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THE RELATIONS BETWEEN THE MOTOR AND COGNITIVE ABILITIES OF ADOLESCENT FEMALES

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Abstract. *A battery of 21 motor skills tests and 3 cognitive skills tests was applied on a sample of 100 female participants, aged 18 ±6 months, with the aim of determining the existence of any statistically significant relations between the motor skills system of variables and cognitive abilities. The data were processed using the canonical correlation analysis. Between the system of motor variables and the system of cognitive variables, a single pair of canonical correlations was determined (Rc=.64). By using Bartlett's Chi-square test (□2), which was used to test the significance of the canonical correlation, it was confirmed that the canonical correlation is statistically significant at the p=.02 level. The results of the research have shown that adolescent females achieve better results for the motor variables used to evaluate movement structure, tonus regulation and synergetic regulation and the intensity of excitation if they also have increased values for the cognitive variable of efficiency of the perceptive processor (IT–1), the efficiency of the serial processor (AL–4) and the efficiency of the parallel processor (S–1). On the basis of the results obtained in this study, we can conclude that two-way connections exist between cognitive mechanisms and motor functioning. A factor obtained in such a manner is an indication that, in the case of adolescent females, the results of the motor skills tests undoubtedly depend on the interrelations between the input processor, that is, on the ability to receive and process information and solve those problems whose elements can be found in the field of perception, as well as on the ability which is formed during the process of acculturation. Nevertheless, cognitive factors are not solely responsible for success in a certain activity, as the overall influence of other anthropological dimensions is necessary as well.*

Key words: *adolescent females, the teaching process, motor and cognitive skills, interrelationship.*

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INTRODUCTION

The determination of the relations between motor skills and other segments of the anthropological status of adolescent females currently represents a heatedly debated practical and theoretical problem. Its significance is primarily reflected in the efficient monitoring of the development of the relevant anthropological characteristics, but also in the possibility of forming increasingly rational procedures in the technology of physical education and sports, the planning, programming and control of physical exercise (Popović, Stanković, Popović, Petković, & Stanković, 1987; Stanković & Popović 1988; Malacko & Popović, 2001; Stanković, 2001; Stanković, Malacko & Doder, 2009).

The cortex necessarily needs to be active during the process of learning a complex motor task, since the set task must first be understood. What is also included during the course of learning a motor task, through the system of reflexive connections (muscle receptors, kynesthetic receptors for joint movement and those which react to the increase in speed and changes in balance), is the regulation process. In the case of simple motor tasks, once the motor task becomes automatic, regulation is no longer necessary, only the managing process is needed. In the case of complex tasks, the regulation process plays a more important role which also includes cognitive functioning. The regulation process takes place on several levels, while the highest level is the one related to the cortex. When solving a certain motor task, three basic levels of inclusion of the cortex are included: 1) the minimal activity of the cortex in simple movements or motions, 2) partial activity of the cortex in the case of complex movements or motions and 3) the dominant activity of the cortex during the process of solving very complex motor tasks of a cognitive nature. For this reason, being familiar with the relations between motor and cognitive skills is very important (Popović, 1990).

The aim of this study was the precise determination of the relations between cognitive and motor skills on a sample of participants whose complete structures of the central nervous system were fully developed and were physiologically able to integrate the appropriate combinations of stimuli and reactions, which results in the proper, even above average, perception of complex motor tasks (Wolff, Gunnoe & Cohen, 1985; Largo, Fischer & Rousson, 2003; Stanković & Popović, 2009).

THE METHOD

The sample of participants

The study was carried out on a sample of 100 female participants, who were high school seniors. In addition to the above mentioned, the participants had to meet certain special requirements:

The age of the participants was defined on the basis of chronological age, so female participants aged 18 ±6 months were included in the study,

The female participants regularly attended their physical education classes, which was determined on the basis of the class attendance,

The participants did not have any form of somatic deformities and deviations, and were physically and mentally healthy.

In defining the population from which the sample was extracted, in addition to the above mentioned, no other limitations or stratification variables were used.

The sample of variables

A battery of 21 motor skills tests and 3 cognitive skills tests were used in the research. In order to evaluate the motor skills, we used the following motor variables (Gredelj, Metikoš, Hošek & Momirović, 1975) of the structuring of movement: 1. the three ball slalom (S3L); 2. hand tapping (TAR); 3. foot tapping (TAN); 4. foot tapping against a wall (TAZ), 5. the forward –backward bend (PZK); tonus regulation and synergic regulation: 6. standing on one foot (RZO); 7. balance on a low beam (ROK); 8. balance on a transverse beam (RPK); 9. Hyper-extensions (DPR); 10. darts (PIK); the regulation of excitation intensity: 11. the standing depth jump (SDM); 12. the 20m sprint with a high start (20V); 13. the high jump (VIS); 14. the triple jump (TRS); 15. throwing a medicine ball from a prone position (BML); the regulation of excitation duration: 16. dead hang pull-ups (VUZ); 17. push-ups on a bench (SKL); 18. 30s torso lifts (PTR3); 19. torso lifts until muscle exhaustion (PTR); 20. torso extensions (IST), 21. torso extensions on a vaulting box (ISTS).

In order to evaluate the cognitive skills from the battery of KOG3 (Wolf, Momirović & Džamonja, 1992), the following tests were used: to evaluate the efficiency of the perceptive processor: 1. IT-1; to evaluate the effectiveness of the parallel processor: 2. S-1; to evaluate the serial processor: 3. AL-4.

The statistical analysis of the data

In addition to the basic statistical parameters and the evaluation of their discriminant value for both groups of variables, in order to calculate the relations between the systems of basic motor skills and cognitive skills, a canonical correlation analysis was used. The testing of the statistical significance of the hypothesis regarding the global connection between two different anthropological systems of variables was carried out by means of: λ - statistically significant characteristic roots, Rc - the canonical correlation coefficient of the statistically significant pairs of canonical factors, Rc2 - the square of the canonical correlations, χ^2 – Bartlett's Chi-square test for the evaluation of canonical correlations and p – the statistical probability of the significance, calculated automatically.

The canonical correlation analysis, which is usually defined as the maximization of the correlation between the stochastic independent linear composites derived from two groups of variables, can also be defined as the maximization of the scalar products between two groups of orthogonalized, centered and normalized vectors, in other words, as the solution of an essentially geometric problem (Popović et al., 1987). Of course, it is extremely easy to show that all, or almost all the elementary statistical methods can be reduced to a very simple model of a canonical correlation analysis, for the very simple reason that these methods are only special cases of a general linear model, and therefore, special cases of a regression analysis. Nevertheless, a canonical correlation analysis is not, on its own, a statistical method (Popović, 1993). It can only become one if certain conditions have been met, one of which is the deciding factor that the variables from the sets B1 and B2 should have multivariate normal distributions in the population P with nonsingular covariance matrices. In that case the variables

$$\chi_p^2 = (n - 1/2(m_1 + m_2 + 3)\log_e \prod_p^n (1 - \rho_p^2)$$

have, if ρ^2_p, as the population value of a certain canonical correlation has a value of 0, an asymptotic χ^2 distribution with (m1-p)(m2-p) degrees of freedom. The identification of

the canonical variables on the basis of the coefficients in the vectors x1p and x2p is as a rule very difficult, as it is obvious that these coefficients, are in fact parallel projections of the vectors which are used to represent the canonical variables onto the coordinate systems defined by the vectors which are used to represent the variables from B1 and B2. For this reason, for the purpose of the identification of the significant canonical variables, the structural vectors of canonical factors are usually used, defined through the operations:

$$s_{1p} = Z_1^t k_{1p} = R_{11} x_{1p}$$
$$s_{2p} = Z_2^t k_{2p} = R_{22} x_{2p}$$

but at times the cross structural vectors are used as well, defined through the operations:

$$c_{1p} = Z_1^t k_{2p} = R_{12} x_{2p}$$
$$c_{2p} = Z_2^t k_{1p} = R_{21} x_{1p}$$

Of course, the coefficients in these vectors are the standard, non-extreme correlations, so that the variances of these elements, within the hypothesis that their population value equals 0, are of the order n-1. Even though, by definition, the variances of the canonical variables are equal to 1, their actual variances can be determined on the basis of the square forms of the matrices of the range 1, defined by the operations:

$$R_{11p} = s_{1p} s_{1p}^t$$
$$R_{22p} = s_{2p} s_{2p}^t$$

Obviously, these variances are actually the squares of the norms of the structural vectors, therefore:

$$\sigma_{1p} = s_{1p}^t s_{1p}$$
$$\sigma_{2p} = s_{2p}^t s_{2p}$$

In order to determine the importance of the canonical factors, for some obscure reasons, relative variances are most often selected, that is, variances σ^2_{1p} and σ^2_{2p} divided by m1, or m2. Nevertheless, by using the elementary hypotheses of the classic theory of measuring, it can easily be proven that the lowest limit of the generalizability of the canonical variables is:

$$\alpha_{1p} = 1 - \sigma_{2p}^{-2}$$
$$\alpha_{2p} = 1 - \sigma_{1p}^{-2}$$

and that these measurements are a more valid basis for the evaluation of the significance of the canonical factors (Bosnar, Prot & Momirović, 1984; Popović, 1993).

THE RESULTS

In the procedure used to determine the statistically significant relations, that is, in the process of obtaining the maximum correlation between the multivariate system of motor variables and the system of cognitive variables, a canonical correlation analysis was used, along with the parameters of the canonical correlation (Rc), the determinant coefficient (Rc^2), the Chi-

square test (χ^2) and its statistical significance (p). Using Bartlett's Chi-square test (χ^2=86.53) we tested the statistical significance of the canonical correlation coefficient (Rc=.64), which explains the linear combinations between the variables, that is, the connection between two different systems of variables (Table 1). By solving the characteristic equations of the cross-correlation matrix, we obtained, as the roots of those equations, the squares (the determinant coefficients) of the canonical correlation (Rc^2 =.41), which explain the common variance of the variables from the two groups from the overall variability of the analyzed system of variables.

Table 1. The canonical functions.

Rc	Rc^2	χ^2	p
.64	.41	86.53	.02*

Legend: Rc – the canonical correlation, Rc^2 – the square of the canonical correlation
χ^2 – Bartlett's Chi-square test, p – statistical significance

In the further data analysis procedure, a pair of statistically significant canonical factors were also identified (p=.02) on the one hand, in the system of motor variables, and on the other hand, in the system of cognitive variables.

Table 2. The canonical structure of the motor and cognitive variables.

Variable	Fc - 1
	Motor variable
S3L	.09
TAR	.03
TAN	.39*
TAZ	.54*
PZK	.34*
RZO	.06
ROK	.24*
RPK	.33*
DPR	.19
PIK	-.07
SDM	.26*
20V	.01
VIS	.22*
TRS	.05
BML	-.12
VUZ	.05
SKL	.01
PTR3	-.12
PTR	-.12
IST	-.18
ISTS	-.47*
	Cognitive variable
it-1	.81*
al-4	.71*
s-1	.43*

Legend: Fc - 1 = the first canonical factor

Based on the results contained within the matrix of the canonical structure of the motor and cognitive variables (Table 2) we were able to determine a statistically significant correlation between the motor variables and the first canonical factor. The isolated first canonical factor was defined with the relatively high values of the statistically significant canonical correlation coefficients. Considering that the structure of the first isolated canonical factor is made up of the variables TAZ - foot tapping against a wall (.54), ISTS – torso extensions on a vaulting box (-.47), TAN - foot tapping (.39), PZK - the forward-backward bend (.34), RPK - balance on a transverse beam (.33), SDM - the standing depth jump (.26), ROK - balance on a low beam (.24) and VIS - the high jump (.22), it is complex and could tentatively be defined as the canonical factor of the central regulation of movement and intensity of the excitation.

The same table also shows the matrix of the structure of the canonical factor of cognitive skills which indicates that there are very high correlations between the applied tests and the obtained canonical factor. Considering the fact that the isolated canonical factor presents all three cognitive variables IT–1 – used to evaluate the efficiency of the perceptive processor (.81), AL–4 – used to evaluate the efficiency of the serial processor (.71), S–1 – used to evaluate the efficiency of the parallel processor (.43) it can also be defined as the canonical factor of the general cognitive skills (G).

THE DISCUSSION

During the discussion on the relations between canonical factors from two different anthropological spaces, obtained by means of the canonical correlation analysis, we usually rely on the rule that for the linear increase in the value of the resulting vector of the variables of the canonical factor from the first space, there is a proportional linear increase in the value of the resulting vector of the variables of the canonical factor from the other space, under the condition that if the correlation between the two studied systems of variables in the different spaces is statistically significant. Furthermore, the same rule applies for the inverse direction of the relation: for the linear decrease of the values of the results for the canonical factor of the first space, a proportional linear decrease in the values of the results for the first canonical factor in the second space can be found (Stanković & Malacko, 2008).

A further line of inquiry on the relations between motor and cognitive skills could lie in the fact that approximately 40% of the axons in the motor neurons and muscle tissue practically represent sensory tissue which transfers impulses to the brain (Ismail, 1976; Bala, 1999). If we take into consideration the fact that muscle tissue makes up, in the case of an average man, half of his body weight, and in the case of athletes even more so, it is clear that muscles function, in addition to all else, to transfer information from the muscles to the central nervous system and the appropriate centers. Naturally, this is only one of the aspects of the possible line of reasoning on the relations between motor and cognitive dimensions, adapted to the subject matter of this research and the analyzed sample of participants.

The ability of people to note, understand, learn and reproduce certain complex movement structures primarily depends on their cognitive skills. Cognitive processes and cognitive functioning represent central mechanisms of cortical regulation. The central nervous system primarily has an integrative function, and thus enables the purposeful and

adaptable behavior of any human. What is of primary importance is the integration at the cortical level, since purposeful behavior is directly linked to integrated cortical function. Integration also exists at the subcortical level, but it is less flexible and enables reactions in standard situations, which demand automatic responses.

Within this particular study, the relations between the first canonical factor from the system of motor variables, interpreted as the canonical factor of the central regulation of movement and the intensity of the excitation, and the canonical factor from the system of cognitive variables, interpreted as the general factor of cognitive skills, indicate that adolescent females achieve good results in the structuring of movement, tonus regulation and excitation intensity if they have increased values of cognitive functioning and vice versa (Stanković & Popović, 2009). This is in accordance with the modified cybernetic model (Malacko & Fratrić, 1997), based on which the central cognitive processor (G), used for the analysis of information and the decision-making process, has the greatest influence on the regulator of the trajectory of movement and the synergic regulator and the tonus regulator to which it is doubly bound. It must be noted that the results of the torso extension on a vaulting box test were inversely proportional to proper cognitive functioning.

The ability that humans have to note, understand, learn and reproduce certain complex structures of movement primarily depends on their cognitive skills. Cognitive processes and cognitive functioning represent the central mechanisms of cortical regulation. The central nervous system primarily has an integrative function, and thus enables the purposeful and adaptable behavior of a person. It is of primary importance for the integration at the cortical level, as purposeful behavior is directly related to the integrated cortical function. Integration can also be found at the subcortical level, but it is less flexible and enables reacting in standard situations, which demand automatic responses (Bala, 1999; Popović & Simonović, 2008). The influence of cognitive regulative mechanisms on success in a certain activity has varying intensity, depending on the type of mechanism and type of activity, as well as on other anticipated and non-anticipated situations and circumstances, so that the achievement would be optimal, depending on the cognitive abilities, knowledge, movement structure and level of training (Kirkendall & Gruber, 1970; Popović, 1993; Wolf et al., 1992; Stanković & Malacko, 2008).

CONCLUSION

The study has justified the expectations stated at the outset, since on the basis of the obtained results, we can confirm the general assumption that in the case of female adolescents there are statistically significant relations between motor and cognitive skills. On the basis of the results obtained in this study, we can conclude that a two-way connection exists between cognitive mechanisms and motor functioning. A factor obtained in such a manner is an indication that, in the case of adolescent females, the results of motor skills tests undoubtedly depend on the interrelations between the input processor, that is, on the ability to receive and process information and solve those problems whose elements can be found in the field of perception, as well as on the ability which is formed during the process of acculturation. In addition, it is clear that motor activity is in the function of the central cognitive processor, which practically means that motor activity is actually an intellectual activity. This hypothesis could be corroborated by the behavioral thesis that the relations obtained in the study are the result of the fact that motor tasks are permeated

with certain cognitive factors. Also, there is the neuro-physiological thesis according to Ismail (1976), by which in the case of participants who score high results on motor and cognitive tasks, there is one physiological element which facilitates the performance of activities in both the first and second field, and vice versa. We could say, that all of the influences, including institutional-informal ones (those originating from the family) and those institutional and formal ones (those originating from education) have, ultimately, two possible outcomes: they either interfere with the "internal capacities" which would optimize achievement, or they inhibit it, which would reduce the capacities, that is, the potentials that a child possesses. High school aged children are exposed to very unpredictable changes in a psycho-somatic sense and it is necessary to view motivation for physical exercise as an integral part of their growth and development, precisely because of the high relations between motor and cognitive space. Nevertheless, cognitive factors are not solely responsible for success in a certain activity, as the overall influence of other anthropological dimensions is necessary as well.

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ODNOSI IZMEĐU MOTORIČKIH I KOGNITIVNIH SPOSOBNOSTI ADOLESCENTKINJA

Veroljub Stanković, Dragan Popović

Baterija koju je činio 21 test motoričkih sposobnosti 3 testa kognitivnih sposobnosti primenjena je na uzorku od 100 učesnica, starosti 18 ±6 meseci, sa ciljem određivanja postojanja statistički značajnih odnosa između sistema varijabli motoričkih sposobnosti i kognitivnih sposobnosti. Podaci su analizirani upotrebnom analize kanoničke korelacije. Između sistema motoričkih varijabli i sistema kognitivnih varijabli, jedan par kanoničke korelacije je utvrđen (Rc=.64). Upotrebom Bartlett's Chi-square testa (□2), koji smo koristili za utvrđivanje značajnosti kanoničke korelacije, potvrđeno je da je kanonička korelacija statistički značajna na p=.02 nivou. Rezultati istraživanja su pokazali da adolescentkinje postižu bolje rezultate motoričkih varijabli kojima se procenjuje struktura pokreta, regulacija tonusa i sinergijska regulacija i intenzitet eksitacije, ukoliko imaju povećane vrednosti kognitivne varijable efikasnosti perceptivnog procesora (IT–1), efikasnost serijalnog procesora (AL–4) i efikasnost paralelnog procesora (S–1). Na osnovu rezltata postignutih u ovom istraživanju, zaključujemo da postoji dvostruka veza između kognitivnih mehanizama i motoričkog funkcionisanja. Ovakav faktor je indikacija da, u slučaju adolescentkinja, rezultati testa motoričkih sposobnosti bez sumnje zavise od međusobnih odnosa između input procesora, odnosno, od sposobnosti da se prime i procesuiraju informacije i reše problemi čiji se elementi mogu uočiti u polju percepcije, kao i od sposobnosti koja se formira tokom procesa akulturacije. Ipak, kognitivni faktori nisu jedini odgovorni za upseh u nekoj aktivnosti, s obzirom na to da je ukupan uticaj drugih antropoloških dimenzija takođe neophodan.

Ključne reči: *adolescentkinje, process instrukcije, motoričke i kognitivne sposobnosti, međuodnos.*