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Callous-unemotional Traits with Mental Disorders in Adolescents by Two-Way Log-Ratio Analysis

Luca Rossi[1]

ABSTRACT

Psychopathy is complex phenomenon associate to personality disorder that manifests at a relatively early age and tends to be relatively stable throughout life. Psychopathy in adolescents is currently being studied using the approach of callous-unemotional (CU) traits. Recent studies have shown that adolescents with these traits have different causal factors leading to their behavior problems and mental disorders. Here I propose to use the log-ratio analysis, for two-way contingency table, for assessing the correlation between CU traits and mental disorders in adolescents. The data are provided by H.E.R.A.C.L.E. Lab (Unicusano research center on health education) and obtained submitting to a sample of 689 high school students two questionnaires: The Inventory of Callous-Unemotional Traits (ICU) and The Strengths and Difficulties Questionnaire (SDQ)). In two-way tables obtained, an odds ratio reflects the likelihood that a ICU trait (callousness, uncaring and unemotional) will have with SDQ values (normal, borderline and abnormal). Log-ratio analysis presents many advantages, among which the computation and the visual representation in a biplot map of the odds ratio that allows the correlation in terms of distances between points.

Keywords: ICU, SDQ, Log-ratio analysis, RC (M) association model, odds ratios.

1. Introduction

Psychopathy is complex phenomenon associate to personality disorder characterized by affective, interpersonal, and behavioral characteristics (Hare and Neumann 2008). Recent studies (Lynam, 1996; Frick P.J., Cornell A.H., Bodin S.D., Dane H.E., Barry C.T. and Loney B.R. ,2003; Loeber and Farrington, 2000; Dadds et al., 2005) have highlighted that psychopathy manifests at a relatively early age (it can also emerge in children of 4 years) and it tends to be relatively stable throughout life. Psychopathy in children and adolescents is currently being studied using the approach of callous-unemotional (CU) traits. Frick in 2004 showed that these traits might be the precursors to the development of psychopathy. The early detection of CU traits might help the implementation of early treatment for young people who have a high risk of severe conduct disorder. Further, CU traits have been associated with distinct cognitive and affective characteristics which could suggest that children and adolescents with these traits have different causal factors leading to their behavior problems and mental disorders (Frick, Ray, Thornton and Kahn, 2013). The Inventory of Callous-Unemotional Traits (ICU) is one

[1] Niccolò Cusano University, Italy. Email: luca.rossi@unicusano.it

of the most widely used measurements to assess CU traits (Frick, 2004). It is a 24-item questionnaire designed to provide a comprehensive assessment of callous and unemotional traits and has three subscales: Callousness, Uncaring, and Unemotional. These traits have proven to be important for designating a distinct subgroup group of antisocial and aggressive youth. In literature there are various studies that validated this test (Essau, Sasagawa and Frick, 2006; Fanti, Frick and Georgiou, 2009; Ciucci, Baroncelli, Franchi, Golmaryami, e Frick, 2014).

Many epidemiological studies, furthermore, conducted by Kessler (2005), Meikangas (2010) and Polancyzyk (2015) have showed that a large chunk of adolescents (13-25%) might meet the criteria for a mental disorder during their lifetime. Mental health problems often in adolescents go very unnoticed (Mellor and Stokes, 2007; Boe, Hysing, Skogen and Breivik, 2016). The use of screening tools can be an excellent method of detecting these problems early and allowing early access to effective treatments. The Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997 and 1999) is a brief emotional and behavioural screening questionnaire for mental health problems in children and young people. The SDQ is an open-access 25-item questionnaire used to screen adolescents for behavioral problems: five items refer to prosocial skills, and 20 refer to difficulties. These items are divided into five scales (emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, and prosocial behaviors) and each scale has five questions answered on a scale of "not true," "somewhat true," or "certainly true.". Using the total difficulties score and basing on cutoff points of the SDQ the researchers can classify subjects as normal, borderline, or abnormal. In literature there are various studies that validated this test (Goodman, 2001; Lundh, Wangby-Lundh, and Bjarehed, 2008; Law and Wolpert, 2014; Hall, Guo, Valentine, Groom, Daley, Sayal, Hollis, 2019).

Frick and Ray in 2015, highlighted that adolescents with elevated CU traits tend to respond less positively to typical interventions provided in mental health and juvenile justice settings, they show positive responses to certain intensive interventions tailored to their unique emotional and cognitive characteristics. This paper wants, in particular, to validate the correlation between personality disorders and mental disorder.

In physical sciences but also in social sciences the odds ratios have been widely used by researchers in their applications (Greenacre 2009; Aitchinson and Greenacre 2002). Firstly, they give a measure of association among two variables. Secondly, have found general application in log linear, RC(M) association models (Goodman 1985; de Rooij and Anderson 1985). In this work the application of log-ratios analysis is used for assessing the correlation between CU traits and mental disorders in adolescents (Walters, Knight, Grann and Dahle, 2008; Frick, Ray, Thornton and Kahn, 2013) using the data provided by H.E.R.A.C.L.E. Lab (Unicusano research center on health education) and obtained submitting to a sample of 689 high school students the two questionnaires (ICU and SDQ).

This paper is divided into further six sections. The notation in section 2. In section 3 is showed Altham's index. Section 4 and 5 provide a theoretical description of use of Odds ratios in RC(M) association and Log linear models, respectively. In section 6 are showed the results applying the two models to the data. Some final remarks are made in section 7.

2. Notation

Let A(n_{ij})be a two way-contingency table that cross-classifies N units into I row categories and J column categories. Let the cell probability define by $p_{ij} = P(I = x_i \cap J = y_j)$, where x_i is the i-th category of I and y_j is the j-th category of J (Agresti 2002). The odds ratio (OR) is a measure of association between I and J (Altham 1970; Goodman 1979; Greenare 2009) and is defined by a complete set of ORs:

$$\mathrm{OR}_{\mathrm{ii'jj'}} = \frac{\mathrm{p_{ij}p_{i'j'}}}{\mathrm{p_{ij'}p_{i'j}}} \qquad 1 \le \mathrm{i} \le \mathrm{i'} \le \mathrm{I}^* \text{ and } 1 \le \mathrm{j} \le \mathrm{j'} \le \mathrm{J}^* \qquad (1)$$

Where $I^* = I(I-1)/2$ and $J^* = J(J-1)/2$

If we suppose all the probabilities follow a Poisson sampling $p_{ij} = \frac{n_{ij}}{N}$, the ORs can be defined also as:

$$\mathrm{OR}_{\mathrm{ii'jj'}} = \frac{\mathrm{n_{ij}n_{i'j'}}}{\mathrm{n_{ij'}n_{i'j}}} \qquad 1 \le \mathrm{i} \le \mathrm{i'} \le \mathrm{I}^* \text{ and } 1 \le \mathrm{j} \le \mathrm{j'} \le \mathrm{J}^* \qquad (2)$$

The complete set of ORs is composed by $\left(I^* = \frac{I(I-1)}{2}\; x\; J^* = \frac{J(J-1)}{2}\right)$ elements and is redundant. However there exist basic sets of $((I-1)\; x\; (J-1))$ ORs that contain all the information about association between I and J. The principal basic sets (Edwardes and Baltzan 2000) are the local ORs defined by

$$\mathbf{local\ OR_{ij}} = \frac{\mathbf{p_{ij}p_{i+1\,j+1}}}{\mathbf{p_{ij}p_{i+1\,j}}} \qquad \mathbf{1 \le i \le (I^* - 1)\ and\ 1 \le j \le (J^* - 1)} \qquad \mathbf{(3)}$$

and spanning cell odds ratios defined by

$$\mathbf{spanning\ OR_{ij}} = \frac{\mathbf{p_{11}p_{ij}}}{\mathbf{p_{1j}p_{i1}}} \qquad \mathbf{where\ the\ spanning\ cell\ is\ i = j = 1} \qquad \mathbf{(4)}$$
$$\mathbf{2 \le i \le I^*\ and\ 2 \le j \le J^*}$$

Although these sets reduce the number of ORs from $\left(\mathrm{I}^* = \frac{\mathrm{I(I-1)}}{2}\ \mathrm{x}\ \mathrm{J}^* = \frac{\mathrm{J(J-1)}}{2}\right)$ to of $((\mathrm{I}-1)\ \mathrm{x}\ (\mathrm{J}-1))$, there are various applications in which the number of ORs to be calculated, to verify the relationship between the two variables, is yet too large. Therefore, there are various strategies to apply:

to use a measure of synthesis of ORs;

The construction of models for frequencies (RC(M)-association model and Log linear model) and to verify the interaction of I and J trough the ORs.

3. Synthesis index

A measure of synthesis of ORs can be defined using Altham's index (Altham 1970) and can be computed using the following formula:

$$\mathbf{A} = \left[\frac{\sum_{\mathbf{i}}\sum_{\mathbf{j}}\left(\mathbf{logOR_{ii'jj'}}\right)^{\mathbf{2}}}{\mathbf{I^*J^*}}\right]^{\frac{\mathbf{1}}{\mathbf{2}}} \qquad \mathbf{(5)}$$

Altham's index summarizes the ORs but doesn't consider the size of the table and doesn't give a direction of association and is appropriate to use it for nominal variables.

4. The RC (M) association model and odds ratio

The RC(M) association model was defined by Goodman in 1979 and can be computed using the following formula:

$$\mathrm{p_{ij}} = \alpha_\mathrm{i}\beta_\mathrm{j}\exp\left(\sum_{\mathrm{m}=1}^{\mathrm{M}} \theta_\mathrm{m}\,\rho_\mathrm{im}\delta_\mathrm{jm}\right) \qquad (6)$$

where α_i and β_j are the effects of I and J respectively, θ_m is a measure of strength of the association between I and J and ρ_{im} and δ_{jm} are respectively the m-th component of i-th row score and j-th column score. With respect to the scores the following constraints are employed:

$$\textstyle\sum_{i=1}^{I}\rho_{im}p_{i+} = \sum_{j=1}^{J}\delta_{jm}p_{+j} = 0;\ \sum_{i=1}^{I}\rho_{im}{}^{2}p_{i+} = \sum_{j=1}^{J}\delta_{jm}{}^{2}p_{+j} = 1;$$

$$\textstyle\sum_{i=1}^{I}\rho_{im}\rho_{i'm}p_{i+} = \sum_{j=1}^{J}\delta_{jm}\delta_{j'm}p_{+j} = 0,\ \text{where}\ p_{i+} = \sum_{j=1}^{J}p_{ij}\ \text{and}\ p_{+j} = \sum_{i=1}^{I}p_{ij}.$$

Eshima and Tabata (1997) showed that the RC(M) association model is a discretized version of canonical correlation analysis in the multivariate normal distribution.

For graphical display of the RC(M) association model (De Rooij and Anderson 2007) we have to compute a vector for rows of elements $\theta_m{}^{\frac{1}{2}}\rho_{im}$ and one for columns of elements $\theta_m{}^{\frac{1}{2}}\delta_{jm}$ and consider the inner product.

The ORs related to RC(M) association model can be computed using the inner product rule and are:

$$OR_{ii'jj'} = exp\left(\sum_{m=1}^{M} \theta_m \left(\rho_{im} - \rho_{i'm}\right)\left(\delta_{jm} - \delta_{j'm}\right)\right) \quad (7)$$

The graphical representation of RC(M) association model can be given also using a distance rule (De Rooij and Heiser 2005). Define $r_i = \sum_m \theta_m \rho_{im}$ the i-th principal coordinate of variable I and $c_j = \sum_m \theta_m \delta_{jm}$ the j-th principal coordinate of variable J. When using the Euclidean distance (d^2), the ORs can be computed as:

$$OR_{ii'jj'} = exp\left[\frac{1}{2}\left(d^2\left(r_{i'}, c_j\right) + d^2\left(r_i, c_{j'}\right) - d^2\left(r_i, c_j\right) - d^2\left(r_{i'}, c_{j'}\right)\right)\right] \quad (8)$$

5. Log odds ratio

Log linear model formula (Goodman 1979; Agresti 2002; Rossi, Lombardo and D'Ambra ,2019) for a two way contingency table of expected frequencies n_{ij} is:

$$\log n_{ij} = \lambda + \lambda_i^I + \lambda_j^J + \lambda_{ij}^{IJ} \quad (9)$$

Where λ is a constant, λ_i^I and λ_j^J represent the row and column effects respectively. The term λ_{ij}^{IJ} measures interactions between I and J, whereby the effect of one variable on n_{ij} depends on the level of the other.

The ORs related to log linear model can be computed as:

$$\log\left(OR_{ii'jj'}\right) = log\left(\frac{n_{ij}n_{i'j'}}{n_{ij'}n_{i'j}}\right) = log\left(n_{ij}\right) + log\left(n_{i'j'}\right) - log\left(n_{ij'}\right) - log\left(n_{i'j}\right) =$$

$$= \lambda_{ij}^{IJ} + \lambda_{i'j'}^{IJ} - \lambda_{ij'}^{IJ} - \lambda_{i'j}^{IJ} \text{ , so}$$

$$OR_{ii'jj'} = exp\left(\lambda_{ij}^{IJ} + \lambda_{i'j'}^{IJ} - \lambda_{ij'}^{IJ} - \lambda_{i'j}^{IJ}\right) \quad (10)$$

The log odds ratio analysis affords, making use of the Singular Value Decomposition (SVD) (De Rooij and Anderson 2007), a direct graphical representation of ORs. Let L be a complete two-way matrix of dimension $(I^* x\, J^*)$ containing the basic set of log ORs. The SVD of L is a factorization of form

$$L = U\Lambda V^T \quad (11)$$

Where U and V are two matrices of dimensions $(I^* x\, I^*)$ and $(J^* x\, J^*)$ respectively. Λ is a rectangular diagonal matrix of dimension $(I^* x\, J^*)$ where the diagonal entries are the singular values of L. The joint plot of SVD of L is obtained considering the principal coordinates and so by plotting the rows of L as vectors with coordinates $R = U\Lambda$ and the columns of L as vectors with coordinates $C = \Lambda$V. The inner product of two vectors represents the values in the cells of matrix L.

6. Case study

In this section, we investigate the relationship between the psychopathic traits on emotion recognition (callousness, uncaring and unemotional) measured using the Inventory of Callous-Unemotional Traits (ICU) and the behavioral problems of adolescents (normal, borderline and abnormal) measured using Strengths and Difficulties Questionnaire (SDQ) (Aspan, Bozsik, Gadoros, Nagy, Inantsy-Pap, Vida and Halasz 2014). The data have been provided by H.E.R.A.C.L.E. Lab (Unicusano research center on health education). The questionnaires have been submitted to a sample of 689 high school students 14 to 19 years of age in Veneto and Lazio (two Italian regions of North and South Italy respectively). The sample was diverse in regards to parental educational level but representative of families in the school districts.

The investigation of data is carried out applying two-way log odds ratio analysis and comparing the results obtained with the graphical representation of the outcomes got using RC(M) association model. The two-way contingency table (Table1) summarizes the number of students according to a particular trait of ICU (no_trait, callousness, uncaring and unemotional) and the potential diagnosis of SDQ (normal, borderline and abnormal).

Table 1.

ICU/SDQ

		SDQ totale		
		Normal	Borderline	Abnormal
	No_trait	218	64	46
	callousness	134	60	72
ICU	uncaring	107	44	61
	unemotional	25	13	15

The association between row and column variables is statistically significant, with Pearson's chi squared statistic (Rossi L., Lombardo R. and D'Ambra A., 2019). equal to 28.071 on 6 degrees of freedom and p-value equal to 9.11*10-05.

Table 2.

Complete set of Log ORs

		SDQ totale		
		Normal-borderline	Normal - abnormal	Abnormal -Borderline
	No_trait - callousness	0.42199441	0.93452350	0.51282363
	No_trait - uncaring	0.33718627	0.99399224	0.65700173
ICU	No_trait - unemotional	0.57154436	1.04485983	0.47312376
	Callousness - uncaring	-0.08555789	0.05921186	0.14410034
	Callousness - unemotional	0.14928170	0.11064652	-0.03874083
	Uncaring - unemotional	0.23507212	0.05069311	-0.18392284

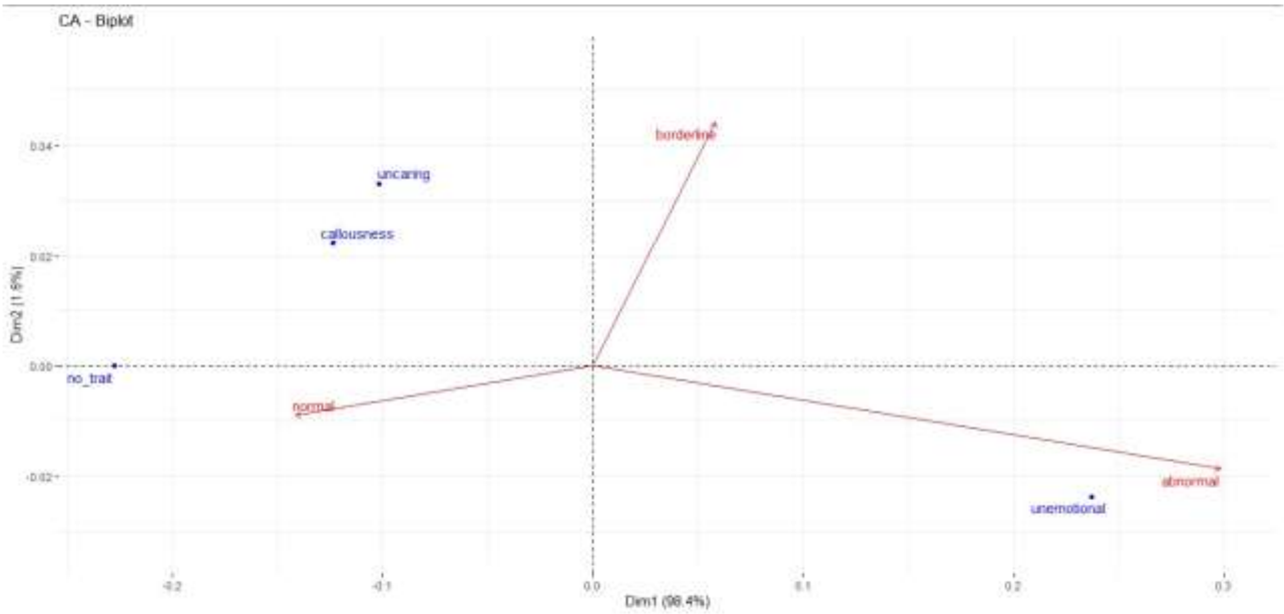
The complete set of 18 log ORs is shown in table 2. Many of these values are positive so the general association between the variables seems to be positive. A synthetic analysis of the complete set of ORs computed using Altham index (A=0.37) shows the relationship between the two variables too. For sake, in table 3, are reported the ORs values.

Table 3.

Complete set of ORs

		SDQ totale		
		Normal-borderline	Normal - abnormal	Abnormal -Borderline
	No_trait - callousness	1.525	2.546	1.670
	No_trait - uncaring	1.401	2.702	1.929
ICU	No_trait - unemotional	1.771	2.843	1.605
	Callousness - uncaring	0.918	1.061	1.155
	Callousness - unemotional	1.161	1.117	0.962
	Uncaring - unemotional	1.265	1.052	0.832

The figure 1 gives the classical interactive biplot of log ORs (table 2), where the scores are portrayed using the inner product (De Rooji and Anderson 2007). The graphic representation of each column categories is given by the use of standard coordinates and is drawn using a vector that joins the



origin of axis to its position. The row categories are drown using principal coordinates and the association with column categories depends by their distance from column vectors.

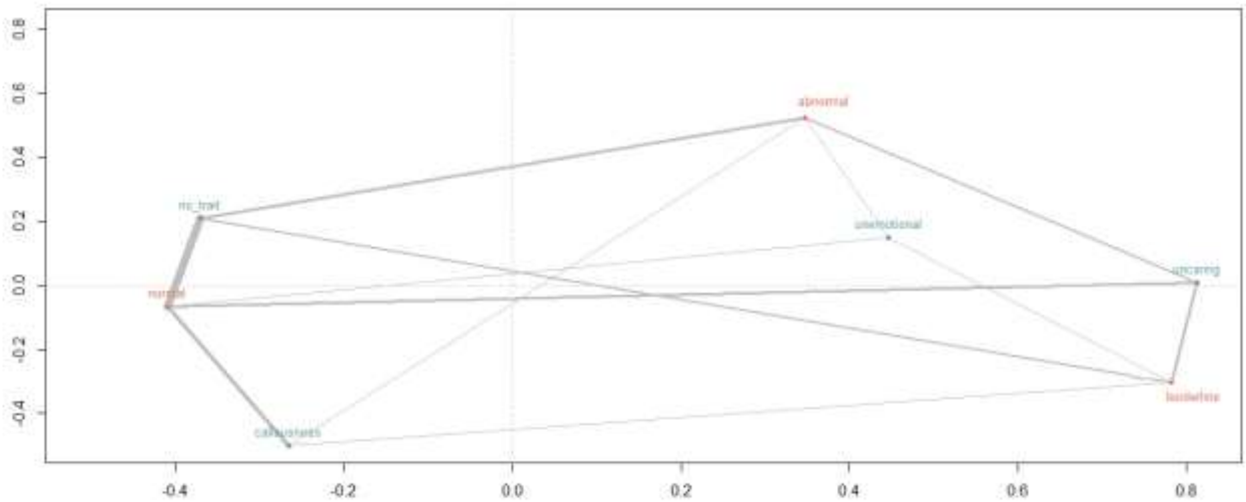
By observing, we can conclude that:

the adolescents that highlight no particular trait of ICU (no_trait) are characterized by a close association with normal value of SDQ;

the adolescents that highlight the callousness or uncaring trait of ICU are characterized by a dispute between normal and borderline values of SDQ;

the adolescents that highlight the unemotional trait of ICU are characterized by a close association with abnormal value of SDQ.

Figure 2 is an interactive biplot in which log ORs are graphically represented using solid and



dashed lines. In the graph plot the column scores are represented by red points and the row scores by blue points. The thickness of the connecting lines reflects the frequency of the table 2. The distances

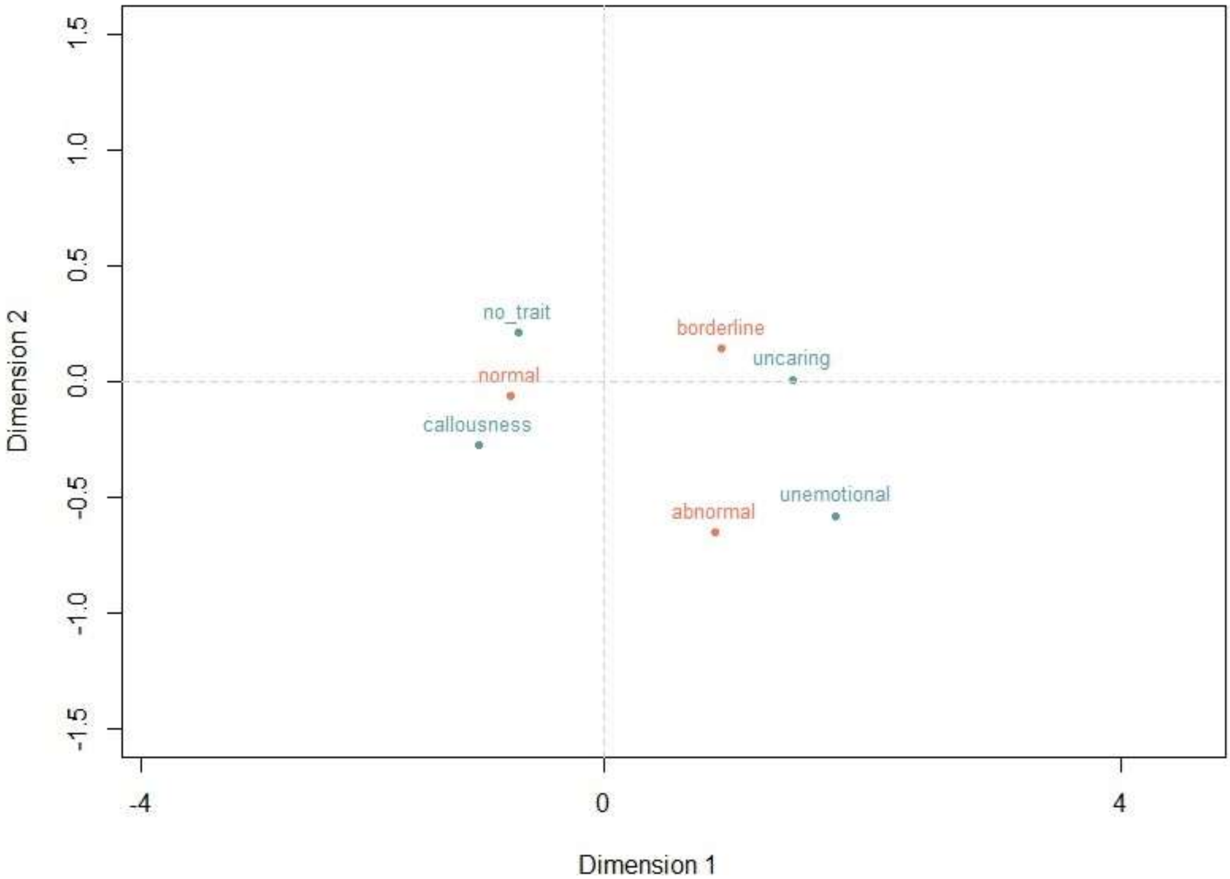
Figure 2. The interactive biplot from the log-ratio analysis with solid and dashed lines

between row and column categories can be interpreted.

Observing the figure 2 we can analyze in detail the relationship between the traits of ICU and the potential diagnosis of SDQ:

the adolescents that highlight no particular trait (no_trait) or callousness trait of ICU are characterized by a close association with normal value of SDQ;

the adolescents that highlight the uncaring trait or the unemotional trait of ICU are characterized



by a close association with borderline and abnormal value of SDQ respectively.

In figure 3 is portrayed the graphical representation of table 1 using the RC(M) association model in which the ORs are computed using variable coordinates and expressed in terms of distances within these coordinates.

The column scores are represented by red points and the row scores by blue points. Observing the graph, we have an immediate comparison between the two variables finding the same relationship of previous figures:

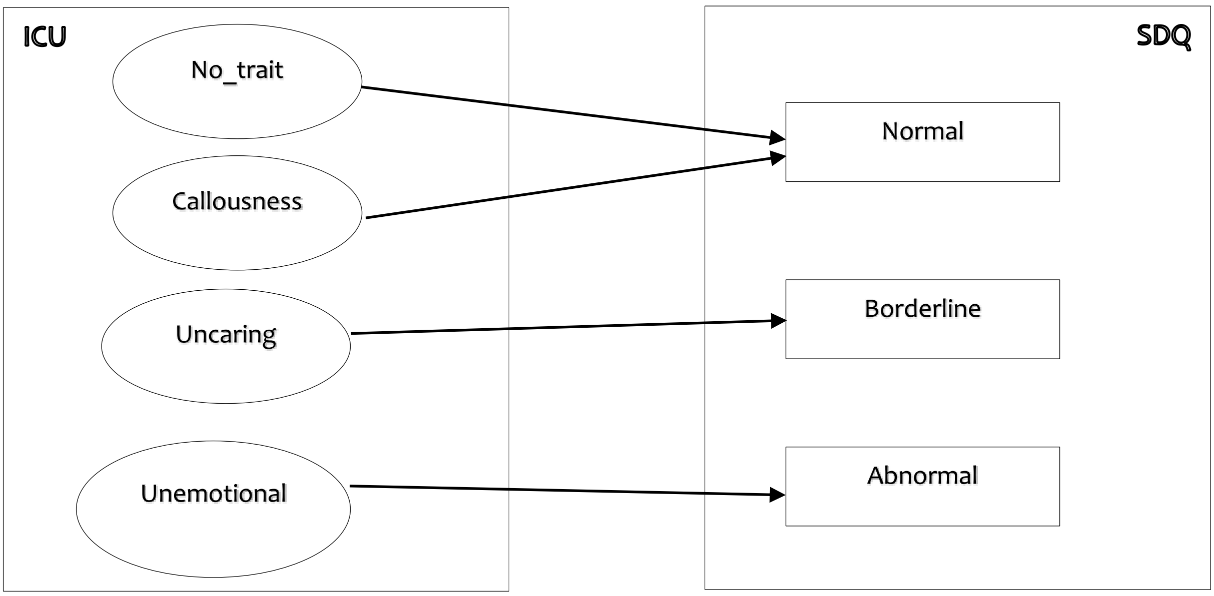


Figure 3. The interactive biplot from the RC(M) association model

The analysis has been carried out using the R packages.

7. Conclusion

Relative recent studies (Walters, Knight, Grann and Dahle, 2008; Frick, Ray, Thornton and Kahn, 2013) have highlighted that adolescents with callous-unemotional traits could have casual factors leading to mental disorders. Here I have investigated the data provided by H.E.R.A.C.L.E. Lab (Unicusano research center on health education) and obtained submitting to a sample of 689 high school students the two questionnaires (ICU and SDQ). In this paper, a two-way log-ratio analysis has been proposed for studying the association between categorical variables of a two-way contingency table. Simultaneous representations of two variables, through interactive biplots, have been showed in figures 1,2 and 3. The figures 1 and 2 give the association of two variables, in terms of distance, using the log ORs. The figure 3 shows the representation of complete set of ORs using RC(M) association model and used to confirm the results obtained with log ORs analysis. The results have highlighted that adolescents with callousness or no trait of ICU have a normal state of SDQ. Furthermore, the data show a strong relationship between the uncaring and unemotional traits of ICU and borderline and abnormal states of SDQ respectively.

This paper wants to be a first step in verifying the relation between personality and mental disorders in adolescents. Future researches should, first of all, continue to explore the association using a larger sample to better understand the important correlation among personality disorders in adolescents and their behavior problems and mental disorders, but also analyze, in more detail, the correlation between elevated CU traits with emotional, biological, environmental, and personality characteristics.

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