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PERCEPTUAL-MOTOR ABILITIES AND PREREQUISITES OF ACADEMIC SKILLS²

This paper reports the results of the relation analysis between the development of perceptual-motor abilities and prerequisites of academic skills in typically developing younger school children. The sample consists of 1165 children of both genders, aged between 7.5 and 11, from urban, suburban and rural parts of Belgrade.

Motor abilities, perceptual abilities, sensory integration, and sensory-motor integration were defined as independent variables, while constructive praxis, auditory and visual memory, strategy formation, and language abilities were defined as dependent abilities.

ACADIA test, Ozeretski test, and Levine tests were used for the assessment of perceptual-motor, cognitive, and language abilities. The results clearly indicate the importance of perceptual-motor functions for the development of all the assessed abilities which are prerequisites of academic skills.

Key words: *perceptual-motor abilities, academic skills, cognitive abilities, language abilities*

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INTRODUCTION

In recent studies there is more and more evidence that a range of variations in the quality of psychosocial functioning in typically developing persons result from cumulative effect of the interaction between hereditary potential and the environment. Studies support the interrelation and interdependence of a number of factors in the development process, including both different abilities and organic and environmental factors (Diamond, 2007).

Genetic weaknesses can be alleviated by stimulating environmental influences, while undesirable environmental influences can be alleviated by protective genetic ones (Deater-Deckard, Cahil, 2006). Environmental factors largely determine the survival of neural connections, in a way that a lack of specific experience leads to elimination of synapses, while environmental stimulation leads to the formation of new ones, some of which become permanent. In this way, the brain adapts to the environment by processes of forming, eliminating, and strengthening synapses (Couperus, Nelson, 2006), which represents the basis of individual differences in different ranges of ability (Nelson, 2000). Environmental influence on the development of abilities is backed by a number of crosscultural studies, which indicate the difference in development dynamics of a range of motor, cognitive, and adaptive functions in different sociocultural milieus (Ruizi, Graupera, Gutiérrez, & Miyahara, 2003; Adolph & Berger, 2005; Vig & Sanders, 2007; Dixon, 2007). In some cultures different approaches and expectations are associated with different genders, and mastery of certain skills is stimulated accordingly (Dixon, 2007).

According to the results of MRI studies, there are clear parallels between the cerebral cortex maturation and cognitive development. Areas responsible for basic perceptual and motor functions develop first, followed by associative areas responsible for basic language and spatial abilities. Higher-order associative brain areas, which enable information integration and modulate basic processes of attention and language abilities, develop last (Gogtay et al., 2004). The first study to confirm the relation importance between motor and cognitive functions appeared at the beginning of the 20th century

(Walin, 1916). Most subsequent studies postulated that the quality of perceptual-motor abilities is an important determinant of cognitive development and potential for acquiring academic knowledge and skills. Maturation of perceptual-motor functions is closely related to maturation of higher functions (Munakata, Casey, & Diamond, 2004). Thus, their stimulation may have a positive effect on emotions and cognitive functions, which influences socialization and academic achievements (Serrien, Ivry, & Swinnen, 2007). Early perceptual-motor development plays an important role in emotional, social, cognitive, academic and adaptive development (Burns, O'Callaghan, McDonell, Rogers, 2004; Cummins, Piek, Dyck, 2005; Pataki, Spence, 2005; Murray et al., 2006; Astill, 2007; Piek, Dawson, Smith, Gasson, 2008; Bumin et al., 2008; Jasmin et al., 2009; Cairney, Veldhuizen, Szatmari, 2010).

Studies support the need for ipsative or profile analysis of abilities as an integral part of assessing children with suspected learning disabilities, with the aim to determine their strengths and weaknesses, as well as the causes of difficulties in some areas of academic achievements (Kaufman & Kaufman, 2004); Flanagan, Ortiz, Alfonso, Dynda, 2006).

Bearing in mind the importance of perceptual-motor abilities in all spheres of life, it is important to monitor them from early childhood, in order to detect and timely treat possible difficulties. In our country there is no unique methodological framework of early detection and treatment of children with disabilities. The instruments for assessing abilities in the field of special education are inhomogeneous, and most tests are not standardized. The aim of this research is to analyze the relation between the developmental level of perceptual-motor abilities and the abilities which are prerequisites of academic skills in typically developing younger school children, in order to identify the factors which determine child's strengths and weaknesses in the education process. We also wanted to point out the inevitability of consistent systemic solutions in the field of special education and rehabilitation, which would lead to defining an efficient detection and treatment program of developmental disabilities.

METHOD

Participants

The sample consists of 1165 children, aged between 7.5 and 11 (mean=8.85), of both genders (603 – 51.8% boys and 562 – 48.2% girls), from urban, suburban and rural parts of Belgrade. There are 344 (29.5%) 2nd grade children, 422 (36.2%) 3rd grade children, and 399 (34.2%) 4th grade children in the sample.

Instruments and procedures

Motor abilities (motor persistence, balance, and coordination), perceptual abilities (tactile-kinesthetic functions, auditory and visual discrimination), sensory integration (audiovisual integration), and sensory-motor integration (visuomotor coordination) were defined as independent variables, or factors. Constructive praxia (an indispensable factor of graphomotor abilities, necessary for writing, drawing and geometry), memory (visual and auditory, as a prerequisite of acquiring and accumulating knowledge), ability to form strategies in solving tasks (necessary for all ranges of academic abilities), and language abilities (concept formation, lexis, morphology and syntax) were selected from a multitude of abilities and skills which are considered important in acquiring academic skills.

Methods of formal and informal assessment were used to test the defined variables – ACADIA test of developmental abilities (Atkinson, Johnston, Lindsay, 1972), translated and adapted in Croatia in 1985 (Novosel, Marvin Cavor, 1985), and additionally adapted and standardized in Serbia (Gligorović et al., 2005), parts of Ozeretski Test (Bele Potočnik, 1976), and informal (clinical) assessment of motor persistence and tactile-kinesthetic functions. ACADIA test of developmental abilities consists of 13 subtests designed for the assessment of different abilities and skills necessary for successful mastery of academic skills in elementary school. It can be applied individually or in groups. Since speed is not important in this test, it can be adapted to the pace of each child.

Assessment of motor abilities

Motor persistence is tested by instructing a child to stand upright for 30 seconds, with arms and fingers outstretched in front of him, mouth open and eyes closed. The assessment is based on the ability to maintain the instructed position without vocalization or moving fingers, tongue and other body parts.

Balance and coordination are assessed by means of Ozeretski Test adapted to the child's age. Static and dynamic balance, and coordination are assessed.

Assessment of perceptual abilities

The assessment of tactile-kinesthetic functions was performed in the field of tactile gnosis and graphesthesia. Tactile gnosis involves recognizing objects by sense of touch, with eyes closed. This process includes exteroceptive sensibility and kinesthesia of hands and fingers (the experience of body parts position and movement in relation to body axis). A child is expected to identify given familiar objects by sense of touch with eyes closed. At assessing graphesthesia a child is expected to recognize shapes (letters, numbers, and geometric shapes) which the examiner "draws" on the child's skin, usually at the back of the hand.

Auditory discrimination was assessed by Subtest I of ACADIA test – *Auditory Discrimination*. It consists of 20 tasks which test the ability to distinguish mainly one syllable words and non-words which sound similar. One point is awarded for each correct answer. Visual discrimination was assessed by Subtest III of ACADIA test – *Visual Discrimination*. It consists of 20 tasks in which a child is expected to choose one out of four options based on a given model. The first part consists of drawings, while the second and the third part consist of words arranged from simple to more complex ones. One point is awarded for each correct answer. Sensory integration was assessed by Subtest VI of ACADIA test – *Audiovisual Association*. The Subtest consists of 3 parts. In the first part a child is expected to choose a picture that matches the sentence uttered by the examiner. In the second part a child is expected to recognize the word uttered by the

examiner out of four given words, and in the third part to match words with pictures whose pronunciation rhymes. It consists of 20 tasks. One point is awarded for each correct answer.

Assessment of integrative functions

Visuomotor integration was assessed by Subtest II of ACADIA test – *Visuomotor Coordination and Sequencing*. It consists of 10 tasks which test the ability to follow a marked path between different types of lines (concentric circle, square, triangle, etc.) and complete the shapes. A certain number of points is awarded for each task, counting mistakes, and the maximum number of points is 20.

The results of Subtests I, II, III and VI of ACADIA test were ranked according to age norms, and grouped into three categories: achievements which are age-appropriate (the average), achievements which departure by one standard deviation (1SD), and achievements which departure by two standard deviations (2SD) from the average achievements.

Assessment of abilities necessary for successful mastery of academic skills

Constructive praxia was assessed by Subtest IV of ACADIA test – *Shapes Drawing*. It includes 20 models which a child has to copy. One point is awarded for each correct answer.

Visual memory was assessed by Subtest V of ACADIA test – *Visual Memory*. After seeing the model, a child has to choose one of the given answers, or draw the appropriate shape. It consists of 10 tasks. Two points are awarded for each correctly completed task.

Auditory memory was assessed by Subtest VIII of ACADIA test – *Auditory Memory*. In the first part of the test a child has to memorize and write down numerous sequences of increasing number of stimuli. In the second part a child has to recognize a number and its place in a sequence (verbal working memory), and in the third part to memorize and write down as many words as possible in increasing sequences. It consists of 15 tasks, and assessment depends on their complexity. The maximum number of points is 20.

Strategy formation was assessed by Subtest VII of ACADIA test – *Sequence and Coding*. It consists of 20 tasks. In the first part a child is expected to choose a geometric shape, a number or a word that continues the given sequence, and in the second part to discover and apply the principle of forming words by decoding numbers into letters. One point is awarded for each correct answer.

Concept formation was assessed by Subtest IX of ACADIA test – *Concept Formation*. It consists of four sets of tasks the completion of which requires identifying, comparing, and naming characteristics, knowing concept relations, classifying and organizing lexemes into subordinate and superior classes. Drawings and verbal instructions are combined in the Subtest. It consists of 20 tasks. One point is awarded for each correct answer.

Lexical abilities were assessed by Subtest X of ACADIA test – *Acquired Language Treasure*. It consists of 20 tasks divided into three sets. In the first set of tasks a child is expected to recognize a picture or a written word orally presented by the examiner. In the second set of tasks a child is required to make a choice from a number of written words as instructed by the examiner. In the third set of tasks the participants confirms or denies the veracity of certain statements. One point is awarded for each correct answer.

Morphology and syntax were assessed by Subtest XI of ACADIA test – *Automatic Language Treasure*. It consists of 20 tasks in which the participants has to choose a word or a set of words to complete the sentence uttered by the examiner. One point is awarded for each correct answer.

Non-verbal reasoning was assessed by Subtest XII of ACADIA test – *Visual Association*. It consists of 10 tasks. In the first part of the test a child is expected to establish a functional relationship between the given model and one of the given options (e.g. ear and a receiver), and in the second part to reconstruct a whole from elements. Assessment depends on the complexity of tasks, and the maximum number of points is 20.

Drawing quality was assessed by Subtest XIII of ACADIA test – *Drawing*. A child is expected to draw a man standing under a tree, next to a house. Assessment depends on the accuracy of proportions,

the number of details, and correlation between the set elements. The maximum number of points is 20.

Data analyses

Central tendency measures (arithmetic mean) were used to present basic statistical indicators. One-way variance analysis (ANOVA) and Scheffe Post hoc Test were used to determine the relation significance between defined variables.

RESULTS

Previously published results of assessing motor abilities indicate the existence of difficulties in maintaining body posture in 26.2% of the participants. Balance difficulties are present in 30.1% and coordination problems in 27.7% of the children (Nikolić, Ilić Stošović, 2009).

The results of tactile kinesthetic sensibility assessment indicate high incidence of difficulties (54.1%). However, these difficulties occur symmetrically, and thus do not indicate neurological pathology. This supports predominant reliance on visual and auditory information processing, and neglecting tactile kinesthetic input. Below average results, i.e. the results which departure from age norms by one or two standard deviations (SD), are present in 182 (15.6%) of children on Auditory Discrimination Subtest, 128 (11%) of children on Visual Discrimination Subtest, 147 (12.6%) on Audiovisual Association Subtest, and 210 (18%) on Visuomotor Coordination and Sequencing Subtest. These results support the attitude that there is a significant presence of motor and perceptual difficulties in younger school children.

By assessing defined prerequisites of academic skills, developmental departures were observed on all the applied subtests, ranging from 135 (11.6%) participants on Acquired Language Treasure Subtest, 138 (11.8%) participants on Visual Association Subtest, 156 (13.4%) participants on Visual Memory Subtest, 178 (15.2%) on Drawing Subtest, 173 (14.8%)

on Concept Formation Subtest, 171 (14.7%) participants on Sequence and Coding Subtest, 186 (15.9%) on Automatic Language Treasure and Shapes Drawing subtests, to 204 (17.5%) participants on Auditory Memory Subtest.

Motor abilities and prerequisites of academic skills

Motor development is manifested in the ability to control movements, from first voluntary ones to complex forms of adaptive behavior. Gross motor skills, which involve movement of the whole body and/or large joints, develop first, followed by fine motor skills, which involve movements of hands and fingers (Adolph et al., 2003). Table 1 shows the relation between motor abilities and prerequisites of academic skills.

Table 1 – Motor abilities and prerequisites of academic skills (means score)

Motor abilities	SD	VM	SF	AM	CF	L	MS	NR	D	
MP	Neg.	12.49	17.48	14.33	10.38	13.90	16.24	14.88	15.05	14.27
	Pos.	13.83	17.88	15.30	11.38	14.61	17.24	16.19	16.44	15.04
	F(1)	24.181	4.817	21.076	21.639	13.166	30.335	23.346	35.095	16.267
	Sig.	0.000	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B	Neg	13.85	17.89	15.32	11.38	14.40	17.07	16.37	16.00	14.89
	Pos.	13.32	17.72	14.92	11.01	14.44	16.94	15.62	16.11	14.81
	F(1)	4.020	0.980	3.891	3.042	0.057	.538	8.924	0.263	0.150
	Sig.	0.045	0.322	0.049	0.081	0.812	0.463	0.004	0.608	0.699
C	Neg	11.07	16.98	13.73	9.71	13.12	15.97	13.67	14.69	14.18
	Im.	12.76	17.57	14.64	10.96	14.28	16.57	15.17	15.53	14.64
	Pos.	14.08	17.95	15.38	11.36	14.65	17.27	16.4	16.48	15.00
	F(2)	29.610	6.527	14.532	11.022	11.432	14.002	24.602	15.711	4.318
Sig.	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.014	

MP – motor persistence; B – balance; C – coordination; SD – shapes drawing; VM – visual memory; SF – strategy formation; AM – auditory memory; CF – concept formation; L – lexical abilities; MS – morpho-syntactic abilities; NR – non-verbal reasoning; D – drawing

Statistically significant relations were identified by variance analysis, between motor persistence and all assessed prerequisites of academic skills ($p < 0.000-0.028$). Children with difficulties in maintaining body postures achieve considerably poorer results on all subtests which assess the abilities necessary for successful mastery of academic skills (More details in Table 1). Statistically significant relation was identified between balance and shapes drawing ($p = 0.045$), strategy formation ($p = 0.049$), and morpho-syntactic abilities ($p = 0.004$) (More details in Table 1). Children with balance problems achieve better results in constructive praxia (shapes drawing), strategy formation, and morpho-syntactic abilities. It can be assumed that children with postural control difficulties, which may be the result of kinesthetic and vestibular stimuli integration deficit, rely on processing visual information. This is then manifested in tasks which require higher levels of visual analysis, such as Shapes Drawing Subtest, which assesses identification and reproduction of elements in space, rather than graphomotor expression. Sequence and Coding Subtest assesses the ability to manipulate formed concepts by means of tasks in which the participants are expected to find given elements in a group, and a key, i.e. strategy for solving tasks, for which a necessary prerequisite is visual analysis of the stimuli. In Automatic Language Treasure Subtest, which assesses morphology and syntax, the participants have to write a word or a group of words in the appropriate place in order to complete the sentence uttered by the examiner, which involves visual analysis of word position in a sentence.

This research assessed only kinesthetic sensibility of hands and fingers, important for the development of graphomotor abilities. A more detailed assessment of vestibular system and kinesthetic functions, and their relation with balance, is necessary to reach conclusions on the nature of the relation between balance and the abilities which are prerequisites of academic skills.

Statistically significant relations were identified between coordination and all assessed prerequisites of academic skills ($p < 0.000-0.014$) (More details in Table 1). Coordination involves rhythmically organized sequential and/or simultaneous use of both sides of the body, which can be divided into two categories – bimanual

coordination, and coordination of upper and lower extremities. Both coordination types depend on the quality of inter-hemispheric communication (Kennerley, Diedrichsen, Hazeltine, Semjen, Ivry, 2002; Brakke, Fragaszy, Simpson, Hoy, Cummins-Sebree, 2007; Muetzel, Collins, Mueller, Schiessel, Lim, Luciana, 2008). Significant developmental changes in coordination occur between the ages of 4 and 10 (Otte, Van Mier, 2006).

Post hoc analysis revealed homogeneity in arithmetic mean differences in the results of subtests Shapes Drawing, ($p=0.000-0.001$), Sequence and Coding ($p=0.000-0.050$), and Automatic Language Treasure ($p=0.00-0.050$), in children with poor, immature, and good coordination. Coordination quality is a significant discrimination parameter in the areas assessed by these subtests. Mean differences in the results of subtests Visual Memory and Drawing, in children with poor, immature, and good coordination, are significant between the groups of poor and good results ($p=0.004$). Coordination quality is manifested as a significant discrimination parameter of polarized categories (good-poor). Mean differences in the results of subtests Auditory Memory and Concept Formation, in children with poor, immature, and good coordination, are significant between the categories of poor and immature results ($p=0.003-0.004$), and poor and good results ($p<0.000$), while there are no significant differences between the categories of immature and good results. A group of children with poor results is clearly distinguished by such distribution of significance, while the results of children with immature and good coordination are homogenous. Mean differences in the results of Acquired Language Treasure Subtest in children with poor, immature, and good coordination, are not significant between the categories of poor and immature results, while statistical significance was identified between the categories of poor and good results ($p<0.000$), and immature and good results ($p<0.000$). A group of children with good results is clearly distinguished by such distribution of significance, while the results of children with immature and poor coordination are homogenous. The same relation was identified by analyzing mean differences in the results of Visual Association Subtest ($p<0.000$). This indicates that movement coordination difficulties, regardless of level, significantly correlate with lexical abilities and nonverbal reasoning.

Perceptual abilities and prerequisites of academic skills

Perception includes the ability to identify, coordinate, and organize information. Perceptual deficits can influence learning abilities, especially in early stages of education process (Kulp, Cline, Wheeler, Loraine, 2004). One should bear in mind that perception is the basis of the ability to differentiate, which is a prerequisite of establishing systems of series and classes as foundations of logical thinking. A child starts forming general categories and subcategories very early, based on object characteristics such as size, shape, color, consistency, etc. (Gligorović, 2010^b). Table 2 shows the relation between perceptual functions and the abilities which are prerequisites of academic skills.

Table 2 – Perceptual abilities and prerequisites of academic skills (means score)

Perc. abilities	SD	VM	SF	AM	CF	L	MS	NR	D	
S	Neg.	13.20	17.76	14.75	10.83	14.27	16.82	15.42	15.79	14.67
	Pos.	13.81	17.79	15.39	11.47	14.61	17.16	16.35	16.42	15.04
	F(1)	6.355	0.031	11.883	11.529	3.812	4.509	15.098	9.204	4.804
	Sig.	0.012	0.860	0.001	0.001	0.050	0.034	0.000	0.002	0.029
	2SD	11.44	16.82	13.46	10.35	12.41	15.20	14.21	14.22	14.14
	1SD	10.63	16.95	12.9	9.62	12.75	15.19	12.62	13.39	13.26
AD	Av.	13.94	17.93	15.39	11.34	14.77	17.31	16.31	16.5	15.05
	F(2)	42.365	11.601	40.780	15.211	44.817	48.410	45.832	49.697	20.261
	Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2SD	9.41	15.28	10.8	8.44	10.19	12.8	10.06	12.09	12.67
	1SD	10.57	16.04	12.84	9.72	11.57	14.93	12.22	13.32	13.74
VD	Av.	13.90	18.03	15.42	11.36	14.85	17.34	16.41	16.48	15.03
	F(2)	54.552	45.475	82.736	29.307	121.45	107.05	108.56	69.553	23.589
	Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

S – sensibility; AD – auditory discrimination; VD – visual discrimination;
 SD – shapes drawing; VM – visual memory SF – strategy formation;
 AM – auditory memory; CF – concept formation; L – lexical abilities;
 MS – morpho-syntactic abilities; NR – non-verbal reasoning; D – drawing

Statistically significant relations were identified by variance analysis, between tactile-kinesthetic sensibility and all prerequisites of academic skills ($p < 0.000-0.050$), except visual memory ($p = 0.860$).

Children with better sensibility achieve considerably better results on most subtests which assess the abilities necessary for successful mastery of academic skills (More details in Table 2). Tactile sensibility and kinesthesia are among the most significant sources of child's early experiences, which are the foundations of higher cognitive abilities. Regardless of the fact that so-called distance senses, sight and hearing, become dominant later on, statistically significant relation with almost all the parameters is not unexpected. Statistically significant relations were identified between auditory discrimination and all prerequisites of academic skills ($p < 0.000$) (More details in Table 2). Post Hoc analysis revealed considerable result differences on subtests: Shapes Drawing ($p < 0.000$), Sequence and Coding ($p < 0.000$), Auditory Memory ($p = 0.000-0.026$), Visual Association ($p < 0.000$), and Drawing ($p = 0.000-0.019$), in children whose results significantly departure from age norms, and children with average results on Auditory Discrimination Subtest. The results of these subtests indicate a certain mean difference in favor of the children whose results departure by one SD, in comparison with the children whose results departure by two SD. This can be explained by the fact that children with significant difficulties in auditory discrimination rely on visual information processing, while children with milder difficulties do not have a developed compensation mechanism, which is a significant practical implication. Significant differences between children whose results departure from age norms, and children with average results on Auditory Discrimination Subtest, also occur on subtests Visual Memory ($p = 0.001-0.003$), Concept Formation ($p < 0.000$), and Acquired Language Treasure ($p < 0.000$). Homogenous means of the results on Automatic Language Treasure Subtest occurs in groups of participants with different achievements in auditory discrimination ($p = 0.001-0.026$). The obtained results clearly indicate that even less conspicuous departure from developmental norms in auditory discrimination represent a significant failure factor in the areas which are prerequisites of academic skills.

Statistically significant relations were identified by variance analysis, between visual discrimination and all the abilities which are prerequisites of academic skills ($p < 0.000$) (More details in Table 2). Difficulties in visual discrimination hinder mental representation of

objects, which can influence a child's ability to consistently recognize objects, letters, numbers, symbols, words, or pictures. These difficulties are manifested in positioning elements in space, and determining that position with regard to other elements, which influences reading, writing, and mathematical skills.

Post Hoc analysis revealed considerable result differences on subtests Shapes Drawing ($p < 0.000$), Visual Memory ($p < 0.000$), Auditory Memory ($p < 0.000$), Concept Formation ($p < 0.000$), Visual Association ($p < 0.000$), and Drawing ($p = 0.000-0.001$), in children whose results significantly departure from age norms, and children with average results on Visual Discrimination Subtest. A group of children with average achievements is clearly distinguished by such distribution of significance, while the results of children whose results departure from age norms by one or two SD are homogenous. Homogenous mean of the results on subtests Sequence and Coding ($p = 0.000-0.001$), Acquired Language Treasure ($p < 0.000$), and Automatic Language Treasure ($p < 0.000$) occurs in groups of participants with different achievements in visual discrimination. Thus, this area may be considered a clear discrimination parameter in strategy formation, lexis, and syntax. The obtained results indicate that even less conspicuous departures from developmental norms in visual discrimination represent a significant failure factor in the areas which are prerequisites of academic skills.

Integrative functions and prerequisites of academic skills

The ability to integrate information of different sensory modalities is essential for gaining comprehensive experience of phenomena and activities around us. Sensory integration includes linking spatial and time aspects of stimuli of different sensory modalities, with the aim to interpret, connect and consolidate them. Learning process largely depends on sensory integration quality of different modal aspects of stimuli, which enables simultaneous perception and integration of shapes, consistency, sound, and objects, creating a unique sensory impression. Sensory integration, primarily integration of auditory and visual information, represents the foundation for forming, defining, and interpreting concepts. Disabilities in this area may

have a direct influence on the development of all academic skills (Gligorović, & Radić Šestić, 2010^o). Integration of perception and motor activity primarily refers to visuomotor and audiomotor integration. Visuomotor integration includes the ability to coordinate sight and motor activities. Difficulties in this area potentially interfere with all aspects of child's life: social, academic, sport, practical. Due to a lack of coordination between visual and motor ability, a child inadequately organizes movements and objects in space. Audiomotor integration includes coordination of motor activities with verbal or nonverbal auditory stimuli, such as melody, rhythm, etc. Table 3 shows the relation between integrative functions and the abilities which are prerequisites of academic skills.

Table 3 – Integrative functions and prerequisites of academic abilities (means score)

	Integr. functions	ShD	VM	SF	AM	CF	L	MS	NR	D
AVA	2SD	10.05	15.00	11.46	8.18	10.68	13.12	10.61	11.67	13.40
	1SD	11.73	16.64	13.52	10.11	12.72	15.58	14.07	14.86	14.13
	Av.	13.83	18.03	15.38	11.38	14.79	17.32	16.30	16.43	14.98
	F(2)	32.947	45.016	56.627	32.423	76.881	84.991	67.299	59.128	11.057
	Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
VMC	2SD	8.67	15.20	13.73	9.57	12.57	14.27	11.63	12.97	14.17
	1SD	11.48	17.13	14.22	10.19	13.7	16.32	14.56	15.59	14.07
	Av.	14.01	17.97	15.24	11.35	14.62	17.19	16.22	16.27	15.00
	F(2)	53.605	21.878	10.528	13.254	13.734	23.052	29.771	14.710	8.854
	Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

AVA – audiovisual integration; VMC – visuomotor coordination;
 VD –visual discrimination; ShD – shapes drawing; VM – visual memory;
 SF – strategy formation; AM – auditory memory; CF – concept formation;
 L – lexicas abilities; MS – morpho-syntactic abilities;
 NR – non-verbal reasoning; D – drawing

Statistically significant relations were identified by variance analysis, between audiovisual integration and all assessed prerequisites of academic skills ($p < 0.000$). Children with better audiovisual integration achieve considerably better results on most subtests which assess the abilities necessary for successful mastery of academic skills (More details in Table 3).

Post Hoc analysis revealed considerable result differences on subtests Shapes Drawing ($p < 0.000$) and Drawing ($p = 0.000-0.028$), in children whose results departure from age norms, and children with average results on Audiovisual Association Subtest. This indicates that sensory integration difficulties, regardless of level, significantly correlate with constructive abilities. Arithmetic mean differences of the results on subtests Visual Memory ($p = 0.000-0.001$), Sequence and Coding ($p < 0.000$), Auditory Memory ($p = 0.000-0.002$), Concept Formation ($p < 0.000$), Acquired Language Treasure ($p < 0.000$), Automatic Language Treasure ($p < 0.000$), and Visual Association ($p < 0.000$) are homogenous in groups of participants with different achievements in visual discrimination, which therefore may be considered a clear discrimination parameter in these areas.

Statistically significant relations were identified by variance analysis, between visuomotor coordination and all assessed prerequisites of academic skills ($p < 0.000$). Children with better visuomotor integration achieve considerably better results on most subtests which assess the abilities which are prerequisites of academic skills (More details in Table 3).

Post Hoc analysis revealed considerable result differences on subtests Shapes Drawing ($p < 0.000$), Auditory Memory ($p = 0.000-0.009$), Concept Formation ($p < 0.000$), Automatic Language Treasure ($p = 0.000-0.001$), and Drawing ($p = 0.000-0.003$), in children whose results departure from age norms, and children with average results on Visuomotor Coordination and Sequencing Subtest. This indicates that sensory integration difficulties, regardless of level, significantly correlate with the assessed abilities. Arithmetic mean differences of the results on subtests Sequence and Coding ($p = 0.000-0.031$), Acquired Language Treasure ($p < 0.000$), and Visual Association ($p = 0.000-0.050$) are homogenous in groups of participants with different achievements in visuomotor integration, which therefore may be considered a clear discrimination parameter in these areas.

DISCUSSION

Research results indicate a significant relation between perceptual-motor abilities and all assessed ranges of ability necessary for acquisition of academic skills. Children with difficulties in maintaining body postures achieve considerably poorer results on all subtests which assess the abilities which are prerequisites of academic skills. This finding indicates the possibility that the lack of inhibitory control, which is one of the basic mechanisms of executive functions, is a very important factor in achieving poorer results on all assessed prerequisites of academic skills. Inhibitory control is a term used for mechanisms of interference control, modulating or stopping activities in progress, which are a basis of a number of other cognitive functions and abilities, such as attention, working memory, cognition, planning, regulation of motivation and emotions (Brocki, Bohlin, 2004; Eisenberg, Smith, Sadovsky, Spinrad, 2004), theory of mind, and spatial competence (Carlson, Moses, 2001). The inhibition of motor activities mainly develops around the ages of 6-7, unlike the inhibition of linguistic, conceptual, and mnemonic stimuli, which have a longer developmental process (Welsh, 2002). Statistically significant relation was identified between difficulties in delayed response, as well as difficulties in predominant stimulus suppression (of the given model) and achievements, by examining the influence of motor aspect of inhibitory control on achievements in Art education in children with mild intellectual disabilities by means of Go no Go test (Gligorović, Buha Đurović, 2010^a). These findings indicate the need for further research of the relation between inhibitory control and all the abilities relevant for acquiring and implementing knowledge. By testing neural basis and inhibitory control development with Go/ no Go task and fMRI, it was noticed that the ability to inhibit interferential stimuli and activities develops together with the maturation of associative parts of the cortex (Brown et al., 2005; Durston et al., 2006). Social and cultural contexts can also be the potential factors in inhibitory control development. For example, it has been determined that preschool children in China master impulsivity control sooner than American children of the same age (Sabbagh, Xu, Carlson, Lee, 2006). One possible explanation is that societies whose system of values is based on Confucian philosophy and ethics, are less tolerant towards uncontrolled

behavior (Rubin et al., 2006). Our research includes children from urban, suburban, and rural parts of Belgrade. However, we did not analyze the potential influence of sub-cultural factors on motor persistence. The significance of relations between motor imperistence and the abilities which are prerequisites of academic skills indicates the need for a more extensive research in the development of inhibitory mechanisms in preschool and younger school children.

A significant relation was identified between coordination and the abilities which are prerequisites of academic skills. Coordination of motor activities is the result of a complex system of interaction among perceptual, motor, and cognitive abilities (especially executive functions responsible for motivation, planning, and activities control). Thus, a significant relation with all the assessed parameters of the abilities which are prerequisites of academic skills is expected. It is a known fact that difficulties in motor abilities, especially in coordination, influence a wide range of practical skills, social, cognitive, and language abilities. Other studies confirmed the predictive validity of trajectory motor skills in achievements on working memory tasks and information processing speed (Piek, Bradbury, Elsley, Tate, 2008). It is considered that 2-10% of children with difficulties in coordination have various language problems, which are manifested in speaking, reading, and writing (Rutter, 1978; Gaddes, 1985). Children with specific language disorders, identified by discrepancy criterion, have heterogeneous non-verbal potentials, and their abilities vary over time both in language and in non-verbal domains (Dockrell, Lindsay, Connelly, Mackie, 2007). The idea that conceptual knowledge is based on sensory-motor system, i.e. that perceptual and motor experiences represent the foundation of more complex cognitive functions, is not a new one. However, in the past few decades neuropsychological studies have been suggesting that perceptual and action features crucially determine semantic representation of objects and brain actions. Perceptual features are mapped in the sensory system, while action features are mapped in the motor system (Chao et al., 2000). In the context of language, this means that perception of words activates parts of brain related to perceptual (Goldberg, Perfetti, Schneider, 2006; Martin, 2007) and motor (Pulvermüller, 2005) experience, except the part responsible for semantic representation. For example,

if we hear or read the word “lemon”, sensory parts of the brain activate, which provide visual, tactile, gustatory (usually causing salivation), or olfactive reinforcement. Motor areas activate as well, which evoke lemon cutting, chewing, squeezing, etc. activities. However, this hypothesis can only be applied to concrete and not abstract concepts. In our study, language development was assessed by means of subtests which do not include abstract concepts or categories. Therefore, with regard to the above mentioned assumptions, a significant correlation between perceptual-motor and language abilities is understandable.

By analyzing arithmetic mean differences of subtests which assess prerequisites of academic skills in relation to perceptual and integrative abilities, it was noticed that the results are grouped into two large categories. In the first category, there are considerable result differences between children whose results departure from age norms (by one or two SD), and children with average results on subtests. This indicates the effect of perceptual and/or integrative difficulties in those areas, regardless of their level. The second category consists of homogenous arithmetic mean differences in results, which distinguishes children whose results departure by one SD, two SD, and children whose results are age appropriate. On all mentioned subtests, the results of assessing abilities which are prerequisites of acquiring and implementing knowledge in children with small departure (1SD) are significantly different from the results of children with average results. The noticed grouping of the results which departure by one and two SD from age norms supports relativisation of discrepancy concept. All the children in the sample are of typical intellectual abilities (which was determined by means of standardized intelligence tests). Thus, difficulties that are present in the group of children whose results departure by one SD cannot be explained by lower general cognitive potential. By using the discrepancy criterion, departures by two or more SD in one or more areas, milder difficulties are ignored, and they can evidently result in severe problems in the range of abilities which are prerequisites of academic skills. This result supports critical views towards the discrepancy model (e.g. Fuchs et al., 2006; Hallahan et al., 2007; Fuchs et al., 2008). The obtained results lead to the conclusion that even though certain limitations are attributed to the Response to Intervention (RTI) model (Kavale et

al., 2008; McKenzie, 2010), replacing the concept of unexpectedly low achievements with the parameter of low achievements provides far more possibilities for detection and timely intervention in children with developmental difficulties.

CONCLUSION

This research showed that difficulties in perceptual-motor abilities appear in a significant number of typically developing, younger school children from Belgrade. Results clearly indicate the importance of perceptual-motor functions in the development of the abilities which are prerequisites of academic skills. Since this paper analyzes the relation between perceptual-motor abilities and the abilities which are prerequisites of academic skills, a guideline for further research is the relation between perceptual-motor abilities and basic academic skills – reading, writing, and mathematical skills, academic achievements and the quality of socialization in younger school children. The observed developmental departures in perceptual abilities (11%-16%) raise the question of the relation between functionally different aspects of information processing in children with difficulties in this area. By applying the Sequential Processing Scale and Simultaneous Processing Scale, which belong to the Kaufman Assessment Battery for Children (KABC II), in children with mild intellectual disability, it was determined that they achieve better results in simultaneous than in sequential information processing. Thus, simultaneous processes, especially visual and visuomotor integration, can be regarded as a sphere of potentials, which could be a significant support in the education process (Gligorović, & Radić Šestić, 2010^d). This represents a stimulus for further research on the specifics of cognitive information processing in children with various difficulties in perceptual development.

Results of our study indicates the necessity of timely detection and intervention. When younger school children with difficulties in perceptual-motor development are concerned, practical implications are primarily related to treatment modalities. We believe that the prevention model which is conceptually most acceptable is the one in which a child is included in secondary prevention program if he/

she cannot cope with standard education program. If that secondary prevention program is also inappropriate, then he/she is included in tertiary prevention, which means developing individual education program (Fuchs et al., 2008). Our concept of secondary prevention includes special education intervention aimed at the overall life situation of the child. Specificity of the approach is conditioned by the aspect of expressing perceptual-motor development difficulties, general cognitive abilities, and developmental characteristics of each child (Gligorović, 2009).

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PERCEPTIVNO-MOTORIČKE SPOSOBNOSTI I PREDUSLOVI ZA RAZVOJ AKADEMSKIH VEŠTINA

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Sažetak

U ovom radu prikazani su rezultati analize odnosa između nivoa razvoja perceptivno-motoričkih sposobnosti i preduslova za usvajanje akademskih veština kod dece mlađeg školskog uzrasta tipične populacije. Uzorkom je obuhvaćeno 1165 dece iz urbanih, suburbanih i ruralnih delova Beograda, oba pola, uzrasta 7.5-11 godina.

Kao nezavisne varijable definisane su motoričke sposobnosti, perceptivne sposobnosti, senzorna integracija i senzomotorička integracija, a kao zavisne varijable konstruktivna praksija, auditivno i vizuelno pamćenje, sposobnost stvaranja strategije i jezičke sposobnosti.

Za procenu perceptivno-motoričkih, kognitivnih i jezičkih sposobnosti korišćeni su ACADIA test, Motorički test Ozeretskog i neformalno ispitivanje. Rezultati nedvosmisleno ukazuju na značaj perceptivno-motoričkih funkcija za razvoj svih procenjenih sposobnosti koje su preduslov usvajanja akademskih veština.

Ključne reči: perceptivno-motoričke sposobnosti, akademske veštine, kognitivne sposobnosti, jezičke sposobnosti.

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