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EXECUTIVE FUNCTIONS AND INTELLIGENCE IN TYPICALLY DEVELOPING CHILDREN[1]

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With regard to conceptual similarity between executive functions and intelligence, the aim of this research was to determine their correlation in typically developing children.

The sample included 114 children of both sexes (59/51.8% of girls), between 8.7 and 10.8 years of age (M=9.80; SD=0.57).

Dodrill's Stroop Test, Go/No-Go Task, Listening Span Task, Digit Span Backward, Odd-one-out span, Figure Span Backward, Wisconsin Card Sorting Test, Twenty Questions Task and Tower of London were used for the assessment of executive functions. Intelligence was assessed by Raven's Progressive Matrices.

Pearson's correlation and partial correlation coefficients were used in statistical analysis of the results.

A low to moderate correlation was determined between intelligence and the variables of all applied executive functions tasks, both in verbal and non-verbal domain (p≤0.000-0.05). Inhibitory control, cognitive flexibility, and planning ability correlated with fluid intelligence in the range of r=0.20-0.30, while the correlation with working memory was in the range of r=0.40-0.50.

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The obtained results confirmed the assumption that intelligence and executive functions were different constructs regardless of their conceptual similarity.

***Key words**: executive functions, intelligence, typical population*

INTRODUCTION

Although there is no single definition of executive functions (EF), there is a general agreement that EF are the basis of problem solving ability and the ability to adapt to different situations. Their main characteristic is that they become expressed in every new, non-routine or complex situation, in situations which require integration of knowledge and experience, or demonstration and application of knowledge (Welsh, 2002). Thus defined, executive functions are conceptually close to understanding of intelligence (Ardila, Pineda & Rosselli, 2000; McCloskey, Perkins & Van Diviner, 2008).

The distinction between intelligence and EF concept is one of the significant questions in studying cognitive functions (Dennis et al., 2009). Although some of EF constructs, such as planning, decision making, and controlling of behavior in everyday situations, are considered as a reflection of intelligent behavior (Friedman et al., 2006), results of different studies indicate that this question is not easy to answer. The problem related to the presence or absence of correlation largely depends on the tested population, their age, and the applied tests and tasks (for the assessment of both intelligence and EF). However, the results of recent studies indicate that there is a certain relation between these two constructs (e.g. Friedman et al., 2006), despite initial results of earlier neuropsychological studies (Saggino, Perfetti, Spitoni & Galati, 2006; Welsh, Pennington & Groisser, 1991). In general, results of different studies point to the fact that there are statistically significant, usually low to moderate correlations between intelligence and some aspects and tests/tasks of EF. Furthermore, in some EF aspects, this relation is much more stable and generally stronger in the population of children (e.g. Brydges, Reid, Fox

& Anderson, 2012; Floyd et al., 2006; Friedman et al., 2006). To our knowledge, studies of this type have not been conducted in our country so far (Serbia), except in the population of children with mild intellectual disability (e.g. Buha & Gligorović, 2012a; Buha & Gligorović, 2012b; Gligorović & Buha, 2013c; Gligorović & Buha, 2013d).

AIM OF RESEARCH

The aim of this research is to determine the relation between the achieved developmental level of executive functions and intellectual functioning in typically developing children.

METHOD

Participants

Selection criteria were: absence of intellectual disability, absence of evident physical, neurological, and sensory disorders, absence of evident emotional problems, equal socio-economic status (middle SES), absence of bilingualism, parents' consent, and students' willingness to participate in this research.

The sample included 114 students of both sexes, attending the third (48.2%) and fourth (51.8%) grade of elementary school.

The sample was balanced with regard to sex; it included 59 girls (51.8%) and 55 boys (48.2%). The participants were between 8.7 and 10.8 years of age (M=9.80; SD=0.57). Boys (M=9.86; SD=0.55) and girls (M=9.74; SD=0.59) were equal in age ($F_{(1)}$=1.243; p=0.267). Based on six months distance, participants were divided in three age groups: 8.7-9.3 years (N=32/28.1%), 9.4-10.0 years (N=37/32.5%) and 10.1-10.8 years (N=45/39.5%).

Research instruments

Data on age, socio-economic status, bilingualism, socio-emotional functioning and medical history were obtained from official school documentation.

Assessment of intellectual functioning

The level of intellectual functioning was assessed by Raven's Progressive Matrices (RPM; Raven, Styles & Raven, 1998). Results of most studies in which achievement in RPM was compared to other intellectual functioning tests, indicate convergent validity of 0.70 and more (Raven, Raven & Court, 2003). RPM norms were given in groups of 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th}, and 95^{th} percentile. However, this way of presenting achievement limits the possibilities for finer discrimination among the participants. Thus, raw score was used in analyzing the results. The threshold for including the participants in this research was achievement $\geq 25^{th}$ percentile.

Assessment of executive functions

Basic (inhibitory control, working memory, and cognitive flexibility) and more complex (planning ability) aspects of EF, in verbal and non-verbal modality, were assessed.

Inhibitory control was assessed by classic *Stroop paradigm* for verbal domain and *Go/No-Go paradigm* for non-verbal domain.

Adapted version of Dodrill's Stroop Test (Dodrill, 1978) was used within classic Stroop paradigm. The material included one A4 sheet of paper with 176 color terms printed in a non matching color. In the first part of the test, participants read the printed words, while in the second part they were required to name the colors those words were printed in. Time needed to complete the task, and the number of errors in the second part of the test, were noted. Variables which measure response speed were used in this paper. The variables were marked as Stroop1 (speed of reading color terms) and Stroop2 (speed of naming colors).

Non-verbal inhibitory control was assessed by a variant of *Go/No-Go Task* (Spinella & Miley, 2004) which combines conflict/non-congruent motor response and lack of motor response at an agreed signal. Both parts rely on activation and inhibition processes. The first part, Conflict Response Set, represents a paradigm derived from the Tapping Task, and belongs to the group of Stroop-like tasks (Rosey, Keller & Golomer, 2010), in which stroop paradigm is adapted to motor response. Participants were required to give an answer opposite to the one presented: if the examiner tapped once on the desk, the participant had to do it twice, and vice versa (non-congruent response). The number of imitative errors and the number of latency errors (response after two seconds minimum) were noted. The score on this part of the task was presented through the total number of errors (GnG-CR). The second part, Response Delay Set, is a paradigm of classic Go/No-Go task, in which the participants were required to selectively give (i.e. stop) a motor response at an agreed signal: when the examiner tapped once, participants had to repeat the same thing, and when the examiner tapped twice, participants had to delay their response. The number of commission errors (response to "stop" signal), the number of omission errors (lack of response to "go" signal), and the number of latency errors at "go" signal (response after two seconds minimum) were noted. The score on this part of the task was presented through the total number of errors (GnG-DR).

Working memory was assessed by *Listening Span Task* and *Digit Span Backward* in verbal domain, and *Odd-one-out span* and *Figure Span Backward* in non-verbal domain.

Listening Span Task was adapted according to the model given in the research conducted by Henry (2001). The task consists of listening short sentences which may be true or false (e.g. “Children go to school” or “Grass is growing in the house”). The sentences were presented in sets of one to five sentences, where each set consisted of three tasks (sentences). A child was required to listen to each sentence, say whether it was true or false, and then remember the last word of each sentence. The test began with a one-sentence set. If the child was successful in all three attempts (i.e. two attempts minimum), a two-sentence set was applied. The test was continued until the child was no longer able to reproduce words from two groups of sentences within one set. Stimuli words could be reproduced in any order. There were 15 possible correct answers, and the variable was marked as LST.

Digit Span Backward (Gligorović, 2013; Gligorović et al., 2015) assesses verbal working memory and it is almost identical to classic Digit Span task, only participants are required to repeat presented digits in reverse order. Participants were presented with sets of digits increasing in complexity (from three to eight). After that they were expected to repeat those digits in reverse order. The task was divided into six levels, and each level consisted of three items equal in length. The test was continued if a participant gave a correct answer to at least one item from the previous level. If a participant incorrectly reproduced all three items at one level, testing procedure was stopped. Total correct score was noted. There were 18 possible correct answers, and the variable was marked as DSB.

Test material of *Odd-One-Out Span* task (Henry, 2001) consists of stimuli cards with three drawings (two identical and one similar), and A4 sheet of paper with drawn rectangles divided into three parts (sections). Each of the sections on A4 paper corresponds to the layout of the drawings on a card. The participants were required to choose a different drawing in a set of three, and then mark its position on an answer sheet. The test started with a span of two sets, while the maximum was a span of five sets of drawings. Each set was presented by three stimuli cards. Total correct score (Odd) was noted. There were 12 possible correct answers.

Figure Span Backward is a task based on the principles of assessment and treatment of working memory (Gligorović, 2013). The task structure corresponds to *Digit Span Backward* task. Participants were presented with sets of nonsense drawings increasing in complexity (from three to eight). After that they were expected to show in reverse order which nonsense drawings were presented. Each level consisted of three tasks. The test was continued if a participant gave a correct answer to at least one item from the previous level. The test was stopped if a participant incorrectly reproduced both items at one level. The total number of successfully repeated sets of nonsense drawings (FSB) was noted. There were 18 possible correct answers.

Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Talley, Kay & Curtiss, 1993) was used for the assessment of **cognitive flexibility**. This test is based on discovering the classifying principles of a set of cards according to one of the three successively changing criteria (color, shape, number). A participant should draw a conclusion according to the examiner's feedback on previous response. Test material consisted of two decks of cards (64 cards in each deck). Out of nine variables provided by this test, our paper analyzed the following: the number of sorted categories (Wcat), the percentage of conceptual responses (Wcr), and the percentage of perseverative errors (Wpe).

Twenty Questions Task and *Tower of London* were used for the assessment of **planning ability**.

Twenty Questions Task (20QT; Levin et al., 1991) is based on a popular children's game of guessing an imagined object, and is used for the assessment of forming a strategy, and its implementation in verbal problem solving. Children were presented with a poster containing 42 different pictures (wild and domestic animals, fruit and vegetables, musical instruments, means of transport, furniture) (detailed in Gligorović & Buha, 2013d). A participant had to guess which picture the examiner imagined by asking yes/no questions.

Twenty questions were allowed. Success in solving the task, and the approach to problem solving (number and type of asked questions) were noted. Main variables in this test were: the percentage of general questions (constraint-seeking questions, 20QTg); efficiency score (20QTes), and initial conceptualization (20QTic).

Tower of London test is aimed at the assessment of problem solving ability, i.e. planning ability in non-verbal domain. Adapted version of this test, consisting of 15 tasks, was applied (detailed in Buha & Gligorović, 2012a; Gligorović et al., 2015), while the procedure followed the standard examiner's manual instructions of this test (Culbertson & Zillmer, 2005). Total correct score (TOLt) was used as the main variable of Tower of London test in this research. Maximum number of correct answers is 15 (i.e. possible score range is 0-15).

Statistical method

Participants' achievements in the applied tests were presented by basic descriptive measures: arithmetic mean, standard deviation, minimum and maximum values. Population differences were analyzed by one-way and two-way analysis of variance and *Spearman's* rank correlation coefficient. Standard correlation techniques were used to determine the relation between intelligence and executive functions: simple (Pearson's coefficient of linear correlation) and partial correlation.

RESULTS AND DISCUSSION

Basic descriptive indicators of executive functions (EFs) and intellectual ability (RPM) variables, and their correlation with age and sex, are shown in Table 1.

Table 1 – Basic descriptive parameters of RPM and EFs variables scores and their correlation with age and sex

Variables	M	SD	min	max	r / age	p	ρ / sex	p
Intelligence								
RPM	33.63	7.79	15	51	0.237	**0.011**	0.117	0.215
Inhibitory control								
Stroop1	135.71	33.34	84	279	-0.177	0.060	0.250	**0.007**
Stroop2	282.17	59.45	188	519	-0.222	**0.018**	0.070	0.457
GnG-CR	4.32	3.18	0	14	-0.201	**0.032**	-0.010	0.914
GnG-DR	2.28	2.02	0	9	-0.089	0.345	0.010	0.913
Working memory								
LST	7.80	1.84	3	12	0.142	0.133	-0.062	0.511
DSB	5.73	2.17	2	12	0.102	0.279	0.069	0.469
Odd	7.83	2.11	3	12	0.105	0.267	0.077	0.681
FSB	3.23	1.72	0	10	0.041	0.665	-0.012	0.896
Cognitive flexibility								
Wpe	15.19	7.61	5	53	-0.045	0.632	-0.203	**0.031**
Wcr	62.82	16.35	18	89	-0.039	0.684	0.176	0.062
Wcat	5.04	1.54	0	6	-0.017	0.858	0.227	**0.015**
Planning								
20QTg	26.84	24.42	8	83	0.048	0.611	-0.127	0.178
20QTes	21.50	14.13	0	38	0.036	0.702	0.043	0.650
20QTic	6.32	5.90	1	25	-0.077	0.414	-0.127	0.177
TOLt	8.76	1.78	5	15	-0.168	0.074	-0.039	0.681

Statistically significant values are marked in bold. Legend: RPM=Raven's Progressive Matrices; Stroop1=speed of reading color terms; Stroop2=speed of naming colors; GnG-CR=total number of errors in Conflict Response Set of Go/No-Go Task; GnG-DR=total number of errors in Response Delay Set of Go/No-Go Task; LST=Listening Span task; DSB=Digit Span Backward; Odd=Total correct score in Odd-One-Out Span Task; FSB=Total correct score in Figure Span Backward Test; Wpe=percentage of perseverative errors in WCST; Wcr=percentage of conceptual responses in WCST; Wcat=number of sorted categories in WCST; 20QTg=percentage of general questions in Twenty Questions Task; 20QTes=efficacy score in Twenty Questions Task; 20QTic=initial conceptualization in Twenty Questions Task; TOLt=Total correct score in Tower of London;

There was a significant, positive, and low correlation between RPM achievement, measured by raw score, and age ($p<0.01$). Older children gave a larger number of correct answers.

Participants of different sexes were equal in the level of intellectual functioning ($p>0.05$). Boys and girls made similar progress in the development of fluid intelligence, which was further supported by the lack of interaction between age and sex ($F_{(2;108)}=0.233$; $p=0.793$). Absence of sex differences at this age corresponds to the results of one meta-analytic study (Lynn

& Irwing, 2004), as well as with the results obtained from a much larger sample of local population similar in age (Buha & Gligorović, 2015a).

This age range was relatively steady with regard to the development of most EF aspects, i.e. the level of achievements in different EF tests/tasks. Exceptions were the observed developmental changes in inhibitory control, both verbal and non-verbal. A low and negative correlation was determined between achievement in the second part of Stroop Test (Stroop2) and age ($p<0.05$), which indicated that smaller Stroop effect was present in older children. Identical correlation with age was determined in the non-verbal domain of inhibitor control. Older children made fewer errors in Conflict Response Set ($p<0.05$). With regard to the fact that this set belongs to Stroop-like tasks (Rosey et al., 2010), in which Stroop paradigm is adapted to motor response, it can be assumed that non-congruent response ability in verbal and non-verbal domain has similar developmental dynamics.

Sex was not significantly related to achievement in most EF variables. Exceptions were the achievement in the first part of Stroop Test (speed of reading color names) ($p<0.01$), as well as the achievement in WCST (percentage of perseverative errors and number of sorted categories; $p<0.05$).

With regard to the fact that RPM achievements, as well as some EF variables, were significantly related to age, partial correlation was determined by separating the influence of age in examining the correlation between EF and intelligence (Table 2).

Table 2 – Executive functions and intelligence

Raven's Progressive Matrices	Simple correlation		Partial correlation (age)	
	r	p	r	p
Inhibitory control				
Stroop1	-0.144	0.126	-0.107	0.259
Stroop2	-0.312	**0.001**	-0.274	**0.003**
GnG-CR	-0.330	**0.000**	-0.297	**0.001**
GnG-DR	-0.216	**0.021**	-0.201	**0.032**
Working memory				
Listening Span Task – correct score	0.348	**0.000**	0.327	**0.000**
Digit Span Backward – correct score	0.451	**0.000**	0.442	**0.000**
Odd-One-Out – correct score	0.508	**0.000**	0.496	**0.000**
Figure Span Backward – correct score	0.378	**0.000**	0.377	**0.000**
Cognitive flexibility				
WCST – number of sorted categories	0.254	**0.006**	0.251	**0.008**
WCST – percentage of conceptual responses	0.321	**0.001**	0.329	**0.000**
WCST – percentage of perseverative errors	-0.305	**0.001**	-0.293	**0.002**
Planning				
20QT – percentage of general questions	0.260	**0.005**	0.256	**0.006**
20QT – efficacy score	-0.233	**0.012**	-0.249	**0.008**
20QT – initial conceptualization	0.232	**0.013**	0.259	**0.006**
TOL – total correct score	0.217	**0.021**	0.268	**0.004**

Statistically significant values are marked in bold.

Results analysis determined statistically significant correlations between all EF variables and RPM achievements (except Stroop1 variable), which ranged from 0.22 to 0.51 (Pearson r coefficient) and were all highly statistically significant ($p<0.01$), except total correct score in Tower of London and number of errors in Response Delay Set of Go/No-Go Task, where statistical significance was $p<0.05$ (Table 2).

Apart from the influence of age, the level of correlation and statistical significance did not change. A somewhat different result was obtained by examining the correlation between intelligence and Tower of London score (TOL). Correlation range did not change; however, there was a change in significance of the determined correlation. Correlation significance between total correct score in Tower of London and RPM score increased to $p<0.01$.

A low to moderate correlation was determined between practically all variables of different EF aspects and fluid intelligence. Variable of the first part of Stroop Test (Stroop1) measured basic level of selective attention, and was not significantly related to intelligence ($p>0.05$). This was not the case in the population of children with mild intellectual disability (Gligorović & Buha, 2013a), although we should bear in mind that Day/Night Stroop paradigm was used in the assessment of attention selectivity and inhibitory control. Usually, higher order functions are considered more significant factors of intellectual abilities, with attention certainly being one of them (Schweizer & Moosbrugger, 2004). However, with regard to attention, it is necessary to consider the contribution of its different aspects (Schweizer, Moosbrugger & Goldhammer, 2005). This result indicates that, in the population of typically developing children, attention at the level of automatic response was not significantly related to intelligence, at least when RPM is concerned.

With regard to the relation between sex and success in the first part of Stroop Test ($\rho=0.250$; $p=0.007$), the correlation between RPM and Stroop1 variable was examined, with the control of sex influence. It was determined that correlation between these two variables remained low and not statistically significant ($r=-0.134$; $p=0.159$).

When it comes to situations which require attention selectivity in the presence of a strong distractor, specifically Stroop paradigms, research results indicate a significant relation with intelligence. In a sample of more than 1000 participants from the Netherlands, a low and negative correlation was determined between the classic Stroop test and the results of Wechsler Intelligence Scale in subsamples of children 9, 12, and 18 years of age (Polderman et al., 2009). It was determined that the correlation became stronger with age, which was further supported by the research conducted in a population of Chinese children aged between 7 and 12, regardless of the applied Stroop paradigm or intelligence test (Duan & Shi, 2011). Similar results were obtained from comparing children with different levels of intellectual functioning (Arffa, 2007; Johnson, Im-Bolter & Pascual-Leone, 2003), adult population (Salthouse, Atkinson & Berish, 2003), and the population of children with mild intellectual disability (Gligorović & Buha, 2013a).

Motor inhibitory control is also closely related to intelligence, and its role in cognitive performance is considered important. Results of neuropsychological studies indicate that brain areas, which are considered a neural basis of intelligence, are also responsible for the development of the ability to control conflict stimuli (Jonkman, Sniedt & Kemner, 2007). By comparing twelve-year old gifted and average children, it was determined that gifted children made significantly fewer omission and commission errors, and that they expressed lower latency in solving Go/No-Go task (Duan et al., 2009). Behavioral differences in controlling distractors in a population with similar characteristics (age and the level of intellectual functioning) were confirmed by comparing brain activity which determined that gifted children had more mature frontal functions and stronger frontoparietal network which is the basis of distractor control (Liu et al., 2011). Similar functional differences were observed in comparing typically developing children and children with mild intellectual disability (Buha & Gligorović, 2015b). However, these differences are less prominent within certain levels of intellectual functioning. Results of our research indicate the presence of a low correlation (r=0.20-0.30) in the population of children with average intellectual abilities, which is contrary to the results of other studies. Usually, there is no significant relation between intelligence and achievement in tasks which require delaying responses or controlling interfering stimuli either in the population of children with average abilities (regardless of whether they have learning disabilities or not) or in children with mild intellectual disability (Archibald & Kerns, 1999; Casey et al., 1997; Gligorović & Buha, 2013b; de Weerdt, Desoete & Roeyers, 2013).

There has been a consistent relation between verbal working memory and intellectual abilities. Regardless of the applied intelligence tests, results of almost all studies indicate the presence of significant correlations with working memory, which range from low to very high depending on statistical approach (analysis of raw correlations or latent variables), implying that these two constructs are almost isomorphic (Ackerman, Beier & Boyle, 2005; Colom et al., 2006). Furthermore, research indicates that working memory capacity has significant potential in predicting fluid and crystallized intelligence (Buehner, Krumm & Pick, 2005; Friedman et al., 2006). The differences in working memory based on IQ are less pronounced in the population with average intellectual abilities. They are noticeable only between children/persons with extreme variations in the level of intellectual functioning. For example, children with above-average intellectual abilities had a greater working memory capacity compared to children whose IQ was within the average range (see Johnson et al., 2003). By contrast, differences between children with average abilities and children with borderline IQ were less pronounced and far below the level of statistical significance (Henry, 2001). Differences in working memory capacity become more obvious and sensitive with lower IQ score (Henry, 2001). Thus, in children with mild intellectual disability, intelligence accounted for 19% of working memory capacity results variability (in a model which included both verbal and non-verbal aspect of working memory) (Buha & Gligorović, 2012b). In this research, a highly statistically significant moderate correlation ($p \leq 0.000$) was determined between fluid intelligence and scores in verbal and non-verbal working memory tasks in typically developing children.

Correlation between intelligence and performance in WCST is not always confirmed in studies. It could be said that it depends on applied intelligence tests, analyzed WCST variables, participants' age and their homogeneity in intellectual functioning. For example, no significant relation with performance in WCST (number of perseverative errors) in children 6-12 years of age was determined by applying Iowa Test of Basic Abilities, which gives similar scores as Wechsler scale (Welsh et al., 1991). Similar result was obtained from a sample of adults aged between 45 and 83, by applying WAIS-R and analyzing a relation with eight WCST variables. The participants of the mentioned research had an average of 14 years of education and IQ which ranged from 90 to over 130

(Boone, Ghaffarian, Lesser, Hill-Gutierrez & Berman, 1993). On the other hand, by assessing military recruits aged between 20 and 24, it was determined that intelligence, measured by WAIS-R, significantly correlated with achievement in WCST (number of sorted categories, level of conceptual responses, percentage of perseverative errors, initial conceptualization, and the number of interrupted sets). Apart from that, logistic regression analysis determined that the level of conceptual responses was a valid predictor of intellectual disability (Chien, Huang & Lung, 2009).

In the population of children with average intellectual abilities of early school and adolescent age, it was determined that fluid and crystallized intelligence significantly correlated (low to moderate correlation) with the number of perseverative errors (Ardila et al., 2000; Brydges et al., 2012), but not with the number of sorted categories and the number of non-perseverative errors (Ardila et al., 2000). These differences were not observed in groups of children with more extreme levels of intellectual functioning (children with above-average abilities and children with mild intellectual disability) (Gligorović & Buha, 2013c; Tanabe, Whitaker, O'Callaghan, Murray & Houskamp, 2014). In the population of children with mild intellectual disability, it was determined that, of all analyzed WCST variables, intellectual abilities had a significant influence only on initial task conceptualization (Gligorović & Buha, 2013c). Only when research includes population with wider range of intellectual functioning we can get a clearer picture of the relation between intelligence and performance in WCST.

In the population of children, from preschool to adolescent age, it was determined that children with above-average intellectual abilities gave a significantly higher percentage of conceptual responses and made fewer perseverative errors than children with average or above average IQ (Arffa, Lovell, Podell & Goldberg, 1998; Tanabe et al., 2014). Also, it was determined that intelligence accounted for about 10-12% of variance in the number of perseverative and non-perseverative errors (Arffa, 2007), and that total IQ score, in children whose IQ score was from 110 to over 130, proved to be a significant factor which defined the total number of errors in WCST (Arrfa et al., 1998).

Bearing in mind the determined correlation between sex and success in WCST variables (number of sorted categories, percentage of perseverative errors) (Table 1), partial correlation excluded the influence of sex in the mentioned variables. Previously determined relation between these variables and intelligence (with controlling age) remained unchanged (Wcat: $r=0.251$; $p=0.008$; Wpe: $r=-0.293$; $p=0.002$).

It is believed that a higher level of intellectual functioning is related to better performance in tasks which require planning, i.e. developing and using strategies. More precisely, it is assumed that there is a mechanism, like g factor, independent of the content of knowledge (semantic memory). Information processing speed in children and adults with higher IQ scores is greater, which gives them a system advantage in specific cognitive activity. This advantage is especially noticeable when information processing demands are high, as in tasks which require a strategic approach or response in a limited time period (Alexander, Johnson, Leibham & DeBange, 2004).

Performance in Twenty Questions Task (20QT) is usually related to intelligence in the population of children, but not in adults (Floyd et al., 2006). Children who function at a somewhat lower intellectual level have a tendency to use non-efficient strategies in this task (Alexander et al., 2004), which also depends on the level of meta-cognitive knowledge. Logistic regression determined that efficient initial strategy was influenced by meta-cognitive knowledge, but only in children with a lower level of intellectual functioning (Alexander, Johnson, Albano, Freygang & Scott, 2006). Differences in performace on 20QT also exist between typically developing children and children with intellectual disability (Denney, 1974), although no correlation was determined between the ability to develop verbal strategies and achievement in intelligence test in children with mild intellectual disability (Gligorović & Buha, 2013d).

Planning ability in non-verbal domain is also related to intellectual functioning. In complex problem solving tasks, such as Tower of London or Tower of Hanoi, fluid intelligence is a significant predictor of performance (Zook, Davalos, DeLosh & Davis, 2004). It was determined that the relation between fluid intelligence and Tower of London results was about 0.40 in children (Malloy-Diniz et al., 2008) and students (Zook et al., 2004). Similarly to our findings, Luciana, Collins, Olson & Schissel (2009) determined a low correlation (r=0.20) between total correct score in Tower of London and intelligence, assessed by specific subtests of WISC-III, WAIS-III and WASI. Although there is a belief that the relation with fluid intelligence is stronger, which was also assumed by the authors of the previously mentioned study, results of our research did not support this hypothesis.

CONCLUSION

The aim of this research was to determine the relation between different aspects of executive functions and intelligence in typically developing children. A low to moderate correlation was determined between intelligence and variables of all applied executive functions tasks, both in verbal and non-verbal domain ($p \leq 0.000$-0.05). The obtained results to a great extent correspond to results of foreign studies.

Even though there is a conceptual similarity between executive functions and intelligence, operationalization of these constructs as specific tests and tasks indicates the presence of clear differences manifested in lower correlation levels, usually in the range of 0.20-0.30 with regard to inhibitory control, cognitive flexibility, and planning ability, and somewhat stronger correlations (0.40-0.50) with regard to working memory. It could be said that the obtained results confirm the assumption that executive functions and intelligence are different, but closely related constructs. Apart from that, such finding further indicates the possibility of double dissociation of executive functions from cognitive abilities measured by intelligence tests: presence of well-developed executive functions with parallel existence of certain limitations in reasoning abilities, and vice versa, very good reasoning ability with relative limitations in all or some areas of executive functions.

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EGZEKUTIVNE FUNKCIJE I INTELIGENCIJA KOD DECE TIPIČNOG RAZVOJA

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Rezime

S obzirom na konceptualnu sličnost egzekutivnih funkcija i inteligencije, cilj istraživanja je da se utvrdi njihov međusoban odnos u populaciji dece tipičnog razvoja.

Uzorkom je obuhvaćeno 114 dece, oba pola (59/51,8% devojčica), uzrasta 8,7-10,8 godina (AS=9,80; SD=0,57).

Za procenu egzekutivnih funkcija korišćeni su *Stroop Test (Dodrilova verzija)*, *Kreni-stani zadatak, Raspon rečenica, Raspon cifara unazad, Izbaci uljeza, Raspon figura unazad, Viskonsin test sortiranja karata, Test 20 pitanja i Londonska kula*, dok su za procenu inteligencije upotrebljene *Ravenove progresivne matrice*.

Rezultati su statistički obrađeni primenom proste (Pirsonov koeficijent linearne korelacije) i parcijalne korelacije.

Analizom rezultata utvrđeno je da inteligencija nisko do umereno korelira sa varijablama svih primenjenih zadataka egzekutivnih funkcija, i u verbalnom i u neverbalnom domenu ($p \leq 0{,}000-0{,}05$). Inhibitorna kontrola, kognitivna fleksibilnost i sposobnost planiranja koreliraju sa fluidnom inteligencijom u rangu od $r=0{,}20-0{,}30$, dok se veza sa radnom memorijom kreće u rangu od $r=0{,}40-0{,}50$.

Dobijeni rezultati potvrđuju stav da su inteligencija i egzekutivne funkcije različiti konstrukti, bez obzira na njihovu konceptualnu sličnost.

Ključne reči: egzekutivne funkcije, inteligencija, tipična populacija

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