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INFLUENCE OF INHIBITORY CONTROL ON PLANNING ABILITIES IN CHILDREN WITH MILD INTELLECTUAL DISABILITY[1]

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With regard to the fact that the tendency toward unsophisticated strategies is often related to difficulties with basic components of executive functions, the aim of this research was to determine the relation between planning abilities and inhibitory control in children with mild intellectual disability (MID).

The sample included 56 children with idiopathic MID (IQ 50-69, M=61.13, SD=7.14), of both genders (26/46.3% of girls), between 9.11 and 14.03 years of age (M=11.61; SD=1.29).

Go no Go Task and Day/Night Stroop Task were used for the assessment of inhibitory control (delayed response to the agreed signal, conflict provoking motor responses, and inhibition of arrogant verbal responses), while Tower of London Test (ToL) was used for the assessment of planning abilities.

Multivariate analysis of covariance (MANCOVA), paired samples t-test, Pearson's correlation, and partial correlation coefficients were used in statistical analysis of the results.

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The results showed that the mistakes in Response delay set of Go-no-Go task were the only significant factor of primary Total move score variable (ToL). The influence of the ability to delay motor activity, assessed by Response delay set, on all ToL variables was statistically significant (p=0.003).

The results lead to a conclusion that, during the processes of planning and executing activities, children with MID primarily rely on simple inhibitory mechanisms.

Key words*: mild intellectual disability, planning ability, inhibitory control*

INTRODUCTION

Planning ability is one of the most complex aspects of executive functions (EFs) which depends on the integrity of numerous other functions and requires coordination of different and independent cognitive and motivational processes (Barrouillet & Lepine, 2005; Bull, Espy & Senn, 2004; Lezak, Howieson & Loring, 2004; Miyake, Friedman, Emerson, Witzki & Howerter, 2000). It involves creating a mental representation of a problem, choosing the appropriate solving strategy, and evaluating the effect of activities (Owen, 2005; Ward & Morris, 2005).

The results of studies on planning and using problem solving strategies in children with intellectual disability (ID) indicate that these children spontaneously develop and use these strategies less frequently than typically developing children (Facon & Nuchadee, 2010; Pressley & Hilden, 2006; Spitz, Webster & Borys, 1982). Furthermore, due to difficulties in generalizing information, persons with ID are often not able to apply the acquired strategies in new situations (Gallagher, 1994). They typically use rudimentary strategies, and they break the rules in solving tasks more frequently than persons of the same chronological and mental age (Buha & Gligorović, 2012; Gligorović & Buha 2013a; Numminen, Lehto & Ruoppila, 2001). Similar results were obtained in one of the studies, by applying Raven's Colored Progressive Matrices in children with ID of different etiology, aged between 5 and 18. These children expressed immature approaches to solving problems (positional responding) more frequently than typically developing children in the control group who were equal in nonverbal mental age. Also, children with ID made the same mistakes as much younger typically developing children (Goharpey, Crewther & Crewther, 2013).

Bearing in mind that the appropriate strategic behavior is associated with the ability to evaluate demands and contexts, and with the ability to control, monitor and flexibly apply previously acquired strategies in new situations, limited spontaneous usage and transfer of strategies may be the result of limitations in basic executive functions, inhibitory control, working memory, and cognitive flexibility (Dermitzaki, Stavroussi, Bandi & Nisiotou, 2008; Gligorović & Buha, 2013b). A planning strategy requires keeping relevant information, inhibiting the activities which initially seem logical but do not lead to the ultimate goal, and flexibly selecting and varying different stages of a task. Our previous studies determined that 10-14 year-old children with mild intellectual disability (MID) had difficulties in solving verbal and non-verbal problems (Buha & Gligorović, 2012; Gligorović & Buha 2013b). By applying Tower of London (ToL) test, aimed at assessing the ability to solve non-verbal problems, it was determined that children with MID were characterized by the so called unstable (wavering) approach to a problem, which involves alternating perceptive strategies and higher order strategies. They used higher order strategies in simpler tasks, which led to success in solving them. However, more complex tasks led to systematic approach degradation and going back to perceptive way of solving problems (Buha & Gligorović, 2012). Tendency toward unsophisticated strategies is often related to difficulties in basic EFs, working memory (Spitz et al., 1982), inhibitory control (Miyake et al. 2000), and cognitive flexibility (Bull et al., 2004). The results of numerous studies indicate the existence of these difficulties in children with MID (Carretti, Belacchi, & Cornoldi, 2010; Gligorović & Buha, 2013a, 2013b; Gligorović & Buha Đurović, 2014).

AIM OF RESEARCH

The aim of this research was to determine the relation between planning ability and inhibitory control in 10-14 year-old children with MID.

METHOD

Participants

The sample included 56 children with idiopathic MID (IQ 50-69, M=61.13, SD=7.14), of both genders (26/46.3% of girls and 30/53.7% of boys), aged between 10 and 14 (M=11.61; SD=1.29). The participants attended elementary schools for children with disabilities in Belgrade.

The sample included children with no neurological and/or genetic disorders and no multiple disabilities (sensory disorders, autism, etc.). There was no significant correlation between the participants' IQ and chronological age (r=-0.044, p=0.748) or gender (F(1,56)=0.568, p=0.454).

Instruments and procedure

Data on age, medical history, and the results of standardized psychometric instruments (IQ) were collected by analyzing official school documentation.

Go no Go Task and *Day/Night Stroop Task* were used for the assessment of inhibitory control (delayed response to the agreed signal, conflict provoking motor responses, and inhibition of arrogant verbal responses).

Go no Go Task (Spinella & Miley, 2004) consists of two parts. The first part is *Conflict Response Set* in which the participants are required to give an answer opposite to the one presented by the examiner. For example, if the examiner hits a desk once, the participant has to do it twice, and vice versa. The second part is *Response Delay Set* in which the participants are required to delay their reaction (imitation of the given model) after the agreed signal. Each set consists of 30 items. The number of errors (omission errors, commission errors, and latency between order and execution) is noted. Number of errors in each set was used as a variable in this research.

The adapted version of *Day/Night Stroop Task* (Gerstadt, Hong & Diamond, 1994), aimed at the assessment of arrogant response inhibition, consists of two parts. It consists of 50 pictures arranged on two A4 sheets of paper, each including five rows with five items. In the first part, a participant is instructed to name bright pictures with the illustration of the Sun as "day" and dark pictures with the Moon and stars as "night". In the second part, a child is expected to disregard the content of the picture and use opposites in naming (say "night" for a picture representing day, and vice versa). Time needed for solving the second part of the test was used as a variable in this research.

Tower of London Test, ToL (Culbertson & Zillmer, 2005) was used for the *Assessment of Planning Ability*, aimed at the assessment of the ability to plan/solve non-verbal problems. The testing material includes two identical wooden constructions (each including three pegs of different heights and three beads of different colors), one of which is used by an examiner and the other by a participant. Initially, three beads are arranged on three pegs in a specific arrangement. Participants are required to give the minimum number of times the beads will have to be moved to get the target beads arrangement. Two rules have to be followed in moving the beads. The first rule requires that only one bead can be moved at a time, and the second that the maximum number of beads on one peg should correspond to its height. The standardized version of Tower of London includes 10 tasks of different complexity. The version applied in this research included 15 tasks (three tasks for each level, where "the level" refers to the minimum number of times the beads have to be moved), while the procedures of setting the task and scoring corresponded to the original. Six variables were monitored in this research: initiation time, total move score, rule violation, execution time, total problem solving time, and total correct score.

Data analysis

Central tendency measures, variability measures, and ranges of results were used to present basic statistical parameters. Multivariate analysis of covariance (MANCOVA), paired samples t-test, Pearson's correlation and partial correlation coefficients were used to determine the significance of relations between variables. Due to the MANCOVA implementation, the results of inhibitory control measure were divided into four groups, each on a percentile ranks basis (a transformation with three cross-sections). The first group contained scores up to 25^{th} percentile ranks, the second from $25\text{-}50^{th}$ percentile, the third up to 75^{th} percentile and the fourth above 75^{th} percentile.

RESULTS AND DISCUSSION

Tower Tasks, based on the so called transfer paradigms, are often used for the assessment of planning abilities in children and adults in clinical and experimental settings. They involve moving the beads (disks) from initial to target position with a minimum number of moves. In clinical settings, the Total move score, considered as the most indicative for planning abilities, is used as primary ToL score. Lower score generally indicates a better planning ability. The remaining scores are considered for the purpose of better understanding of the primary score (Culbertson & Zillmer, 2005; Lehto, Juujärvi, Kooistra & Pulkkinen, 2003; Miyake et al., 2000).

Compared to typically developing children's results obtained by Culbertson and Zillmer (Culbertson & Zillmer, 1998), the arithmetic mean of Total move score in children with MID (M=59.96) is higher than the results of 10-12 year-old children (M=46.5), and closer to 7-9 year-olds (M=61.4) (detailed in Table 1).

Table 1 – Descriptive statistics for basic EFs and planning ability variables

	Variables	Min	Max	Mean	SD
Planning/ problem solving	ToL – Total move score	18	129	59.96	24.390
	ToL – Rule violation	0	25	5.05	5.498
	ToL – Initiation time	15	331	67.43	51.114
	ToL – Execution time	266	1208	579.88	222.48
	ToL – Total problem solving time	281	1253	647.30	225.024
	ToL – Total correct score	1	10	5.32	1.96

Apart from the Total move score, researchers also use Total correct score (the number of successfully completed tasks with a minimum number of moves), which is considered to be related with several EFs, especially non-verbal working memory and inhibitory control (Culbertson & Zillmer, 2005). Some authors believe that the combination of scores related to correctness and time may provide information on the acquired planning strategies which cannot be seen from the Total move score (Owen, Downes, Sahakian, Polkey & Robbins, 1990). Initiation time, also called *first move time* or *preplanning time*, is a period between the presentation of a task (problem) and the first move aimed at its solving. Execution time is a period between the first and the last move, and Total problem solving time is the sum of Initiation and Execution time.

The correlation between Total correct score and Execution time of ToL tasks in children with MID was significant and negative (r=-0.332, p=0.012), while the correlation between Total correct score and Initiation time was positive but not significant (r=0.223, p=0.099). This indicates that correct answers are not necessarily the result of additional time spent on planning prior to solving a task. Similar findings were determined in persons with frontal lobe lesions who did not use Initiation time efficiently. Thus, longer Initiation time does not necessarily mean a greater number of correct answers (Owen et al., 1990). Our participants spent much more time on executing activities, although the strategies they developed at that period were not always useful since they did not lead to correct answers.

The average value of Initiation time in children with MID is similar to values obtained by Culbertson and Zillmer (Culbertson & Zillmer, 1998) in 10-12 year old typically developing children (M=68.2, SD=53.8). However, the average moving time was significantly longer than the mean values for the ages of 10-12 (M=318, SD=109.8) and 7-9 (M=450.1, SD=172.9), which also influenced Total problem solving time.

It is believed that the time a person uses before moving the first bead accounts for inhibitory processes distributed over a continuum from minimum response control (uncontrolled approach) to maximum response modulation (overly controlled approach) (Culbertson & Zillmer, 2005). A broad range of Initiation time (15-331s) in our sample points to the presence of both types of control, impulsive reactions and excessive inhibition. Fast response increases the probability of errors, while overly inhibited style may hinder fast development and implementation of an action plan.

Some authors believe that it is necessary to make a distinction between plan development (cognitive aspect), i.e. planning, and execution (Goel & Grafman, 1995, according to Koppenol-Gonzalez, Bouwmeester & Boonstra, 2010). Thus, the comparison between Initiation and Execution time is used to get an insight into the efficacy of planning. Our research determined a significant difference in these scores ($t(55,56)=-16.566$, $p \leq 0.000$). There was no significant correlation between Initiation and Execution time ($r=-0.065$, $p=0.635$), which means that Execution time was in no way determined by previous planning. Furthermore, Execution time was more significantly related to Total move score ($r=0.775$, $p \leq 0.000$) than Initiation time ($r=-0.351$, $p=0.008$). Children whose Initiation time was longer made fewer moves, which indicates planning ahead. However, the significance level of Total move score and Execution time points to the fact that most children primarily planned during execution, making trial attempt-error strategies which led to a greater number of moves. Rule violation significantly correlated with Execution time ($r=0.530$, $p \leq 0.000$), as opposed to Initiation time ($r=-0.215$, $p=0.111$), which additionally points out that children with MID primarily plan during execution (often unsystematically and with a lot of errors).

Initiation time is in most studies used as a dependent variable (Kaller, Rahm, Spreer, Mader & Unterrainer, 2008; Luciana, Collins, Olson & Schissel, 2009), and the results of studies on its influence on ToL performance (Asato, Sweeney & Luna, 2006; Phillips et al., 1999; Unterrainer et al., 2004) are limited and inconsistent. Some researchers (Phillips et al., 1999) did not determine any differences in ToL performance between the participants who did and did not plan ahead, while others point to the relation between Initiation time and success in problem solving. Persons successful in tests on planning spend twice as much Initiation time as less successful participants (Unterrainer et al., 2004). Also, younger children, who spend less time on planning, achieve poorer results than older age groups (Asato et al., 2006).

During the test, children from our sample ignored task requirements about five times on average ($M=5.07$), which is much more frequent than the results of 10-12 year-old typically developing children ($M=0.6$) obtained by Culbertson and Zillmer (Culbertson & Zillmer, 1998). Dispersal of the results was also great ($SD=5.498$) since some participants followed the rules in solving tasks, while others violated them up to 25 times. Rule violation may be related to difficulties in verbal regulation of behavior, impulsivity, or difficulties in keeping the rules in working memory. However, some children with behavioral problems, or those frustrated by their inability to solve a problem, may deliberately ignore the set rules of behavior.

There was a significant negative correlation between IQ and Total move score ($r=-0.341$, $p=0.010$), while the correlations between IQ and Initiation time ($r=0.243$, $p=0.071$)

or Total correct score (r=0.243, p=0.071) were not statistically significant. Age significantly negatively correlated with Total move score (r =-0.393, p=0.003), Total correct score (r=0.272, p=0.042), and Total problem solving time (r=-0.351, p=0.008).

Planning and inhibitory control

Although there is no agreement on which cognitive processes are involved in the planning process assessed by primary ToL variable (Total move score) (Berg & Byrd, 2002; Koppenol-Gonzalez, Bouwmeester & Boonstra, 2010), it is believed that working memory and inhibition are the most significant components of EFs which influence the performance in Tower Tasks (ToL or Tower of Hanoi) (Huizinga, Dolan & van der Molen, 2006; Miyake et al., 2000). Results of studies on the influence of inhibitory control on ToL performance in typically developing persons are diverse. The influence of inhibitory control did not prove to be significant in some studies (Koppenol Gonzalez et al., 2010; Pulos & Denzine, 2005), while it was moderate (Zook, Davalos, DeLosh & Davis, 2004) or significant (Luciana et al., 2009; Welsh, Satterlee-Cartmell & Stine, 1999) in others. It is possible that such findings resulted from the design and requirements of the applied tasks. In fact, most studies used Stroop test, while *Go no Go* task was used in only one study (Luciana et al., 2009).

The results of inhibitory control assessment, done by *Go no Go* task and the second part of Day/night Stroop Task, are shown in Table 2.

Table 2 – Results of inhibitory control assessment in children with MID

	Variables	Min	Max	Mean	SD
Inhibitory Control	*Go no Go – RDS*	0	16	3.46	3.56
	Go no Go – CRS	0	24	7.29	5.04
	Day/Night Stroop–2	36	125	62.02	17.464

Note: RDS – Response delay set; CRS – Conflict response set.

By applying partial correlation coefficient, controlled by intelligence and age, a significant correlation was determined between certain aspects of inhibitory control and different ToL variables (Detailed in Table 3).

Table 3 – Partial correlations between EFs and ToL variables (controlled by chronological age and IQ score)

Control Variables IQ and CA		*Go no Go* RDS	*Go no Go* CRS	Day/Night Stroop2
TMS	r	0.301	0.194	0.087
	p	**0.027**	0.160	0.530
RV	r	0.556	0.149	0.206
	p	**0.000**	0.281	0.134
IT	r	-0.049	-0.041	0.179
	p	0.725	0.770	0.195
ET	r	0.416	0.260	0.311
	p	**0.002**	0.058	**0.022**
TPST	r	0.386	0.239	0.339
	p	**0.004**	0.082	**0.012**
TCS	r	-0.067	0.050	-0.036
	p	0.632	0.721	0.793

Note: TMS = total move score; RV = rule violation; IT = initiation time; ET = execution time; TPST = total problem solving time; TCS = total correct score; RDS = Response delay set; CRS = Conflict response set. Statistically significant values are marked in bold.

The results of Response delay set of *Go no Go* task were significantly related to primary ToL variable (Total move score). MANCOVA was applied for the purpose of a more detailed analysis of the relation between inhibitory control and ToL performance.

By applying MANCOVA, no significant relation was determined between the solving time of the second part of Day/Night Stroop task and ToL performance in children with MID.

With regard to the analysis of relations between the number of errors in *Go no Go* task and ToL performance, the number of errors in Conflict response set of *Go no Go* task did not prove to be a significant factor of ToL variables, while errors in Response delay set were significantly related to Total move score, Rule violation, Execution time and Total problem solving time (detailed in Table 4). The influence of response delay ability was not statistically significant in Initiation time

($F(3)=0.954$, $p=0.422$) and Total correct score ($F(3)=0.579$, $p=0.632$). Initiation time is often considered dependent on inhibitory mechanisms, which was not confirmed in our research.

The influence of response delay on all ToL variables, assessed by Response delay set, was statistically significant (Wilks'$\lambda=0.513$; $F(15)=2.505$, $p=0.003$, partial $\eta^2=0.219$).

Table 4 – Response delay set and ToL variables

ToL	*Go no Go* –RDS Percentile ranks	Mean	SD	F(3)	p	Partial η^2
TMS	up to 25th	45.00	18.463	3.846	0.015	0.188
	25-50th	50.84	17.503			
	50-75th	69.25	24.511			
	above 75th	74.07	26.776			
RV	up to 25th	1.20	1.687	7.274	0.000	0.304
	25-50th	3.32	3.528			
	50-75th	6.07	4.906			
	above 75th	9.75	7.325			
ET	up to 25th	398.40	60.313	6.582	0.001	0.283
	25-50th	493.37	160.315			
	50-75th	674.87	227.622			
	above 75th	749.33	223.654			
TPST	up to 25th	491.40	137.472	5.634	0.002	0.253
	25-50th	551.95	173.483			
	50-75th	735.13	224.850			
	above 75th	818.42	209.423			

Note: TMS = total move score; RV = rule violation; ET = execution time; TPST = total problem solving time; RDS = Response delay set

Inhibition of dominant response (tendency to move the disk directly to target position) is necessary in Tower Tasks to enable careful planning of all the moves required for solving the task (Bull et al., 2004; Miyake et al., 2000). For successful task solving, it is often necessary to make the moves opposite to what is directly observed, i.e. moves which require moving the beads in the direction opposite to the ultimate, target position. This approach in problem solving requires planning and inhibition of the moves which seem obvious at first, but do not lead to a solution, or lead to a solution through more moves than necessary. Solving simple Tower of London tasks, which involve moving two or three beads, requires a rudimentary strategy, while tasks with moderate (moving four beads) and high (moving five or more beads) level of complexity require planning ahead (Culbertson & Zillmer, 2005). With regard to the fact that solving more complex items requires planning several steps ahead, it is clear that success also depends on working memory capacity, and the ability to inhibit impulsive approach to task solving. According to the obtained results, overcoming perception based reactions in children with MID is significantly related to response delay ability. The development of more complex levels of inhibitory control in children with MID is much slower than response delay ability (Gligorović & Buha Đurović, 2014), so it is understandable that these children primarily rely on it in solving ToL tasks. Perceptive strategies are characteristic of younger typically developing children, due to limited cognitive capacities and/or metacognitive (executive) skills (Bull et al., 2004).

CONCLUSION

Children with MID, aged between 10 and 14, achieved significantly poorer results in ToL when compared to the achievements of typically developing children. It was determined that IQ (r=-0.341) and age (r=-0.393) significantly negatively correlate with Total move score variable, observed as the primary ToL score.

By analyzing the relation between inhibitory control assessment results and ToL performance, it was determined that errors in Response delay set of Go-no-go task were the only significant factor of Total move score variable. The influence of the ability to delay motor activity on all ToL variables, assessed by Response delay set, was statistically significant ($p=0.003$, partial $\eta^2=0.219$).

The obtained results lead to a conclusion that, during the processes of planning and executing activities, children with MID primarily rely on simple inhibitory mechanisms.

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UTICAJ INHIBITORNE KONTROLE NA SPOSOBNOST PLANIRANJA KOD DECE SA LAKOM INTELEKTUALNOM OMETENOŠĆU

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Summary

Polazeći od saznanja da je sklonost upotrebi nesofisticiranih strategija često povezana sa teškoćama bazičnih komponenata egzekutivnih funkcija, cilj istraživanja je da se utvrdi odnos između sposobnosti planiranja i inhibitorne kontrole kod dece sa lakom intelektualnom ometenešću (LIO).

Uzorkom je obuhvaćeno 56 dece sa idiopatskom MID (IQ 50-69, AS=61,13, SD=7,14), oba pola (26/46.3% devojčica), uzrasta 9,11-14,03 godine (AS=11,61; SD=1,29).

Za procenu inhibitorne kontrole (odlaganje odgovora na dogovoreni signal, konfliktni motorički odgovori i inhibicija prepotentnog verbalnog odgovora) korišćeni su Kreni/stani zadatak i Dan-noć verzija Strup testa, a za procenu sposobnosti planiranja test Londonska kula.

Rezultati su statistički obrađeni primenom multivarijatne analize varijanse, t testa, Pirsonovog koeficijenta korelacije i parcijalne korelacije.

Analizom rezultata utvrđeno je da su greške na Setu odlaganja odgovora Kreni/stani zadatka jedini značajan činilac ukupnog broja pokreta, primarne varijable Londonske kule. Uticaj mogućnosti odlaganja motoričke aktivnosti, procenjene Setom odlaganja odgovora, na posmatrane varijable Londonske kule u celini je statistički značajan (p=0,003).

Sumirajući rezultate možemo zaključiti da se, tokom procesa planiranja i izvršavanja aktivnosti, deca sa LIO prvenstveno oslanjaju na jednostavne inhibitorne mehanizme.

Ključne reči: laka intelektualna ometenost, sposobnost planiranja, inhibitorna kontrola

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