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# The structure of musical abilities of dancers

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## 1. Introduction

Music is an art that uses tones as a means of its expression. It reaches our consciousness through the sense of hearing. We, therefore, understand music by listening.

There are various theories about the origin of music. It was considered that music appeared as a result of great energy, at the moment of affect (Spencer), as well as it is a means of rapprochement between the opposite sexes (Darwin), still some relate it to the production, meaning working process (Buher). It may be stated that the simplest theory is the one which relates music to magic.

In his book "The State" Plato wrote : "The better music in a state, the better the state will be". Bergon established that only music may reveal the secret of life, and Pythagoreans believed that cosmos is music in large, and music is cosmos in small.

For a man of the postmodern era, music is the subject of business, a sort of entertainment, or a symbol of social status (opera equally as rock or folk concert). Music is incomparably more beautiful to experience through immediate performance or listening than to think, read, learn or write about it. But playing music has always been followed by this other aspect. The mysterious power that music has, awareness of it was long ago symbolically transformed into the myth of Orpheus, awakened a desire to learn more about its nature. The word "music" among the ancient Greeks meant the overall development of the spiritual life, "a musical person" was an educated man. Therefore, in this research one of the aims which have been set is to determine the structure of dancers' musical abilities.

# 2. The methods of research

## 2. 1. The sample of examinees

The sample of examinees is conditioned by the financial opportunities necessary of the research procedure. Besides, the sample depends on the number of qualified and trained measurers, on the instruments and standardized conditions in which the planned research may be realized.

In order to conduct a correct research with satisfactorily stable results, in the sense of sampling error, it is necessary to include a sufficient number of examinees into the sample. The size of the sample for research of this type is conditioned by the aims and tasks of the research, size of the population and the degree of variability of the applied system of parameters.[23]

According to the selected statistical-mathematical model and the aim of the research, the sample of examinees included 131 female dancers and 136 male dancers, aged from 11 to 13, actively involved with standard and Latin American dances 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 enables as many degrees of freedom as necessary for any coefficient in a pattern or correlation matrix which is equal to or bigger than 0.22, to be considered 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.

23 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.

During all 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 transformation of information: the sample of variables, sample of examinees, and the selected extraction, that is rotation method.[24]

## 2. 2. The sample of variables

The evaluation of musical abilities has been accomplished according to the well-known Seashore test battery that estimates musicality. This test lasts for 30 minutes and it consists of 6 groups of tasks that are listened to from an audiotape, and the answers are noted on the prepared answer sheets for that purpose. Auditory is provided by the regular schedule of the sound system and their volume so that all the examinees could be exposed to the equal experimental conditions.

This test estimates the following dimensions:

- Pitch discrimination test: it consists of five columns, and each column contains ten tasks. For each task two tones are played. An examinee is to determine whether the second tone was higher or lower than the first one.
- Tone intensity discrimination test: it consists of five columns. Each column contains ten tasks. For each task two tones are played. An examinee is to determine whether the second tone was louder or quieter than the first one.
- Rhythm recognition test: it consists of three columns. Each column contains ten tasks. For each task two rhythmical structures are played. An examinee is to determine whether the second rhythmical structure was the same or different from the first one.
- Tone duration discrimination test: it consists of five columns. Each column contains ten tasks. For each task two tones with different duration are played. An examinee is to determine whether the second tone was longer or shorter than the first one.
- Timbre discrimination test: it consists of five columns, and each column contains ten tasks. For each task two tones are played. An examinee is to determine whether the second tone was the same or different from the first one.

24 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.

- Tonal memory test: it consists of three columns. Each column contains ten tasks. On the column A for each task two melodies are played three times. On the column B two melodies of four tones are played, and on the column C two melodies of five tones are played. An examinee is to determine for each task in which tone the second played melody differs from the first one. For the column A: the first, second or third tone, for the column B: the first, second, third or fourth tone and for the column C: the first, second, third, fourth or fifth tone.

The evaluaton is carried out so that each correct answer for each task in all the tests is worth one point. The total sum of points scored in particular tasks of each test separately, constitutes the result. The result expressed in points should be converted to percentages. The female examinees, according to the number of points obtained on particular tests, depending on their age, are classified in certain classes from "A" to "E".

## 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. There are several reasons for defining an algorithm and writing a program for component analysis of some set of quantitative variables derived by the orthoblique transformation of type II (Harris & Kaiser, 1964) of the principal components whose number is determined according to PB criterion of Štalec and Momirović (Štalec and Momirović, 1971) and whose reliability is estimated by the procedures recently suggested for this type of analysis of the latent dimensions (Momirović, 1996). The first reason is that from all the commercial statistical programs available on the computers that work in DOS or Windows environment (SAS, SPSS, CSS, CS, Statistica, Statgraphics, MicroStat, SyStat etc.) only SAS enables the orthoblique transformation of some basic solution, although, for the majority of problems in psychology and other anthropological sciences, precisely this type of transformation of the principal components is the most frequent solution that is closest to the real latent structure of the analyzed set of variables. The second reason is that none of these programs contains an option to determine the number of the retained components so that their total variance reaches or even exceeds the common variance of the analyzed variables, although this criterion in almost all cases provides more certain evaluations of the actual number of the latent dimensions than the usual Guttman – Kaiser criterion. The third reason is that none of the commercial statistical packages estimates the reliability of the latent dimensions in any manner, especially the one that is consistent with the algorithm by which those dimensions are determined.

Due to this, the aim of this work is to propose one consistent algorithm for latent structures analysis which is included in the orthoblique transformations of the principal components significant according to PB criterion with the additional operations for the analysis of variance components of manifested and latent variables, and for the evaluation of reliability of latent variables, and to describe a program, written in the Matrix language for SPSS which functions in Windows environment, that is a program available to nearly all users of personal computers or workstations.

## *THE ALGORITHM*

Let Z be the standardized data matrix obtained by the description of some set E of n entity on the set V of m quantitative, normally or at least elliptically distributed variables. Let R be an intercorrelation matrix of those variables. Assume, R to be surely a regular matrix and we can surely reject the hypothesis that the variables from V have spherical distribution, that is the eigenvalues of the correlation matrices in population P out of which the sample E has been drawn, are equal.

Let

$$U^2 = (\text{diag } R^{-1})^{-1}$$

be Guttman's estimate of the unique variances of variables from V, and let $\lambda_p$, p = 1,...,m be the eigenvalues of the matrix R. Let

$$c = \text{trag } (I - U^2).$$

If the scalar k is defined as

$$\Sigma_p^k \lambda_p \geq c, \Sigma_p^{k-1} \lambda_p < c.$$

k is now the number of the principal components of the matrix Z determined according to PB criterion of Štalec and Momirović (Štalec and Momirović, 1971).

Let $\Lambda = (\lambda_p)$; p = 1,...,k be the diagonal matrix of the first k eigenvalues of the matrix R and let $X = (x_p)$; p = 1,...,k be the matrix of the associated eigenvectors scaled so that $X^tX = I$. The principal components of the analyzed set of variables will be the vectors of the matrix

$$K = ZX$$

with the covariance matrix

$$K^tK = \Lambda;$$

if the so defined latent dimensions are standardized by the operation

$$P = K\Lambda^{-1/2}$$

the elements of the matrix

$$H = Z^tPn^{-1} = X\Lambda^{1/2}$$

therefore correlations between the variables and the principal components will, simultaneously, be the coordinates of the vectors of variables in the space stretched by the standardized vectors of the principal components. The variances of standardized variables, projected into k – dimensional space of the principal components, will consequently be the elements of the vector

$$h^2 = \text{vec diag } (HH^t) = \text{vec diag } (X\Lambda X^t);$$

and since, evidently,

$$H^tH = \Lambda,$$

the principal components analysis does not maximize only the variances of the so defined latent dimensions, but also the correlations between those dimensions and the analyzed variables.

Although the principal components have a simple and clear mathematical meaning, their interpretation is frequently extremely complex, especially when the vectors of variables form clusters in the component space. Consequently, practically always, the coordinate system composed of the vectors of the principal components undergoes some parsimonic transformation, while the primary aim of all such transformations is to make it possible for the new coordinate axes to pass through the clusters of the vectors of variables. For that purpose, many methods have been proposed; but orthoblique transformation of type II, proposed by Chester Harris and Henry Kaiser (Harris & Kaiser, 1964) is not only the simplest of them all, but also closest to the basic idea of parsimonic transformations.

Let T be an orthonormal matrix so that it optimizes the function

$$XT = Q = (q_p) \mid p\,(Q) = \text{extremum}, \; T^tT = I,$$

where p (Q) is a parsimonic function, for example, the regular Varimax function

$$\Sigma_j^m \Sigma_p^k q_{jp}^4 - \Sigma_p^k (\Sigma_j^m q_{jp}^2)^2 = \text{maximum}$$

where the coefficients $q_{jp}$ are the elements of the matrix Q (Kaiser, 1958).

Now the transformation of the principal components, defined by the vectors in the matrix

$$K = ZX,$$

into the semiorthogonal latent dimensions determined by the type II orthoblique procedure (Harris and Kaiser, 1964), is defined by the operation

$$L = KT = ZXT.$$

The covariance matrix of those dimensions is

$$C = L^tLn^{-1} = Q^tRQ = T^t\Lambda T;$$

denote the matrix of their variances as

$$S^2 = (s_p^{\ 2}) = \text{diag } C.$$

If the latent dimensions are standardized by the operation

$$D = LS^{-1},$$

in the matrix

$$M = D^tDn^{-1} = S^{-1}T^t\Lambda TS^{-1}$$

there will be their intercorrelations; notice, that C, and therefore M, cannot be diagonal matrices, so thus obtained latent dimensions are not orthogonal in the space of the entity from E.

The matrix of correlations between the variables from V and latent variables, that is commonly classified as a factor structure matrix, will be

$$F = Z^tDn^{-1} = RXTS^{-1} = X\Lambda TS^{-1};$$

But since the elements of the matrix F of the orthogonal projection of the vector from Z to the vectors from D, the coordinates of those vectors in the space stretched by the vectors from D are the elements of the matrix

$$A = FM^{-1} = XTS.$$

But since

$$A^tA = S^2$$

then the latent dimensions, obtained by this procedure are orthogonal in the space stretched by the vectors of the variables from Z; the squared norms of the vectors of those dimensions in the space of variables are equal to the variances of those dimensions.

Naturally, the matrices A and F are the factor matrices of the matrix R since

$$AF^t = AMA^t = FM^{-1}F^t = HH^t = X\Lambda X^t;$$

Consequently the operation

$$W = (w_{jp}) = A \bullet F$$

where • is a sign of Hadamard multiplication, forms the matrix whose rows include the variance components of variables that may be attributed to orthoblique factors, and the columns contain variance components of orthoblique factors that may be attributed to variables.

Because of its simplicity and clear algebraic and geometric meaning and latent dimensions, as well as identification structures attributed to those dimensions, the reliability of the latent dimensions obtained by the orthoblique transformation of the principal components could be determined in a clear and unambiguous manner (Momirović, 1996).

Let $G = (g_{ij})$; $i = 1,...,n$; $j = 1,...,m$ be a permissibly unknown matrix of measurement errors when describing the set E on the set V. Then the matrix of the real results of the entity from E on the variables from V will be

$$Y = Z - G.$$

If we, according to the classical measurement theory, assume that the matrix G is such that

$$Y^tG = 0$$

and

$$G^tGn^{-1} = E^2 = (e_{jj}^2)$$

where $E^2$ is a diagonal matrix, the covariance matrix of the real results will be

$$J = Y^tYn^{-1} = R - E^2$$

if

$$R = Z^tZn^{-1}$$

is an intercorrelation matrix of the variables from V defined on the set E.

Assume that, the coefficients of reliability of the variables from V are known; let P be a diagonal matrix whose elements $\rho_j$ are those reliability coefficients. Then the variances of measurement errors for the standardized results on the variables from V will be just the elements of the matrix

$$E^2 = I - P.$$

Now the true values on the latent dimensions will be the elements of the matrix

$$\Gamma = (Z - G)Q$$

with the covariance matrix

$$\Omega = \Gamma^t\Gamma n^{-1} = Q^tJQ = Q^tRQ - Q^tE^2Q = (\omega_{pq}).$$

Therefore, the true variances of the latent dimensions will be diagonal elements of the matrix $\Omega$; let's denote these elements by $\omega_p^2$. Based on the formal definition of reliability coefficient of some variable

$$\rho = \sigma_t^2 / \sigma^2$$

where $\sigma_t^2$ is the true variance of some variable, and $\sigma^2$ is the total variance of that variable, hence the variance which includes the variance of error; the coefficients of reliability of latent dimensions, if reliability coefficients of the variables from which those dimensions have been derived are known, will be

$$\gamma_p = \omega_p^2 / s_p^2 = 1 - (q_p^tE^2q_p)(q_p^tRq)^{-1}$$

$$p = 1,...,k.$$

The coefficients $\gamma_p$ vary in the range (0,1) and may adopt the value 1 only if P = I, accordingly if all the variables have been measured without error, what is, evidently, theoretically impossible, and the value 0 if and only if P = 0 and R = I, that is, if the total variance of all the variables consists of only one variance of the measurement error, and variables from V have spherical normal distribution. Because if the total variance of each variable from some set of variables consists only of the variance of measurement error, then necessarily $E^2 = I$ and R = I, so that all the coefficients $\gamma_p$ are equal to zero.

However, the matrix of reliability coefficients $P = (\rho_j)$ is usually unknown, so the matrix of the variances of measurement error $E^2$ is unknown as well. But, if the variables from V are selected so that they represent some universe of U variables with the same field of meaning, the upper limit of variance of measurement error is defined by the elements of the matrix $U^2$ (Guttman, 1945), that is, the unique variances of those variables. Consequently, in that case, the lower limit of reliability of latent dimensions can be estimated by the coefficients

$$\alpha_p = 1 - (q_p^tU^2q_p)(q_p^tRq_p)^{-1}$$

$$p = 1,...,k$$

which are derived by the procedure identical to the procedure by which the coefficients $\gamma_p$ are derived with the definition $E^2 = U^2$, that is, in the same way as

Guttman derived his measure $\lambda_6$. Of course, the coefficients $\alpha_p$ vary in the range (0,1), but they cannot reach the value 1. Because if R = I, then $U^2$ = I, so all the coefficients $\alpha_p$ are equal to zero. But, since $U^2 = 0$ is not possible if the matrix R is regular, all the coefficients $\alpha_p$ are inevitably less than 1 and tend to 1, when the unique variance of the variables from which the latent dimensions have been derived tends to zero.

Equally, it is simple to derive measures of the absolute lower limit of reliability of latent dimensions defined by the orthoblique factors. For that purpose, presume $E^2$ = I. Then

$$\beta_p = 1 - (q_p^t R q_p)^{-1}$$

will be the measures of the absolute lower limit of the latent dimensions reliability, since, evidently, $Q^tQ = I$.

It is obvious that inevitably all the coefficients $\beta_p$ are less than 1, and that they tend to 1 when m, the number of variables in the set V, tends to infinity, because then each squared form of the matrix R tends to infinity. If R = I, then, naturally, all the coefficients $\beta_p$ are equal to zero. However, the lower limit of these coefficients does not have to be zero, since it is possible, although not for all the coefficients $\beta_p$, that the variance $s_p^2$ of some latent dimension may be less than 1. Naturally, the latent dimension which emits less information than any other variable out of which it has been derived, has no sense, and it is probably best to discover on the basis of the values of coefficients $\beta_p$.

## 3. Results and discussions

The analysis of the system of six primary musical factors by which the efficiency of the functioning of the regulative mechanisms of musical abilities was estimated, has shown that it contains about 80.90% of the common variance.

At that percentage of the common variance, based on PB criterion of Štalec and Momirović (Štalec and Momirović, 1971), three characteristic roots are isolated. On the basis of the isolated characteristic roots and their corresponding characteristic vectors, the main axes of the covariance of the variables presented in table 2 are calculated.

THE FIRST PRINCIPAL COMPONENT which exhausts 33.00% of a variance, is obviously, a measure of efficient functioning of the whole set of musical abilities. The sequence of definitions of the factors that define musicality is expressed as follows: in the first place there is a mechanism for estimating rhythm, and in the second place is a mechanism for estimating pitches.

THE SECOND PRINCIPAL COMPONENT with a relative variance of 30.30% has a bipolar character. At one pole it is defined by the mechanism for estimating memory, and at the second pole by the mechanism for estimating volume.

THE THIRD PRINCIPAL COMPONENT with a relative variance of 17.60% represents a single factor. This component is defined by the mechanism for estimating timbre.

The factor structure of musical abilities is simultaneously analyzed on the basis of information provided by oblimin transformation of the significant principal components, i.e. on the basis of parallel projections of the variables on the factors (table 3) of the matrix of correlations between variables and factors (table 4) and intercorrelation matrix of factors (table 5).

In respect to the size of variance, the first factor is the most significant among all isolated dimensions. It is defined by the test for estimating volume, rhythm and finally pitch.

The second latent dimension is best defined by the test for estimating duration of a tone on the one hand, and by the test for estimating memory on the other.

The third latent dimension is defined only by the test for estimating timbre.

*MATRIX OF INTERCORRELATIONS*

Table 1.

| Variable | VIT | JAT | RIT | DUT | BOT | MEM |
|---|---|---|---|---|---|---|
| VIT | 1.00 | | | | | |
| JAT | .35 | 1.00 | | | | |
| RIT | .42 | .40 | 1.00 | | | |
| DUT | -.12 | -.09 | .47 | 1.00 | | |
| BOT | .36 | .12 | .13 | -.01 | 1.00 | |
| MEM | -.10 | - .30 | .18 | .58 | .20 | 1.00 |

*MATRIX OF PRINCIPAL COMPONENTS*

Table 2.

| Variable | FAC1 | FAC2 | FAC3 | $h^2$ |
|---|---|---|---|---|
| VIT | .65 | -.48 | .22 | .70 |
| JAT | .51 | -.57 | -.35 | .72 |
| RIT | .85 | .07 | -.35 | .86 |
| DUT | .46 | .76 | -.27 | .87 |
| BOT | .49 | -.11 | .77 | .86 |
| MEM | .31 | .80 | .27 | .82 |
| LAMBDA | 1.97 | 1.81 | 1.05 | |
| % | 33.00 | 30.30 | 17.60 | |
| CUM % | 33.30 | 63.30 | 80.90 | |

*PATTERN MATRIX*

Table 3.

| Variable | FAC1 | FAC2 | FAC3 |
|---|---|---|---|
| VIT | .55 | -.12 | .54 |
| JAT | .82 | -.20 | -.01 |
| RIT | .77 | .52 | .02 |
| DUT | .14 | .92 | -.17 |
| BOT | -.04 | .04 | .93 |
| MEM | -.29 | .81 | .25 |

*STRUCTURE MATRIX*

Table 4.

| Variable | FAC1 | FAC2 | FAC3 |
|---|---|---|---|
| VIT | .63 | -.11 | .62 |
| JAT | .82 | -.22 | .09 |
| RIT | .76 | .50 | .15 |
| DUT | .09 | .90 | -.11 |
| BOT | .09 | .08 | .92 |
| MEM | -.28 | .83 | .24 |

*MATRIX OF INTERCORRELATIONS OF OBLIMIN FACTORS*

Table 5.

| Variable | OBL1 | OBL2 | OBL3 |
|---|---|---|---|
| OBL1 | 1.00 | | |
| OBL2 | -.02 | 1.00 | |
| OBL3 | .14 | .04 | 1.00 |

# 4. Conclusion

The research was conducted to determine the structure of musical abilities of dancers, occupied with Standard and Latin American dances.

In order to determine the structure of musical abilities, 267 dancers engaged in standard and Latin American dances, aged from 11 to 13, were examined.

For estimating musical abilities, the well-known Seashore battery of tests for the assessment of musicality was used. This battery evaluates the following tests: pitch discrimination test, tone intensity discrimination test, rhythm recognition test, tone duration discrimination test, timbre discrimination test and tonal memory test.

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 factor structure of musical abilities was simultaneously analyzed on the basis of information obtained by oblimin transformation of the significant principal components, actually on the basis of parallel projections of the variables on the factors (table 3), matrix of correlation between variables and factors (table 4) and intercorrelation matrix of factors (table 5). Judging by the value of variance, the first factor is the most important among all the isolated dimensions, it is defined by the test for estimation of tone intensity, test for recognition of rhythm and finally the test for estimation of pitches. Another latent dimension is best defined by the test for estimating the tone duration, on the one hand, and test for estimating tonal memory, on the other hand. The third latent dimension is defined by the test for estimating the timbre of tones.

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## *Summary*

*The research was conducted to determine the structure of musical abilities of dancers engaged in standard and Latin American dances. For estimating the structure of musical abilities, 267 dancers, aged from 11 to 13, were involved. For estimating musical abilities, the well-known Seashore battery of tests for the assessment of musicality was used. This battery evaluates the following tests: the pitch discrimination test, tone intensity discrimination test, rhythm recognition test, tone duration discrimination test, timbre discrimination test and the tonal memory test. 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 factor structure of musical abilities was parallel analyzed on the basis of information obtained by the oblimin transformation of the significant principal components, actually on the basis of parallel projections of the variables on factors (table 3), the matrix of correlations between variables and factors (table 4) intercorrelation matrix of factors (table 5). Judging by the value of variance, the* *first factor is the most important among all the isolated dimensions, it is defined by the tone intensity test, test for the evaluation of rhythm and finally the test for the evaluation of pitches. Another latent dimension is best defined by the test for estimating tone duration on the one hand, and the test for estimating the tonal memory, on the other hand. The third latent dimension is defined by the test for estimating the timbre of tones.*

*Key words: /tone/ matrix/correlation/variable/factor/rhythm/duration/timbre/memory/*

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