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TRANSFORMATION OF BINOMIAL VARIABLES FOR ANALYSIS ACCORDING TO A RANDOMIZED BLOCK DESIGN

Transformación de variables binomiales para su análisis según un Diseño de Bloques al Azar

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ABSTRACT. The research aimed to evaluate the transformation of variables with Binomial distribution applied to randomized block design. For the analysis was considered 5, 10 and 30 observations per experimental unit (n) and probability of success of the event (p) of 0,10; 0,20; ...; 0,90. Through the Monte Carlo method, 100 experiments with 3, 5 and 9 treatments (t) were simulated; 4 and 8 replicates (r); with 5, 10 and 30 observations per experimental unit (n) and probability of success of the event (p) of 0,10; 0,20; ...; 0;90. It was evident that the arcsine and family transformations Box- Cox power transformation angle: natural logarithm, square root and inverse were not able to solve the deviations with respect to the assumptions of ANAVA. It should be mentioned that in recent years little input regarding such research are made.

RESUMEN. La investigación tuvo como objetivo valorar la transformación de variables con distribución Binomial en diseño de bloques al azar. Para el análisis se consideró 5, 10 y 30 observaciones por unidad experimental (n) y probabilidad de éxito del evento (p) de 0,10; 0,20; … 0,90. Mediante el método de Monte Carlo, se simularon 100 experimentos con tres, cinco y nueve tratamientos (t); cuatro y ocho réplicas (r); con 5, 10 y 30 observaciones por unidad experimental (n) y probabilidad de éxito del evento (p) de 0,10; 0,20; … 0,90. Se evidenció que la transformación angular arcoseno y de la familia de transformaciones de potencia de Box-Cox: logaritmo natural, raíz cuadrada e inversa no fueron capaces de solucionar las desviaciones, respecto a los supuestos del ANAVA. Es preciso mencionar, que en los últimos años se realizan pocos aportes relacionados con este tipo de investigación.

Key words: ANAVA assumptions, Monte Carlo, simulation, dichotomous variable

Palabras clave: ANAVA, Monte Carlo, simulación, supuestos, variable dicotómica

INTRODUCTION

The work of the statistician, together with the researcher, is to obtain a model, which reflects as far as possible the situation and, from here, to apply the analysis procedures that are most suitable (1). Undoubtedly, one of the most widespread models is the Analysis of Variance, which is used efficiently, becomes a powerful analysis tool. However, this technique requires certain requirements of the random error terms of the linear model as independent errors, normally distributed and with homogeneous variances for all observations, conditions that are often not fulfilled (2-5).

In research practice, there are frequently situations of variables that may, in some way, fail to satisfy the requirements that ANAVA demand (6, 7); Such is the case, of variables of counts, that by their discreet nature can move away from the normality. In this sense, it is pointed out (8-11) that given the “hardiness” of the “F” test in this analysis procedure, its non-compliance has no serious consequences in the analysis. Likewise, (6), they point out that it is practically irrelevant as regards the probability of committing a type I error; therefore, does not depart from the value α determined by the experimenter. However, the “hardiness” of the test can be lost when this non-compliance is severe, since it increases the probability of exceeding the nominal value of the test (12, 13).

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Given their nature and frequent existence in many branches of science, those variables of counts that come from dichotomous variables or binomial distribution are important, in which a close relationship of dependence between variance and average of treatments is established; an aspect that may be present in other types of variables (14). Therefore, it is assumed that if there are differences between the means in each variant being tested, possible differences between their respective variances and with it the non-compliance of this assumption.

There are many aspects that can receive the unfavorable impact when these assumptions are broken, among others: the percentage in which the null hypothesis is rejected; the minimum difference that can be detected between treatments; the observed power of the ANAVA; rejection number of equal means of treatment. Hence, to identify, take into account and know their degree of affectation, review great importance.

In order to increase the efficiency of the statistical treatment in research with variables with Binomial distribution in the model of Analysis of Variance, it is possible to use alternatives such as data transformation and non-parametric statistical methods.

In this context, the aim of this article is to evaluate the impact of the variable transformations with binomial distribution applied to random block design.

MATERIALS AND METHODS

To fulfill the proposed objective, the Monte Carlo simulation process (15-18) was used to generate populations of random variables with Binomial distribution with homogeneous and heterogeneous variances, according to Levene's test (19), ap <0,05 for 5, 10 and 30 observations per experimental unit (n) and event probability of 0,10, 0,20, ..., 0,90 (p). Experiments were carried out in the Design of Random Blocks with three, five and nine treatments (t); four and eight replicates (r). The combination of means of treatments was defined such that the differences among these means were detectable by the Minimum Significant Difference (DMS according its acronyms in Spanish) test at a significance level of 0,05. (Table I); For each t-r-n combination, 100 experiments were generated.

To the data with binomial distribution with heterogeneous and homogeneous variances, the arcosene angular transformation was applied, since it is the suggested transformation for this type of data (20) and of the family of transformations of Box-Cox power: natural logarithm, root Square and inverse, which proved to be the most frequently suggested in the experiments analyzed.

Table I. Structure of means and variances of treatments for the different variants of analysis

Treatment	n	5		10		30	
	p	μ	σ²	μ	σ²	μ	σ²
1	0,10	0,5	0,5	1,0	0,9	3,0	2,7
2	0,30	1,5	1,1	3,0	2,1	9,0	6,3
3	0,50	2,5	1,3	5,0	2,5	15,0	7,5
1	0,10	0,5	0,5	1,0	0,9	3,0	2,7
2	0,20	1,0	0,8	2,0	1,6	6,0	4,8
3	0,30	1,5	1,1	3,0	2,1	9,0	6,3
4	0,40	2,0	1,2	4,0	2,4	12,0	7,2
5	0,50	2,5	1,3	5,0	2,5	15,0	7,5
1	0,10	0,5	0,5	1,0	0,9	3,0	2,7
2	0,20	1,0	0,8	2,0	1,6	6,0	4,8
3	0,30	1,5	1,1	3,0	2,1	9,0	6,3
4	0,40	2,0	1,2	4,0	2,4	12,0	7,2
5	0,50	2,5	1,3	5,0	2,5	15,0	7,5
6	0,60	3,0	1,2	6,0	2,4	18,0	7,2
7	0,70	3,5	1,1	7,0	2,1	21,0	6,3
8	0,80	4,0	0,8	8,0	1,6	24,0	4,8
9	0,90	4,5	0,5	9,0	0,9	27,0	2,7

The Proportion Comparison test was used in order to compare the difference between the percentage of experiments with reference Binomial distribution and the Box-Cox angular and power transformations for experiments with variance between homogeneous and heterogeneous treatments.

RESULTS AND DISCUSSION

The behavior of some statistical indicators related to ANAVA theoretical assumptions is discussed: percentage of experiments showing distribution asymmetry, correlation between mean and variance of treatments and independence of experimental errors.

ASYMMETRIC EXPERIMENTS

Table II shows the results of the variables with Binomial distribution for 3, 5 and 9 treatments; It is observed that 80 % of the experiments had an asymmetric behavior for three and five treatments, independently of homoscedasticity, which is due to the fact that the populations that make up both groups of experiments were generated with p-parameters less than 0,50. However, when using 9 treatments it is evident that the asymmetric experiments did not exceed 15 %, since these experiments were generated with p near 0,50. This is associated to the influence of this parameter on the probability distribution characteristic of the Binomial variable (21).

In general, for experiments with p-parameter values lower than 0,50 (3 and 5 treatments), in which their asymmetry, from the theoretical point of view, is more pronounced, even though they have or do not homogeneity in their variances, angular arcosene reduced the percentage of asymmetric experiments with respect to the untransformed Binomial variable, which means an approach to the normality of the transformed data, a result that is in line with what has been reported by other investigations (22), in pointing out the correctness of this transformation for data with binomial distribution. In this context, an acceptable behavior of the square root transformation was found.

For 9 treatments, where the asymmetry is less severe, the arcosene transformation causes significant deviations from normality when compared to untransformed data, as with all other Box-Cox power transformations; this constitutes an alert to the danger posed by the researcher and the statistical expert, if they decide on a transformation, without carrying out a critical analysis of the specific situation they face (23).

RELATIONSHIP BETWEEN MEAN AND VARIANCE

In Table III, it can be seen that neither the angular transformation nor any of the power transformations succeeded in breaking the relationship between mean and variance in binomial-distributed data experiments, even if they have or do not have homogeneous variances among their treatments. Moreover, for the experiments with nine treatments, in which the asymmetry is less pressing, the power transformations accentuated the relation between these two parameters of the distribution.

These results disagree with those obtained by other authors (24), since in addition to eliminating the dependence between mean and variance, they succeeded in stabilizing the variance of insect populations, through the use of some power transformations. However, using a set of power transformations, it was not possible to break the dependence relationship between these two parameters, in data coming from an insect population that fit a Negative Binomial distribution (25).

INDEPENDENCE OF ERRORS

Table IV shows that for the binomial variables, the percentage of experiments that presented absence of first-order correlation in their errors remained between 60 and 80 %, regardless of whether or not the homoscedasticity assumption was fulfilled. Can be associated with the very definition and nature of these variables, in which their variance is a direct function of their mean.

None of the power transformations, nor the angular transformation itself, were able to solve the presence of correlation between errors. This should not be interpreted as a mistake only of the transformation, since there are other causes with no negligible effect in the deviation of this assumption to take into account, as the emanation of the research design itself, which can be solved with a Successful recommendation on the redesign of the research.

CONCLUSION

In general, a comprehensive analysis of the indicators: asymmetry, mean-variance ratio and independence of errors, showed that the applied transformations were not able to solve deviations, with respect to these assumptions of ANAVA, which coincides with that reported by others Investigators (24), who found that of all the analyzed works that were carried out a transformation of power, only in 10% of them, was satisfied to fulfill the assumptions, and in more than 28 %, it applied the transformation improperly. In this sense, the transformations are not always able to solve the non-compliances of the theoretical assumptions of the ANAVA, related to the indicators studied.

Table II. Percentage of asymmetric experiments

r	n	Binomial (%)	Transformation Arcosen (%)	Transformation Box-Cox			Signification α=0,05	$ES_{\bar{x}}$
				Logarithmic (%)	Square root (%)	Reverse (%)		
Heterogeneous variances							Three treatments	
4	5	78 a	69 a	61 b	67 a	92 b	*	4
	10	74 a	65 a	78 a	50 b	93 b	*	4
	30	63 a	47 b	85 b	45 b	99 b	*	5
8	5	85 a	50 b	61 b	37 b	95 b	*	5
	10	85 a	49 b	98 b	29 b	100 b	*	4
	30	55 a	27 b	93 b	28 b	100 b	*	5
Homogeneous variances								
4	5	79 a	51 b	86 a	44 b	99 b	*	4
	10	55 a	75 b	92 b	70 b	100 b	*	4
	30	44 a	57 a	94 b	69 b	100 b	*	4
8	5	82 a	48 b	87 a	34 b	100 b	*	5
	10	67 a	72 a	97 b	63 a	100 b	*	4
	30	38 a	36 a	99 b	56 b	100 b	*	5
Heterogeneous variances							Five treatments	
4	5	82 a	59 b	78 a	42 b	99 b	*	4
	10	80 a	66 b	90 a	53 b	98 b	*	4
	30	57 a	44 a	92 b	43 a	100 b	*	5
8	5	86 a	53 b	92 a	16 b	100 b	*	5
	10	81 a	54 b	98 b	47 b	100 b	*	4
	30	60 a	27 b	100 b	43 b	100 b	*	5
Homogeneous variances								
4	5	79 a	59 b	94 b	35 b	99 b	*	4
	10	71 a	63 a	97 b	55 b	100 b	*	4
	30	40 a	52 a	94 b	59 b	100 b	*	5
8	5	84 a	61 b	92 a	29 b	100 b	*	4
	10	68 a	72 a	98 b	61 a	100 b	*	4
	30	40 a	52 a	100 b	72 b	100 b	*	4
Heterogeneous variances							Nine treatments	
4	5	19 a	14 a	100 b	90 b	100 b	*	5
	10	15 a	39 b	100 b	86 b	100 b	*	5
	30	3 a	22 b	100 b	91 b	100 b	*	5
8	5	6 a	5 a	100 b	97 b	100 b	*	5
	10	3 a	13 b	100 b	96 b	100 b	*	5
	30	1 a	5 a	100 b	96 b	100 b	*	5
Homogeneous variances								
4	5	16 a	14 a	100 b	93 b	100 b	*	5
	10	10 a	37 b	100 b	92 b	100 b	*	5
	30	3 a	21 b	100 b	89 b	100 b	*	5
8	5	4 a	6 a	100 b	96 b	100 b	*	5
	10	3 a	14 b	100 b	97 b	100 b	*	5
	30	1 a	6 b	100 b	98 b	100 b	*	5

Ns: Significance level greater than 0,05

* Significance level less than 0,05

a b: Comparisons are made only with the Binomial

Table III. Percentage of correlated experiments between means and variances

r	n	Binomial (%)	Transformation Arcosen (%)	Transformation Box-Cox			Signification α=0,05	$ES_{\bar{x}}$
				Logarithmic (%)	Square root (%)	Reverse (%)		
Heterogeneous variances							Three treatments	
4	5	95	90	94	88	97	ns	3
	10	96	89	96	89	96	ns	3
	30	97	96	96	94	99	ns	2
8	5	96	91	89	94	97	ns	2
	10	98	93	100	95	100	ns	2
	30	97	95	93	90	100	ns	2
Homogeneous variances								
4	5	93 a	90 a	96 a	91 a	100 b	*	2
	10	92 a	95 a	98 a	94 a	100 b	*	2
	30	96	95	96	96	100	ns	2
8	5	99	94	99	95	100	ns	2
	10	96	93	97	92	100	ns	2
	30	98	92	100	94	100	ns	2
Heterogeneous variances							Five treatments	
4	5	91	84	86	85	88	ns	3
	10	95	87	94	87	99	ns	3
	30	92	96	88	83	98	ns	3
8	5	98 a	96 a	95 a	96 a	88 b	*	2
	10	99	94	98	94	99	ns	2
	30	98	92	96	92	100	ns	2
Homogeneous variances								
4	5	92	87	89	89	97	ns	3
	10	93 a	84 a	98 a	87 a	100 b	*	3
	30	90 a	88 a	97 a	84 a	100 b	*	3
8	5	95 a	89 a	94 a	87 a	100 b	*	3
	10	97	90	98	90	100	ns	2
	30	98	92	100	92	100	ns	2
Heterogeneous variances							Nine treatments	
4	5	69 a	77 a	97 b	84 b	100 b	*	4
	10	72 a	85 b	100 b	87 b	99 b	*	3
	30	58 a	75 b	100 b	83 b	100 b	*	4
8	5	69 a	74 a	98 b	87 b	100 b	*	4
	10	70 a	80 a	100 b	97 b	100 b	*	3
	30	68 a	82 b	100 b	94 b	100 b	*	3
Homogeneous variances								
4	5	68 a	74 a	98 b	94 b	100 b	*	3
	10	72 a	85 b	100 b	96 b	99 b	*	3
	30	84 a	90 a	100 b	94 b	100 b	*	2
8	5	68 a	67 a	100 b	96 b	100 b	*	3
	10	65 a	80 b	100 b	98 b	100 b	*	3
	30	66 a	84 b	100 b	98 b	100 b	*	3

Table IV. Percentage of experiments that fulfill the assumption of independence of errors

r	n	Binomial (%)	Transformation Arcosen (%)	Transformation Box-Cox			Signification $\alpha=0,05$	$ES_{\bar{x}}$
				Logarithmic (%)	Square root (%)	Reverse (%)		
Heterogeneous variances							Three treatments	
4	5	84	88	88	85	80	ns	4
	10	78	82	81	75	88	ns	4
	30	86 a	89 a	95 b	87 a	98 b	*	3
8	5	68	63	61	62	66	ns	5
	10	75 a	76 a	77 a	67 a	92 b	*	4
	30	65 a	62 a	63 a	56 a	94 b	*	5
Homogeneous variances								
4	5	86	84	86	84	90	ns	3
	10	80	86	87	80	92	ns	4
	30	86 a	88 a	93 b	87 a	98 b	*	3
8	5	69	68	62	65	68	ns	5
	10	64 a	69 a	75 a	66 a	88 b	*	4
	30	70 a	75 a	86 b	76 a	99 b	*	4
Heterogeneous variances							Five treatments	
4	5	87	81	78	78	78	ns	4
	10	86	88	88	85	92	ns	3
	30	99	92	96	92	97	ns	2
8	5	82	78	72	74	74	ns	4
	10	74	78	75	73	86	ns	4
	30	75 a	80 a	78 a	77 a	92 b	*	4
Homogeneous variances								
4	5	91	90	88	90	86	ns	3
	10	82 a	80 a	86 a	80 a	95 b	*	4
	30	82	85	88	84	93	ns	3
8	5	79	77	76	76	76	ns	4
	10	74	81	82	74	87	ns	4
	30	75 a	79 a	86 a	79 a	95 b	*	4
Heterogeneous variances							Nine treatments	
4	5	84	88	88	85	80	ns	4
	10	78	82	81	75	88	ns	4
	30	86 a	89 a	95 b	87 a	98 b	*	3
8	5	68	63	61	62	66	ns	5
	10	75	76	77	67	92	*	4
	30	65	62	63	56	94	*	5
Homogeneous variances								
4	5	86	84	86	84	90	ns	3
	10	80 a	86 a	87 a	80 a	92 b	*	4
	30	86 a	88 a	93 b	87 a	98 b	*	3
8	5	69	68	62	65	68	ns	5
	10	64 a	69 a	75 a	66 a	88 b	*	4
	30	70 a	75 a	86 b	76 a	99 b	*	4

Ns: Significance level greater than 0,05 * Significance level less than 0,05
a, b: Comparisons are made only with the Binomial

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