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ABSTRACT

Published studies of the sampling distribution of chi-square with and without Yates' correction for continuity have been interpreted as discrediting the correction. Yates' correction actually produces a biased chi-square value which in turn yields a better estimate of the exact probability of the discrete event concerned when used in conjunction with the usual tables of significant chi-square values for one degree of freedom. Data from a computer simulation demonstrate the validity and importance of using the continuity correction for chi-square with one degree of freedom. (Author)

IN DEFENSE OF THE CHI-SQUARE CONTINUITY CORRECTION[1]

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Empirical studies of the sampling distributions of parameters such as *t*, *F*, *r*, and χ^2 can be helpful to the researcher who is concerned about the dangers of breaking the assumptions of the tests he employs. Outstanding examples are the works of Norton (Lindquist, 1953), Box (1953), and Bonneau (1962), which demonstrated the "robustness" of the *F* distribution when the assumptions of normality and homogeneity are broken.

Occasionally, however, simulation (monte carlo) studies have been reported in which empirical data -- although sound in themselves -- have been misinterpreted, in that the wrong question was addressed. A study by Grizzle (1967) is illustrative of this type of error. In the present paper we will describe a replication of Grizzle's findings and then another simulation study which makes clear the validity of Yates' (1934) correction for chi-square with one degree of freedom.

Average Chi-Square Values

A computer program (Veldman, 1969) was written to compute 10,000 chi-square tests from randomly-derived frequency data using a population proportion of 0.5 for the dichotomy. Each sample had N = 40. Chi-square values were computed with and without the continuity correction. The average chi-square value without correction was 1.00, as expected, but the average of the corrected chi-square values was only 0.77. Even more striking is the fact that when corrected chi-squares were used, the numbers of chi-square values exceeding the tabled significance levels were far fewer than expected.

Discrete Events and Continuous Distributions

The flaw in the previous study is not in the way the empirical data were derived; it is in the conceptualization of the problem itself. The purpose of the continuity correction is not to provide a more accurate estimate of the continuous chi-square distribution when discrete (frequency) data are employed. Although the need for the correction does arise from the fact that discrete events are not well-fitted by continuous distributions under some conditions, Yates' correction actually yields a biased estimate of chi-square, which results in a more accurate estimate of the exact probability of the event concerned.

The ultimate criterion, thus, is the exact probability of the discrete observed event, which can be calculated for the example problem by means of formula [1], which yields a two-tailed P value.

$$[1] \quad P = \frac{2N!}{K!(N!-K)} 0.5^N$$

where N = the sample size
and K = the observed frequency for one of the two cells.

Exact Probabilities and Chi-Square Values

To demonstrate the validity of the continuity correction, 10,000 random samples (N = 100) were generated by a computer program from a dichotomous population with P = 0.5. For each sample outcome an exact probability value was calculated with formula [1]. Chi-square values were then calculated with and without the continuity correction, and these were converted to probability estimates by reference to the theoretical chi-square distribution, using a computer routine (Veldman, 1967, p. 131[2]).

Table 1 contains the frequencies of samples which produced probability values exceeding levels between 0.01 to 0.10, using each of the three methods of deriving probabilities.

Obviously, the continuity-corrected chi-squares yield probabilities closer to the exact values than do the raw chi-squares, when both are referenced against the theoretical chi-square distribution.

The reason for the curious fact that fewer than the expected numbers of samples reach significance may be inferred from consideration of the more extreme case of discreteness when N = 10. There are only six possible "splits" that can occur, as shown in Table 2.

At the 5% level, only 10-0 and 9-1 splits produce chi-square values larger than 3.841, with or without the continuity correction. The exact probability of a 10-0 split is .002, while that for either a 10-0 or a 9-1 split is .0215. The counts will usually be less than the theoretical expectation, particularly when N is small.

Conclusions

Yates' continuity correction for chi-square with one degree of freedom is both valid and necessary.

Simulation studies concerning statistical theory must be carefully designed to avoid misleading recommendations to research workers.

Footnotes

[1]This investigation was supported in part by the Research and Development Center for Teacher Education, United States Office of Education Contract OE6-10-108.

[2]The published Fortran routine can be improved for probabilities near 0.5 by retaining the signed value of Z as ZZ, and inserting the following statement just before RETURN: IF (ZZ .LT. 0.0) PRBF = 1.0 - PRBF

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Table 1. Numbers of samples reaching statistical significance

Method of Calculation	Significance Level									
	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10
Exact Probability	76	142	249	385	385	610	610	610	932	932
Raw χ^2	142	249	385	385	610	610	932	932	932	932
Corrected χ^2	76	142	249	385	385	610	610	610	932	932

Table 2. Possible outcomes with N = 10*

Split	Exact P	Raw χ^2	Corrected χ^2
10-0	.0020	10.0 (.0020)	8.1 (.0047)
9-1	.0215	6.4 (.0111)	4.9 (.0252)
8-2	.1094	3.6 (.0545)	2.5 (.1097)
7-3	.3438	1.6 (.2031)	0.9 (.3448)
6-4	.7539	0.4 (.5344)	0.1 (.7505)
5-5	1.0000	0.0 (1.0000)	0.0 (1.0000)

*Values in parentheses are probabilities derived from the theoretical χ^2 distribution.