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# The structure of intellectual abilities of dancers

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## 1. Introduction

In the psychological literature three types of definitions of intelligence are most frequently mentioned. In behavioristic circles intelligence is usually identified with the "capacity for learning", that is the ability to acquire new knowledge. Rarely it is the identification of intelligence with the "ability of abstract thinking". The definition of intelligence as the "ability of adaptation in new situations" deserves special attention. It is the most frequent definition in animal psychology. Here, it is, certainly, referred neither to the adaptation in the sense of tolerance to exogenous factors, nor to the adaptation in the clinical sense.

The central nervous system primarily has an integrative function, so that it enables purposeful and adaptive behavior of a human being. Of the utmost importance is the integration at the cortical level, since purposeful behavior is in direct relation to intelligence at the cortical level, although it is less flexible. Integration of functions at the subcortical level provides reaction in standard situations, the situations that require automatic performance of routine programs. Cognitive

processes and cognitive functioning are the central mechanisms of cortical integration.

# 2. The methods of research

## 2. 1. The sample of examinees

The sample of examinees is determined by financial capabilities which are required for performing the research procedure. Besides, the sample also depends on the number of qualified and trained measurers, on the instruments and standardized conditions in which the planned research should be realized.

In order to conduct the research properly and provide satisfactorily stable results, in the sense of sampling error, it is necessary to include a satisfactory number of examinees into the sample. The size of the sample for this type of research is conditioned by the aims and tasks of the research, size of the population and degree of the applied variability of the system of parameters.[18]

Based on the selected statistical-mathematical model and the aim of the research, the sample of examinees included 267 dancers, aged from 11 to 13, actively involved in standard and Latin American dance in the Serbian dancing clubs.

The size of the so defined sample should satisfy the following criteria:

- the effectives of the sample should be planned so that it allows as many degrees of freedom as any coefficient in the pattern or correlation matrix which is equal to or higher than 0.22 could be considered as different from zero with an inference error less than 0.01
- in order to successfully apply the adequate statistical methods according to the latest convictions, the number of subjects in the sample must be five times bigger than the number of the applied variables.

During all these factor procedures, it should always be kept in mind that the results of the analysis depend on three major systems which determine the selection and transformations of information: the sample of variables, the sample of examinees and the selected extraction, or rotation, method.[19]

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18 Popović, D.: Determining the structure of psychosomatic dimensions in fights and developing the procedures for their evaluation and monitoring - The Monograph, the Faculty of Physical Education, University of Priština, Priština, 1993.

19 Popović, D.: Determining the structure of psychosomatic dimensions in fights and developing the procedures for their evaluation and monitoring - The Monograph, the Faculty of Physical Education, University of Priština, Priština, 1993.

## 2. 2. The sample of variables

For estimating cognitive dimensions some measuring instruments have been selected so that the cybernetic model may be covered, paying attention to the fact that the selected tests measure three types of cognitive processing.

For estimating the efficiency of the input processor, that is, perceptual reasoning, there has been selected the test:

IT-1: the test of matching the drawings is designed for the evaluation of perceptual identification and discrimination. The test consists of 30 tasks, and the test execution time is limited to 4 minutes. The analysis of the test has shown that the difficulty of the tasks and their intercorrelation indicate that this is a typical speed test.

For estimating the efficiency of the parallel processor, that is the identification of relations and correlates, the following measuring instrument has been selected:

S-l: the spatial reasoning test is designed to evaluate fast simultaneous of spatial relations. It consists of 30 tasks, where should be determined which of the 4 transversal projections of the brick cluster corresponds to the specified picture of brick cluster. The test execution time is 10 minutes.

For estimating the efficiency of the serial processor, or symbolical reasoning, the following measuring instrument has been selected:

AL-4: the synonym-antonym test is designed to evaluate identification of the denotative meaning of the verbal symbols. It consists of 40 tasks of double choice format. The test execution time is 2 minutes, so this test belongs to the category of speed tests. The first major subject for measuring is defined mostly by the tasks from the second half of the test and interpreted as the ability of rapid identification of the denotative meaning of verbal symbols.

## 2. 3. The methods of data processing

All the data collected in this research were processed in the Multidiscipline Research Centre of the Faculty of Sports and Physical Education, The University of Priština, supported by the system of data processing programs developed by D. Popović, 1980, 1993, K. Momirović and D. Popović 2003. Apart from the very old but even today in many respects unrivalled textbook on factor analysis, intended primarily to psychologists (Thomson, 1951; 1956), in the textbooks on factor analysis, there is not now and never was before, a mention of the a

criterion-oriented factor analysis.[20] Therefore, that method is not mentioned, at least in the explicit form, in any statistical software package or system, except the software package SRCE*SS-MACRO, written in SS, one of the many presently dead statistical metalanguages.

Still, the criterion-oriented factor, and even more, criterion-oriented component analysis, is not unknown to either specialists for factor analysis or researchers from various areas, above all, of course, psychologists. Although most of them believe that H. J. Eysenck (1950) proposed the method, and that it was his greatest, and perhaps the only real contribution to the statistics, virtually the same method had been applied long before by Reyburn and Taylor in the analysis of the structure of conative characteristics (Reyburn i Taylor, 1939; 1941). A formal description of the criterion-oriented factor analysis may be found in the previously mentioned Eysenck's work and in the later editions of Thomson's textbook (Thomson, 1951; 1956), a logical discussion about its significance, and, of course, a formal description of that method in one of Fruchter's papers (Fruchter, 1966), and the proofs of several important theorems on a class of the methods of component analysis, which also includes the criterion-oriented component analysis, in one of Schoenemann and Steiger (Schoenemann i Steiger, 1976). One algorithm for the criterion-oriented component analysis, which is still relevant today, was proposed by Momirović, Gredelj and Štalec (1977), who also wrote a program for deriving, by that method, latent structure analyses of variables in several researches within the sphere of biological anthropology, kinesiology, psychology and sociology.

Unfortunately, since it is mentioned neither in the actual textbooks, nor in popular statistical program products, this plain, but, by its properties, extremely significant method is slowly falling into oblivion. But as Eysenck was right when, proposing that method, he claimed that the criterion-oriented factor analysis was one of the major means of the hypothetical-deductive research method, nowadays accepted by the vast majority of researchers in psychology, as well in the derived from psychology sciences or related sciences, it was reasonable to make an effort to revitalize it. Consequently, the aim of this work was to propose an algorithm from which the properties of that method would be immediately clear, and to propose a computer program which enables the application of criterion-oriented component analysis in the standard SAS environment, in which most users of the ready made statistical software products work today.

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20 View, for instance, Thurstone, 1947; Cattell, 1952; Fruchter, 1954; Horst, 1965; Harman, 1967; Lawley and Maxwell, 1971; Mulaik, 1972; Jolliffe, 1986; Flury, 1988, etc. Certainly, because of this not a single word is written about the criterion-oriented factor or component analysis in the chapters devoted to the factor and component analyses in the textbooks of the multivariate statistical analysis or multivariate data analysis.

*THE DEFINITIONS*

Let

$$E = \{e_i; i = 1,...,n\} \subset P$$

be a random sample from some homogeneous population P. Let

$$V = \{v_j; j = 1,...,m < n\} \subset U$$

be a sample of the quantitative, normally distributed variables in P, selected according to some theoretical model in order to be representative of the universe of the variables U. Let

$$W = \{w_p; p = 1,...,k < m\} \subset U$$

be a set of normally distributed hypothetical latent dimensions by which the structure of the universe U is defined; assume that the variables from W can be determined or estimated independently of the variables from V.

Let $e = (e_i) \mid e_i = 1 \ \forall \ e_i$, $i = 1,...,n$ be a summing vector of order n and let $I_m$ and $I_k$ be identity matrices of order m, respectively of order k. Let

$$Z = E \otimes V \mid Z^t e = 0, \text{ diag } (Z^t Z) = I_m$$

be a data matrix, in a standard normal form, obtained by the description of the set E over the set V, and let

$$X = E \otimes W \mid X^t e = 0, \text{ diag } (X^t X) = I_k$$

be a data matrix, also in a standard normal form, obtained by the description of the set E over the set of the hypothetical latent dimensions W. In this case

$$R = Z^t Z$$

will be an intercorrelation matrix of variables from V,

$$U = X^t X$$

will be an intercorrelation matrix of hypothetical variables from W, and

$$Q = Z^t X$$

will be a cross-correlation matrix of variables from V and hypothetical variables from W, all the three estimated under the maximum likelihood criterion.

If $V \cap W = 0$, and W is a set of hypothetical latent dimensions that indeed determines the structure of the set U, the latent structure of variables from V may be determined in a very simple way (Eysenck, 1950; Thomson, 1956; Schoenemann and Steiger, 1976; Momirović, Gredelj and Štalec, 1977).

*THE ALGORITHM*

The criterion-oriented component analysis is, actually, based on the solution of the multivariate regression problem

$$Z\beta = X - E \mid \varepsilon^2 = \text{trag}\,(E^tE) = \text{minimum},$$

where some $\beta$ is an unknown matrix of order (m,k).

Since

$$\varepsilon^2 = \text{trag}\,((X - Z\beta)^t(X - Z\beta)) = \text{trag}\,(U - \beta^tQ - Q^t\beta + \beta^tR\beta),$$

and trag (U) = k and trag ($\beta^tQ$) = trag ($Q^t\beta$), the function that should be minimized is

$$\varepsilon^2 = k - \text{trag}\,(2\beta^tQ + \beta^tR\beta).$$

By differentiation of this function by the elements of the matrix $\beta$

$$\partial\,\beta^2 / \partial\,\beta = - 2Q + 2R\beta,$$

so by dividing by 2 and reducing to zero

$$R\beta = Q,$$

is obtained, from which it follows that

$$\beta = R^{-1}Q$$

is a matrix of partial regression coefficients for estimating hypothetical latent variables from X by linear combinations of variables from Z.

Those evaluations will be the elements of the matrix

$$\Phi = Z\beta$$

with the covariance matrix

$$C = \Phi^t\Phi = \beta^tR\beta = Q^tR^{-1}Q.$$

Let

$$D^2 = (d_p^{\,2}) = \text{diag}\,C$$

be a variance matrix of variables from $\Phi$.

*Proposition 1.*

The elements $d_p^{\,2}$, p = 1,...,k of the matrix $D^2$ are the determination coefficients of the hypothetical latent dimensions from X based on the linear combinations of variables from Z, therefore $\rho_p = d_p$, p = 1,...,k are the multiple correlations of the hypothetical latent dimensions from X with variables from Z.

*Proof:*

Let

$$\Psi = \Phi D^{-1} = ZR^{-1}QD^{-1}$$

be a matrix of standardized evaluations of variables from X by linear combinations of variables from Z. The covariances of the hypothetical latent dimensions and their evaluations will be the elements of the matrix

$$X^t\Phi = Q^tR^{-1}Q = C,$$

and their cross-correlations will be the elements of the matrix

$$X^t\Psi = Q^tR^{-1}QD^{-1} = CD^{-1};$$

thus the elements of the matrix

$$\rho = (\rho_p) = (\text{diag } C)(\text{diag } C)^{-1/2} = D^2D^{-1} = D = (d_p)$$

will be the multiple correlation coefficients of variables from V and hypothetical latent dimensions from W, and the elements $d_p^2$, p = 1,...,k of matrix $D^2$ will be the determination coefficients of latent dimensions, what was required to be proved.

The factor structure matrix of latent dimensions from Ψ, thus the cross-correlation matrix of variables from Z and variables from Ψ will be

$$F = Z^t\Psi = QD^{-1};$$

and since the intercorrelation matrix of variables from Ψ is

$$M = \Psi^t\Psi = D^{-1}CD^{-1},$$

then the pattern matrix of those dimensions, or the matrix of the projections of the vectors of variables from Z to the coordinate axis defined by the vectors from Ψ, will be

$$A = FM^{-1} = QC^{-1}D.$$

*Proposition 2.*

A and F are factor matrices of the correlation matrix R.

*Proof:*

$$AF^t = AMA^t = FM^{-1}F^t = Q(Q^tR^{-1}Q)^{-1}Q^t$$

which is reduced to the Guttman theorem on the factorization of the squared symmetrical matrix R by the operator Q, from which it follows that

$$T = Q(Q^tR^{-1}Q)^{-1}Q^t$$

is a factor approximation of the matrix R with a matrix of rank k, what was required to be proved.

Therefore the communalities of variables will be the elements of the matrix

$$H^2 = (h_j^2) = \text{diag } T,$$

and the matrix

$$L = R - T$$

will be the matrix of the residual variances and covariances of the variables whose latent structure is determined by this method of the confirmative component analysis.

## 3. Results and discussion

Examining the matrix of the tests for estimating the intellectual abilities (table 1), it can be noticed that there is the greatest connection between the test IT-1 designed to evaluate perceptual identification of the denotative meaning of verbal symbols with equal correlations IT-1 and AL-4 and the S-l test of spatial reasoning designed to evaluate rapid simultaneous eduction of spatial relations. In some case, even on the basis of the intercorrelation matrix, it is possible to assume factor patterns.

In this case it may be concluded that the whole system of intellectual variables is based on the substantial common variability, sufficient for the approximation of one general factor of intellectual abilities.

The factor structure of intellectual abilities is analyzed on the basis of all the information provided by the matrix of significant principal components (table 2). Based on the Kaizer-Guttman criterion, only one latent dimension was isolated, which signifies the entire space of the three cognitive tests with about 47% of the common variance. This may be accepted as satisfactory for this type of research.

The isolated latent dimension may be interpreted as a general cognitive factor. The minimun projection is in the test IT-1 by which the efficiency of the input processor, or perceptual reasoning, was estimated, then in the test S-l by

which the efficiency of the parallel processor, that is, discerning the relations and correlates, was estimated and finally in the test AL-4 of synonyms-antonyms for estimating the efficiency of the serial processor, or symbolical reasoning.

*THE INTERCORRELATION MATRIX*

Table 1.

| Value | IT1 | AL1 | SI |
|---|---|---|---|
| IT1 | 1.00 | | |
| AL1 | .21 | 1.00 | |
| SI | .14 | .24 | 1.00 |

*THE MATRIX OF THE PRINCIPAL COMPONENTS*

Table 2.

| Value | FAC1 | $h^2$ |
|---|---|---|
| IT1 | .63 | .40 |
| AL1 | .74 | .55 |
| SI | .67 | .45 |
| LAMBDA | 1.41 | |
| % | 47.0 | |
| CUM % | 47.0 | |

## 4. Conclusion

The research was conducted with the aim to determine the structure of intellectual abilities of female dancers involved in standard and Latin American dance.

For estimating the structure of intellectual abilities, 267 dancers, aged from 11 to 13, were involved, who were actively occupied with standard and Latin American dance.

For the evaluation of intellectual abilities, three measuring instruments were applied so that the structure analysis could be resolved according to the cybernetic model of Das, Kirby and Jarman, respectively, Momirović, Bosnar and

Horge (1982.), especially regarding the fact that the selected tests could measure three types of intellectual processing.

For estimating the efficiency of the perceptual processor, test IT-1 was selected, for estimating the efficiency of the serial processor-test AL-4, and for estimating the efficiency of the parallel processor-test S-l.

All the data collected in this research were processed in the Multidiscipline Research Centre of the Faculty of Sports and Physical Education, The University of Priština, supported by the system of data processing programs developed by D. Popović, 1980, 1993, K. Momirović and D. Popović 2003.

The analysis of the factor structure of cognitive dimensions indicates that the whole system of cognitive variables is based on the substantial common variability, sufficient for the approximation of *the general factor of intellectual abilities*.

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## *Summary*

*The research was conducted in order to determine the structure of intellectual abilities of dancers involved in standard and Latin American dance. The research involved 267 dancers, aged from 11 to 13. For the evaluation of intellectual abilities, three measuring instruments were applied, previously selected so as to solve the structure analysis on the basis of the cybernetic model of Das, Kirby and Jarman, respectively Momirović, Bosnar and Horge 1982, taking into account the fact that the chosen tests could measure three types of intellectual processing. For estimating the efficiency of the perceptual processor, test IT-1 was selected; for estimating the efficiency of the serial processor, test AL-4; and for estimating the efficiency of the parallel processor, test S-1. All the data collected in this research were processed in the Multidiscipline Research Centre of the Faculty of Sports and Physical Education, the University of Priština, supported by the system of data processing programmes developed by D. Popović, 1980, 1993, K. Momirović and D. Popović 2003. The analysis of component structure of cog-*

*nitive dimensions indicates the fact that the whole system of cognitive variables is based on the substantial common variability, sufficient for the approximation of the general factor of intellectual abilities.*

*Key words: /structure/analysis/dimension/factors/reasoning/processor/model/*

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