Degrees of Freedom: *df* = 3 (k-1 or 4-1)

(c) Substitute into Formula 11.5: See Data Table where $\chi^2 = 13.908$

(d) Critical Value: 7.815 at for $\partial = .05$ & *df* = 3 (Spatz, 2011, p. 393; Triola 1998, p. 716).

(9) Apply Decision Rule: Since $\chi^2 = 13.908 \geq 7.815$, reject H_o: $\rho_1 = \rho_2 = \rho_3 = \rho_4$, $p < .05$.
(a) *GraphPad Software QuickCalcs*. (n.d.) computes an exact probability of 0.0030, which is less than the specified alpha (∂) = 0.05. The traditional hypothesis testing method is confirmed. We express this finding as $\chi^2 = 13.908$, $p < 0.05$.
(b) A critical chi-square value table may be found at <http://home.comcast.net/~sharov/PopEcol/tables/chisq.html>.

(10) There appears to be a relationship between purchase decision and taste preference. It seems that customers prefer to purchase the Apple, and Peach brands of oatmeal; Prune was almost purchased as expected, but Cherry didn't appear too popular.

(11) Effect Size Estimate: Since the Ho was rejected, we compute **Cohen's w** (Cohen, 1988, pp. 216-218).

$$\sqrt{\sum \frac{(\mathrm{Proportion}_{expected} - \mathrm{Proportion}_{observed})^2}{\mathrm{Proportion}_{expected}}} = \sqrt{\frac{0.039}{0.25}} = \sqrt{0.156} = 0.395$$

Given Cohen's criteria, taste preference had a moderately strong influence on the purchasing decision.

Table 11.2b
*Computing Cohen's **w** Effect Size Index*

Oatmeal	Proportion Expected	Proportion Observed [c]	Difference [c]	Difference Squared [c]
Apple	0.25[a]	0.409[b]	-0.159	0.025
Peach	0.25	0.239	0.011	0.000
Cherry	0.25	0.136	0.114	0.013
Prune	0.25	0.216	0.034	0.001
			Total	0.039

[a] 22/88=0.25 [b] 36/88=0.409 [c] Rounded to 3 decimal places

D. Chi-Square Test of Independence (Also called Association)

1. Theory and Formula
   a. Welkowitz, Ewen, & Cohen (1991, pp. 293-297) and Daniel (1990, pp. 181-185) report that this test is applied when two variables, from the same sample, are to be tested. See also Spatz (2011, pp. 304-310).
      (1) The Test of Independence can be computed in the same manner as the Goodness of Fit.
      (2) Formula 11.7 Chi-Square Test of Independence (Spatz, 2011, p. 303)

$$\chi^2 = \sum\left[\frac{(O-E)^2}{E}\right]$$

   b. Measure of Association: The phi ϕ (pronounced "fee") Coefficient
      (1) The phi coefficient is a symmetric index with a range between 0 and 1, where zero equals statistical independence.
         (a) Maximum value is attained only under strict perfect association.
         (b) The phi coefficient is depressed by skewed marginal totals. (i.e., imbalanced marginal totals). The greater the skewness is the greater the depression.
      (2) Before the phi coefficient is applied, there should be a statistically significant chi-square value where a 2 x 2 contingency table has been applied. Apply the phi coefficient only to a 2 x 2 Contingency Table.

      (3) Formula 11.8 phi Coefficient (Spatz, 2011, pp. 307-308):

$$\phi = \sqrt{\frac{\chi^2}{N}}$$

where: ϕ = phi coefficient
$X^2 = X^2$ test statistic
N = total number of subjects

   c. Measure of Association: Cramer's C or V Statistic

(1) Cramer's C or V statistic (Daniel, 1990, pp. 403-404; Spatz 2011, p. 315) is applied as a measure of association when "r x c" or "i x j" tables larger than the 2 x 2 Contingency Table are tested. The "r x c" or "i x j" terminology is used interchangeably. The metric is also referred to as Cramer's ϕ or ϕ_c.

(2) Characteristics
   (a) Value varies between "0" and "1."
   (b) Where no association is present, C = 0.
   (c) When r = c, a perfect correlation is indicated by C = 1.
   (d) When r ≠ c, a perfect correlation may not be indicated even when C = 1.

(3) Formula 11.9 Cramer's C or V Statistic (Daniel, 1990, p. 403)

$$C = \sqrt{\frac{\chi^2}{n(t-1)}}$$

where: χ^2 = computed χ^2 test statistic
n = sample size
t = the number of r or c whichever is less

(4) If χ^2 is significant, then Cramer's C is significant (Ewen, 1991, p. 178)

d. <u>Measure of Association: Contingency Coefficient (CC)</u>
   (1) Siegel (1956, p. 196) describes the contingency coefficient, "a measure of the extent of association or relation between two sets of attributes [variables]. It is applied as a measure of association when "r x c" or "i x j" tables larger than the 2 x 2 Contingency Table are tested.
   (2) CC will have the same value regardless of how the categories are arranged in the columns or rows.
   (3) Formula 11.10 The Contingency Coefficient (Siegel, 1956, p. 196)

$$CC = \sqrt{\frac{\chi^2}{N + \chi^2}}$$

where: *CC* = contingency coefficient
$X^2 = X^2$ test statistic
N = total number of subjects

e. <u>Effect Size Index</u>
   (1) For a 2 x 2 Contingency Table, the phi coefficient does double duty as a measure of association and effect size (Spatz, 2011, pp. 307-308).
   (2) For "r x c" tables (e.g., 3x2, [3 rows, 2 columns], 3x4 [3 rows, 4 columns, etc.]) with more than one degree of freedom, where

df = (r-1)(c-1), use Formula 11.8 (Spatz, 2011, p. 315).

2. **Case 11.3**: Training Product Sales Approach
   a. Example: A product manager within your training organization has recommended that your company's historically most successful product needs a new sales approach to boost sales. You randomly selected 305 former trainees and through the mail, asked them to evaluate the current product sales approach. One demographic variable you assessed was gender. This is a two variable analysis. The null hypothesis states attitudes towards the current sales approach is the same across both genders.

   b. Apply the Hypothesis Testing Model
      (1) Is there a difference in supporting the current sales approach and gender?
      (2) $\rho_1 = \rho_2$
      (3) $\rho_1 \neq \rho_2$
      (4) H_o: $\rho_1 = \rho_2$
      (5) H_1: $\rho_1 \neq \rho_2$
      (6) $\alpha = 0.05$
      (7) Chi-Square Test of Association
      (8) Compute the test statistic and select the relevant critical value(s).
         (a) Data Table

> To compute expected frequency, for the Test of Independence:
>
> Expected = (row total) (column total) / (grand total)

Table 11.3
Training Sales Approach Case Data

Variable	**Men**	**Women**	**Row Total**
Like Sales Approach	43 (38.87)	35 (39.12)	78
Disliked Sales Approach	109 (113.13)	118 (113.87)	227
Column Total	152	153	305

(b) Compute Degrees of Freedom: *df* = 1 (r-1)(c-1)

(c) Substitute into Formula 12.3 Chi-Square Test of Association

Table 11.4
Training Sales Approach χ^2 *Data*

Taste	**0**	**E**	**O-E**	**(O-E)²**	**(O-E)²/E**
M/Like	43	38.87	4.13	17.057	0.439
W/Like	35	39.12	-4.12	16.974	0.434
M/Dislike	109	113.13	-4.13	17.057	0.151
W/Dislike	118	113.87	4.13	17.057	0.150
					χ^2 =1.174

(d) Critical Value: 3.841 at $\partial = .05$ & $df = 1$ (Spatz 2011, p. 393; Triola 1998, p. 716)

(9) Apply Decision Rule: Since $\chi^2 = 1.174$ is < 3.841, retain H_o: $\rho_1 = \rho_2$ as p > .05. *GraphPad Software QuickCalcs*. (n.d.) computes an exact probability of 0.2786, which is less than the specified alpha (∂) = 0.05. The traditional hypothesis testing method is confirmed. We express this finding as $\chi^2 = 1.174$, $p > 0.05$.

(10) There is insufficient evidence to conclude that there is a relationship between liking current sales approach and gender. It appears that both men and women disliked the current training product's sales approach.

(11) Effect Size Estimate: Doesn't apply as H_o is retained. (If H_o was rejected, we could use the ϕ coefficient, Formula 11.8.)

3. **Case 11.4**: Education Attainment and Training Preference

a. The 2 x 2 or Contingency Table

(1) The Contingency Table can be used when two categorical variables with two levels each are being tested for an association.

(2) Formula 11.11 2 x 2 Contingency Table (Spatz, 2011, p. 307):

$$\chi^2 = \frac{N(AD-BC)^2}{(A+B)(C+D)(A+C)(B+D)}$$

b. Apply the Hypothesis Testing Model

(1) Are education level (high school or college graduate) and training preference (active or traditional learning) related? The null asserts that training preference is the same regardless of educational level.

(2) $\rho_1 = \rho_2$

(3) $\rho_1 \neq \rho_2$

(4) H_o: $\rho_1 = \rho_2$

(5) H_1: $\rho_1 \neq \rho_2$

(6) $\alpha = 0.05$

(7) Chi-Square Test of Association (2 x 2 Contingency Table)

(8) Compute the test statistic and select the relevant critical value(s).

(a) Data Table

Table 11.5
Training Preference Case Data

Preference	**High Sch.**	**College**	**Row Total**
Active Learning	45 (A)	55 (B)	100
Traditional	27 (C)	53 (D)	80
Column Total	72	108	180

(b) Compute Degrees of Freedom: *df* = 1 (always)

(c) Substitute into Formula 11.11 2 x 2 Contingency Table

$$\chi^2 = \frac{N(AD-BC)^2}{(A+B)(C+D)(A+C)(B=D)} = \frac{180 \bullet 810,000}{62,208,000} = \frac{145,800,000}{62,208,000} = 2.34$$

(d) Critical Value: 3.841 at $\partial = .05$ & *df* = 1 (Spatz, 2011, p. 393; Triola 1998, p. 716),

(9) Apply Decision Rule: Since $\chi^2 = 2.34$ is < 3.841, retain H_o: $\rho_1 = \rho_2$, as $p > .05$.

(10) There is insufficient evidence to conclude that there is a relationship (or difference) between education attainment and training preference.

(11) Effect Size Estimate: Does not apply, as H_o is retained. If H_0 was rejected, a phi coefficient (Formula 11.8) would have been computed.

4. **Case 11.5**: Age and Environmental Preference (urban vs. suburban**)**
   a. Apply the Hypothesis Testing Model
      (1) Are age and environmental preference related? (The null asserts environment preference is the same regardless of age.)
      (2) $\rho_1 = \rho_2$
      (3) $\rho_1 \neq \rho_2$
      (4) H_o: $\rho_1 = \rho_2$
      (5) H_1: $\rho_1 \neq \rho_2$
      (6) $\alpha = 0.05$
      (7) Chi-Square Test of Association (2 x 2 Contingency Table)
      (8) Compute the test statistic and select the relevant critical value(s).
         (a) Data Table

Table 11.6
Age and Environment Case Data

Preference	**≤ 40**	**≥ 41**	**Row Total**
Urban	15	28	43
Suburban	35	22	57
Column Total	50	50	100

(b) Compute Degrees of Freedom: *df* = 1 (always)

(c) Substitute into Formula 11.11 2 x 2 Contingency Table

$$\chi^2 = \frac{N(AD-BC)^2}{(A+B)(C+D)(A+C)(B=D)}$$

$$\chi^2 = \frac{100(15\bullet22-28\bullet35)^2}{(43)(57)(50)(50)} = \frac{42,250,000}{6,127,500} = 6.895$$

(d) Critical Value: 3.841 at ∂ = .05 & *df* = 1 (Spatz, 2011, p. 393; Triola 1998, p. 716)

(9) Apply Decision Rule: Since $\chi^2 = 6.895 > 3.841$, reject Ho: $\rho_1 = \rho_2$, $p < .05$. *GraphPad Software QuickCalcs*. (n.d.) computes an exact probability of 0.0086, which is less than the specified alpha (∂) = 0.05. The traditional hypothesis testing method is confirmed. We express this finding as $\chi^2 = 6.895$, $p < 0.05$.

(10) There is sufficient evidence to conclude that there is a relationship between age and environmental preference. People 40 and younger prefer the suburban environment.

(11) Apply Measure of Association: Since this is a 2 x 2 contingency table, we will use the phi-coefficient.
(a) Substitute into Formula 11.8

$$\phi = \sqrt{\frac{\chi^2}{N}} = \sqrt{\frac{6.895}{100}} = \sqrt{.06895} = .26$$

(b) This appears to be a moderate positive association, as Φ = .26.

(12) Effect Size Estimate: Using the guidelines, the preference appears to be "medium." The Φ coefficient is also an index of effect size for the contingency table. Interpretation guidelines are (Spatz, 2011, p. 308).
(a) Small Effect, Φ = .10
(b) Medium Effect, Φ = .30
(c) Large Effect, Φ = .50

5. **Case 11.6**: <u>Mastery Status and Teaching Style</u>
   a. Apply the Hypothesis Testing Model
      (1) Is there a relationship between type of mastery (e.g., passing a test) and teaching style? (The null asserts that mastery status is the same regardless of teaching style.)

(2) $\rho_1 = \rho_2 = \rho_3$
(3) $\rho_1 \neq \rho_2 \neq \rho_3$
(4) H_o: $\rho_1 = \rho_2 = \rho_3$
(5) H_1: $\rho_1 \neq \rho_2 \neq \rho_3$
(6) $\alpha = 0.05$
(7) Chi-Square Test of Association (2 x 3 [2 rows, 3 columns] Table)
(8) Compute the test statistic and select the relevant critical value(s).
(a) Data Table

Table 11.7
Mastery and Teaching Style Case Data

Mastery Status	**Style (A)**	**Style (B)**	**Style (C)**	**Row Total**
Master (L)	36 (30)	12 (12)	12 (18)	60
Non-Master (R)	14 (20)	8 (8)	18 (12)	40
Column Total	50	20	30	100 (N)

(b) Compute Degrees of Freedom: *df* = 2 (r-1)(c-1) or (2-1)(3-1) = 2 (Degrees of freedom are based on the number of rows and columns when placed in a table similar to Table 11.7 and not the computational sequence as presented in Table 11.8.)

(c) Substitute into Formula 11.7 Chi-Square Test of Association (or Independence)

Table 11.8
Mastery and Teaching Style Case Data

Category	**O**	**E**	**O-E**	**$(O-E)^2$**	**$(O-E)^2/E$**
L/A	36	30	6	36	1.2
L/B	12	12	0	0	0.0
L/C	12	18	-6	36	2.0
R/A	14	20	-6	36	1.8
R/B	8	8	0	0	0.0
R/C	18	12	6	36	3.0
					$\chi^2 =$ 8.0

(d) Critical Value: 5.991 at $\partial = .05$ & *df* = 2 (Spatz, 2011, p. 393; Triola 1998, p. 716).

(9) Apply Decision Rule: Since $\chi^2 = 8.0$ is > 5.99 so reject, H_o: $\rho_1 = \rho_2 = \rho_3$ as p < .05. *GraphPad Software QuickCalcs*. (n.d.) computes an exact probability of 0.0183, which is less than the specified alpha (∂) = 0.05. The traditional hypothesis testing method is confirmed. We express this finding as $\chi^2 = 8.0$, $p < 0.05$.

(10) There is sufficient evidence to conclude that type of teaching style is related to student/trainee mastery. Masters seemed to prefer Style A,

while Non-masters preferred Style C. (Hint: Compare observed to expected)

(11) Apply Measure of Association: Since more than one degree of freedom is involved, (1 *df* suggests a 2x2 Contingency Table; this is a 3x2 Table) we will apply Cramer's C or V Statistic.

(a) Substitute into Formula 11.9.

$$C = \sqrt{\frac{\chi^2}{n(t-1)}} = \sqrt{\frac{8.0}{100(1-1)}} = \sqrt{\frac{8.0}{100}} = \sqrt{.08} = .283$$

The strength of the association is moderate.

(b) Effect Size Estimate: Spatz (2011, p. 315) offers Cramer's C as an effect size index. Applying Cohen's (1988, pp. 224-225) criteria, the effect of teaching style on trainee mastery is medium.

b. See Spatz (2011) or any introductory statistics book for more computational exercises.

E. Chi-Square Test of Homogeneity

1. This version of the chi-square test is applied when data are drawn from two or more independent samples, i.e., samples drawn from different populations (Daniel 1990, pp. 192-194; Siegel, 1956, pp. 104-111, 175-179). The usual X^2 assumptions hold.
2. The computation process is the same as for the Test for Independence. Two sample comparisons can be displayed and tested in a 2 X 2 Contingency Table as well.
3. Daniel (1990, pp. 195-196) asserts that three or more populations can be tested in an *r* X 2 Contingency table, where *r* = the number of populations from which the *r* samples have been drawn and *c* = the two mutually exclusive categories of interest.
4. Further, three or more *r* populations can be tested across three or more *c* categories of classification in a *r X c* table (Daniel, 1990, pp. 196-198), where *r* and *c* have the same definitions as above.
5. The *df* are computed by (r-1) * (c-1) [r = # rows & c = # columns] and *e* = (row total)*(column total)/N.

F. The Point Biserial Correlation (r_{pb})

1. The Point Biserial Correlation is not a member of the Chi-Square family; but, it is a specialized statistical tool for analyzing data when one variable is nominal (i.e., dichotomous or only two categories) and the other is interval or ratio, i.e., continuous (Daniel, 1990, pp. 409-411).
   a. One dichotomous category is labeled "O" and the other "1".
   b. The continuous variable is labeled "Y".

2. Formula 11.12a Point Biserial Correlation (Everitt, 2003, p. 288)

$$r_{pb} = \frac{\bar{Y}_1 - \bar{Y}_0}{\sigma y}\sqrt{pq}$$

where: p = proportion labeled "1"
q = proportion labeled "1"
$\bar{Y}_1$ = $\bar{X}$ of the continuous scores for "1"
$\bar{Y}_0$ = $\bar{X}$ of the continuous scores for "0"
σ_y = standard deviation of "Y"

Formula 11.12b $\sigma_y^2 = \dfrac{\sum Y^2 - \frac{(\sum Y)^2}{N}}{N}$ Formula 11.12c $\sigma_y = \sqrt{\sigma^2 y}$

3. **Case 11.7**: A foundation is going to invest money in programs that help girls become scientists, provided it can be shown that the investment is worthwhile. A measure of science achievement was given to scholarship applicants with a possible score range from zero to 30.
   a. Is there a relationship between gender and science achievement?
   b. $r_{pb} = 0$
   c. $r_{pb} \neq 0$
   d. H_o: $r_{pb} = 0$
   e. H_1: $r_{pb} \neq 0$
   f. $\partial = .05$
   g. The Point Biserial Correlation (r_{pb})
   h. Compute Test Statistic
      (1) Construct Data Table (See Table 11.9)

      (2) Compute degrees of freedom (*df* = N) or 20

      (3) Substitute into Formula 11.12a Point Biserial Correlation

$$r_{pb} = \frac{\bar{Y}_1 - \bar{Y}_0}{\sigma y}\sqrt{pq} = (\frac{11.25 - 21.67}{9.15}\sqrt{(.4)(.6)}) = (-1.14)\sqrt{.24} = -.56$$

$$\sigma_y^2 = \frac{\sum Y^2 - \frac{(\sum Y)^2}{N}}{N} = \frac{7{,}800 - \frac{122{,}500}{20}}{20} = 83.75 \qquad \sigma_y = \sqrt{\sigma^2 y} = \sqrt{83.75} = 9.15$$

      (4) Critical value = 0.44 9 (Triola, 1998, p. 724) at $\partial = .05$ & *df* = 10 for a two-tail test. Terrell (1982) provides critical value tables for the Point-Biserial correlation or you can find these and other statistical critical value tables online.

Table 11.9
Point Biserial Correlation Case Data

Female	**Y**	Y^2	**Male**	**Y**	Y^2
0	30	900	1	10	100
0	20	400	1	15	225
0	25	625	1	15	225
0	20	400	1	20	400
0	25	625	1	05	25
0	30	900	1	10	100
0	05	25	1	10	100
0	10	100	1	05	25
0	20	400			
0	30	900			
0	35	1,225			
0	10	100			
Q = 60%	$\sum Y_0 = 260$	$\sum Y_0^2 = 6,600$	P = 40%	$\sum Y_1 = 90$	$\sum Y_1^2 = 1,200$
	$\bar{Y}_0 = 21.67$			$\bar{Y}_1 = 11.25$	
$\sum Y = 350$	$(\sum Y^2) = 122,500$	$\sum Y^2 = 7,800$	$\delta_y = 9.15$	N = 20	

i. Apply Decision Rule: Since r_{pb} = /-0.56/ ≥ .44, we reject H_o: $r_{pb} = 0$, as $p < 0.05$.or $r_{pb\ (10)}$ = /-0.56/, $p < 0.05$.

j. There is a relationship between gender and science achievement. Females scored higher on measure of science knowledge.

k. Effect Size Estimate: Applying Cohen's (1988, pp. 79-80) effect size criteria, *r* = /-0.56/ indicates a large effect. We conclude that gender does exert a large influence upon science achievement, in this study.

Review Questions

Directions: Read each item carefully. There is one correct answer per item.

1. Concerning "*r*", which one of the following statements is inaccurate?
   a. Ranges from -1 to +1, exclusive.
   b. The closer the "*r*" value is to zero, the more accurate is the assumption of no association.
   c. The value of "*r*" is unaffected by measurement scale conversion.
   d. Measures the strength of an association.

2. Which one of the following statements concerning "*r*" is <u>incorrect</u>?
   a. When squared, "*r*" is an estimate of shared variance between two variables.
   b. When squared, "*r*" is called the coefficient of determination.
   c. A series of bi-variate plots on a grid sloping downward to the right represents positive relationship.
   d. A series of bi-variate plots on a grid sloping upward to the right represents positive relationship.

3. A correlation between two variables establishes a causal relationship.
   a. True b. False

4. If the Coefficient of Determination is .49, which one of the following statements is <u>not</u> accurate?
   a. Represents the degree of shared variance between two variables.
   b. $r = 0.7$
   c. $r = 0.07$
   d. Is the opposite of the Coefficient of Alienation.

5. When an observed correlation is said to be lower than the "true" correlation, ___ is said to be operating.
   a. Restriction of Range
   b. Attenuation
   c. Skewed Distribution
   d. Outliers

6. Lowering the correlation coefficient due to instrument unreliability is called:
   a. Skewness
   b. alienation
   c. eta
   d. Attenuation

7. Which of the following correlations shows the strongest relationship?
   a. 0.48 b. 0.63 c. -0.76 d. -0.32

8. Which relationship is inverse?
   a. -0.62 b. 0.62

9. When data are interval, which correlational procedure is recommended?
   a. r_{pb} b. r c. r_{pb} d. r_s

10. Which single statement is <u>not</u> true about simple regression?
    a. Only linear relationships are predicted.
    b. If the x and y variables lack a significant correlation, the $\bar{y}$ is the best predicted y value.
    c. If the x and y variables are significantly correlated, then substitute the appropriate x value into the regression (or prediction) equation to obtain the best predicted y value.
    d. y is called the predictor variable.

11. When subjects are ranked on an ordinal criterion, which measure of association is most appropriate?
    a. r_{pb} b. r c. r_{pb} d. r_s

12. A medium effect size is
    a. 0.01 b. 0.1 c. 0.3 d. 0.5

13. Which statistical test would be applied to assess differences in frequencies based on gender?
    a. Chi-square Goodness of Fit
    b. Mann-Whitney U Test Big Samples
    c. Mann-Whitney U Test Small Samples
    d. Wilcoxon Matched Pairs Test

14. Which <u>one</u> of the following statements concerning Chi-square is <u>not</u> accurate?
    a. Chi-square can be used to test whether observed nominal data conforms to some theoretical or expected.
    b. When the sample size is $N \geq 30$, the chi-square is approximately normal.
    c. While a statistically significant X^2 establishes a relationship between two variables, it reveals little else.
    d. A statistically significant chi-square is a measure of the strength of an association.

15. Which <u>one</u> of the following statements concerning Chi-square is <u>not</u> accurate?
    a. The null (or statistical) hypothesis (H_o) states that there is either "no differences between observed or expected frequencies" (Goodness of Fit) or "the variables or samples are not related, i.e., are independent" (Test for Independence) or are homogeneous (Test of Homogeneity).
    b. As normally applied, the X^2 is not directed at any specific alternative hypothesis.
    c. Degrees of freedom, alpha, and power must be specified or determined. The applicable degrees of freedom (*df*) depends on the test applied. Alpha is specified, a priori, usually at the .05 or .01 level.
    d. Each statement is incorrect.

16. Chi-square assumptions include all but….
    a. The distribution is symmetric.
    b. Chi-square values can be zero or positive but never negative.
    c. Chi-square distribution is different for each degree of freedom. As the number of degrees of freedom increase, the distribution approaches the SNC.
    d. Degree of freedom (df) varies depending on the chi-square test being used.

17. Which <u>one</u> of the following statements about the phi (ϕ) is <u>not</u> accurate?
    a. The phi coefficient is a symmetric index with a range between 0 and 1, where zero equals statistical independence.
    b. Maximum value is attained only under strict perfect association.
    c. Before the phi coefficient is applied, there should be a statistically significant chi-square value.
    d. Apply the phi coefficient only to any chi-square problem.

Answers: 1. a, 2. c, 3. b, 4. c, 5. b, 6. d, 7. c, 8. a, 9. b, 10. d, 11. d, 12. c. 13. a, 14. d, 15. d, 16. a, 17. d.

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