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NEXUS BETWEEN THE MOTOR PERFORMANCE AND COGNITIVE ABILITIES OF PRE-SCHOOL GIRLS

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ABSTRACT

The main objective of the present study was to establish whether there are connections between the motor performance and cognitive abilities of pre-school girls. The sample of tested children included 138 girls, aged five. The psychological part of the testing was implemented with the test RAZKOL. The girls were tested with 28 tests for measuring motor abilities. The results show that there is a positive correlation between the motor performance and cognitive abilities. The motor variables that show the highest correlations with cognitive variable are those having the characteristics of movement coordination, speed of movement and explosive strength. The results confirm the arguments that it is reasonable to treat the anthropological dimensions as components of an integral and organized system.

Key words: motor performance, cognitive abilities, nexus, pre-school girls

NESSO TRA PRESTAZIONI MOTORIE ED ABILITÀ COGNITIVE DI BIMBE IN ETÀ PRESCOLARE

SINTESI

Lo scopo principale del presente studio è stato quello di stabilire eventuali nessi tra prestazioni motorie ed abilità cognitive in bimbe in età prescolare. Il campione considerato ha compreso 138 bimbe di 5 anni di età. La parte psicologica della verifica è stata eseguita con il test RAZKOL. Al fine di valutare le abilità motorie, le bimbe sono state sottoposte a 28 test. I risultati indicano che esistono correlazioni positive tra prestazioni motorie ed abilità cognitive. Le variabili motorie che hanno evidenziato maggiori correlazioni con le variabili cognitive sono quelle con caratteristiche di coordinazione del movimento, velocità del movimento e forza esplosiva. I risultati confermano l'ipotesi che nel bambino bisogna considerare le differenti dimensioni antropologiche come parti integranti di un sistema completo ed organizzato.

Parole chiave: capacità motorie, capacità cognitive, nesso, bimbe in età prescolare

INTRODUCTION

The functioning of the whole human psychosomatic system, as well as the individual dimensions of this system, is to a great extent connected with the relation between these dimensions.

The question has often been posed about the nature of the relationship between human motor performance and cognitive abilities. A more detailed analysis of this relationship is of particular importance with regard to children who are in the phase of dynamic development, since its results enable a better explanation of complex developmental processes. A better understanding of the laws of the motor development requires an exploration into motor dimensions and their relationship with other psychosomatic dimensions.

The main objective of the present study was to establish whether there are connections between the motor performance and cognitive abilities of pre-school girls and, in case it is established that they do exist, to analyse them in greater detail. The questions connected with samples of a similar age group have been treated by several researchers (e.g. Leithwood, 1971; Thomas & Chissom, 1972; Eggert & Schuck, 1978; Dickes, 1978; Zimmer, 1981; Madić, 1986; Clymer & Silva, 1988; Strel & Žagar, 1993; Krombholz, 1997; Planinšec, 2001), who have determined a positive correlation between motor and cognitive abilities. However, comparisons of their studies are almost impossible, as they use different samples of tested persons, battery of tests and data processing and offer different interpretations of the obtained results.

Researches established there are two groups of factors that are important for the connections between motor and cognitive abilities. When a motor task does not contain problem situations, the connection can be explained by the speed of the information flow in the nervous system (e.g. Mejovšek, 1977; Mohan & Bhatia 1989; Reed & Jensen, 1991; Vernon & Mori, 1992). On the other hand, when a motor task does present a problem, the connection can be explained by the cognitive activities during the solving of a motor problem (Mejovšek, 1977; Planinšec, 2001).

In our opinion, a relatively big problem with preschool children is posed by the implementation of testing, which causes more complications at this age than with older subjects. Pre-school children make a relatively great number of mistakes in the implementation of test tasks, which is particularly true of more demanding motor tasks. It can be concluded that certain problems connected with the implementation of test tasks by preschool children simply cannot be avoided, which has also been established by other authors (Pišot, 1997; Rajtmajer, 2000).

Researchers have found that there are significant gender-related differences with regard to motor abilities (Thomas & French, 1985; Rajtmajer, 1993; Rajtmajer & Pišot, 1999). In spite of the conclusions that there are no greater gender-related differences with regard to the relations between cognitive and psychomotor abilities (Carretta & Ree, 1996; Planinšec, 2001), it is necessary to carry out the study separately according to gender, particularly when the study involves young children. For this reason, the sample of the study presented below includes only girls.

METHODS

Tests were performed within the framework of the research project that has been in existence for several years as cooperation between the Faculty of Education and the Health Clinic of Maribor (Slovenia).

Participants

The sample comprised 138 girls, coming from northeast Slovenia. The average age of girls was exactly five. The selection of girls for the sample was random.

Cognitive test

The psychological part of the testing was implemented with the test RAZKOL (Praper, 1981) that has been standardized on the Slovenian population of preschool children. Test tasks are the following: drawing, matching of objects and geometric shapes, repetition of numbers, words and sentences, logical completion of sentences, the fulfilment of a sequence of commands, analogy of opposites, the recognition of the doer, the finding of differences, definition of usage, the understanding of numbers, and simple calculation. The exercises are adapted to different age periods and they increase according to the level of difficulty. During testing, different instruments were used. The test gives a global assessment of an individual's cognitive abilities, using verbal and non-verbal test tasks, while the results of the tests depend on the relation between the mental and chronological age of the individual.

Motor tests

28 tests were used for measuring the children's motor abilities (Rajtmajer & Proje, 1990), which have also been standardized on the Slovenian population and are appropriate for use on the chosen sample of tested girls. Motor tests belong to the following hypothetical dimensions: whole-body coordination (rolling the ball around the hoop, walking on rungs backwards, walking through hoops backwards, polygon backward, crawling under the bench, crawling with a ball, running after crawling), hand coordination (circulating the ball around the body, rolling the ball around the feet, leading the ball with two

hands in a standing position, building a tower from big foam rubber cubes, building with hollow cubes, building a tower from small wooden cubes), agility (stepping sideways, running with changing directions, running in a zigzag), explosive strength (standing long jump, standing triple jump, standing high jump), repetitive strength (stepping on a bench, sideways jumps, sideways jumps with hand support), speed of simple movements (hand tapping - two fields, foot tapping, hand tapping - 4 fields), balance (standing on a block longitudinally, standing on a block crosswise, standing on a vertical block). The girls carried out three repetitions of each motor test.

Procedure

The measurements of motor and cognitive abilities were always carried out in specially prepared rooms. The entire testing of one child did not exceed two hours. The measurements were carried out by qualified experts.

Statistics

The data was processed on PC with SPSS statistical program. Motor variables were treated in latent and manifest space. Factor analysis was used for establishing the latent space of motor dimensions. The determination of the number of important principal components was based on the Kaiser-Guttman criterion ($\lambda > 1$). The simpler definition of the structure of motor factors was based on the rotation of factors with the oblimin method. The relation between motor and cognitive variables was calculated using the method of multiple regression analysis. The system of predictors was represented by two groups of the motor variables: the first group contains the manifest variables, and the second group the latent factors. The criterion was in both cases represented by the result of the cognitive test.

RESULTS

The results show that there is a positive correlation between the motor and cognitive variables. In the first case (Tab. 1) there is a statistically significant correlation ($p = 0.00$) between the whole system of manifest motor variables and the cognitive variable. The coefficient of multiple correlation is quite high ($R = 0.58$). Between the motor and cognitive variables there is 33% of common variance ($R^2 = 0.33$). The individual motor variables which have a statistically significant correlation with the cognitive variable on the $p < 0.05$ level are the following: building with hollow cubes ($\beta = 0.270$), foot tapping ($\beta = 0.229$), standing triple jump ($\beta = 0.217$), running with changing directions ($\beta = 0.196$), running after crawling ($\beta = 0.184$), and walking on rungs backwards ($\beta = 0.171$).

Tab 1: Summary of regression analysis for manifest motor variables and cognitive variable (β – standardized coefficient of partial regression; p – the level of statistical significance; R – coefficient of multiple correlation; R^2 – coefficient of determination).

Tab. 1: Povzetek regresijske analize motoričnih in kognitivnih spremenljivk (β – standardiziran koeficient delne regresije; p – raven statistične pomembnosti; R – koeficient večkratne korelacije; R^2 – koeficient determinacije).

No.	Motor variable	β	p
1	Building a tower from big foam rubber cubes	.017	.8324
2	Standing on a block longitudinally	.084	.3424
3	Standing high jump	.025	.7433
4	Hand tapping - two fields	.039	.5790
5	Rolling the ball around the feet	-.002	.9709
6	Crawling with a ball	-.034	.6594
7	Running with changing directions	-.196	.0423*
8	Standing on a vertical block	-.035	.6524
9	Standing triple jump	.217	.0189*
10	Stepping on a bench	.071	.4346
11	Running after crawling	-.184	.0180*
12	Building with hollow cubes	-.270	.0004*
13	Sideways jumps	-.025	.8036
14	Walking on rungs backwards	.171	.0288*
15	Stepping sideways	.121	.2240
16	Leading the ball with two hands	-.101	.1879
17	Running in a zigzag	-.054	.4548
18	Crawling under the bench	.112	.1924
19	Standing on a block crosswise	.061	.5048
20	Sideways jumps with hand support	-.049	.6178
21	Walking through hoops backwards	.050	.6391
22	Rolling the ball around the hoop	-.009	.9027
23	Building a tower from small wooden cubes	-.102	.2163
24	Foot tapping	.229	.0055*
25	Hand tapping – 4 fields	.111	.2112
26	Circulating the ball around the body	-.150	.0797
27	Standing long jump	.008	.9272
28	Polygon backward	.007	.9488
	$R^2 = .335$, $R = .578$, $p = .0000$		

*$p \leq .05$

With the method of factor analysis, 8 motor factors were extracted. These factors are: speed of simple movements (Factor 1), balance (Factor 2), agility (Factor 3), speed of complex movements (Factor 4), explosive strength (Factor 5), eye-hand coordination (Factor 6), whole-body coordination (Factor 7), hand coordination (Factor 8). The obtained factors were used in the regression analysis. In this case (Tab. 2), there is a statistically significant correlation ($p = 0.00$) between the whole system of motor factors and the cognitive variable. The coefficient of multiple correlation is slightly lower ($R = 0.40$). There is 16% of common variance ($R^2 = 0.16$) between the motor factors and the cognitive variable. Among the motor variables, six factors have a statistically significant correlation with the cognitive variable on the $p < 0.05$ level: speed of simple movements (β = 0.239), speed of complex movements (β = 0.216), explosive strength (β = 0.207), eye-hand coordination (β = 0.180), whole-body coordination (β = 0.129), and hand coordination (β = 0.167).

Tab. 2: Summary of regression analysis for motor factors and cognitive variable (β – standardized coefficient of partial regression; p – the level of statistical significance; R – coefficient of multiple correlation; R^2 – coefficient of determination).
Tab. 2: Povzetek regresijske analize motoričnih faktorjev in kognitivne spremenljivke (β – standardiziran koeficient delne regresije; p – raven statistične pomembnosti; R – koeficient večkratne korelacije; R^2 – koeficient determinacije).

No.	Motor factor	β	p
1	Speed of simple movements	.239	.0016*
2	Balance	.063	.3523
3	Agility	.117	.0882
4	Speed of complex movements	-.216	.0018*
5	Explosive strength	.207	.0053*
6	Eye-hand coordination	-.180	.0114*
7	Whole-body coordination	-.129	.0501*
8	Hand coordination	-.167	.0208*
R^2 = .165, R = .407, p = .0001			

* $p \leq .05$

DISCUSSION

The results of both regression analyses show that the significant and highest correlation coefficients with the cognitive variable have the motor variables, in which the characteristics of movement coordination, the speed of movement and explosive strength are generally predominant. On the basis of the obtained results we can explain the connections between motor performance and cognitive abilities with different causes.

The connection between the coordination of movement and cognitive abilities has been established in preschool children by several researchers (Leithwood, 1971; Clymer & Silva, 1988; Pišot, 1999, 2000; Planinšec, 2001). An important part of the variance of coordination abilities is explained by the cognitive factors of dynamic visual processing, visuo-spatial processing, working memory, and partly processing speed (Tirre & Raouf, 1998). Coordinational complex movements (Variables: running with changing directions, building with hollow cubes, walking on rungs backwards, running after crawling; Factors: eye-hand coordination, whole-body coordination, hand coordination) require cognitive activity for the recognition and formation of an effective motor program on the basis of which movement tasks is implemented. And during the implementation of movement the motor program has to be adapted to different (intrinsic and extrinsic) feedback information. All this requires the integration of information and the integration of functions that are necessary for a successful processing of information, which in turn constitutes the basis of cognitive activity. The implementation of informationally complex movement tasks involves problem situations that have to be effectively solved, and this requires cognitive activity.

In the case where the predominant characteristic of motor variables is the speed of simple movements (Variable: foot tapping; Factor: speed of simple movements, speed of complex movements), the connection between motor and cognitive variables can be explained mainly by the general speed of the information flow in the nervous system, which enables a quick and effective communication among different areas of the central and peripheral nervous system and is very important for the efficacy of motor and cognitive processes. Our assumptions are somehow confirmed by the findings of Reed & Jensen (1991) and Vernon & Mori (1992), who established that there is a positive correlation between the measure of intelligence and the measure of nerve conduction velocity.

The connection between the variables of explosive strength (Variable: standing triple jump; Factor: explosive strength) and cognitive variables is somewhat surprising, and it can be ascribed to various factors. To the motor dimension of explosive strength belong the following tests: standing long jump, standing triple jump and vertical jump, *i.e.* tasks with predominant leg movement. These are obviously tasks that require, among other things, a complex structured motor action. In general, the children of this age probably do not have this kind of specific experience and such movements present a kind of problem situation to them. It should be noted that similar results were obtained by Madić (1986), who established that the connection of this kind is due to the ontogenetic development. Motor programs for leg are formed later than those for arm, which is why carrying out motor tasks in which leg movement is predominant requires high level of motor control. It seems that at the age of 5 the cognitive activities are probably important for complex leg movements as well. In addition to this, factor of explosive strength has a strong correlation with the factors of movement coordination and the speed of movement, which are also connected with cognitive abilities.

A comparison between the results of both regression analyses shows that the coefficient of the multiple correlation attains a higher value when the system of predictors is represented by manifest motor variables. This is perfectly logical, since the factor analysis accomplishes a reduction of data, which obviously has an important influence on the decrease of the level of correlation. On the other hand, we have established that out of 8 motor factors there are 6 of those that have statistically significant correlation coefficients with the cognitive variable. This can be explained by the fact that the motor factors present abilities with a wider range of activities, in which a greater number of different factors play an important role, including cognitive factors.

CONCLUSIONS

The results obtained on a sample of Slovenian preschool girls have confirmed the assumptions about the existence of a positive correlation between motor performance and cognitive abilities. The fact is that in the course of development, changes occur in individual human abilities as well as in the relation between them. In the future it will thus be necessary to establish how the relation between motor performance and cognitive abilities changes. This will require similar analyses with the same tests on samples differing according to age, and the same will be necessary for a sample of boys. The above results confirm the arguments that it is reasonable to treat all the anthropological dimensions as components of an integral and organized system.

POVEZANOST MED MOTORIČNO UČINKOVITOSTJO IN KOGNITIVNIMI SPOSOBNOSTMI PREDŠOLSKIH DEKLIC

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POVZETEK

Glavni namen raziskave je bil ugotoviti, ali obstaja povezanost med motoričnimi in kognitivnimi sposobnostmi pri deklicah v predšolskem obdobju. Vzorec je obsegal 138 deklic, starih natančno 5 let. Psihološki del meritev je bil opravljen s testom RAZKOL. Za oceno motoričnih sposobnosti je bilo uporabljenih osemindvajset testov. Relacije med motoričnimi in kognitivnimi spremenljivkami so bile izračunane z metodo multiple regresijske analize. Rezultati kažejo, da obstaja pozitivna povezanost med motoričnimi in kognitivnimi sposobnostmi. Motorične spremenljivke, ki kažejo najvišje korelacije s kognitivno spremenljivko, imajo značilnosti koordinacije gibanja, hitrosti gibanja in eksplozivne moči. Rezultati potrjujejo predvidevanja, da je pri otroku treba upoštevati različne antropološke dimenzije kot sestavne dele celovitega in organiziranega sistema.

Ključne besede: motorične sposobnosti, kognitivne sposobnosti, povezanost, predšolske deklice

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