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COHERENCE AMONG CHILDREN'S VERBAL, MATHEMATICAL, NON-VERBAL AND MOTOR SKILLS

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Abstract

The aim of the research is to explore the relationship between the level of cognitive abilities and motor skills of children in younger school age. The research group consisted of 150 children (boys 77, girls 73) from the 1st stage of primary schools in the Czech Republic with an average age of 9.35 ± 0.61 years. The MABC-2 (Movement Assessment Battery for Children-2) test battery was chosen to determine the level of motor skills in children. Cognitive abilities with a focus on verbal, quantitative component and fluid intelligence were monitored through the Cognitive Ability Test (CAT). The research was assessed and approved by the Ethics Committee of the Faculty of Education, Palacký University in Olomouc. Data were obtained within the project IGA_PdF_2021_017. The obtained data indicate the relationship between some components of the motor skills level and the observed components of cognitive abilities ($p \leq 0.05$). A closer examination of the issue can help in the specific development of interventions in the field of motor skills in order to support the cognitive functions of the child.

Keywords: Children, cognitive skills, motor skills, primary school

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1. Introduction

Movement is an irreplaceable part of reproduction, maintenance and development of life. It cannot be seen just in sense of locomotion, nor like the movement of muscles, but it also contains thoughts, emotions and moods. It includes not only psychological or psychophysiological aspects, but is a force that motivates the cohesion of human society. Movement harmoniously connects the physical, mental and spiritual components, even in individual form and individual relations to the surrounding world. Movement also belongs to the basic means of expression of humans; it is the primary form of human communication. In the initial stages of ontogenesis primary motor skills are the building blocks for more complex motor skills. In addition, they represent a part of the competencies necessary for participation in various forms of children's activities and thus contribute to the process of integration of individuals into the school group (Cadoret et al., 2018; Liu-Ambrose & Best, 2017; Payne & Isaacs, 2011; Sgró et al., 2013;). Of the important cognitive processes closely linked to the development of thinking, it is possible to mention verbal development. Along with the development of thinking, it is significantly enriched in this period. Verbal development is a cognitive process that is one of basic predictor of a successful process of learning, socialization and overall functioning in the society (Šimíčková-Čížková, 2010; Thorová, 2015; Vágnerová, 2007). Wider vocabulary enables and increases the quality of communication with peers, enables friendships and has a positive effect on common interests. It shows a new way and possibility in resolving children's disputes and conflicts. Motor skills also enable personal growth and balanced development of the physical, cognitive, emotional and social components, and are an indispensable means of promoting health and preventing diseases - both physical and mental (Bailey, 2006; Colella & Morano, 2011). According to U.S. Department of Health (2011) more than 16 million people in the United States live with cognitive impairments. These are mainly problems associated with Alzheimer's dementia. The number of people living with cognitive disabilities is expected to rise up dramatically in the future. Cognitive functions are mental processes that allow to receive, select, store, transform, develop and renew information. These processes make it possible to understand the world more effectively. They relate to the mechanisms by which an individual learns, remembers, solves problems, shifts attention, etc. (Ackerman & Friedman-Krauss, 2017; Klucká & Volfová, 2016).

All cognitive processes and their development are especially important in the school environment. Their growth, or rather development, is greatly influenced by school activities. According to Piaget and Inhelder (2014), at the beginning of this period, the child enters the stage of concrete logical operations (period of concrete operations), which means that he can think logically and respect the properties of known reality. At this time, the child is already realistic and able to think about what he or she knows. A child in younger school age already better understands causal relationships, can classify objects according to criteria, understand the conservation of quantity, etc. Langmeier and Krejčířová (2006) states that thought operations are dependent on learning, and their development can be encouraged and accelerated using an appropriate approach (Fuhs et al., 2015; Langmeier & Krejčířová, 2006; Pugnerová & Kvintová 2019). In children, executive functions help maintain attention, self-control, and promote required behavior (Cuevas et al., 2012; Garon et al., 2008; Ursache & Noble, 2016). Stenfors (2013), Zelazo et al. (2016) and others confirm that cognitive functions are also important for later work management and the organization of life in general. However, subjective cognitive complaints (SCC), which include difficulty concentrating,

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memory, decision-making and thinking, are common in the working population in general and can be associated with reduced well-being as well as work ability or ontogenetically earlier in school success. Research aimed on importance of motor levels in relation to brain function support and academic performance has grown significantly over the past decade (Haapala et al., 2019; MacDonald et al., 2018). Rudd et al. (2017) emphasize the importance of manipulation skills in supporting children's sensory skills, which are related to the fulfilment of school obligations and the improvement of the child's learning outcomes. The effects poor motor skills on a child's success in meeting compulsory schooling is currently an issue. Based on some articles (Akshoomoff et al., 2018; Gärtner, et al., 2021; Rose, et al., 2012), which include in executive functions attention, processing speed, memory, working memory, inhibition, and shifting, we use this term synonymously to term cognitive abilities or skills, which includes fluid intelligence and abilities embedded in multiple overlapping theories of cognition (Alekseeva, 2021; Schneider & McGrew, 2018).

2. Problem Statement

Research studies published so far show that advanced motor skills can be a stimulator in the development of executive functions and cognitive abilities (Haapala et al., 2019; Gashaj et al., 2019; Schmidt et al., 2017). Influencing the level of motor skills can be most easily realized in the youngest age categories - in preschool and younger school age. In the child's pre-school period, specific support for motor skills is related to preparation for compulsory school education (school maturity and school readiness). At a younger school age, then with the development of the quality of neuromuscular coordination through the acquisition more complex movement skills. Therefore, it is necessary to obtain further information through researches on the spectrum of relationships between cognitive abilities, executive functions and motor skills of children and the possibilities of mutual interaction of these factors through aimed interventions.

3. Research Questions

The following research questions were solved within the research:

- In which of the monitored cognitive areas (verbal, nonverbal and mathematical skills) is the higher level of motor skills projected the most?
- Will there be a greater degree of coherence of cognitive skills (verbal, nonverbal and mathematical) with the level of fine or gross motor skills?
- Will there be significant gender differences in cognitive abilities or in motor skills?

4. Purpose of the Study

The aim of the research is a description of the relationships and assessment of coherence between the level of motor skills and components of cognitive abilities (verbal, nonverbal and mathematical skills) in younger school age children.

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5. Research Methods

The research group consisted of 150 children (boys 77, girls 73) with an average age of 9.35 ± 0.61 years (girls 9.51 ± 0.75, boys 9.20 ± 0.40) from primary schools in the Czech Republic. Children were included in the research group on the basis of the consent of their legal representatives, and also on the basis of the consent of primary school management with testing on their premises, in compliance with the legislative criteria applicable to education in public schools. None of the children met the criteria for obesity, nor had a disability or other special educational needs. The level of motor skills was monitored by MABC-2 (Movement Assessment Battery for Children-2) test battery (Henderson et al., 2007; Czech version by Psotta, 2014). The evaluation of an individual's motor skills is based on the assumption that its quality is expressed by the final performance / execution of specific movement skills and levels of technical execution of sensorimotor tasks. The components of motor competence are represented by manual skills, which express the level of fine motor skills, skills in the field of gross motor skills and skills expressing the level of balance. Manual skills subtests include: pin placement (MD 1), lacing (MD 2), and drawing the path (MD 3). Gross motor skills include: catching the ball with both hands (AC 1) and throwing a small bean bag on the mat (AC 2). Subtests focused on balance are: standing one-legged on a balance board on a preferred and then on a non-preferred leg (BAL1), walking forward along the line “heel to toe” (BAL2) and jumping one-legged on pads on a preferred and non-preferred leg (BAL3). Partial results in individual subtests are expressed in accordance with the MABC-2 Examiner’s Manual (Henderson et al., 2007) as total scores (hereinafter CTS) and these are further converted to standard scores (hereinafter SS). Standard scores subsequently expressed by percentile are interpreted as the percentile equivalent, where values typical of the population are above the 15th percentile, the risk of motor problems is expressed by the 6th - 15th percentile, and diagnosed motor problems are 5th and lower percentiles. New Czech standards with standard and percentile values are available in the Czech Republic (Psotta, 2014).

The Cognitive Ability Test (CAT) (Thorndike et al., 1986; Czech version by Vonkomer & Jílek, 1997) was used to determine of cognitive skills level. The test is designed for children from 7.6 to 15.9 years of age and allows the assessment of an individual's ability to use abstract and symbolic relationships and manipulate them. The level of cognitive abilities of a child is expressed by a summary of performances in the areas: verbal, quantitative and non-verbal (so-called fluid intelligence). The verbal area includes the vocabulary (hereinafter S1), the ability to complete sentences (hereinafter S2), the ability to classify concepts (hereinafter S3) and the concepts analogy (hereinafter S4). Mathematical skills are monitored through subtests: solving numerical relations (hereinafter P1), creating numerical series (hereinafter P2) and solving equations (hereinafter P3). The individual tasks are also expressed by pictures, so the solution does not require high fluency in reading. The ability to understand quantitative symbols together with verbal expression reflects academic abilities. The third area - nonverbal skills are assessed based on the results of three subtests: classification of images (hereinafter O1), analogy of images (hereinafter O2) and synthesis of images (hereinafter O3). Individual items do not contain words or numbers, but use only geometric shapes. Images are not related to school environment, rather to the manipulation with images and the creation of relationships between image symbols and structures. Success in this sub-battery can express potential that has no application in school education, but we can find a positive effect more in the everyday life of an individual, outside of school. The result in each of the sub-test batteries is a rough score (hereafter

HS), which is the number of correct answers. A maximum of 100 points of HS can be obtained in the verbal area, the risk level is 20. In the mathematical area, a maximum of 60 can be obtained, the risk level is 15. In the non-verbal area, the maximum of correct answers is 80, the risk level is 24. The gross score thus obtained is converted into a standard age score (hereinafter SVS) with respect to the child's age, to the percentiles or to statins. The standard age score higher than 126 is rated as very high, in the range 111-125 as an above-average score, in the 89-110 as an average score, in the 81-88 as a below-average score, and less than 72 is classified as a very low score.

The consignment of management of each primary schools was obtained for the implementation in the research. Compliance with the valid legislation for compulsory basic education (the so-called Framework Educational Program for Basic Education, 2021) as amended was guaranteed. The legal representatives of the children were informed about the aim and process of the research and the anonymity of the obtained data were guaranteed. In the case of their written consent, the child was included in the research. Participation in the research was voluntary and free of charge. During the research, children's questions were answered, in case of negative reactions they could withdraw from the research at any time. The relationships among the observed variables, the subcategories of cognitive abilities and the subtests of the motor levels were evaluated by correlation analysis, as well as the relationship between the total CAT score and the total MABC-2 score. HS was used to analyze the effect of age factor on performance in both motor test and verbal skills. Gender specificity was assessed by t-test. Results were obtained within the project IGA_PdF_2021_017. The research was approved by the Ethics Committee of the Faculty of Education of Palacký University in Olomouc, i.e. the workplace of the authors of the article.

6. Findings and Discussion

In the field of motor skills, none of the children was evaluated as an individual with motor difficulties. The research group reached a standard score of 9.68 ± 3.49 in the MD 1 subtest, 11.31 ± 3.91 in the MD 2 subtest and 8.61 ± 2.53 in the MD 3 subtest. The average SS in the field of fine motor skills shows a value of 9.93 ± 3.24, which corresponds to the 37th percentile - children without motor difficulties (diagnostic interpretation: 1st range - no motor difficulties). In the subtest of catching the ball with both hands (AC 1) the standard score was 9.99 ± 2.58 and for the targeted throw of a small bean bag on the mat (AC 2) 8.81 ± 2.89. Throwing and catching is one of the fundamental movement skills that is used in primary schools in a number of movement games and, of course, in sports games (basketball, handball, football, etc.). Their training is part of the educational plans of the educational subject of physical education from the 1st year of compulsory school education. The target throw is used minimally in school physical education in the Czech Republic, the placement of objects (without throwing) is used more. The average standard score for object control skills achieved by the research group was 9.93 ± 3.24, which corresponds to the 37th percentile (diagnostic interpretation: 1st range - no motor difficulties). In the balance subtests, the average value of the standard score for standing one-legged on a balance board (BAL1) was 8.96 ± 2.37, walking forward along a line “heel to toe” (BAL 2) 9.51 ± 1.69 and for jumping on a mat (BAL3) 9.91 ± 0.81 (Table 1). Here the values were already close to the 50th percentile (diagnostic interpretation: 1st range - no motor difficulties). Balance exercises are a part of the so-called basic gymnastics, which has a long tradition in school educational programs of basic school education and in the Czech Republic is the

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basis for the acquisition of other, more complex movement skills. The total score achieved by the research group in the MABC-2 test battery was 77.23 ± 10.34, which corresponds to the 50th percentile of the population.

Table 1. Gender differences between girls and boys in MABC-2 (n=150, nb=77, ng=73)

MABC-2 categories	Boys		Girls	
	Means	Standard deviation	Means	Standard deviation
MD1 (pref.)	9.50	3.63	9.88	3.35
MD1 (nonpref.)	8.60	4.26	9.40	4.15
MD2	11.57	4.01	11.03	3.82
MD3	8.92	2.34	8.29	2.69
AC1	10.22	2.16	9.74	2.99
AC2	9.16	2.97	8.45	2.76
BAL1 (pref.)	8.71	2.42	8.95	2.19
BAL1 (nopref.)	8.58	2.48	9.35 *	2.20
BAL2	9.28	1.99	9.74	1.27
BAL3 (pref.)	9.91	0.80	9.90	0.81
BAL3 (nonpref.)	10.13	1.95	9.95	2.09
ManD	10.13	3.28	9.72	3.20
AC	9.70	2.34	8.91	2.75
BAL	9.43	2.45	9.97	2.21
MABC-2	9.64	2.85	9.26	2.59

Legende: MD1 (pref.)… Placement of pins by preferred hand; MD1 (nonpref.)… Placement of pins by non-preferred hand; MD2… lacing; MD3… drawing the path; AC1… catching the ball with both hands; AC2… targeted throw of a small bean bag on the mat; BAL1 (pref.)… Stand one-legged on the preferred leg on the balance board; BAL1 (nonpref.)… One-legged stand on a non-preferred leg on a balance board; BAL2… walking forward along the line "heel to toe"; BAL3 (pref.)… Single-legged jumps on the preferred leg on pads; BAL3 (nonpref.)… Single-legged jumps on a non-preferred leg on pads; ManD… total fine motor score; AC… overall handling skills score; BAL… overall balance skills score; MABC-2… total score of the MABC-2 test battery.

In case of gender differences in motor skills was only one significant difference. T-test revealed significant difference in one-legged stand on a non-preferred leg on a balance board (p = 0,05; t = 0,01) between genders, where girls performed better (Table 1). Other differences were not significant.

In the field of verbal cognitive skills, the research group reached an average SVS of 105.03 ± 10.74. The most successful were children in the ability to complete sentences (20.40 ± 3.34) and in the area of vocabulary (18.33 ± 4.72). The most problematic seems to be the ability of verbal analogy (14.96 ± 4.24), as well as the classification of terms (16.98 ± 3.38). In all four areas of verbal skills, the monitored children achieved only the level of a very low score, i.e. the risk area. The problem of communication can be secondarily reflected in activities in everyday life, limiting academic and social activities (Case-Smith & O'Brien, 2015; Mancini et al., 2016). Developing academic skills and cognitive abilities is critical for children's development (Peng & Kievit, 2020). This can subsequently affect self-esteem, self-concept, higher anxiety, and can lead to social isolation. The opposite problem can be aggressive behavior and the resolution of conflicts by physical violence.

In the numerical sub-battery children scored in average 102.59 ± 12.77 SVS, which corresponds to the average level. In solving numerical relations, the monitored children were successful (18.19 ± 2.96), but in terms of SVS they achieved only a below-average result. In the areas of numerical series formation

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(15.48 ± 3.60) and solving equation (10.61 ± 3.23), the SVS results were also classified as below-average to very low scores, but they reached risk areas only in equation solving. In the nonverbal sub-battery, a very low score was found in the classification of images (20.39 ± 3.28) and the analogy of images (19.98 ± 6.22). The relatively best result was achieved in the synthesis of images (24.28 ± 4.61), but even this result is classified in the context of the age of children in the category of very low scores. Fluid intelligence, which is expressed by this component is relatively independent on learning and cultural environment, is rather genetically conditioned (Araujo et al., 2014).

Table 2. Gender differences between girls and boys in CAT (n=150, nb=77, ng=73)

CAT subtest	Boys		Girls	
	Means	Standard deviation	Means	Standard deviation
S1	19.23 *	3.00	17.37	5.90
S2	19.69	4.04	21.15 *	2.18
S3	16.73	3.03	17.24	3.73
S4	14.87	3.55	15.06	4.90
P1	17.65	2.75	18.77 *	3.08
P2	15.75	3.17	15.19	4.01
P3	11.30 *	2.71	9.88	3.57
O1	20.66	2.60	20.11	3.86
O2	21.03 *	4.81	18.89	7.30
O3	24.01	4.50	24.56	4.73
SVSs	105.60	9.72	104.44	11.76
SVSp	105.51 *	8.94	99.51	15.32
SVSo	100.64	9.80	98.85	13.63

Legende: S1…vocabulary subtest; S2…completing sentences subtest; S3…classification of terms subtest; S4…concepts analogy subtest; P1…numerical relations subtest; P2…numerical series subtest; P3…equitation solving subtest; O1…classification of images; O2… images analogy; O3…synthesis of images; SVSs…Standard age score from verbal subtests; SVSp… Standard age score from numerical (quantitative) subtests; SVSo… Standard age score from non-verbal (fluid intelligence) subtests.

In case of gender differences in cognitive abilities there were found more significant differences in comparison with motor skills (Table 2). In the verbal sub-battery boys performed better in vocabulary subtest (p=0,02, t=2,46). On the contrary girls showed skills in completing sentences (p=0,01; t=2,74). Significant differences were also found in the numerical battery. In the numerical relation subtest girls achieved better results (p=0,02; t=2,35) than boys. Again, boys performed significantly better in the third numerical subtest dealing with solving equitation (p=0,01; t=2,76). Also, the results in the overall numerical sub-battery was marked as significant, where boys were better than girls (p=0,01; t=2,95). In the last cognitive part dealing with fluid intelligence was found significant difference in the images analogy subtest, where boys again achieved better results (p=0,04; t=2,13).

No significant relationships were found in the coherence between cognitive ability and motor skills. In the field of motor skills, the monitored children showed an average level in individual subtests. From this point of view, the research group appeared to be homogeneous. Thus, a significant relationship between the level of motor skills and the level of cognitive abilities in the research group was not observed. Higher coherence of cognitive skills was seen in connection with gross motor skills. The sum of the standard age score (SVS) in the CAT test battery correlates weakly with the AC2 component (target throw: rs = 0.18; p

$\leq$0.05) and the BAL2 balance component (walking along the line: rs = 0.14; p $\leq$0.05). With the area of fine motor skills, SVS shows a very weak dependence in the MD1 subtest (placing pins: rs = 0.16; p $\leq$0.05). A weak correlation was found in girls between the overall SVS and handling skills in the AC2 subtest (targeted throw: rs = 0.25; p $\leq$0.05). In boys, the correlation coefficient showed a value of rs = 0.20 (p$\leq$0.05). A similarly weak correlation was found in girls in the BAL2 subtest (walking along the line: rs = 0.23; p $\leq$0.05). In the sub-batteries of CAT, there were weak correlations between mathematical skills and one of the components of the MABC-2 test, namely in the overall score of manipulation skills (AC: rs = 0.17), especially in girls (rs = 0.24).

If we look back to motor skills differences between genders we can compare our results to Eather et al. (2018), who confirmed that girls in primary school do not perform as well as boys. They found differences in younger age categories, but our research did not prove the same in older children. Research of (Fu & Burns, 2018) also suggests that for partial motor skills, boys generally reach higher levels of development compared to girls. Gonzalez Alvarez and Nelson (2019) showed that both gross and fine motor skills can support the development of verbal skills from childhood to adulthood. Especially in our case, where children achieved mostly only average level of motor skills, is evident, that possible improvement of motor skills can lead to better result in verbal sub-battery, where children from our research group did not reached even the average level. In terms of mathematical skills also Průcha (2013) confirms that boys shows better results, but his research was done on older children. Our research conforms this also on younger children.

7. Conclusions

Further research carried out on larger groups of children, including in an international context, could be focused not only on deepening knowledge in this area, but also on the possibilities of developing verbal skills through the development of motor skills and the development of other executive functions. The research yielded both positive and negative findings. In the field of motor skills, the research group from Czech children reached an average of 37-50 percentiles. The boys achieved better results. However, the monitored children showed problems in the area of cognitive abilities. Verbal skills show risky results in the monitored children. In the area of mathematical skills, children achieve only below-average results. Serious problems also appeared in the area of so-called fluid intelligence (non-verbal communication). We consider the limits of research to be the low number of monitored persons and also the impossibility of implementing random selection of participants in the conditions of Czech educational system. The out-of-school movement regime of children (family lifestyle) was not monitored, which can be involved in the development of cognitive skills since early childhood. Early childhood intervention could help reduce the primary differences between children in motor skills, especially in some motor development disorders that seems to lead to other learning disabilities. Meaningful intervention in the field of motor skills in this direction during the life of an individual can lead to their aimed support. School physical education can play an irreplaceable role here, mainly because educators working in this field are qualified professionals who can work with a wide range of children, including children with disabilities or gifted (talented) children.

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References

Ackerman, D. J., & Friedman-Krauss, A. H. (2017). Preschoolers' executive function: Importance, contributors, research needs and assess-ment options (Research Report No. RR-17-22). Princeton, NJ: Educational Testing Service). https://doi.org/10.1002/ets2.12148

Akshoomoff, N., Brown, T., Bakeman, R., & Hagler, D. J. (2018). Developmental differentiation of executive functions on the NIH Toolbox Cognition Battery. *Neuropsychology, 32*(7), 777-783. https://doi.org/10.1037/neu0000476

Alekseeva, O. (2021). Fluid Reasoning Among Other Cognitive Abilities. Child In The Digital World. https://doi.org/10.26226/morressier.60783894dc2fa1af56246ac3

Araujo, B. F., Teixeira, M. L., Cruz, P. B., & Malini, E. (2014). Understanding the adaptation of organisational and self-initiated expatriates in the context of Brazilian culture. *The International Journal of Human Resource Management, 25*, 2489-2509. https://doi.org/10.1080/09585192.2012.743470

Bailey, R. (2006). Physical Education and Sport in Schools: A Review of Benefits and Outcomes. *J School Health, 76*(8), 397-401. https://doi.org/10.1111/j.1746-1561.2006.00132.x

Cadoret, G., Bigras, N., Duval, S., Lemay, L., Tremblay, T., & Lemire, J. (2018). The mediating role of cognitive ability on the relationship between motor proficiency and early academic achievement in children. *Human Movement Science, 57,* 149-157. https://doi.org/10.1016/j.humov.2017.12.002

Case-Smith, J., & O'Brien, J. C. (2015). *Occupational Therapy for Children and Adolescents* (7th Ed.), Elsevier Mosby.

Colella, D., & Morano, M. (2011). Gross motor development and physical activity in kindergarten age children. *International Journal of Pediatric Obesity, 6*(S2), 33–36, https://doi.org/10.3109/17477166.2011.613661

Cuevas, K., Hubble, M., & Bell, M. A. (2012). Early childhood predictors of post-kindergarten executive function: Behavior, parent-report, and psychophysiology. *Early Education and Development, 23*, 59–73. https://doi.org/10.1080/10409289.2011.611441

Eather, N., Bull, A., Young, M., Barnes, A., & Pollock, E. (2018). Fundamental movement skills: Where do girls fall short? A novel investigation of object-control skill execution in primary-school aged girls. *Preventive Medicine Reports, 11.* https://doi.org/10.1016/j.pmedr.2018.06.005

Fu, Y., & Burns, R. D. (2018). Gross Motor Skills and School Day Physical Activity: Mediating Effect of Perceived Competence. *Journal of Motor Learning and Development, 6*(2), 287-300. https://doi.org/10.1123/jmld.2017-0043

Fuhs, M. W., Farran, D. C., & Nesbitt, K. T. (2015). Prekindergarten children's executive functioning skills and achievement gains: The utility of direct assessment and teacher ratings. *Journal of Educational Psychology, 107*, 207–221. https://doi.org/10.1037/a0037366

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psycho-logical Bulletin, 134*, 31–60. https://doi.org/10.1037/0033-2909.134.1.31

Gärtner, A., Grass, J., Wolff, M., Goschke, T., Strobel, A., & Strobel, A. (2021). No relation of Need for Cognition to basic executive functions. *Journal of Personality, 89*(6), 1113-1125. https://doi.org/10.1111/jopy.12639

Gashaj, V., Oberer, N., Mast, F. W., & Roebers, C. M. (2019). Individual differences in basic numerical skills: The role of executive functions and motor skills. *Journal of Experimental Child Psychology, 182,* 187-195. https://doi.org/10.1016/j.jecp.2019.01.021

Gonzalez, S. L., Alvarez, V., & Nelson, E. L. (2019). Do Gross and Fine Motor Skills Differentially Contribute to Language Outcomes? A Systematic Review. *Front. Psychol, 10*, https://doi.org/10.3389/fpsyg.2019.02670

Haapala, E. A., Lintu, N., Väistö, J., Tompuri, T., Soininen, S., Viitasalo, A., Eloranta, A. M., Venäläinen, T., Sääkslahti, A., Laitinen, T., & Lakka, T. A. (2019). Longitudinal Associations of Fitness, Motor Competence, and Adiposity with Cognition. *Med Sci Sports Exerc., 51*(3), 465-471. https://doi.org/10.1249/MSS.0000000000001826

Henderson, S. E., Sugden, D. A., & Barnett, A. L. (2007). Movement Assessment Battery for Children-2 second edition (Movement ABC-2). The Psychological Corporation. https://doi.org/10.1037/t55281-000

Klucká, J., & Volfová, P. (2016). *Kognitivní trénink v praxis* [Cognitive practice training]. Grada

Langmeier, J., & Krejčířová, D. (2006). *Vývojová psychologie* [Developmental Psychology]. Praha: Portál.

Liu-Ambrose, T., & Best, J. R. (2017). Exercise is medicine for the aging brain. *Kinesiology Review, 6*(1), 22-29. https://doi.org/10.1123/kr.2016-0035

Macdonald, K., Milne, N., Orr, R., & Pope, R. (2018). Relationships between Motor Proficiency and Academic Performance in Mathematics and Reading in School-Aged Children and Adolescents: A Systematic Review. *International Journal of Environmental Research and Public Health, 15*(8), 1603. https://doi.org/10.3390/ijerph15081603

Mancini, V. O., Rigoli, D., Heritage, B., Roberts, L. D., & Piek, J. P. (2016). The relationship between motor skills, perceived social support, and internalizing problems in a community adolescent sample. *Frontiers in Psychology, 7*, 1–11. https://doi.org/10.3389/fpsyg.2016.00543

Payne, G., & Isaacs, L. (2011). *Human motor development: a lifespan approach* (8th edition). MacGraw Hill.

Peng, P., & Kievit, R. A. (2020). The Development of Academic Achievement and Cognitive Abilities: A Bidirectional Perspective. *Child Dev Perspect, 14*, 15-20. https://doi.org/10.1111/cdep.12352

Piaget, J., & Inhelder, B. (2014). *Psychologie dítěte* [Child psychology]. Portál.

Průcha, J. (2013). Moderní pedagogika (5., aktualizované a doplněné vydání). Portál.

Psotta, R. (2014). MABC – 2, Test motoriky pro děti [MABC – 2, Movement Assessment Battery for Children]. Hogrefe – Testcentrum, Praha.

Pugnerová, M., & Kvintová, J. (2019). Přehled poruch psychického vývoje [Overview of mental development disorders]. Grada.

Rámcový vzdělávací program pro základní vzdělávání [Framework Educational Program for Basic Education] (2021). MŠMT ČR.

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2012). Implications of Infant Cognition for Executive Functions at Age 11. *Psychological Science, 23*(11), 1345-1355. https://doi.org/10.1177/0956797612444902

Rudd, J. R., Barnett, L. M., Farrow, D., Berry, J., Borkoles, E., & Polman, R. (2017). The Impact of Gymnastics on Children's Physical Self-Concept and Movement Skill Development in Primary Schools. *Measurement in Physical Education and Exercise Science,* https://doi.org/10.1080/1091367X.2016.1273225

Schmidt, M., Egger, F., Benzing, V., Jäger, K., Conzelmann, A., Roebers, C. M., & Pesce, C. (2017). Disentangling the relationship between children's motor ability, executive function and academic achievement. *PLoS ONE, 12*(8), e0182845. https://doi.org/10.1371/journal.pone.0182845

Schneider, W. J., & McGrew, K. S. (2018). The Cattell–Horn–Carroll theory of cognitive abilities. In D. P. Flanagan & E. M. McDonough (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 73–163). The Guilford Press.

Sgró, F., Schembri, R., Nicolosi, S., Manzo, G., & Lipoma, M. (2013). A mixed-method approach for the assessment of fundamental movement skills in physical education. *Procedia - Social and Behavioral Sciences, 106,* 102-111. https://doi.org/10.1016/j.sbspro.2013.12.013

Šimíčková-Čížková, J. (2010). Přehled vývojové psychologie [Developmental psychology overview]. Univerzita Palackého.

Thorndike, R. L., Hagen, E. P., & Sattler, J. M. (1986). *Stanford-Binet Intelligence Scale: Guide for administering and scoring the Fourth Edition.* Riverside.

Thorová, K. (2015). Vývojová psychologie [Developmental Psychology]. Portál.

Ursache, A., & Noble, K. G. (2016) Pediatric Imaging, Neurocognition and Genetics Study Socioeconomic status, white matter, and executive function in children. *Brain and Behavior*, *6*(10). https://doi.org/10.1002/brb3.531

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Vágnerová, M. (2007). Základy psychologie [Introduction to psychology]. Praha: Karolinum.

Vonkomer, J., & Jílek, J. (1997). Test kognitivních schopností (TKS) [Cognitive Ability Test]. Psychodiagnostika s.r.o. Brno.

Zelazo, P. D., Blair, C. B., & Willoughby, M. T. (2016). Executive function: Implications for education (Report No. NCER 2017–2000). National Center for Education Research, Institute of Education Sciences, U.S. Department of Education.