SAKARYA UNIVERSITY JOURNAL OF COMPUTER AND INFORMATION SCIENCES
VOL. 5, NO. 3, DECEMBER 2022
DOI: 10.35377/saucis.05.03.1121388

Research Article

Using of Hierarchical Loglinear Model in Multiway Frequency Tables and an Application on Suicide Cases

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Received 25 May 2022; Revised 10 August 2022; Accepted 26 August 2022; Published online 31 December 2022

Abstract

The aim of this study was to use Hierarchical Loglinear Model (HLLM) in the analysis of multiway frequency tables and to interpret the main and interaction effects of this model on suicide cases.

The data set used in this study was taken from the Turkish Republic State Statistical Institute (TUIK). A total of 6479 cases in 2016 and 2018 years were used in this analysis and the analyzes were made by considering gender, year and age variables.

As a result of HLLM analysis, Year, Gender and Age, which are the main effects in suicide cases, and the interactions of Year × Gender and Gender × Age were found significantly ($P<0.05$). There was a significant decrease in the suicide cases in 2018 compared to 2016 ($P<0.001$). In the sum of the years 2016 and 2018, among the age groups; 2: Suicide cases were observed in the 29-49 age group with a higher rate of 41.45%, while in the 1: 0-19 age group there were fewer suicide cases observed to 11.99%. When factor Gender is Male, factor Year changed from 50.61% to 49.39% at 2016 and 2018, respectively. However, when factor Gender is Female, factor Year changed from 55.71% to 44.29%. This differences in the amount of these changes caused significantly to the interaction of the Gender×Year.

The results has showed that, the main and interaction effects of multiway frequency tables can be interpreted by using HLLM analysis without another statistical method. Hence, it is thought that researchers may prefer HLLM models for the multiway frequency tables.

Keywords: contingency table, frequency table, loglinear model, suicide

1. Introduction

Categorical variables are widely used in the field of health. These variables are frequently analyzed for statistics with tests such as Pearson Chi-square, Likelihood Ratio or Fisher Exact test [1]. The use of Loglinear Model (LLM) method is very limited in the field of health. The main reason for this is that the method is not well known, its theoretical structure and the difficulty of interpreting the results.

LLM is a method that has been used to determine the relationships among variables of multiway frequency table obtained by cross-classifying sets of nominal, ordinal or discrete interval level variables. In this method, the variables can also be called as factor or categorigal variable. It allows to be evaluated as a contingency table of categorical factor [2]. The above mentioned tests are used for independence test in the statistical controls of contingency tables. However, when there are more than two categorical variables and interaction between categories out of the main effects, the above mentioned statistical methods are inadeuqate [3]. Interaction is the different effect of any level of a categorical variable or factor on various levels of other variable [4]. When investigating the presence of interaction in the contingency tables, the above-mentioned statistical methods are not used to explain this relationship [5]. Therefore, LLM, Configural Frequency Analysis (CFA) or Decision Tree (DT) methods are used for large data sets [6-9]. LLM is divided into three separate classes as general, logit and hierarchical. Hierarchical Loglinear Model (HLLM) is a method that checks whether the interaction effects are significant starting from the main effects in the analysis of data sets in multiway frequency table form of two or more dicrete variables [5]. Therefore, it differs from the general and logit methods [10, 11].

Although Öğüş and Yazıcı [1], Şıklar et al. [3] and Yılmaz and Kesin [9] used LLM analysis in their studies, they interpreted through the Multidimensional scaling or Correspondence analysis (CA) methods because of the difficulties in interpreting the interaction effects.

Suicide is an important public health problem [12]. In a previous study, Topaloglu and Atay [13] reported that, according to a report published by the World Health Organization, the suicide cases are among the top ten causes of death in the world, and a person commits suicide every 40 seconds [14]. The total number of suicides in Turkey in 2016 and 2018 was 6479, with an average of 8.8 people committing suicide every day.

The aim of this study was to create a resource for researchers on the interpretation of interaction effects with HLLM analysis, by taking into account the number of suicides in Turkey in 2016 and 2018.

2. Materials and Methods

The suicide data used in this study were obtained from the open access database of the Turkish Republic State Statistical Institute (TUIK) [15]. Data of totally 6479 people in 2016 and 2018 were used. Three variables were considered within the scope of suicide data. Respectively, by Year (1: 2016 - 2: 2018), Gender (1: Male, 2: Female), Age (1: 0-19, 2:20-39, 3: 40-59 and 4: 60 and above) it is recorded.

Considering three categorical variables in this present study, saturated HLLM, which includes all main and interaction effects, is written as follows [6]:

$$\ln(mijk) = \theta + \lambda_i^A + \lambda_j^B + \lambda_{ij}^{AB} + \lambda_k^C + \lambda_{ik}^{AC} + \lambda_{jk}^{BC} + \lambda_{ijk}^{ABC} \quad (1)$$

Here, the λ's are called effects. The predicted cell count m_{ijk} based on the current hierarchical model. The prediction equation is the superscripts represent the variables and the subscripts represent the category numbers or levels of the variables. However, for the three categorical variables, in the saturated Loglinear model including all the main effects and interaction effects, the main effects of the A, B and C variables, respectively; AB, AC, BC and ABC terms show interaction effects [16].

2.1.Testing the fit of the model and choosing the model

Likelihood – Ratio (G^2) and Pearson (χ^2) Chi-square statistics are used, respectively, to test the suitability of a saturated model considered in Equation (1) to the data.

$$\chi^2 = 2\sum_{i,j,k} \frac{(fijk - \hat{m}ijk)^2}{\hat{m}ijk} \quad (2)$$

and Likelihood – Ratio,

$$G^2 = 2\sum_{i,j,k} fijk\ ln\left(\frac{fijk}{\hat{m}ijk}\right) \quad (3)$$

Here f_{ijk} is the observed number for a three-way table. These statistics are; It is used to test whether the agreement between the observed and expected frequencies calculated according to the model is significant [17].

NCSS package program version 7.0 was used for HLLM calculations [18]. In calculation; Delta value as module: 0.2, Model definition: Full model, and hierarchical model, Maximum number of repetitions: 25, maximum difference: 0.25, Alpha value: 0.05 was accepted as goodness of fit.

2.1.2. Parameter Estimation Section

The program uses the Maximum likelihood model parameter estimation algorithm suggested by Haberman [19] to determine the best saturated model. The Step Down method is used to determine the best saturated model, and the G^2 test is used as the fit statistic of the model. In the step down method;

The algorithm starts the operation from the most complex model. It performs the process of finding the most suitable model by removing the terms from the model. The aim here is to determine the best model with the fewest parameters [20]. As a result, the NCSS Program proposes the best goodness of fit model among many prediction models.

The fact that the P-value of both G^2 and χ^2 values is nonsignificant in the fit of the final model indicates a goodness fit of the saturated model. For this reason, it is expected that the best saturated model will come out with P-value nonsignificant.

3. Result

In Table 1, the significance of the terms that should be included in the HLLM model is analyzed. It is seen that the model with three or higher is significant. In the lower section, the significance results of whether single effects are significant or not are given. Since all three factors are significant, they will be included in the hierarchical model. Then, in the model selection section, the results of the best saturated model are given in Table 2.

Table 1 Multiple-Term Test Section

Multiple-Term Test Section					
K-Terms	**DF**	**Like. Ratio Chi-Square**	**Prob Level**	**Pearson Chi-Square**	**Prob Level**
1WAY & Higher	15	3078.48	<0.0001	3428.43	<0.0001
2WAY & Higher	10	162.19	<0.0001	173.55	<0.0001
3WAY & Higher	**3**	**7.27**	**0.0637**	**7.25**	**0.0644**
K-Terms	**DF**	**Like. Ratio**	**Prob**		
1WAY Only	5	2916.28	<0.0001		
2WAY Only	7	154.92	<0.0001		
3WAY Only	**3**	**7.27**	**0.0637**		

Note: Simultaneous test that all interactions of order k are zero. These Chi-Squares are differences in the above table. P≤0.20: Significance reference value: 0.20.

Table 2 Statistical results for determination of the best saturated model

Step-Down Model-Search Section									
Step No	**Best No**	**DF**	**Chi-Square**	**Prob Level**	**Deleted Term**	**DF**	**Chi-Square**	**Prob Level**	**Hierarchical Model**
1	1	0	0.0	1.0000	None	0	0.0	<0.0001	ABC
2	1	3	7.3	0.0637	ABC	3	7.3	0.0637	BC,AC,AB
3	2	6	147.6	<0.0001	BC	3	140.3	0.0000	AC,AB
4	2	6	8.4	0.2135	AC	3	1.1	0.7825	BC,AB
5	2	4	19.7	0.0006	AB	1	12.5	0.0004	BC,AC
6	4	9	149.2	<0.0001	BC	3	140.8	<0.0001	AB,C
7	4	7	21.4	0.0033	AB	1	13.0	0.0003	BC,A
Best model found: BC, AB									
4	**4**	**6**	**8.4**	**0.2135**	**AC**	**3**	**1.1**	**0.7825**	**BC, AB**
Model Section : Hierarchical Model: BC, AB									

The main purpose of Table 2 was to exhibit the best model with the fewest terms. The NCSS Program defined the model in Step 4 as the best saturated model. The results of the goodness of fit of this saturated model are as follows.

The parameter estimation results of the saturated model were given in Table 3. As can be seen Table 3, the main effects and the interaction effects of the model were found to be significant (P<0.05).

Table 3 Statistical results of the main effects and the interaction effects of the saturated model

Chi-Square Tests Section

DF	**Like. Ratio Chi-Square**	**Prob Level**	**Pearson Chi-Square**	**Prob Level**	**Model**
6	8.35	0.2135	8.33	0.215	BC,AB

Parameter Estimation Section

Model	**Number Cells**	**Count**	**Percent Count**	**Average Log(Count)**	**Effect (Lambda)**	**Effect Std. Error**	**Effect Z-Value**	**P value**
Mean	16	6479	100	5.7632	5.7632	0.0155	371.78	<0.001
A: Year								
1	8	3366	51.94	5.8267	0.0635	0.0155	4.10	<0.001
2	8	3114	48.06	5.6997	-0.0635	0.0155	-4.10	<0.001
B: Gender								
1	8	4789	73.91	6.2395	0.4763	0.0155	30.73	<0.001
2	8	1691	26.09	5.2869	-0.4763	0.0155	-30.73	<0.001
C: Age								
1	4	777	11.99	5.2575	-0.5057	0.03	-16.86	<0.001
2	4	2686	41.45	6.3652	0.602	0.0221	27.21	<0.001
3	4	1912	29.51	5.962	0.1988	0.0253	7.87	<0.001
4	4	1105	17.05	5.4681	-0.2951	0.0293	-10.08	<0.001
B: Gender								
1	8	4789	73.91	6.2395	0.4763	0.0155	30.73	<0.001
2	8	1691	26.09	5.2869	-0.4763	0.0155	-30.73	<0.001
C: Year								
1	4	777	11.99	5.2575	-0.5057	0.03	-16.86	<0.001
2	4	2686	41.45	6.3652	0.602	0.0221	27.21	<0.001
3	4	1912	29.51	5.962	0.1988	0.0253	7.87	<0.001
4	4	1105	17.05	5.4681	-0.2951	0.0293	-10.08	<0.001
AB: Year, Gender								
1,1	4	2424	37.41	6.2518	-0.0512	0.0155	-3.30	<0.001
1,2	4	942	14.54	5.4016	0.0512	0.0155	3.30	<0.001
2,1	4	2365	36.5	6.2272	0.0512	0.0155	3.30	<0.001
2,2	4	749	11.56	5.1723	-0.0512	0.0155	-3.30	<0.001

BC: Gender, Age								
1,1	2	437	6.75	5.3876	-0.3462	0.03	-11.55	<0.001
1,2	2	2008	31	6.9119	0.0704	0.0221	3.18	<0.001
1,3	2	1509	23.3	6.6262	0.188	0.0253	7.44	<0.001
1,4	2	833	12.86	6.0323	0.0879	0.0293	3.00	0.0014
2,1	2	339	5.24	5.1275	0.3462	0.03	11.55	<0.001
2,2	2	677	10.45	5.8186	-0.0704	0.0221	-3.18	<0.001
2,3	2	402	6.21	5.2977	-0.188	0.0253	-7.44	<0.001
2,4	2	271	4.19	4.9039	-0.0879	0.0293	-3.00	0.0014
1,2	2	942	14.54	5.4016	0.0512	0.0155	3.30	<0.001
2,1	2	2365	36.5	6.2272	0.0512	0.0155	3.30	<0.001
2,2	2	677	10.45	5.8186	-0.0704	0.0221	-3.18	<0.001
2,3	2	402	6.21	5.2977	-0.188	0.0253	-7.44	<0.001
2,4	2	271	4.19	4.9039	-0.0879	0.0293	-3.00	0.0014

According to Table 3, Year, Gender and Age main effects and Year × Gender and Gender × Age interaction effects were found significantly (P<0.001). There was a significant decrease in the cases of suicides in 2018 when compared to 2016 (P<0.001). Males (73.91%) attempted suicide at a higher rate than females (26.09%) in the total cases of suicides in 2016 and 2018 (P<0.001). Similarly, While the highest suicide rate was in the 29-49 age group (41.45%), the lowest was in the 0-19 age group (11.99%).

3.1. Interpretation of Interactions

The interactions of Year × Gender and Gender × Age were found to be significant in Table 3. We can construct the following two-way table of percentages from the Count column of Table 3.

Table 4 The table of Year × Gender interaction percentages

Gender	**Year**		**Total**
	1:2016	**2:2018**	
1:Male	**50.61%** (2424/(2424+2365))*100	**49.39%** (2365/(2424+2365))*100	**% 100**
2: Female	**55.71%** (942/(942+749))*100	**44.29%** (749/(942+749))*100	**% 100**

As can be seen in Table 4, it was shown that when factor Gender is Male, factor Year changed from 50.61% to 49.39% at 2016 and 2018, respectively. However, when factor Gender is Female, factor Year changed from 55.71% to 44.29%. This difference in the amount of change is what causes Gender×Year to be significant (Figure 1). This type of table should be created for every significant term.

The suicide rate was found to be higher in men over the age of 20, whereas, the suicide rate in women was higher under the age of 20 (Table 5). This difference in the amount of change is what causes Gender × Age to be significant (Figure 2).

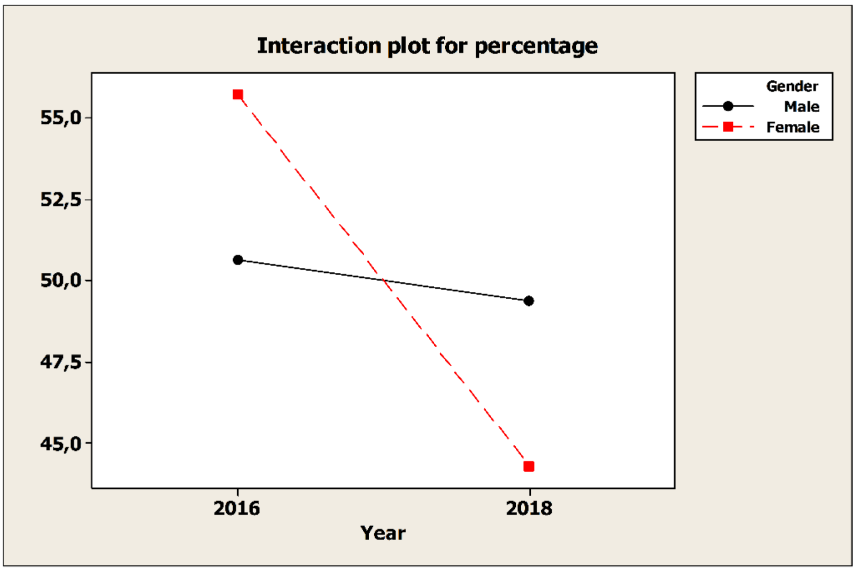

Figure 1 Percentage of Years × Gender interaction

Table 5 The table of Gender × Age interaction percentages

Age	Gender		Total
	1: Male	2: Female	
1:0-19	**56.32%** (437/(437+339))*100	**43.68%** (339/(437+339))*100	**100%**
2:20-39	**74.79%** (2008/(2008+677))*100	**25.21%** (677/(2008+677))*100	**100%**
3:40-59	**78.97%** (1509/(1509+402))*100	**21.03%** (402/(1509+402))*100	**100%**
4:60->	**75.45%** (833/(833+271))*100	**24.5%** (271/(833+271))*100	**100%**

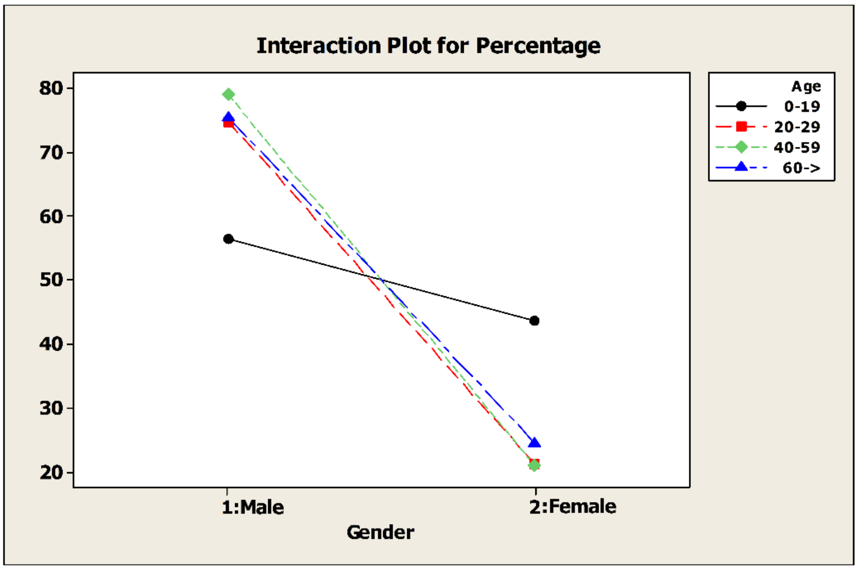

Figure 2 Percentation of Gender × Age interaction

4. Discussion

It was determined that there was a significant decrease in the total number of cases from 2016 to 2018 in the number of suicides. The main reason for this may have be the Istanbul Declaration for Women, which came into force in 2017, and the women who are victims of domestic violence and violence against women, which came into force in 2017. One-click Women's Support Service (KADES) system may have reduced these deaths [21,22]. Similarly, the fact that women aged of 0-19 have fewer suicide cases than men is consistent with both World Health Organization (WHO) and TUIK 2012 data [13]. However, it is highly probable that women in this age group have higher rates of suicide when compared to women in the older age group. This protection system developed by the state to protect women against domestic violence may be effective. It is thought that studies on this system may have reduced suicide rates, especially in women.

When suicide cases were evaluated in terms of gender, the suicide rates of men were found to be higher than women in all ages and years. Kaplan and Sadock [23] reported that men tend to commit suicide more than women. This result is consistent with this study.

Oğuzlar [5] tried to interpret the interactions, according to the estimation value as a result of the LLM analysis, and commented only as an increase or decrease. It is very difficult to make a biological interpretation of the estimation values of the LLM analysis. For this reason, many researchers have preferred the fit analysis.

Öncel and Erdugan [6] analyzed the main effects in the LLM analysis using the Chi-square independence test in a study on smoking addiction. Erdem [11] reported that if the number of categories or factors in the contingency table is more than two, the use of Chi-square independence tests becomes difficult and analysis may be impossible and so it has been argued that the LLM method should be used in such cases.

Many studies such as Yılmaz and Kesin [9], Yılmaz and Aktaş [24], Adıgüzel [25] and Kaşkır [26] also used the LLM method. Since they could not interpret the interaction effects, they tried to interpret these interactions with Multidimensional scaling or Correspondence analysis (CA) methods. Although Yılmaz and Kesin [9] described the variation of the dimensions in the graphical interpretation of the CA analysis, they did not mention the interactions between the variables. In another studies, it has been compared the CA method with the LLM method and has been argued that these two methods are complementary to each other [27,28]. However, the CA method is a dimension reduction method for categorical variables, and allows variables to visually present the relationship between subcategories in a two or three dimensional space [9]. This method uses various distance or proximity measurements and normalization methods. According to these methods are obtained different graphical results, therefore, it should be kept in mind that performing CA analysis on variables whose interaction is significant as a result of LLM analysis may lead to different results [11].

Although three factors were considered in this study, tables using HLLM analysis may contain more factors. However, the number of factors being four or more may complicate the interpretation of the interaction. In such cases, matrix interaction graphs or alternatively decision tree methods can be used to interpret triple or higher order interactions [8].

Brzezinska [2] and Erdugan and Türkan [29] researchers suggested Akaike criteria (AIC), Bayes criteria (BIC) and Coefficient of Determination (R^2) to determine the best model in LLM analysis. However, NCSS programme directly recommends the best model. Therefore, these criteria were not included in this study.

The menu of LLM is available in NCSS, SPSS and many other package programs. NCSS program proposals the best saturated LM model as a standard result compared to widely used SPSS package program.

Öncel and Erdugan [6] were solved manually the detailed analyzes of the contingency tables, the estimation of the model parameters and the statistical results of the parameter estimation section by the LLM. They emphasized these analyzes as a shortcoming of the SPSS package program. Öncel and Erdugan [6] reported that, as a result of the SPSS analysis, it was not clear that a meaningful result would be obtained for which parameter and which level. Similarly, Şıklar et al. [3] firstly applied LLM analysis to the obtained data and it has been explained that it is necessary to use CA for the interpretation of interactions that are found to be significant.

In the NCSS program, the statistical results of the parameter estimation part of the best saturated HLLM are given in detail. There is no need to calculate manually or use any other method for these statistics. In this study, in addition to these statistics, a sample graphical interpretation has also been added to better understand the interpretation of interactions.

As a result, it has been shown that multiway frequency table using HLLM analysis can be analyzed without the need for any other statistical method and how interaction effects can be interpreted together with main effects. It is thought that researchers may prefer HLLM models for multiway frequency tables.

Conflict of Interest

The author declare that there is not any conflict of interest regarding the publication of this manuscript.

Ethics approval

Not applicable.

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