Discriminant Analysis Projected Onto The Standard Metric As A Method For Determining Differences In Intellectual Abilities Between Track-And-Field Athletes And Basketball Players

Dragan Popovic
Evagelia Boli
Vladimir Savic
Milos Popovic
Jasna Popovic
Milica Bojovic
Faculty of Sport and Physical Education, University of Pristina,
temporarily based in Leposavic, Serbia

Abstract

The research was conducted in order to determine the structure and differences in cognitive dimensions of track-and-field athletes and basketball players. For the purpose of determining the structures and their differences in the manifest and latent cognitive spaces, 100 male respondents aged 14 and 18 was tested. This sample can be considered representative of athletes of those ages. For the assessment of cognitive abilities, the researchers used 6 measurement instruments selected so that the structure analysis could be performed on the basis of the cybernetic model designed by (Das, Kirby & Jarman 1979) and by (Bosnar & Horga, 1981), (Momirovic, Bosnar & Horga 1982), taking into account the fact that the selected tests measure three types of cognitive processing . To assess the effectiveness of the input processor, or perceptual reasoning, CF-2 and GT-7 were selected, to assess the effectiveness of the parallel processor, or identification of relations and correlates - IT-2 and D-4S, and to assess the effectiveness of the serial processor, or symbolic reasoning, ALPHA-7 and G-SIN were selected. All the data in this research were processed at the Multidisciplinary Research Center of the Faculty of Sport and Physical Education, University of Pristina, through the system of data processing software programs developed by Popovic, D. (1980), (1993) and Momirovic, K. & Popovic, D. (2003).To determine differences between the groups, canonical discriminant analysis was applied. The researchers calculated the discriminant coefficient values,

canonical correlation coefficients, percentage of the explained group variability, Bartlett`s chi-square test values, degrees of freedom, Wilks' Lambda values, and error probability in the rejection of the hypothesis that the actual canonical correlation value is equal to zero. They also calculated the standardized coefficients of the participation of the tests in the formation of significant discriminant functions, as well as centroids of the groups on the significant discriminant functions. The results of the discriminant analysis of cognitive variables show that athletes of different sports differ from each other significantly. By means of condensation of variables in cognitive space, two discriminant variables, which maximally separated the groups of athletes based on the discriminant coefficients, were isolated.

Keywords: Cognitive dimensions, discriminant, structure, correlation, variables, centroids

Introduction

Transformation processes, incurred as a result of the adaptation of an athlete`s organism to the training stimuli, are the phenomena caused by the regularities in the relations of internal physiological, biomechanical and psychological systems, as well as in the relations between the athlete as an integral anthropological entity and the environment. Today we can only speculate about the transformation processes, induced by synchronous effects of endogenous and exogenous factors, on the basis of the final effects of the exercise, and we know very little about the nature of the phenomena of adaptation of the athlete`s organism to the established exercise load. Modern science uses interdisciplinary approaches to such complex research areas. For the convergence of different scientific disciplines and their compliance with empirical evidence and requirements, a common basis is necessary.

It is cybernetics, with its modern methodological procedures, that significantly contributes to the sciences of physical culture, especially sport, in their transcending the descriptive level. If the process of athlete education is understood in the context of cybernetic planning as a system, familiarization with the system structure and relations in the system, as well as the relations between the system and environment, contributes to discovering the principles, methods and tools that lead to achievement of optimal management, which is the aim pursued in modern sport. Systematic training is essentially a transformation process through which an athlete, as a system, is transformed from one state into another in accordance with the requirements of a given sport or sport discipline. Since it is necessary to master the regularities which the transformation processes undergo to achieve efficient management, it is necessary to know the structure and relations among the constituent elements of the system.

Through modeling, it is possible to receive the sets of the system elements which are considered to be responsible for the studied phenomenon. Modeling as a method is characterized by the creation of a system that is, in its essential characteristics, analogous to the real phenomenon being examined. If the model structures do not represent all the essential characteristics of the studied original, they will be partial models. A partial model, despite its abundance, is a process model and can describe transformation processes in an athlete`s body caused by systematic training in essential characteristics. For the rational creation of a model of transformation processes, "conditio sine qua non" is a model of the anthropological space structure, i.e. a model that integrates all known anthropological qualities considered to be responsible for motor manifestations and therefore, for top sport results.

However, it should be noted that, at the current level of knowledge, the deterministic models of human locomotion can be applied in a limited number of cases. This refers, first of all, to the modeling and then to the simulation of simple movements which generally characterize competition results of primarily individual sports such as track-and-field. In other sports and sport games, which fall under the category of polystructural sports and where athletes` performance takes place under changing conditions, deterministic modeling can be used for the purpose of improvement of crisis technical elements, while competition performance modeling primarily, but not exclusively, should be of stochastic character. Because of that, as well as because of the fact that stochastic models generally have (for the same observed parameters) lower diagnostic and prognostic levels, they should include the highest possible number of athletes` anthropological characteristics that are known or expected with some degree of probability to contribute to sport results. Previous studies show that there are relations between cognitive space and other anthropological subspaces in stochastic modeling.

Sample of respondents

The selection of a sample of respondents is conditioned, among other things, by the organizational and financial capabilities necessary for the implementation of the research process.

It was necessary to ensure a sufficient number of trained and qualified measurers, appropriate instrumentation and standardized conditions under which the research could be implemented. Limited financial resources and organizational capabilities influenced the decision to perform the measurement not throughout Kosovo and Methohia but only in one of its regions.

The research was carried out on randomly selected samples representative of whole Kosovo and Methohia. The measurement was performed in the following sports: track-and-field and basketball. To do the research correctly and obtain results stable enough in terms of sampling error, it was necessary to take a sufficient number of respondents into the sample. The sample size for this type of research is conditioned by the research objectives and tasks, the population size and degree of variability of the applied system of parameters. In addition, the number of respondents in the sample also depends on the level of statistical inference and the choice of mathematical and statistical models.

Based on the selected statistical-mathematical model and program, objectives and tasks, 100 respondents were included in the sample. In all factor procedures, should constantly be kept in mind that the analysis results depend on three main systems that determine the selection and transformation of information: the sample of variables, sample of respondents and selected extraction or rotary methods. Taking these criteria into account, based on the experience from previous studies, the sample of 100 respondents is considered to be sufficient for this study. In defining the population from which the sample was drawn, except for the above, no other restrictions or stratification variables were used.

Sample of variables for assessment of cognitive abilities

The starting basis for the research was the findings of the studies of the structure of cognitive dimensions conducted in Yugoslavia (Bosnar & Horga, 1981), (Momirovic, Bosnar & Horga 1982), (Boli, E., Popovic, D., Popovic, J., 2012) that were largely congruent with the results of studies carried out in other countries.

These studies have provided unequivocal evidence that the structure of cognitive abilities is of hierarchical type, where at the top is the general cognitive factor below which are three primary factors of cognitive abilities related to: the effectiveness of the perceptual processor (perceptual reasoning), effectiveness of the parallel processor (ability to identify relations and correlates), and the effectiveness of the serial processor (symbolic reasoning).

The factor of perceptual reasoning is defined as a latent dimension responsible for receiving and processing information and solving those problems whose elements are given directly in the field of perception or representation. This factor represents the intelligence of Thurstone perceptual factors and is similar to Alexander `s practical factor, Cattell`s general perceptual factor and Horn and Stankov`s general function factor.

The factor of education of relations and correlates is defined as a latent dimension responsible for determining relations between the elements

of a structure and essential characteristics of such structures in solving those problems in which the processes of determining and restructuring are independent of the previously acquired amounts of information. This factor corresponds to Cattell`s factor of fluid intelligence.

The factor of symbolic reasoning is defined as a latent dimension responsible for the processes of abstraction and generalization and for solving those problems whose elements are given in the form of any, and especially verbal, symbols. This factor corresponds to Cattell`s factor of crystallized intelligence which is formed in the process of acculturation and represents the integration of both Thurstone verbal factors and their numerical factors.

To assess the effectiveness of the input processor, or perceptual reasoning, the researchers selected the tests as follows:

TEST CF-2: a test of latent model representing the adaptation of Thurstone`s Drawing Test which is, as a marker test, applied for assessing flexibility, or the factor of convergent production of figural transformations (according to Guilford`s classification). The test contains 20 tasks; the testing time is limited to 3 minutes. The analysis of this test shows that the test had good characteristics.

TEST GT-7: B. Dvorak`s test of matching drawings to assess perceptual identification. It contains 4 blocks of 12-18 geometric drawings made in two differently organized contexts. It consists of 60 tasks, and the testing time is limited to 6 minutes. The analysis of the test shows that this test has all the characteristics of a speed test.

To estimate the effectiveness of the parallel processor, or identification of relations and correlates, the researchers selected the following measurement instruments:

TEST IT-2: Thurstone and Dvorak`s test of general visualization designed to assess the efficiency of perception of spatial relations. It contains 39 multiple choice tasks to determine which of the four given geometric bodies matches the drawing. The testing time is 10 minutes, so this test falls under the category of power tests.

TEST D-4S: Anstey`s Dominoes Test to assess the general factor of intelligence. In this study, the researchers applied a revision of the original form Momirovic that did not contain the four tasks which were very poorly saturated with the common measurement subject of other tasks. The test includes 40 tasks each of which consists of 4-8 dominoes arranged in a certain order where the gap should be filled in with the appropriate value to fit into the given structure. The testing time is 15 minutes, therefore, the test belongs to the category of power tests.

To assess the effectiveness of the serial processor, or symbolic reasoning, the following measurement instruments were selected:

TEST ALPHA-7: F. L. Well`s Analogies Test to measure verbal comprehension. The test contains 39 tasks and the testing time is 3 minutes, which characterizes it as a speed test. The first main subject of measurement of the test is defined, in the first place, by less difficult tasks and interpreted as the ability to perceive simple analogies on symbolic material.

TEST G-SIN: Synonyms Test by for the assessment of rapid identification of semantic meanings of verbal symbols. It contains 39 multiple choice tasks of identifying among 5 words the one closest in the meaning to the given word. The test falls under the category of speed tests because the testing time is 3 minutes.

Data processing methods

The value of a research does not only depend on the sample of respondents and sample of variables, that is, the values of basic information, but also on the applied methods for transformation and condensation of the information. Certain scientific problems can be solved with the help of a number of different, and sometimes equally valuable, methods. However, with the same basic data, from the results of different methods, different conclusions can be drawn. Therefore, the problem of selecting data processing methods is rather complex.

In order to obtain satisfactory scientific solutions in a research, it is necessary to use, first of all, correct, then adequate, unbiased and comparable procedures which correspond to the nature of the problem and provide extraction and transformation of appropriate dimensions, the testing of hypotheses about those dimensions, and establishment of basic regularities within the research area.

Taking this into account, for the purposes of this study, the researchers selected those methods which were considered to correspond to the nature of the problem.

To determine differences between the groups, a method of discriminant analysis was applied. The researchers calculated the discriminant coefficient values (Eigenval.), canonical correlation coefficients (Can. Cor.), percentage of the explained group variability (chi-square test (Chi)), degrees of freedom (DF), Wilks' Lambda values (WL), and error probability in the rejection of the hypothesis that the actual canonical correlation value is equal to zero (Sig).

They also calculated the standardized coefficients of participation of the tests in the formation of significant discriminant functions, as well as the centroids of the groups on the significant discriminant functions.

All the data in this study were processed at the Multidisciplinary Research Center of the Faculty of Sport and Physical Education, University of Pristina, through the system of data processing software programs

developed by Popovic, D. (1980), (1993) and Momirovic, K. & Popovic, D. (2003).

Projection into a space with standard metric

The resulting solution is very easy to convert into a form obtained under the canonical model of discriminant analysis.

The matrix of discriminant coefficients can be defined as a matrix of partial regression coefficients that is obtained by solving the problem $\mathbf{ZW} = \mathbf{K} + \mathbf{E} \mid \text{trag}(\mathbf{E}^t\mathbf{E}) = \text{minimum}$.

As $\mathbf{K} = \mathbf{ZR}^{-1/2}\mathbf{X}$, it is clear that $\mathbf{E} = \mathbf{0}$ and $\mathbf{W} = \mathbf{R}^{-1/2}\mathbf{X}$. Therefore, vectors $\mathbf{w}_k$ from $\mathbf{W}$ are proportional to the coordinates of the vectors of discriminant functions in the tilted coordinate system formed by vectors from $\mathbf{Z}$ with cosines of the angles between the coordinate axes equal to the elements of correlation matrix $\mathbf{R}$. Since discriminant analysis can also be interpreted as a special case of component analysis with principal components transformed by a permissive singular transformation so as to maximize distances between centroids of subsets E_p , or canonical correlations $\square_k$ (Cooley & Lohnes, 1971), the custom is to identify the content of discriminant functions on the basis of structural vectors $\mathbf{f}_k$ from the matrix $\mathbf{F} = \mathbf{Z}^t\mathbf{K} = \mathbf{RW} = \mathbf{R}^{1/2}\mathbf{X} = (\mathbf{f}_k) = (\mathbf{Rw}_k)$, which is analogous to the identification of the content of canonical variables obtained by Hotelling`s method of biorthogonal canonical correlation analysis because it is possible to show by easy calculation that $\mathbf{F}$ is a factor matrix of matrix $\mathbf{R}$

In this metric, the cross structure of discriminant functions will be $\mathbf{U} = \mathbf{Z}^t\mathbf{L}\square^{-1} = \mathbf{Z}^t\mathbf{PZW}\square^{-1} = \mathbf{W}\square$ as, of course, $\mathbf{W}^t\mathbf{Z}^t\mathbf{PZW} = \square^2$, and it is clear that $\mathbf{U}$ is a factor matrix of the matrix $\mathbf{Z}^t\mathbf{PZ}$, or intergroup covariance matrix defined in the space with standard metric.

As elements f_{jk} of matrix $\mathbf{F}$ and elements u_{jk} of matrix $\mathbf{U}$ behave like ordinary product-moment correlation coefficients, and as they are a function of normally distributed variables, and therefore, they themselves are asymptotically normally distributed, their asymptotic variances are, of course, $\square_{jk}^2 \sim (1 - \square_{jk}^2)^2 n^{-1}$ j = 1,..., m; k = 1,..., s, respectively, $\square_{jk}^2 \sim (1 - \square_{jk}^2)^2 n^{-1}$ j = 1,..., m; k = 1,..., s, and can be used for testing hypotheses of type H_{jk}: $f_{jk} = \square_{jk}$, or H_{jk}: $u_{jk} = \square_{jk}$, where $\square_{jk}$ and $\square_{jk}$ are some hypothetical correlations between variables from V and discriminant functions in population P because the asymptotic distribution of coefficients f_{jk} is $f(f_{jk}) \sim N(\square_{jk}, \square_{jk}^2)$, and the asymptotic distribution of coefficients u_{jk} is $f(u_{jk}) \sim N(\square_{jk}, \square_{jk}^2)$, where N is a symbol of normal distribution.

Reliability, informativeness and significance of discriminant functions

Let $\mathbf{V}^2 = (\text{diag } \mathbf{R}^{-1})^{-1}$ be a diagonal matrix whose elements are estimates of unique variances of variables from V. Now, as shown by

Momirovic, reliability, or, more precisely, generalizability of discriminant functions can be assessed based on the values of diagonal elements of the matrix □ = (diag ($\mathbf{W}^t(\mathbf{R} - \mathbf{V}^2)\mathbf{W}$))(diag ($\mathbf{W}^t\mathbf{R}\mathbf{W}$))$^{-1}$, relative informativeness - based on the elements of the diagonal matrix□ ^{2} = ($\mathbf{I}$ - □)$^{-1}$m^{-1}, and redundancy of these functions – based on the elements of the diagonal matrix □ = □^{2}□.

Of course, for making judgments about what is the real meaning of discriminant functions, these data can be of much greater importance than the results of the tests of significance of canonical correlations.

Disc program

This algorithm is almost literally implemented into the program DRDISC written in a matrix language so that it can be realized in the standard SPSS environment. The activation method and some details of the program can be seen from the program symbolic code which is stored at the Multidisciplinary Research Center of the Faculty of Sport and Physical Education, and clear instructions are given to make it possible for anyone, who needs it, to apply the canonical discriminant analysis correctly. Modification of this program and its practical implementation in the SAS environment were carried out by D. Popovic in 2004, and the scientists interested in its application can contact the author at any time.

Discussion

The results of the discriminant analysis of cognitive variables show that athletes of different sports differ from each other considerably. The canonical correlation coefficients (Can. Cor.) are .90 and .51. The significance of this discrimination tested by means of Wilks` test and Bartlett`s chi-test with 8 and 3 degrees of freedom (DF) indicates high significant differences between the groups of the tested athletes because Sig. = .00 for both roots, and chi = 4.88 for the first root and chi = 75.12 for the second root.

Through condensation of variables in the cognitive space, two discriminant variables, which maximally separated the groups of athletes on the basis of discriminant coefficients, were isolated.

The first discriminant function explains the differences with 92.52 percent of intergroup variability in the cognitive space of the applied discriminant variables.

Analyzing Table 2 reveals that the first discriminant function separates the athletes on the basis of IT-2 which is, in its initial subject of measurement, designed to assess the effectiveness of spatial relations. This factor is actually subordinated to the mechanism responsible for the determination of relations between the elements of a structure and essential

characteristics of such structures in solving those problems in which the determination and reconstruction processes are independent of the amounts of the previously acquired information (it is a generally known mechanism for parallel processing).

Another factor that determines this function is CF2 which in the initial measurement estimates convergent productions of figural transformations and it is subordinated to the mechanism responsible for receiving and processing information and solving those problems whose elements are given directly in the field of perception and representation. It is, in fact, a mechanism commonly known in cybernetics as an input processor.

Based on the value and sign of the projection of the centroid onto the first discriminant function, it can be concluded that track-and-field athletes have a better expressed factor of symbolic reasoning, i.e. they better understand verbal contents and it is not so important for them to solve those problems whose elements are given directly in the field of perception and representation, and their movement stereotypes are very important, that means they are very dependent on the previously acquired amounts of information. It is a sport where there is no need for solving complex motor tasks, but the result depends on the level of acquisition of the techniques and on other abilities, primarily motor and cardiovascular ones.

Basketball players must have the ability to efficiently perceive spatial relations, i.e. they must have the ability to receive and process information and solve those problems whose elements are given directly in the field of perception and representation.

The second discriminant function, though it exhausts the smaller variance, can still be meaningfully interpreted, and is determined by ALPHA-7 which assesses the ability to understand verbal contents, or effectiveness of parallel processing, and by GT-7 which assesses perceptual identification, or effectiveness of the input processor.

Based on the value and sign of the centroid on the second discriminant function, it can be concluded that basketball players have a more expressed ability for abstraction and generalization processes and a better ability to receive and process information, which is understandable considering the complexity of the sport discipline and requirements it imposes on the athletes.

Discriminant functions in cognitive space. Table 2

Func.	Eigenval.	Var. %	Cum. %	Can.Cor.	Wilks' Lam	Chi^2 - test	DF	Sig
1*	4.46	92.52	92.52	.90	.13	488.88	6	.00
2*	.36	7.48	100.00	.51	.73	75.12	3	.00

STRUCTURE MATRIX

	FUNC1	FUNC2
IT-2	.98*	-.08
CF-2	.67*	-.05
D-4S	.52	.30*
ALPHA-7	-.17	.24*
GT-7	-.05	.21*
G-SIN	.05	-.09

CENTROIDS OF THE GROUPS

Group	C1	C2
Track-and-field athletes 1	-2.64	-.03
Basketball players 2	1.56	.67

Conclusion

The study was conducted in order to determine the structures and their differences in cognitive dimensions of track-and-field athletes and basketball players.

For the purpose of determining the structure and their differences in manifest and latent cognitive spaces, 100 male respondents aged 14 and 18 were tested. This sample can be considered representative of athletes of those ages.

For the assessment of cognitive abilities, the researchers applied 6 measurement instruments selected so that to the structure analysis could be performed on the basis of the cybernetic model designed by (Das, Kirby, & Jarman 1979), and by (Momirovic, Gredelj, Hosek 1980), taking into account the fact that the selected tests measured three types of cognitive processing. To assess the effectiveness of the input processor, or perceptual reasoning, CF-2 and GT-7 were selected, to assess the effectiveness of the parallel processor, or perception of relations and correlates - IT-2 and D-4S, and to assess the effectiveness of the serial processor, or symbolic reasoning, ALPHA-7 and G-SIN were selected.

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The researchers calculated the discriminant coefficient values, canonical correlation coefficients, percentage of the explained group variability, Bartlett`s chi-square test value, degrees of freedom, Wilks' Lambda values, and error probability in the rejection of the hypothesis that the actual canonical correlation value is equal to zero.

They also calculated the standardized coefficients of participation of the tests in the formation of significant discriminant functions, as well as the centroids of the groups on the significant discriminant functions.

The results of the discriminant analysis of cognitive variables show that athletes of different sports significantly differ from each other.

Through the condensation of variables in the cognitive space, two discriminant variables that maximally separated the groups of athletes on the basis of discriminant coefficients were isolated.

Analyzing Table 2 reveals that the first discriminant function separates the athletes on the basis of IT-2 which is, in the initial subject of measurement, aimed at assessing the effectiveness of spatial relations. This factor is actually subordinated to the mechanism responsible for determining relations between the elements of a structure and essential characteristics of such structures in solving those problems in which the determination and reconstruction processes are independent of the previously acquired amounts of information (mechanism for parallel processing).

Another factor that determines this function is CF-2 which, in the initial measurement, estimates convergent productions of figural transformations and it is subordinated to the mechanism responsible for receiving and processing information and solving those problems whose elements are given directly in the field of perception or representation. It is a mechanism known in cybernetics as an input processor.

Based on the value and sign of the projection of the centroid onto the first discriminant function, it can be concluded that track-and-field athletes have a better expressed factor of symbolic reasoning, i.e. they better understand verbal contents and it is not so important for them to solve those problems whose elements are given directly in the field of perception and representation, and their movement stereotypes are very important, that means they are heavily dependent on the previously acquired amounts of information. It is a sport where there is no need for solving complex motor tasks, but the result depends on the level of acquisition of the techniques and on other abilities, primarily motor and cardiovascular ones.

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Based on the value and sign of the centroids on the second

discriminant function, it can be concluded that basketball players have a better expressed ability for abstraction and generalization processes, as well as a better ability to receive and process information, which is understandable considering the complexity of the sport discipline and requirements it imposes on the athletes.

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