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# CANONICAL RELATIONS BETWEEN MUSICAL AND COGNITIVE ABILITIES OF DANCERS

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**ABSTRACT**

The research was conducted in order to determine relations between musical and intellectual abilities of ballroom dancers.

For the assessment of relations between musical and intellectual abilities, 267 dancers aged 11-13 involved in Standard and Latin American dancing were tested.

In order to assess musical abilities, the well-known Seashore's battery of tests for musicality assessment was applied. The battery evaluates the following tests: pitch perception test, loudness perception test, rhythm perception test, tone duration test, musical timbre perception test, and melodic memory ability test.

To assess cognitive abilities, the researchers applied three measurement instruments selected so as to perform structure analysis based on the cybernetic model designed by Das, Kirby & Jarman, and Momirovic, Bosnar &Horge 1982, and to measure three types of intellectual processing.

For estimating the effectiveness of the perceptual processor, test IT-1 was chosen; for estimating the effectiveness of the serial processor - test AL-4; and for estimating the effectiveness of the parallel processor - test S-1.

All the data in this research were processed at the Multidiscipline Research Center of the Faculty of Sport and Physical Education, University of Pristina, through the system of data processing software programs developed by D. Popovic, 1980, 1993, K. Momirovic & D. Popovic, 2003. Relations within the set of variables for assessment of musical and intellectual abilities of the respondents actively engaged in ballroom dancing were determined by means of canonical covariance analysis.

Keywords : /coefficientst / canonical / matrix / musical abilities / variables /



## 1. INTRODUCTION

When talking about activities in the field of the art of music, it should be mentioned that they are, just like all other human activities, conditioned by the abilities of those who are engaged in them. The human ability to perceive, comprehend, and reproduce rhythmic, melodic and harmonic elements of music, which is classified as musicality, depends primarily on the role of cognitive personality factors. It can be assumed that cognitive factors will influence the success in musical activities, but the influence of the spatial factor seems to be the most significant. Spatialization is defined as the ability to determine relationships in a space or to solve

the problems that can be posed as spatial problems. Nevertheless, other cognitive factors are certainly important for every form of musical activity. However, cognitive factors alone are not crucial for the success in an activity, as well as in a musical activity. In this research, relations between musicality and cognitive abilities will be studied.

## 2. Methods

### 2.1. Sample of respondents

The sample of respondents is conditioned by the financial capabilities necessary of the research procedure. Besides, the sample depends on the number of qualified and fully trained measurers, on the measurement instruments and standardized conditions for the realization of the planned research.

In order to conduct the research correctly and obtain results stable enough in terms of sampling error, it is necessary to include a sufficient number of the respondents into the sample. The size of the sample for this type of research is conditioned by the objectives and tasks of the research, the population size and the degree of variability of the applied system of parameters.[1]

Based on the selected statistical-mathematical model and the research objective, the sample of respondents included 131 female dancers and 136 male dancers aged 11 - 13 actively involved in Standard and Latin American dancing in Serbian ballroom dance clubs.

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

- the size of the sample should be planned so as to provide as many degrees of freedom as to consider any coefficient in the pattern, or correlation, matrix, which is equal to or bigger than 0.22, different from zero with an inference error less than 0.01.
- in order to successfully apply 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.

In all the factor procedures, it should constantly be kept in mind that the analysis results depend on the three major systems which determine the selection and transformation of information: the sample of variables, sample of respondents, and the selected extraction, or rotation, method.[2]

## 3. Sample of variables of musical abilities

The assessment of musical abilities has been performed on the basis of the well-known Seashore's test battery that estimates musicality. The test lasts for 30 minutes and consists of the 6 groups of tasks that are listened to from an audiotape, and the responses are recorded on the answer sheets prepared for this purpose. Auditory is provided by a regular layout of sound-speakers and volume so that all the respondents have equal experimental conditions.

This test assesses the following dimensions:

- Pitch perception test: it consists of five columns, and each column contains ten tasks. For each task, two tones are played. The respondent determines whether the second tone is higher or lower than the first tone.
- Loudness perception test: it consists of five columns. Each column contains ten tasks. For each task, two tones are played. The respondent determines whether the second tone is louder or softer than the first tone.
- Rhythm perception test: it consists of three columns. Each column contains ten tasks. For each task, two rhythmical structures are played. The respondent determines whether the second rhythmical structure is the same or different from the first one.

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[1] Popovic, D.: Determination of the structure of psychosomatic dimensions in martial arts and development of methods for their evaluation and monitoring - The Monograph. Faculty of Physical Culture, University of Pristina, Pristina, 1993.

[2] Popovic, D.: Determination of the structure of psychosomatic dimensions in martial arts and development of methods for their assessment and monitoring - The Monograph. Faculty of Physical Culture, University of Pristina, Pristina, 1993.

- Tone duration discrimination test: it consists of five columns. Each column contains ten tasks. For each task, two tones of different duration are played. The respondent determines whether the second tone is longer or shorter than the first tone.
- Musical timbre perception test: it consists of five columns, and each column contains ten tasks. For each task, two tones are played. The respondent determines whether the second tone is the same or different from the first tone.
- Tonal memory test: it consists of three columns. Each column contains ten tasks. For each task of column A, two three-tone melodies are played. For column B, two four-tone melodies are played, and for column C two-five tone melodies are played. The respondent determines for each task which tone makes the second melody different from the first melody. For column A: the first, second or third tone, for column B: the first, second, third or fourth tone, and for column C: the first, second, third, fourth or fifth tone.

Evaluation is carried out so that one point is given for each correct answer in each task of all the tests. The total sum of points gained for each task in each test separately represents the result. The result expressed in points should be recalculated in percent. The female respondents, according to the scores gained on the particular tests, depending on age, are classified in certain classes from „A" to „E".

**4. Sample of cognitive variables**

For the assessment of the intellectual dimensions, the measurement instruments were selected so as to cover the cybernetic model and measure three types of cognitive processing.

For the assessment of the effectiveness of the input processor, or perceptual reasoning, the following test was selected:

IT-1: test of matching drawings to assess perceptual identification and discrimination. The test consists of 30 tasks, and the testing time is limited to 4 minutes. The difficulty of the tasks and their intercorrelations indicate that this is a typical speed test.

For the assessment of the effectiveness of the parallel processor, or identification of relations and correlates, the following measurement instrument was selected:

S-l: spatial reasoning test designed to assess rapid simultaneous education of spatial relations. It consists of 30 tasks to determine which of the 4 transversal projections of the brick cluster corresponds to the specified picture of the brick cluster. The testing time is 10 minutes.

For the assessment of the effectiveness of the serial processor, or symbolic reasoning, the following measurement instrument was selected:

AL-4: synonyms-antonyms test to assess identification of the denotative meaning of verbal symbols. It consists of 40 double-choice tasks. The testing time is 2 minutes, therefore, this test belongs to the category of speed tests. The first main subject to measure is mostly defined 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.

**5. Data processing methods**

All the data in this research were processed at the Multidiscipline Research Center of the Faculty of Sport and Physical Education, University of Pristina, through the system of data processing software programs developed by D. Popovic, 1980, 1993, K. Momirovic & D. Popovic, 2003.

The method for asymmetry-based overlap analysis proposed in this research is based on the previously published paper written by Momirovic, Stalec and Zakrajsek (1973) on the generalised image transformations and on the method for decomposition of latent structures proposed by Dobric, Karaman and Momirovic (1983). The essence of the proposed method is canonical covariance analysis (Momirovic, Dobric & Karaman, 1983) of a set of variables and image transformation of this set of variables performed by the projection of the set into the space spanned by the vectors of some other set of variables. Although the aim of the proposed method, in a certain sense, is similar to the aim of the classical method for the overlap analysis (Van Den Wollenberg, 1977) and method for canonical factor overlap analysis (De Sarbo, 1981), the criterion function of

canonical covariance analysis in the generalized image space is different from the criterion function of Van Den Wollenberg and De Sarbo's method, thus the interpretation of the obtained measures of association is based on completely different assumptions.

***ALGORITHM***

Let $Z_1$ be a data matrix, in a standard normal form, obtained by the description of a random sample E from n objects on the sample $V_1$ from $m_1$ quantitative or quantified variables, and let $Z_2$ be another data matrix, also in a standard normal form, obtained by the description E on the sample $V_2$ from quantitative and qualified variables that $V_1 \cap V_2 = 0$. Assume, not omitting a possibility of generalisation, that $m_2 \leq m_1$, and define the intercorrelation matrices of variables from $V_1$ and $V_2$, estimated under the maximum likelihood criterion, as $R_{11} = Z_1^tZ_1$ and $R_{22} = Z_2^tZ_2$, and define the matrix of cross-correlations between the variables from $V_1$ and $V_2$ as $R_{12} = R_{21}^t = Z_1^tZ_2$.

Let $B = R_{11}^{-1}R_{12}$ be a matrix of the standardized regression coefficients obtained by resolving the regression problem $Z_1B = Z_2 - E \mid \text{trag}\,(E^tE) = \text{minimum}$, and let $G = Z_1B$ be a matrix of image variables from $V_2$ in the space spanned by the vectors of variables $V_1$. Define, finally, the covariance matrix of variables from G as $M = G^tG = B^tR_{11}B$.

The canonical covariance analysis in the generalized covariance image space can be defined as a solution of the problem $Z_2x_p = k_p$, $Gy_p = l_p \mid c_p = k_p^tl_p = \text{maximum}$, $x_p^tx_q = y_p^ty_q = \delta_{pq}$ where $\delta_{pq}$ are the Kroneker symbols. The covariances $c_p = k_p^tl_p = x_p^tMy_p$
between the linear combinations of variables from $Z_2$ and linear combinations of variables from G can be maximized by maximization of the function $f(x_p, y_p, \lambda_p, \eta_p) = x_p^tMy_p - 1/2\ \lambda_p\ (x_p^tx_p - 1) - 1/2\ \eta_p\ (y_p^ty_p - 1)$ p = 1,...,m2 where $\lambda_p$ and $\eta_p$ are some unknown Lagrange multipliers.

Differentiation of function f in regard to the elements of vector $x_p$ and then in regard to the elements of vector $y_p$ provides, for p = 1, $\partial f/\partial x_p = My_p - \lambda_px_p$ ⇒ $My_p = \lambda_px_p$ $\partial f/\partial y_p = Mx_p - \eta_py_p$ ⇒ $Mx_p = \eta_py_p$ so that, by multiplying the first result by $x_p^t$, and the second result by $y_p^t$, $x_p^tMy_p = \lambda_p$, $y_p^tMx_p = \eta_p$ ⇒ $\lambda_p = \eta_p = c_p$ is obtained, and since $M^t = M$, $x_p = y_p$, the problem comes down to the simple problem of characteristic values and vectors of matrix $M\ (M - \lambda_pI)x_p = 0$ p = 1,...,m2, basically, to the problem of the principal components of variables from G.

Now let $\delta^2 = (\text{trag } M)/m^2$ be a generalized canonical index defined on the relations between the variables from $Z_1$ and $Z_2$. A rational procedure for determining the number of significant latent dimensions, which are the generators of the relations between the analyzed sets of variables, is the well-known MEIG criterion defined by $k = \text{num}\ (\lambda_p \geq \delta^2)$.

If $X = (x_p)$; p = 1,...,k is a matrix of eigenvectors associated with the significant latent dimensions, and $C = (c_p)$; p = 1,...,k is a diagonal matrix of the first k covariances between the variables $k_p$ and $l_p$, the latent dimensions obtained by the linear combinations of variables from $Z_2$ will be the vectors of the matrix $K = Z_2X$, the latent dimensions obtained by the linear combinations of variables from G will be the vectors of the matrix $L = GX$, and $C = K^tL = X^tMX$ will be a covariance matrix of variables from K and L, and, simultaneously, a covariance matrix of variables from L, because, obviously, $C = L^tL = X^tMX$.

Accordingly, the variables from K and L form one semibiorthogonal system, since $V = K^tK = X^tR_{22}X$ is not, in general, a diagonal matrix.

Let $D^2 = \text{diag } V$ be a variance matrix of variables from K. Therefore, the diagonal elements of the matrix $P = D^{-1}K^tLC^{-1/2} = D^{-1}C^{1/2} = (\rho_p)$ will be quasicanonical correlations between the significant latent dimensions of variables from $Z_2$ and image variables from G.

Asymptotic variances of quasicanonical correlations $\rho_p$ are, naturally, $\sigma_p^2 = (1 - \rho_p^2)^2 / n$, thus, equal to the asymptotic variances of product-moment coefficient of any type of correlation. This fact may be used for the construction of approximate intervals of reliability and testing the hypothesis $H_p$: $\rho_p = \rho_{ph}$, where $\rho_{ph}$ are hypothetical quasicanonical correlation coefficients.

Identification of the content of latent dimensions from L is very simple since, because of orthogonality

of those dimensions both in the space of objects and in the space of variables from G, the matrix $S = G^tL = XC$ is, at the same time, a pattern matrix and a structure matrix of nonstandardized latent dimensions, and the matrix $T = G^tLC^{-1/2} = XC^{1/2}$ is a factor matrix of matrix M.

Identification of the content of latent dimensions K is slightly more complicated, since $W = D^{-1}VD^{-1}$, the intercorelation matrix of variables from K, is not generally a diagonal matrix. The structure matrix, in the space of standardized latent dimensions, is
$F = Z_2^tKD^{-1} = R_{22}XD^{-1}$, so that, in the same space, $A = FW^{-1} = R_{22}X(X^tR_{22}X)^{-1}D$ is a pattern matrix of variables $Z_2$; note that A and F are factor matrices of matrix $R_{22}$, because $AF^t = R_{22}X(X^tR_{22}X)^{-1}X^tR_{22}$, which is the proof that variables from K are the factors, in factor-analytical sense, of the variables $Z_2$.

## 6. RESULTS AND DISCUSSION

By canonical covariance analysis (Momirovic, Dobric & Karaman, 1983), relations between the sets of variables for estimating musical and intellectual abilities of female respondents involved in Standard and Latin-American dancing were determined.

In Table 1, cross-correlations of musical and intellectual variables are presented, Table 4 presents canonical correlation coefficients, the square roots of the canonical equation and their significance, and in Tables 2 and 3, correlations of variables for estimating musical and intellectual abilities with canonical dimensions are presented.

By inspecting the matrix of cross-correlations of musical and intellectual variables, it can be noticed that statistically significant relations between the efficient processing of the input processor and the test for the evaluation of pitch, tone loudness and timbre were obtained. Also it may be observed that significant relations between the effectiveness of the serial processor and the tests for the evaluation of tone duration, rhythm, pitch, melodic memory, and musical timbre, were obtained, as well noticeable positive relations between the effectiveness of the parallel processor and the tests for estimating melodic memory, tone duration and rhythm.

The analysis of characteristic roots indicates that the significant connection for rejecting a null hypothesis is possible for two roots, which means that from three hypothetical possible canonical dimensions, two are sufficient to explain the relations between two examined systems of variables (Table 4).

In the space of musical abilities (Table 2), the first canonical factor is defined by a negative sign in the tests to assess melodic memory, tone duration, and rhythm. A correspondent factor in the space of intellectual abilities is defined by the tests for evaluation of the parallel processor and the effectiveness of the serial processing.

From the above, it necessarily follows that in this sport discipline, the ability to memorize musical layouts, recognize the rhythm and tone duration are directly related to the effectiveness of the parallel and serial processors, and the ability to determine the tone pitch and timbre is somehow connected with the input processor. It is also necessary to know that auditory sensitivity depends on tone loudness as well as the tone pitch. Auditory sensitivity is greater to high than low tones so it seems that a higher tone is stronger than a low tone of the same acoustic intensity.

On the other hand, auditory sensitivity does not increase equally with the increase of loudness. The strongest sense of tone is only about 30 times stronger than the weakest one.

The second canonical factor in the space of musical abilities is best defined by the test for recognizing the tone pitch and timbre.

A correspondent factor in the space of cognitive abilities is defined only by the test for estimating the effectiveness of the input processor.

The analysis of both canonical dimensions leads to the conclusion that the input processor and pitch perception ability may probably be subordinated to a common regulatory mechanism which coordinates the functioning of these two abilities. If all the obtained information is summarized, the following can be concluded:

Spatial or simultaneous integration of the information related to the rhythmic figures (or beyond the rhythmic structures) doubtlessly includes a factor of education, which means there are relations between the elements of dance structures and the elements of rhythmic structures as well as there is some regularity which regulates the whole process of thinking regarding rhythmic tasks or problems.

However, since simultaneous information integration almost never appears independently, because most of the problems cannot be solved in only one manner, that is, simultaneously or serially. The information, including the rhythmic information, of the dancers are processed in time-structured series, therefore, serial and successive processing evaluated by verbal and numerical tests, significantly influence the reception, retention and processing of rhythmic operations.

The connection of the input processor with musical abilities of dancers should also be pointed out.

Table 1: CROSS-CORRELATIONS BETWEEN VARIABLES OF MUSICALITY AND COGNITIVE ABILITIES OF DANCERS

| TEST | IT1 | AL4 | SI |
|---|---|---|---|
| PITCH | .33 | .33 | .03 |
| LOUDNESS | .26 | -.04 | -.07 |
| RYTHM | .08 | .36 | .31 |
| DURATION | -.02 | .37 | .39 |
| TIMBRE | .14 | .27 | .10 |
| MEMORY | -.03 | .28 | .57 |

Table 2: CANONICAL FACTOR STRUCTURE OF VARIABLES OF MUSICALITY

| TEST | CAN1 | CAN2 |
|---|---|---|
| PITCH | -.19 | -.85 |
| LOUDNESS | .19 | -.39 |
| RYTHM | -.61 | -.24 |
| DURATION | -.73 | -.00 |
| TIMBRE | -.28 | -.44 |
| MEMPORY | -.84 | .29 |

Table 3: CANONICAL FACTOR STRUCTURE OF COGNITIVE VARIABLES

| TEST | CAN1 | CAN2 |
|---|---|---|
| IT1 | -.01 | -.71 |
| AL4 | -.69 | -.63 |
| SI | -.84 | .27 |

Table 4: CANONICAL VARIABLES

| R | R-sqr. | Chi-sqr. | Lambda | df | p |
|---|---|---|---|---|---|
| .68 | .47 | 123.48 | .47 | 18 | .00 |
| .48 | .23 | 45.93 | .77 | 10 | .00 |

**CONCLUSION**

The research was conducted in order to determine relations between musical and intellectual abilities of ballroom dancers.

For the assessment of relations between musical and intellectual abilities, 267 dancers aged 11-13

involved in Standard and Latin American dancing were tested.

In order to assess musical abilities, the well-known Seashore's battery of tests for musicality assessment was applied. The battery evaluates the following tests: pitch perception test, loudness perception test, rhythm perception test, tone duration test, musical timbre perception test, and melodic memory ability test.

To assess cognitive abilities, the researchers applied three measurement instruments selected so as to perform structure analysis based on the cybernetic model designed by Das, Kirby & Jarman, and Momirovic, Bosnar &Horge 1982, and to measure three types of intellectual processing.

For estimating the effectiveness of the perceptual processor, test IT-1 was chosen; for estimating the effectiveness of the serial processor - test AL-4; and for estimating the effectiveness of the parallel processor - test S-1.

All the data in this research were processed at the Multidiscipline Research Center of the Faculty of Sport and Physical Education, University of Pristina, through the system of data processing software programs developed by D. Popovic, 1980, 1993, K. Momirovic & D. Popovic, 2003. Relations within the set of variables for assessment of musical and intellectual abilities of the respondents actively engaged in ballroom dancing were determined by means of canonical covariance analysis. The analysis of characteristic roots indicates the fact that for rejecting a null hypothesis, significant correlation is possible only for two roots, which means that out of three hypothetic possible canonical dimensions, two are sufficient to explain the relations between the two examined systems of variables. In the space of musical abilities, the first canonical factor is defined by a negative sign on the tests for the assessment of melodic memory, tone duration, and rhythm. The correspondent factor in the space of intellectual abilities is defined by the test for the assessment of the parallel processor and the test for the assessment of the effectiveness of serial processing. The second canonical factor in the space of musical abilities is best defined by the pitch perception test and the musical timbre perception test. The correspondent factor in the space of intellectual abilities is only defined by the test for assessment of the effectiveness of the input processor.

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