Article NIMHANS Journal

Structural Equations Models in Child Behaviour

Volume: 12 Issue: 02 July 1994 Page: 125-134

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Reprints request

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Abstract

Structural Equations Model was presented as a method of choice to analyse data pertaining to cause and effect relations. The method was employed to find whether the conduct disorder and attention deficit constitute two different entities. The result of analysis of data for 531 children and adolescents demonstrated that though conduct disorder and attention deficit correlated highly (r=0.919), they constituted two distinct entities.

Key words -

Structural models,
Conduct disorder,
Attention deficit

The present communication was written with two major aims in mind. Firstly, Structural Equations Model was illustrated as a method of choice to explain cause and effect relations. Secondly, Structural Equations Model was employed to find an answer to the debate whether conduct disorder and attention deficit constitute two different dimensions.

Conduct disorder and attention deficit were two entities which emerged out of many studies of child behaviour [1], [2], [3], [4], [5]. A controversy has arisen and it was debated whether these two areas of child behaviour constitute separate domains [4], [5], [6], [7], [8]. Children scoring high on conduct disorder measures were characterized by oppositional, aggressive and antisocial behaviour, while those scoring high on attention deficit were characterized by impulsiveness, inattention and distractibility [4], [9], [10], [11]. Hinshaw [4] stressed that the controversy was of major theoretical, empirical, and clinical concern, particularly given the high prevalence of such behaviour disturbances, their persistence.

Researchers used three different methods to determine the dimensionality of conduct disorder and attention deficit measures, viz; studies of syndrome overlap, factor analytical studies, and confirmatory factor analytical studies [5]. The aim of the present report is to tackle this problem by structural equation models. These problems would be tackled in this report by Structural Equations Model with a view to demonstrate the utility of this method.

Materials and Method

Sample studied

From February 1, 1982 to March 31, 1983, 702 patients were registered in the Child Guidance Clinic (CGC), Department of Psychiatry, NIMHANS. The data pertaining to 531 patients out of 702 formed the material for the study. Children who were studying in the primary and secondary classes (Standards I-X) only were selected. As the number was small, one parent children or children with no living parent were excluded. Children below the range of 4 years were also excluded as certain information could not be elicited about them. A case was also excluded if the information was not rated as reliable. Thus, the present analysis was carried out on data collected from 531 patients in the age group of 4-16 years, studying the primary and secondary classes, and having both parents alive.

Response variables

A symptom check list was used of each patient and the list included symptoms covering all areas of child and adolescent psychiatry. For the present analysis, only symptoms related to conduct disorder or attention deficit were considered. Table I gives a list of 17 symptoms for conduct disorder and 12 for attention deficit. These symptoms were measured on a binary scale, assigning one if a symptom was present and zero otherwise. The sum score was used as the degree of presence of the respective entity. Theoretically the score would range from 0-17 for conduct disorder and 0-12 for attention deficit.

Table I - Characteristics measuring conduct disorder and attention deficit

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Predictors

Data on several other variables too were collected for each of the patients. These included, the psychosocial and demographic factors, and developmental and school environmental factors. Care was taken in selecting the list of predictors. Variables whose presence was in less than 10% of subjects or in more than 90% of subjects were excluded as the variance of such proportions may not be stabilized. The method of analysis employed in this report would be more applicable to deal with cause and effect relationship and as such the predictors were selected such that they would have some impact on the conduct disorder or attention deficit. While selecting predictors care was taken to see that the predictors occurred before the measurement of response variables at least in time. The list of predictors included in the analysis is given in Table II.

Table II - List of predictor variables

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Structural Equations Model

Structural equations modelling is a major contribution in the development of correlational and observational research approaches in the context of well documented limitations of experimental strategies [12] or controlled clinical trails.

Structural equation modelling is a very general procedure involving simultaneously many linear equations, each with multiple variables. Multiple linear regression and even confirmatory factor analysis could be viewed as particular cases of structural equation modelling. The method is so versatile that specific models could be developed to analyse experimental data [13], panel design [14], multitrait and multimethod design [15], quasi-experimental design [16], decomposition of genetic environment correlations [17], comparison of factor structures across populations [18], [19], analysis of complex correlations structures [20], analysis of correlation of true scores over time, problem of multicollinearity, problem of unmeasured variables, and analysis of categorical treatment variables [21].

Historically speaking, psychologists have worked with latent variable models over the last seventy years. However, structural equation modelling with latent variables became practical only after statisticians working in the areas of factor analysis [22] saw ways to generalize these efforts to encompass linear structural equation modelling [23], [24], [25], [26], [27], [28]. Impressive body of literature is also available in econometric structural equation modelling [29], [30], [31], [32]. S. Wright, a genetist, has developed and continuously used path coefficient analysis to solve problems in agricultural and population genetics [33], [34], [35], [36], [37], [38]. As a direct result of Joreskog's breakthrough, the latent structural equation modelling brought psychometric, econometric, and path coefficient analysis together with path diagram so that the best features of all three methods can be exploited simultaneously.

A latent variable, which could not be measured directly, is a hypothetical construct invented by a scientist for the purpose of understanding a research area. The constructs are related to each other as specified by the researcher's theory. When the relations between the latent variables, and the relations between the latent variables and measurement variables are specified in mathematical form by simultaneous system of highly restricted linear regression equations, one obtains a model having certain structural form and certain unknown parameters. The model purports to explain the statistical properties of the measured variables in terms of hypothesized latent variables. The primary statistical problem is obtaining estimates of parameters to the model, and determining the goodness-of-fit of the model of the data. If the model could not be rejected statistically, then it is a possible representation of the causal structure [39]. Specification, identification, estimation, theory trimming, and tests of significance are some of the important steps in the analysis and a full description of these steps is beyond the scope of this paper.

Path diagram

Path diagrams are useful to display graphically the pattern of causal relationships among sets of measured and latent variables. A brief note on the path diagrams may facilitate to interpret the findings reported in this paper. In causal model, certain variables are singled out as causes and others as effects. In simple path diagrams, measured variables are singled out as causes and others as effects. In simple path diagrams, measured variables are denoted by squares and latent variables by circles. The correlation between causal factors is at both sides. This signifies that one variable is not conceived as the cause of the other. Paths in the form of unidirectional arrows are drawn from the variables taken as causes to the variables taken as effects.

The practical application of path diagrams can be facilitated by a few rules for tracing a connecting path between two or more variables in a causal mode [40].

Rule 1. The first rule in tracing any connecting path is: No "first-forward and then backward"motion.

Rule 2. The reverse motion, "first backward and then forward" is the correct way of tracing a connecting path.

Rule 3. If one is tracing backward, one can continue to trace backward without changing the direction.

Rule 4 The double arrowed correlation line is a two-way path and can be used in either direction, but it does not possess the chain property of rule 3 of path coefficients. This is because,. if x1 and x2 are correlated and if x2 and x3 are correlated it does not imply that x1 and x3 are correlated.

Computer programs

If the model involves simple multiple linear regression equations, one can use any general program for multiple regression after standardizing the data. SSP subroutines (IBM), BMDP or SPSS softwares and even FORTRAN listings given by Cooley and Lohnes [41] are useful sources. However, if the model is a complex one with latent variables, then the available special subroutines could be used. Joreskog with several collaborations wrote COFAMM, EFAP, and ACOVS programs. Finally he brought out LISREL [42] EQS software [43] is another popular one. COSAN, ITAN, LINCS, PLS, and RAMONA are some of the other programs [44]. The analyses reported in this communication were carried out with EQS.

EQS program

The EQS program, which is more recent than LISREL, implements a general mathematical and statistical approach to the analysis of linear structural equation systems. The advantage of this approach, when used in an appropriate hypothesis testing mode, is that structural parameters presumably represent relatively invariant parameters of a causal process and are considered to have more theoretical meaning than ordinary predictive regression equations, especially when the regression equation is embedded in a series of simultaneous equations designed to implement a substantive theory [45].

Maximum likelihood (ML) estimation, least square (LS) estimation, or generalised least square (GLS) estimation of the parameters could be obtained with EQS. The chi-square is used to determine the probability of obtaining a chi-square value as large as or larger than the value actually obtained given that the model is correct. When the null hypothesis is true, the chi-square probability should not exceed the standard ($P<0.05$) cut-off in the chi-square distribution. Bentler-Bonnet [46] Fit Index is based on the fit function as well as in appropriate null model. Value of this index that exceeds 0.9 indicates a goodfit. In the case of a large simple it is possible to get fit index exceeding 0.9, but p-value less than 0.05. In such cases, the overall fit index may be the more appropriate index [47].

Statistical significance tests are performed on the unstandardized parameter estimates. The test statistic is the parameter estimate divided by the standard error and is a normal Z-test. Value which exceeds the standard normal critical value of 1.96 associated with a 0.05 probability level indicates that the parameter is significantly different from zero.

EQS and in general, structural models could be most effectively used to test for the alternative and competing models. In the case where competing models are tested and where there is a difference in the models of single path being eliminated in the most restricted model, the significance of the path in the unrestricted model is equivalent to the chi-square difference test of the two competing models [43].

EQS calculates Mardia's [48] multivariate Kurtosis and also lists possible outliners when original data was the input. Linear dependency among the variables, if any, is listed out. For simulation studies, EQS is much suitable in which Wald test identifies the parameters which could be dropped and Lagrange Multiplier test identifies the parameters which could be added. The parameters of any linear structural model are, the regression coefficients and the variances and covariances of the independent variables including the residual variables.

Results

Simple correlation analysis

Table III gives the correlation coefficients between conduct disorder and attention deficit on one hand and the predictor variables on the other. In terms of both conduct disorder and attention deficit, male children, children at least one of whose parents were professionals or executives, children with a history of delayed milestone, and children who found difficulties in starting school displayed significantly more problems. The problem seemed to be significantly less for the children studying in higher classes, in the higher age group, with longer duration of illness, children whose parents were in business, and non-disturbed school environment. The above stated factors were common for conduct disorder and attention deficit.

The conduct disorder was significantly and positively related to the presence of discordant intrafamilial relation (r=0.118), familial over involvement (0.164), lack of or inadequate parental control (0.317), change in the medium/school (0.111), and help given in studies at home (0.161). Conduct disorder was significantly and negatively correlated with the presence of previous treatment (-0.114), nuclear family (-0.107), higher family size (-0.092), and less educated mother (-0.094). These predictors were not related to attention deficit.

Table III - Correlation of predictors with conduct disorder and attention deficit

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Higher the age of joining the school, lesser was the attention deficit (r=0.093). Also, children whose father studied upto middle or secondary school level displayed less attention deficit (r=0.104). While these two factors were significantly related to attention deficit, they were not related to conduct disorder.

Children whose father had higher education had significantly more attention deficit, but less conduct disorder. Children with longer duration of illness (one year and more), without previous treatment, with a history of delayed milestone and history of difficulties in starting school reported significantly more association with conduct disorder than with attention deficit. The presence of poor school environment had strong association with attention deficit than the conduct disorder.

Structural Equations Model

A structural equation model was tried employing 34 predictor variables to understand how these variables were associated with conduct disorder and attention deficit with a hope that the final model may shed light on whether conduct disorder and attention deficit are two distinct entries. The model employed both latent and measurement variable. The conduct disorder and attention deficit were expressed as linear function of a hypothetical latent variable. Similarly, each of the 34 predictors were also expressed as a linear function of several latent variables. Finally, these two types of latent variables were assumed to be linear functions of one another. Many variables seemed to be linearly depending on the other variables and hence the final model consisted of only smaller number of predictors. The model together with the path diagram is presented in figure I.

.Path diagram for structural equation model for child behaviour

In EQS program, all regression coefficients and variances and covariances of the independent variables (predictors) are the parameters. While Wald test suggests parameters to be dropped. Lagrange multiplier test suggests parameters to be included. Measurement variables are denoted by V and latent variables by F. The residual (error) variables are denoted by E if V was the dependent (criterion-outcome) variable and by D if F was the dependent variable.

The final model consisted of seven predictors and two criterion variables. The Bentler-Bonnet fit index was 0.994, suggesting good fit of the model to the data. The chi-square test was also not significant (X^2=27.207; df=20; p=0.130).

In figure I, measurement variables are shown as squares and latent variables as circles. The latent variable F1 affected both conduct disorder (V35) and attention deficit (V36). The direct effects were negative and significant. F1 also significantly and positively affected duration of illness (< 1 year) (V4) and higher school grade (V31). Furthermore, low maternal education (V15) also directly and positively affected both conduct disorder and attention deficit. Thus, the model suggested that the degree of both conduct disorder and attention deficit would be more for children with duration of illness more than one year, for children who were in the lower school grades, and for children whose mothers had less education.

The conduct disorder was directly and positively affected by the presence of discordant family relation, while attention deficit was not affected directly by this predictor.

Attention deficit was directly affected by school environment (V28), skilled or unskilled parental occupation (V20), and by inadequate parental control. These three predictors did not affect conduct disorder directly.

The model included only seven out of 34 predictors. The rest of the predictors did not find a place in the model either due to identification problem or due to nonsignificant direct effects (regression weights).

Discussion

The result of the present study clearly has shown that conduct disorder and attention deficit are two distinct dimensions of child behaviour, though they correlated highly. Since the correlation between these two dimensions was very high (Simple correlation=0.919; model correlation=0.529; n=531) the practical and clinical utility of this distinction may be limited. While the present study was based on clinical population, a similar finding was obtained on general population by employing confirmatory factor analysis [5]. The common aspect between conduct disorder and attention deficit were explained by duration of illness, school grade, (function of age of the child), and maternal education.

While duration of illness, school grade, and maternal education were common for conduct disorder and attention deficit, certain causal factors were specific to one of these two entities demonstrating their distinctness. Discordant familial relation caused conduct disorder among children while inadequate parental control caused attention deficit. These two factors correlated significantly and hence they had indirect effects.

Illiterate mother and poor school environment has positive effect on attention deficit, while skilled or unskilled parental occupation had negative effect. These results have their implication on the practical and clinical utility.

A large number of studies have attempted to establish a distinction between conduct disorder and attention deficit using methods of common factor analysis [49], [50]. Hinshaw [4] reported that out of 60 such studies, nearly a third produced results favouring single factor solution. Studies of syndrome overlap [51], [52] produced evidence of substantial amount of overlap between conduct disorder and attention deficit. However, these studies demonstrated that these two groups can be discriminated by certain items, including peer status, social cognitive information processing, and prognosis [4], [53]. Results of the present study confirmed the distinct factors of conduct disorder and attention deficit, while establishing syndrome overlap between entities.

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