23

Chi-Square Procedures

The Chi-Square Formula
The Chi-Square Critical Value
Chi-Square Goodness of Fit Test
Chi-Square Test of Independence
Cautions in Using Chi-Square

Dr. Helen Ang studied the relationship between predominant leadership style and educational philosophy of administrators in Christian colleges and universities for her Ed.D. dissertation in 1984.[1]

Leadership Style was a categorical variable with the following five levels (with percentages of the 113 administrators studied): team administrator (high people/high task: 23%), constituency-centered (moderate people/moderate task: 16%), authority-obedience (low people/high task: 4%), comfortable-pleasant (high people/low task: 38%), and caretaker (low people/low task: 19%).[2]

Educational Philosophy Profile was a categorical variable with the following six levels (with percentages): idealism (7%), realism (4%), neo-thomism (15%), pragmatism (58%), existentialism (1%), and "eclectic" (16%).[3]

Applying the Chi-Square Test of Independence, Dr. Ang found that the variables Leadership Style and Educational Philosophy were **independent** (χ^2 = 21.676, χ^2_{cv} = 31.410, a=0.05, df=20).[4]

The ***chi*** in chi-square is the Greek letter χ, pronounced *ki* as in kite. Chi-square (χ^2) procedures measures the differences between observed (**O**) and expected (**E**) frequencies of *nominal variables*, in which subjects are grouped in categories or cells. There are two basic types of chi-square analysis, the **Goodness of Fit Test,** used with a single nominal variable, and the **Test of Independence**, used with two nominal variables. Both types of chi-square use the same formula.

The Chi Square Formula

The chi-square formula is as follows:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

[1]Helen C. Ang, "An Analytical Study of the Leadership Style of Selected Academic Administrators in Christian Colleges and Universities as Related to their Educational Philosophy Profile," (Fort Worth, Texas: Southwestern Baptist Theological Seminary, 1984).

[2]Ibid., 28-29, 46 [3]Ibid., 45 [4]Ibid., 47

where the letter **O** represents the ***Observed frequency*** -- the actual count -- in a given cell. The letter **E** represents the ***Expected frequency*** -- a theoretical count -- for that cell. Its value must be computed.

The formula reads as follows: "The value of chi-square equals the sum of O-E differences squared and divided by E." The ***more O differs from E, the larger*** χ^2 ***is***. When χ^2 exceeds the appropriate critical value, it is declared significant.

The Goodness of Fit Test

The Goodness of Fit Test is applied to a single nominal variable and determines whether the frequencies we observe in ***k*** categories fit what we might expect. Some textbooks call this procedure the ***Badness*** of Fit Test because a significant χ^2 value means that *Observed counts do not fit what we Expect.* The Goodness of Fit Test can be applied with ***equal*** or ***proportional*** expected frequencies (EE, PE).

Equal Expected Frequencies

Equal expected frequencies are computed by dividing the number of subjects (N) by the number of categories (k) in the variable. A classic example of equal expected frequencies is testing the fairness of a die. If a die is fair, we would expect equal tallies of faces over a series of rolls.

The Example of a Die

Let's say I roll a real die 120 times (N) and count the number of times each face (k = 6) comes up. The number "1" comes up 17 times, the number "2" 21 times, "3" 22 times, "4" 19 times, "5" 16 times, and "6" 25 times. Results are listed under the **"O"** column below.

We would Expect a count of 20 (E=N/k) for each of the six faces (1-6). This **E** value of **20** is listed under the **"E"** column below.

	O	**E**	**O-E**	**(O-E)²**	**(O-E)²/E**
1	**17**	20	-3	9	.45 (=9/20)
2	**21**	20	1	1	.05
3	**22**	20	2	4	.20
4	**19**	20	-1	1	.05
5	**16**	20	-4	16	.80
6	**25**	20	5	25	1.25
	120	120	Σ(O-E) = 0		χ^2 = **2.80**

The chart above shows the step-by-step procedure in computing the chi-square formula. Notice that both **O** and **E** columns add to the same value (N=120).

Computing the Chi Square

The **first step** is to subtract expected frequencies (E) from the observed (O). These differences fall under the "O-E" column. Notice that Σ(O-E)=0, just as Σx=0.

The **second step** is to square the differences. These squares are found under the "$(O-E)^2$" column.

The **third step** is to divide the squared differences by the expected values. Each of these values, shown in the last column, is the portion of the chi-square total derived from each category. For example, the largest contributor of the chi-square is the high tally in category "6". It yields 1.25 of the 2.80 total.

The **fourth step** is to sum the values in the last column to produce the final chi-square value — in this case, **2.80**.

Testing the Chi Square Value

The computed value of χ^2 is compared to the appropriate critical value. The critical value is found in the Chi-square Table (see Appendix A3-3). **Using α and df**, locate the critical value from the table.

For the Goodness of Fit Test, the degrees of freedom (df) equal the number of categories (k) minus one (**df=k-1**). In our example above, the critical value (α=0.05, df=5) is **11.07**. Since the computed value (**2.80**) is less than the critical value (11.07), we declare the χ^2 ***not significant***.

Translating into English

What does this non-significant χ^2 mean in English? The observed frequencies of the six categories of die rolls do not significantly differ from the expected frequencies. The observed frequencies have a "good fit" with what was expected. Or, simply stated, **"The die is fair."**

Had the computed value been greater than 11.07, the χ^2 would have been declared significant. This would mean that the difference between observed and expected values is greater than we expect by chance. The observed frequencies would have a "bad fit" with what was expected. Or simply stated, "The die is loaded."

Equal E is usually an unrealistic assumption of the break-down of categories. A better approach is to compute proportional expected frequencies (PE).

Proportional Expected Frequencies

With proportional expected frequencies, the expected values are derived from a known population. Suppose you are in an Advanced Greek class of 100 students. You notice a large number of women in the class, and wonder if there are more women in the class than one might expect, given the student population. Using equal E's, you would use the value (E=N/k) of 50. But you know that women make up only 15% of the student population. This gives you expected frequencies of 15 women (.15 x 100) and 85 men (.85 x 100). This latter design is far more accurate than the EE value of 50.

The Example of Political Party Preference

Suppose you want to study whether political party preference has changed since the last Presidential election. A poll of 1200 voters taken four years before showed the following breakdown: 500 Republicans, 400 Democrats, and 300 Independents. The ratio equals 5:4:3. In your present study, you poll 600 registered voters and find 322 Republicans, 184 Democrats, and 94 Independents.[5] The null hypothesis for this study is that **party preference has not changed in four years.** That is, your hypothesis is that the present observed preferences are in a ratio of 5:4:3.

Computing the Chi Square Value

Compute the expected frequencies as follows. The ratio of 5:4:3 means there are 5+4+3=12 parts. Twelve parts divided into 600 voters yield *50 voters per part* (600/

[5]Dennis E. Hinkle, William Wiersma, and Stephen G. Jurs, *Basic Behavioral Statistics* (Boston: Houghton Mifflin Company, 1982), 308-310

12=50).

The first category, Republicans, has 5 parts (**5**:4:3), or 5x50=***250*** Expected voters. The second, Democrats, has 4 (5:**4**:3) parts, or 4x50=**200** Expected voters. The third, Independents, has 3 parts (5:4:**3**), or 3x50=**150** Expected voters. Putting this in a table as before, we have the following:

	O	E	O-E	$(O-E)^2$	$(O-E)^2/E$
Rep	322	250	72	5184	20.74
Dem	184	200	-16	256	1.28
Ind	94	150	-56	3136	20.91
	600	**600**	Σ(O-E) = 0		χ^2 = **42.93**

Notice that both **O** and **E** columns add to 600 (N). Notice that the **O-E** column adds to zero. Notice that the E values are unequal, reflecting the 5:4:3 ratio derived from the earlier poll. The resulting χ^2 value equals **42.93**.

Testing the Chi Square

The critical value (α=0.05, df=2) is **5.991**. Since the computed value of **42.93** is greater than the critical value of 5.991, we declare the **chi-square value significant**. The observed values **do not fit** the expected values.

Translate into English

Since the recent poll does not fit the ratio of 5:4:3 found in the earlier poll, we can say that ***party preference has changed over the last four years***.

Eyeball the Data

But ***HOW*** has political party preference changed? We can determine this by what some statisticians call "eye-balling the data." The greatest part of the chi square value came from Republicans and Independents.

R	322	250	72 ↑	5184	**20.74**
D	184	200	-16	256	1.28
I	94	150	-56 ↓	3136	**20.91**

Looking at the O-E column, we see that we observed more Republicans than we expected (322 > 250), and fewer Independents than expected (94 < 150), based on data from four years before. It is this twisting (↓↑) effect that causes the large chi-square value.

In summary, the ***Goodness of Fit procedure tests one variable across k categories***. The computed value is tested for significance at α and df = k-1. The expected frequencies for each category can be equal (EE) or proportional (PE).

Chi-Square Test of Independence

The test of independence analyzes the relationship between ***two*** nominal variables. The procedure uses the special terms **independent** to mean *not related*, and **not**

independent to mean *related.* The two nominal variables form a contingency table of cells.

The Contingency Table

My wife's Master's thesis studied the relationship between whether Schools for the Deaf identified giftedness in their students (***Schools***) and whether the schools were predominantly aural/oral, total communication, or a combination (***language preference***).[6] The column variable ***schools*** had two levels: Level I schools of the deaf **did not** identify students as "gifted," while Level II schools of the deaf **did.**

The row variable ***language preference*** had three levels. ***Aural/Oral*** schools are those who emphasized speech-reading methods of education of the deaf — they did not use sign language. ***Total Comm*** schools emphasized the total communication method of deaf education, which includes American Sign Language. ***Both*** schools used both approaches.

Language Preference	Schools I	Schools II	Total
Aural/Oral	3	0	3
Total Comm	20	15	35
Both	4	5	9
Total	27	20	47

Each of the 47 schools in the study were categorized by both variables and placed into one of 6 cells. How many deaf schools identify giftedness in their students (II) and use total communication as their primary approach? [15]. How many schools use aural/oral methods and do not identify giftedness in their students (I)? [3].

The table also includes ***margin totals***, labelled "Total." The total number of aural/oral schools, regardless of school type, for example, was 3. The total number of Type I schools, regardless of language preference, was 27. The margin totals for the row variable are called **row totals (3, 35, 9)**. The margin totals for the column variable are called **column totals (27, 20)**. The sum of column totals (47) equals the sum of row totals (47) — a good check on math accuracy. *Margin totals are the means by which expected values are computed.*

Expected Cell Frequencies

Each cell requires an <u>E</u>xpected value to match its **<u>O</u>** value. Expected cell frequencies are computed from the margin totals. Using the above contingency table, let's focus on the <u>E</u>xpected value for the upper left cell.

The three necessary numbers to compute the upper left cell **<u>E</u>** value are **47** (Total), **27** "category I" (Column total) and **3** "aural/oral methods" (row total).

The number of schools we would **expect** for this cell, *given no relationship between the two variables* is found by multiplying Column 1 Total (27) by Row 1 Total (3),

[6]Barbara Parish Yount, "An Analytical Study of the Procedures for Identifying Gifted Students in Programs for the Hearing-Impaired", (Master of Arts Thesis, Texas Woman's University, 1986). The term "aural/oral" refers to use of speech-reading and speech skills in teaching. The term "total communication" refers to using any mode of communication, especially American Sign Language, in teaching.

divided by the Total (47), or,

```
E  =   (27x3)  /  47  =  1.723
        /   |       \
     col 1  row 1   total
```

Putting this in more general terms, we can show the computation of the **E**xpected values for all cells in a 3x4 contingency table.

	1	2	3	Total
I	AX/T	AY/T	AZ/T	A
II	BX/T	BY/T	BZ/T	B
III	CX/T	**CY/T**	CZ/T	**C**
IV	DX/T	DY/T	DZ/T	D
Total	X	**Y**	Z	**T**

The above table shows three levels of a column variable (1, 2, 3) and four levels of a row variable (I, II, III, IV). Once the observed frequencies are placed in the table and margin totals computed, expected values for each cell can be computed. The **E**xpected value for cell 3,2[7] is found by multiplying the cell's row total (C) by its column total (Y) and dividing by the Table total (T). Once the expected cell frequencies are computed, the remainder of the computation is the same demonstrated before. O-E, $(O-E)^2$, $(O-E)^2/E$ for each cell.

Degrees of Freedom

We determine **df** for the Test of Independence by the formula ***df* = (r-1)(c-1)**, where r = the number of rows and c = the number of columns in the contingency table. For a contingency table of 5 rows and 6 columns, the degrees of freedom would be (5-1)(6-1) or **20**. (Each variable loses one degree of freedom).

Application to a Problem

Let's apply this to our example on deaf schools. The expected frequencies are shown bold-faced in parentheses () below. It is suggested that you compute several of these to insure your understanding of the procedure.

Language Preference	Schools I	II	Total
Aural/Oral	3 (**1.72**)	0 (**1.28**)	3
Total Com	20 (**20.11**)	15 (**14.90**)	35
Both	4 (**5.17**)	5 (**3.83**)	9
Total	27	20	47

[7]Cell 3,2 refers to the cell at row 3, column 2, shown in the table as the shaded cell.

Putting the **O** and **E** values into a chart, we have the following computations:

O	E	(O-E)	$(O-E)^2$	$(O-E)^2/E$
3	1.72	1.28	1.638	0.953
20	20.11	-0.11	.012	.001
4	5.17	-1.17	1.369	.265
0	1.28	-1.28	1.638	1.280
15	14.90	.10	.010	.001
5	3.83	1.17	1.369	.357

χ^2 = **2.857**

df = (3-1)(2-1) = 2

χ^2_{cv} = **5.991**

The computed value of <u>**2.857**</u> is ***smaller than*** the critical value of **5.991**. Therefore, the value is declared not significant. The statistical decision is to <u>**retain the null**</u> hypothesis. In terms of this study, ***language preference and school category are not related***. It appears that educational approach is unrelated to identifying giftedness in deaf students in these 47 deaf schools.

Party Preference Revisited

Does gender relate to party preference? Let's categorize our 600 voters on these two variables and test this. Again, expected values are shown in (). Here's the data:

	Male	Female	Total
Republican	170 (187.83)	152 (134.17)	322
Democrat	112 (107.33)	72 (76.67)	184
Independent	68 (54.83)	26 (39.17)	94
Total	350	250	600

Here's our chart. Identify the **O**'s and **E**'s above in the chart below.

	O	E	(O-E)	$(O-E)^2$	$(O-E)^2/E$
RM	170	187.83	-17.83	317.91	1.69
DM	112	107.33	4.67	21.81	.20
IM	68	54.83	13.17	173.45	3.16
RF	152	134.17	17.83	317.91	2.37
DF	72	76.67	-4.67	21.81	.28
IF	26	39.17	-13.17	173.45	4.43

χ^2 = **12.13**

The computed value of 12.13 is larger than the critical value of 5.991 (0.05, df=2). Therefore, the value is declared **significant**.

The statistical decision is to **reject the null** hypothesis.

In terms of this study, this result means that ***gender and political party preference are related***. One's political preference is influenced by his or her gender. ***How*** are these two variables related? We can answer this by "eyeballing the data" in the table.

The greatest part of the chi square comes from the ❶ FEMALE-INDEPENDENT (**IF**) cell. We observe *fewer women independents* (↓) than we expect by chance (26 vs. 39.17).

The second highest value comes from the ❷ MALE-INDEPENDENT (**IM**) cell. We observe *more male independents* (↑) than we expect by chance (68 vs. 54.83). Notice that ***men outnumber women across independent.***

The third highest value comes from the ❸ FEMALE-REPUBLICAN (**RF**) cell. We observe *more women republicans* (↑) than we expect by chance (152 vs. 134.17).

The fourth highest value comes from the ❹ MALE-REPUBLICAN (**RM**) cell. We observe *fewer male republicans* (↓) than we expect by chance (170 vs. 187.83). Notice that ***women outnumber men across republican.***

RM	170	187.83	↓	-17.83	317.91	**1.69**	❹
DM	112	107.33		4.67	21.81	.20	
IM	68	54.83	↑	13.17	173.45	**3.16**	❷
RF	152	134.17	↑	17.83	317.91	**2.37**	❸
DF	72	76.67		-4.67	21.81	.28	
IF	26	39.17	↓	-13.17	173.45	**4.43**	❶

The arrows show the *twisting motion in the table* that indicates that the two variables are related.

Strength of Association

The chi-square test of independence tells you whether two nominal variables are related or not. It does not tell you how strong that relationship is. When you produce a significant chi-square (two variables are related), it is natural to wonder how strong the relationship is. Two procedures can provide such measures: the **Contingency Coefficient** (**C**) and **Cramer's phi** (ϕ_C).

Contingency Coefficient

The contingency coefficient (C) computes a "Pearson r" type correlation coefficient from a computed value. The formula is

$$C = \sqrt{\frac{\chi^2}{n + \chi^2}}$$

If you get, say, a chi-square value of 63.383 (significant at α = 0.001) with a sample size of 390, then you can compute the degree of association by

$$C = \sqrt{\frac{\chi^2}{n + \chi^2}} = \sqrt{\frac{63.383}{390 + 63.383}} = 0.398$$

If we were to compare this to a maximum value of 1.00, we would conclude that **0.398** is a weak correlation. But the maximum value for C is not 1.00. It is estimated by another formula:

$$C_{max} = \sqrt{\frac{k - 1}{k}}$$

where k is the number of categories in the variable *with the fewer categories*. Let's say in our case that one of our variables has 6 categories and the other has 3. Then, k = 3. The maximum value C can take is then computed as C_{max} = (3-1)/3, or **0.817**. Comparing 0.389 to 0.817, we would say that we have a *moderately strong correlation*.[8]

Cramer's Phi

While the contingency coefficient is popular, a ***better alternative*** to the measurement of association in a contingency table is **Cramer's phi**. The advantage of this procedure is that it ranges from 0.00 to +1.00 and is independent of the size of the table. Cramer's Phi is defined as

$$\phi_C = \sqrt{\frac{\chi^2}{N(k-1)}}$$

Cautions in Using Chi-Square

Chi square is a simple yet powerful statistic. It lends itself well to categorical data gained through questionnaires or interviews. It can also be used with continuous data that has been categorized — dividing test scores into high, medium, and low categories for example. This latter approach is easy, but there may be better ways (z, t, F) to analyze them, as we've already seen.

There are, however, **dangers to avoid** in choosing this technique. These include small expected frequencies, the assumption of independence, the inclusion of non-occurrences, and whether this approach should be your primary statistical tool.

Small expected frequencies

When expected cell frequencies are small, the computed chi square does not fit the distribution of the statistic correctly. In this case, the results of significance testing is suspect. How small is small? Howell takes the conservative position that *all expected frequencies be at least 5.*[9]

Others hold that the ***average expected cell frequency*** *should be 5*. That is, the ratio of subjects to cells must be greater than 5. Plan ahead. Don't make the mistake of one of my students who planned to use chi-square to study two variables: one had 5 levels and the other 6 levels, giving 30 cells. He thought that 50 subjects would be "more than plenty." Dividing 50 by 30 (N/k) gave him an average cell size of 1.67. To get up to the minimum of 5, he needed ***150 subjects***.

Another student of mine, having supposedly read the preceding warning, sug-

[8]Hinkle, p. 320 [9]Howell, p. 105

gested a dissertation using a chi-square table of *16 rows* and *16 columns* (256 cells) and considered 200 subjects more than enough.[10]

The reason is power. Fewer subjects than "5 per cell" will not allow the chi-square procedures to detect relationships that may exist. If you plan correctly, but lose subjects during the study, or find some category tallies to be much smaller than anticipated, remember that your significance tests are suspect.

Assumption of Independence

We noted in Barb's study of deaf schools that each one of the 47 schools were placed in one and only one cell in the contingency table. Each school was independent of every other school. The assumption of independence means that each subject is located in one and only one cell in the contingency table.

This mistake is easy to make — usually by having subjects respond more than once. A student came into my office with a contingency table of tally marks in the fall in 1981 -- my first semester on faculty. His table was the result of $200 in mailings, $300 to a statistician across town, and the prior 10 months of his life. He had listed various educational programs down one side of the contingency table, and five levels of ratings across the top. Each subject checked off a rating for each program. *He had **60 subjects** and **300 tallies**!* The observations were not independent (each subject made five responses in the table). He had produced a chi-square value, but the value was **meaningless**. I encouraged him strongly to go back to his statistican and have him work out another approach to analyzing his data. Proper Planning Prevents Poor Performance — and sleepless nights, as well.

Inclusion of Non-Occurrences

There is one final warning I would make about use of chi-square, and this involves the handling of non-occurances. Let's say you ask 20 men and 20 women whether they favor "Variable" or not. Seventeen men and eleven women say "Yes." With 28 "yes" responses, we can compute equal E's as 28/2=14. The analysis would be set up as follows:

	O	E	O-E	$(O-E)^2$	$(O-E)^2/E$
Male	17	14	3	9	0.643
Female	11	14	-3	9	0.643
			0	χ^2 =	1.286

This **faulty design** produces a chi square of 1.286 and is not significant**.** ***The fault lies in the fact that the number of "no's" for males and females is excluded.***

The correct approach is to build a contingency table as follows, which **includes both yes and no responses:**

	Male	Female	
Yes	**17**	**11**	28
No	**3**	**9**	12
	20	20	40

[10] 16x16x5 = *1280* subjects minimum

	O	E	O-E	(O-E)^2	(O-E)^2/E
Male Yes	17	14	3	9	0.643
Male No	3	6	-3	9	1.500
Female Yes	11	14	-3	9	0.643
Female No	9	6	3	9	1.500
			0		χ^2 = 4.286

Now χ^2 = 4.286 and is significant (χ^2_{cv} = 3.84, df = 1, 0.05). Looking only at "yes" responses (excluding "no"s) invalidated the test. Further, it lowered the value of chi square, leaving us with a non-significant finding -- *incorrectly*.

Chi-Square as Primary Statistic?

Some students make the mistake of depending on a single chi square test as their dissertation's only statistical tool. A doctoral student worked six months collecting data and synthesizing literature. He walked into my office with a 3x5 contingency table. I entered his 15 observed frequencies into my computer, hit the RUN key, and a second later the answer flashed on the screen: NOT SIGNIFICANT.

After a moment of shock, he said, "Six months of my life. . .and it took a second to say its ***not significant***?!" He had very little to say about his subjects because he had rested all his analytical hopes on a single chi-square statistic. His dissertation's ***Chapter Three*** (Procedure for Analysis of Data) was thin. His dissertation passed only after additional (unplanned) weeks of research and writing.

It is better to use the t-Test, ANOVA, or multiple regression as a primary statistic. Then use several chi square tests to analyze secondary variables, or sub-hypotheses, in your study. For example, "Does gender, income level, geographic location, year of birth, marital status, age saved, years in the ministry, education level. . .relate to your main variable?"

Or, spend your time and energy developing the process and meaning of the variable categories themselves. Dr. Helen Ang, featured at the beginning of the chapter, used chi square to test the relationship between "leadership style" and "educational philosophy." The chi square was simple, but *creating the instruments to measure these variables -- the main focus of the dissertation -- was difficult.*

Summary

In this chapter we've introduced the concept of non-parametric, or distribution-free, statistics. We've looked at the chi-square Goodness of Fit tests with both equal and proportional expected frequencies. We've studied the chi-square Test of Independence. The concept of degrees of freedom was discussed. We've illustrated how the chi-square statistic is computed, how the critical value is obtained and what "significance" means in English.

Example

Dr. Roberta Damon's dissertation was cited (p. 19-1) for her use of the one-

[11]This student is now professor at a prominent Christian university, author of many books, and a prominent leader in his professional organization, proving that "unsignificant research findings" need not impair one's career!

[12]Roberta Damon, "A Marital Profile," p. 70

sample z-Test. She also used the chi-square Test of Independence to analyze relationships among several other variables.

First, she found that level of **marital satisfaction** and **age category** were **not independent** among missionary wives of her sample (χ^2 = 7.525, χ^2_{cv} = 5.99, df=2, 0.05). The younger wives expressed higher marital satisfaction than older wives.

Second, she found that **conflict resolution** and **age category** were not independent among missionary wives of her sample (χ^2 = 6.4513, χ^2_{cv} = 5.99, df=2, 0.05). The younger wives were more satisfied with the way conflict is resolved in their marriage than older women.[12]

Vocabulary

contingency coefficient	measures strength of assoc'n between two nominal variables ()
contingency table	table of rows and columns in chi square test of independence
Cramer's phi	measures strength of assoc'n between two nominal variables ($_c$)
distribution-free tests	statistics which **do not assume a normal distribution** of data
equal expected frequencies	E-values computed by **dividing N by k**
expected frequencies	theoretical values by which observed frequencies are tested (E)
margin totals	sums of counts used to compute E's in chi-sq test of independence
observed frequencies	actual counts of subjects in chi-square categories (O)
proportional expected frequencies	E-values **computed by known percentages** in population

Study Questions

1. What are the critical values for the following conditions:
   a. 3 rows, 1 column, p=0.05

   b. 5 rows, 3 columns, p=0.01

   c. 4 rows, 9 columns, p=0.005

2. Define df for both Goodness of Fit and Test of Independence. Demonstrate how that "k-1" and "(r-1)(c-1)" are the proper terms for the two df's.

3. You've done your analysis and your computed chi square is less than the critical value. What does this mean, given you are testing one variable?

4. If you have a table with 5 rows (margin totals A..E) and 6 columns (margin totals U..Z), what would the expected value of the cell at row 4, column 2 be?

Sample Test Questions

1. All of the following kinds of data can be tested with chi square except
   A. dichotomized data
   B. categorized ratio data
   C. nominal data
   D. continuous interval data

2. The term (O-E) in chi square is most closely related to ___ in the z-test.
   A. X^2
   B. X
   C. x
   D. x^2

3. A "significant chi square" for the Test of Independence means that
   A. two nominal variables are related.
   B. two independent groups are different.
   C. two dependent groups are different.
   D. two categorical variables are independent.

4. A contingency table has 2 columns and 8 rows. The proper df is
   A. 16
   B. 14
   C. 7
   D. 1