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BEHAVIORAL ASPECT OF WORKING MEMORY IN CHILDREN WITH SPECIFIC LANGUAGE IMPAIRMENT[a]

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SUMMARY

Despite the normal range of non-verbal intelligence, children with specific language impairment (SLI) can exhibit a number of cognitive limitations, especially in the area of working memory (WM) and inhibition. There is a growing body of research indicating possible common underlying interactive neural substrates for language and nonverbal processing. While there are quite a number of studies that have well documented WM deficits in SLI children in clinical settings, there are very few that have studied WM performance in everyday situations in these children. Aim of this study is to examine behavioral aspect of WM in children with SLI at preschool and early school age. The sample consisted of 51 children with SLI, ages between five and eight years. For the purpose of an assessment of behavioral aspect of WM, Working Memory subscale from Behavior Rating Inventory of Executive function (BRIEF) was used. Results showed that as a group, SLI children are on the verge of underperformance (57.82 average T – scores). Detailed analysis showed that 27.5% of children with SLI have poor performance, while 37.3% of children exhibit underachievement in behavioral aspect of WM. Sex related differences were found in a group of SLI children with normal WM achievement, suggesting some male developmental advantages (p = 0.021). Significant number of SLI children exhibit difficulties in the area of behavioral aspect of WM. This implicates the need for a more extensive assessment of SLI children, as well as the need for interventions that target executive abilities in natural context in these children.

Key words: specific language impairment, working memory, behavioral aspect

INTRODUCTION

Working memory: basic concept, development and evaluation

Generally speaking, working memory is an active memory system responsible for the temporary retention and simultaneous processing of information (Bailiss, Jarrold, Baddeley, Gunn, & Leigh, 2005). Additionally, working memory is also described as the use of temporarily withheld information in performing more complex cognitive tasks (Hulme & Mackenzie, 2014), or as a mental workspace for the use of activated representations from long-term memory (Stoltzfus, Hasher, & Zacks, 1996). Based on Baddeley model (2006), working memory is a multiple resource system connected to a number of limited capacity subsystems. This model also includes a central executive system associated with attention control, high levels of processing and coordination of

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activities within working memory. Described memory system allows one to monitor commands while completing a task, write complex sentences by memory, understand written text, or, for example, verbally solve arithmetic tasks (Buha & Gligorović, 2012).

There is still a debate in the literature on the relationship between working and short-term memory. While some authors consider these to be two inseparable and interdependent systems, other authors consider short-term and working memory to be two completely separable cognitive systems (Dehn, 2011). However, a number of recent studies support the second view and make a clear differentiation of short-term memory (STM) and working memory (WM) (Dehn, 2011):

Short-term memory	**Working memory**
Retains information passively	Actively processes information
Modal related capacity (verbal and visual)	Relatively modal independent
Less closely related to learning and higher cognitive functions	More closely related to learning and higher cognitive functions
Automatically activates information stored in long-term memory	Consciously activates desired information from long-term memory
Has no control function	One of executive abilities
Can be active independently from long-term memory	Activity depends significantly on components of long-term memory
Retains information coming from outside	Retains the "products" of various cognitive processes

Accordingly, working memory manages, manipulates and transforms information retrieved from short-term or long-term memory. However, it is difficult to limit working memory and detach it from related cognitive processes, such as reasoning. In general, working memory is the central cognitive process responsible for the active processing of information. Therefore, working memory underlies both, complex and basic cognitive processes (Ile Lepine, Barrouillet, & Camos, 2005). Working memory supports cognitive processing as a sort of intersection between perception, short-term memory, long-term memory and goal-directed actions.

Although there are individual differences, working memory capacity is quite limited, even in a person with a normal working memory range. Typical individual can only manipulate with around four pieces of information at a time (Cowan, 2001). Additionally, if information is not manipulated, it will remain in working memory for only a short period of time, about 2 seconds (Swanson, 2000). Because of its' central role in cognitive functioning and learning, successful learning is highly dependent of working memory. For example, it is likely that a child with a severe impairment of verbal working memory will have reading difficulties at older age (Masoura, 2006). Moreover, considering working memory limitations, efficient use of all resources is important for all individuals, not just for people with cognitive impairments.

Basically, working memory is one of the main cognitive processes underlying thinking and learning. By efficient utilization of different memory systems, working memory enables us to learn and unify thoughts and ideas. In daily activities, we are constantly dealing with demands and goals that compete within the limited process ability of working memory. However, activation of the working memory is not required for all cognitive operations or behaviors. A number of cognitive functions and behaviors can be performed in a fairly automatic manner, which rely a little or even do not rely on working memory (Unsworth & Engle, 2007). However, working memory is necessary for mastering the skill that leads to the level of automation. It is also necessary for processing of new information, resolving problems or situations, maintaining of main goal awareness, retaining new information, and for consciously retrieving information from long-term memory.

Working memory plays an integral role in higher level cognitive activities, including reasoning, comprehension, and executive functioning (Dehn, 2007). The processes that are linked most closely with working memory include attention, phonological processing, executive functioning, fluid reasoning and processing speed (McNamara & Scott, 2001). Also, working memory capacity sets limits on related higher level processes (Conners, Rosenquist, & Taylor, 2001). Therefore, working memory deficits may affect the poorer performance of other cognitive processes.

During development, working memory increases two to three times between the fourth and sixteenth years, with a steady increase after the eighth year (Gathercole, 1999). According to Gathercole et al., (2004), six-year old child has all components of working memory. Same authors state that the further development of working memory structure does not change significantly, and that it resembles the structure of working memory in adults. However, while the working memory of children and adults is similar in a term of structure and processing, there are still some differences. In children, working memory depends more on phonological short-term memory than in adults. Specifically, the phonological features of words influence processing in children, while adults rely more on semantic associations. Supporting this, research findings have shown that children experience significantly more difficulty in phonological discrimination and non-word tasks comparing to adults (Conlin & Gathercole, 2006). During development, the strength of the links between working memory and other cognitive abilities changes, the functioning and interaction of cognitive components develops, and a person learns how to use working memory for various purposes. Thus, for example, the results of the Gathercole et al., (2004) study showed that, from age six to age fifteen, correlation between working memory and phonological short memory is increasing significantly.

For the purpose of working memory assessment, various memory span tasks are used. Those tasks commonly contain processing elements such as sentence reading or mental rotation, while retaining information that is evoked later. Typically, such tasks are constructed in the direction of more complex and longer ones, measuring the range of capacities until a recall error occurs. As in case of short-term memory assessment, verbal and visuospatial tasks are also used to evaluate working memory. Example of a verbal working memory task is a reading range, in which one is asked to give a meaningful judgment about each sequence of sentences and then remember the last word of each sentence in the sequence (Daneman & Carpenter, 1980). Also, there are numerous tasks that measure the dependency of working memory on other cognitive abilities, as well as those that measure the individual components of working memory. However, some authors state that the main limitation of this kind of assessment is that, by providing materials and instruction in a structured testing context, the examiner is essentially a "surrogate frontal lobe" for the individual (Ylvisaker & DeBonis, 2000;

Anderson, Levin, & Jacobs, 2002). Consequently, due to the strictly controlled structure and organization, one may have normal level of achievement during assessment but still exhibit difficulties in daily activities that require good working memory capacity. To overcome these shortcomings, behavioral scales, such as the Behavior Rating Inventory of Executive Function – BRIEF (Gioia, Isquith, Guy, & Kenworthy, 2000), have been developed. Purpose of this kind of scales is measuring of executive functions in everyday situations, among them working memory too.

Cognitive abilities in children with specific language impairment

Children with specific language impairment (SLI) have difficulties in language development that cannot be attributed to neurological, sensory or environmental factors. However, different genetic and neurological factors may contribute to lag in language development (Bishop, 2009; Law et al., 2004).

According to the International Classification of Diseases (ICD-10), a specific language impairment can be diagnosed to children whose achievement on standardized speech and language assessment tests deviates from at least two standard deviations below average, while non-verbal abilities can deviate a maximum one standard deviation below average (World Health Organization, 2008). Children with SLI demonstrate varying degrees of language comprehension and production problems with deficits in vocabulary, grammatical morphology and syntax. Despite the normal range of non-verbal intelligence, children with SLI can exhibit a number of cognitive limitations, especially in area of memory and executive functions.

The results of previous studies have shown that children with SLI may have short-term memory deficits (Archibald & Gathercole, 2007; Conti-Ramsden, 2003). Moreover, these children can exhibit significant deficit during assessment, averagely 1.27 standard deviations below achievement of typically developing (TD) peers (Graf Estes, Evans, & Else-Quest, 2007). Also, comparing to TD peers children with SLI have significantly lower achievement in the area of both, verbal and nonverbal working memory (Archibald & Gathercole, 2006; Montgomery & Evans, 2009).

Even in the domain of executive functions in general, children with SLI may have significant difficulties. Previous studies have shown that these children have difficulties in sustaining attention in both, auditory and visual domains (Ebert & Kohnert, 2011; Victorino & Schwartz, 2015), as well as with attention shifting (Im-Bolter, Johnson, & Pascual-Leone, 2006). Additionally, the results of numerous studies suggest that children with SLI have significant difficulties in inhibition (Im-Bolter et al., 2006; Marton, Campanelli, Eichorn, Scheuer, & Yoon, 2014; Pauls & Archibald, 2016; Spaulding, 2010). Specifically, when compared to their typically developing peers, children with SLI demonstrate reduced inhibition of prepotent responses (Henry, Messer, & Nash, 2012).

There is a common view that the general processing deficit underlies cognitive impairment in children with SLI, which is associated also with language deficits seen in these children (Tallal, 2004). Difficulties in processing speed are characteristic of children with SLI and children with specific learning disabilities. In support of this, Tallal and Gaab (2006) state that processing speed deficits and delays in sensorimotor development are commonly present in children with SLI.

On the other hand, the results of numerous studies indicate a significant correlation between cognitive and language skills. The role of working memory is particularly emphasized. Van Daal et al., (2008) indicated that phonological working memory is predictive for semantic and syntactic abilities, and that a verbal short-term memory is a strong indicator of vocabulary growth in preschool children (Gathercole, Willis, Emslie, & Baddeley, 1992). Also, verbal short-term memory of young children have been found to be associated with narrative skills (Adams & Gathercole, 1996), utterance length and range of used syntactic constructions (Adams & Gathercole, 2000). Also, there is more than sufficient evidence that linguistic processing is constrained by general working memory capacity and effective utilization of that capacity (Moser, Fridriksson, & Healy, 2007). Moreover, there is a theoretical point of view that a deficit in verbal short-term memory abilities constrains the language development of children with SLI (Adams & Gathercole, 2000).

Based on previous research, Tallal (2004) concludes that there may be common underlying interactive neural substrates for language and nonverbal processing.

Present study

Although the use of behavioral measures of EF have been widely advocated to gain more ecological valid information, studies using rating scales of EF in children with SLI has been very limited. Obtaining information about the children's executive functioning through behavior ratings can be very useful for understanding how children's executive skills impact their activities of daily living. Also, there is a small body of literature about the effectiveness of working memory in everyday situations, while there are only a few such studies in population with SLI. Considering that, we wanted to examine behavioral aspect of working memory in children with SLI. Also, due to the importance of working memory for academic achievement, we wanted to examine the effectiveness of working memory in everyday situations in preschool and early school age SLI children.

METHOD

Participants

The sample consisted of 51 children with SLI, ages between five and eight years. All children were administered the Wechsler Intelligence Scale for Children Revised (Biro, 1997), and inclusion criterion was IQ above 85.

Table 1 and Table 2 provide descriptive data for the sample.

Table 1 – *Participants' age in months*

N	min	max	Mean	SD
51	58.00	100.00	73.69	11.65

Sample included 34 boys (66.70%) and 17 girls (33.30%).

The sample was subsequently divided into two age groups, a subgroup of preschool SLI children (≤ 72.00 months) and a subgroup of school age SLI children (≥ 73.00 months).

Table 2 – *Distribution of boys and girls in age subgroups*

Sex		Age		Total
		≤ 6 yrs.	≥ 7 yrs.	
Boys	N	15	19	24
	%	57.70%	76.00%	66.70%
Girls	N	11	6	17
	%	42.30%	24.00%	33.30%
Total	N	26	25	51
	%	50.98%	49.02%	100.0%

Instruments

For the purpose of an assessment of behavioral aspect of working memory, Behavior Rating Inventory of Executive function – BRIEF (Gioia et al., 2000) was used. The BRIEF Scale - Parent Form is a standardized questionnaire containing 86 items divided into eight subscales that assess 8 components of executive function (inhibition, shifting, emotional control, initiation, working memory, planning/organization, material organization and monitoring). The clinical scales form the two broader indices of behaviour regulation (BRI) and meta-cognition (MI), which are then combined into a Global Executive Composite (GEC). The puropse of this scale is to examine parents' perception of child's behavior related to executive abilities. Additionally, BRIEF scale provides a cutoff criterion for determining whether or not a given child's executive functioning ratings are sufficiently poor to be of clinical concern.

For the purposes of this study, the Working Memory subscale was used. Standard scores (T – scores) from the subscale were used for statistics. According to the norms, the average achievement limit is at the level of 50 standard scores. Standard scores between 50 and 65 (1.5 standard deviation above) correspond with underachievement, while achievement at the level of more than 65 standard scores are considered as poor achievement in the area of behavioral aspect of working memory.

RESULTS

Descriptive statistics showed that mean T – score for the whole sample is 57.82, ranging from 36 up to 85 (SD = 10.53). This results show that, as a group, SLI children are on the verge of underperformance.

Further, more detailed descriptive data give a better insight into distribution of children with normal achievement and those with poor performance. Descriptive indicators of normative deviation on the BRIEF working memory subscale in children with SLI are given in Table 3.

Table 3 – *Distribution of participants in relation to the threshold of typical achievement*

	N	%
< 65	37	72.50
≥ 65	14	27.50
Total	51	100.00

According to the norms, children who have T scores greater than 1.5 standard deviations above the cut-off value (T – score ≥ 65) have poor working memory performance. Data from the Table 3 shows that 27.5% of children with SLI have poor performance in the area of behavioral aspect of working memory.

Table 4 provides a detailed distribution of children with SLI on the BRIEF working memory subscale.

Table 4 - *Distribution of participants in relation to BRIEF achievement*

	N	%
normal achievement	26	51.00
1 sd	19	37.30
2 sd	5	9.80
3 sd	1	2.00
Total	51	100.00

Data from Table 4 show that 51% of children with SLI have good working memory performance. However, as many as 37.3% of children deviate by one standard deviation and are on the verge of underperformance, nearly 10% deviate by two standard deviations, while one child deviates even by three standard deviations. Initially, such data indicate that a number of children with SLI have some difficulties with behavioral performance of working memory.

By using ANOVA, we examined possible differences in achievement between boys and girls (Table 5).

Table 5 - *Sex differences in achievement on BRIEF working memory subscale*

sex		min	max	mean	SD	F	p
WM	boys	38.00	80.00	58.41	10.55	0.314	0.578
	girls	36.00	75.00	56.65	10.72		

WM – working memory

The results show that, relative to total sample, there are no significant differences in achievement between girls and boys. Although boys have a slightly higher T – scores, therefore worse performance, this difference is not statistically significant.

Additionally, we wanted to examine whether there are sex differences in the two subgroups, SLI children with good WM achievement and SLI children with poor WM achievement. Table 6 shows the distribution of boys and girls in SLI groups.

Table 6 – *Sex distribution in two SLI subgroups*

		< 65	≥ 65	total
Boys	N	25	9	34
	%	73.50	26.50	100.00
Girls	N	12	5	17
	%	70.60	29.40	100.00
Total	N	37	14	51
	%	72.50	27.50	100.00

By applying Chi – squared test, no significant differences were found in the number of boys and girls within the subgroups ($\chi^2 = 0.049$; df = 1; p = 0.824). These data show that boys and girls are relatively evenly represented in the different achievement categories, which further indicates that the level of working memory development in children with SJP is not sex related.

Further, using a two-factor analysis of variance, we examined the possible presence of sex-age interaction. Figure 1 shows the developmental tendencies of working memory in boys and girls.

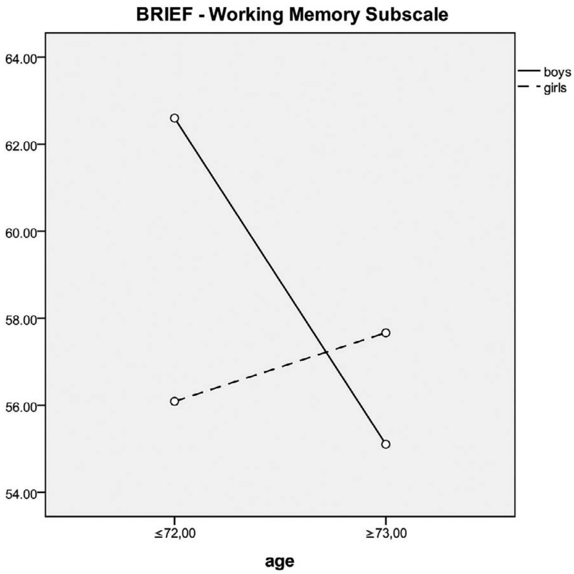

Figure 1 – Developmental trend of working memory in boys and girls with SLI

No interaction between sex and age was found ($F_{(1;50)} = 2.040$; p = 0.160), meaning that both, boys and girls exhibit a similar trend in working memory development. However, in Graph 1 it can be observed that school age girls have slightly worse achievements than preschool age girls (higher T – scores), while in the group of boys the opposite tendency is observed.

Accordingly, in the next step, we examined the sex distribution in two age groups, individually in group of children with normal achievement and group of children who deviate from the norms of average achievement (1, 2 and 3 SD above). Table 7 shows the sex distribution in age groups of children with normal achievement (26 subjects).

Table 7 – *Sex distribution in age subgroups in SLI children with normal achievement*

age		boys	girls	total
≤ 72.00	N	5	8	13
	%)	38.50	61.50	100.00
≥73.00	N	11	2	13
	%	84.60	15.40	100.00
	total	16	10	26

Chi – squared test revealed significant differences in the number of boys and girls within the subgroups ($\chi^2 = 5.850$; df = 1; $p = 0.021$). Such data indicate that in the younger group of children with SLI there are more girls who have average achievement, while in the older group there are more boys with average achievement.

On the other hand, in the group of children deviating by one, two or three standard deviations from the norms of average achievement (25 subjects), no significant difference in sex distribution was found between the age groups ($\chi^2 = 0.326$; df = 1; $p = 0.450$). Such data indicate that the representation of girls and boys does not differ significantly in the group of children with borderline and poor achievement.

DISCUSSION

Although SLI has been defined as a language disorder in the absence of neurological, intellectual, or physical impairments, evidence is accumulating suggesting that children with SLI also manifest difficulties with executive functioning. Problems with executive functioning are especially obvious in the area of working memory (Archibald & Gathercole, 2006; Montgomery & Evans, 2009). This has led to one view that memory limitations may underlie some of the language difficulties that can be seen in these children (Montgomery 2003).

Descriptive analysis in our research showed that in overall, SLI children are on the verge of underperformance. However, a number of SLI children (27.5%) in our sample have poor performance in the domain of behavioral aspect of working memory. Given that a percentage of 5% would be expected in a normal distribution (Cuperus, Vugs, Scheper, & Hendriks, 2014), we can say there is significant number of SLI children having clinically impaired range of WM performance in everyday situations. There is a body of research suggesting that children with SLI exhibit low performance on WM tasks in clinical settings (e.g. Adams & Gathercole, 2000; Archibald & Gathercole, 2006; Van Daal et al., 2008). On the other hand, there are only few studies addressing the impact of WM on daily life activities in different contexts in SLI children. In one such study of Cuperus et al., (2014), results showed similar distribution like in ours, whereas average T–score was in the range of borderline achievement (M = 52) with 12% of SLI children who had poor WM performance. Comparing to Cuperus et al., (2014) study, SLI children from our sample have slightly worse achievements (58 average T–score and 27% with poor performance). This can be explained with overall clinical heterogeneity in SLI population. This variability and heterogeneity increases in everyday performance of language skills and associated difficulties in children with SLI. Moreover, some aspects of executive abilities in children predict later vocabulary development and literacy (McClelland et al. 2007), which can make mustering academic skills even harder for children with SLI.

In one another study, Wittke and colleagues (2013) were examining overall executive functions of children aged 3–5 years using the BRIEF preschool version. They found that the behavioral aspect of executive functions in children with SLI was rated significantly worse than those of their TD peers. However, it is difficult to compare our results with the mentioned study (Wittke, Spaulding, & Schechtman, 2013) because of different methodology and aim of study. Namely, the aim of the aforementioned paper was to compare composite scores of executive functions obtained from parents and teachers, in children with SLI and their TD peers. On the other hand, we considered only scores from the Working Memory subscale, comparing the achievements of children with SLI and TD children. However, both, the results of Wittke and colleagues (2013) study and the results of our study, indicate significant difficulties in the functioning of executive abilities in children with SLI.

As BRIEF scale offers a view of children's executive function profiles in context, our data showed that there are number of children with SLI who are at risk for certain patterns of executive difficulty. Also, our findings further support the idea that many children with SLI have deficits beyond the language domain. More research is needed to investigate which children with SLI are at specific risk for working memory deficits. Also, more research about relations between specific language abilities and WM performance is needed.

Regarding sex differences, initially we did not find differences. However, a more detailed analysis revealed some specifics. Results showed that in the younger group of children with SLI (5 and 6 yrs.) there are more girls who have average achievement, while in the older group (7 and 8 yrs.) there are more boys with average achievement. This indicates the possibility that with maturing SLI boys have better behavioral aspects of working memory, comparing to girls. This can be explained with sex differences during development of working memory in typically developing children. Namely, at an earlier age (4–6 years) there are no significant differences between typically developing boys and girls in terms of working memory. On the other hand, boys exhibit significantly better working memory at the age of 6 to 16 years (Lynn & Irwing, 2008). However, more detailed research on sex differences in working memory found that girls performed better on verbal working memory tasks, while boys performed significantly better on visuospatial working memory tasks (Lowe, Mayfield, & Reynolds, 2003). There is no data in the literature regarding sex differences in the behavioral aspect of working memory, and studies to date have examined only achievement differences exhibited during direct assessment. Accordingly, one of implication for future research goes in this direction. However, we must note that the number of boys and girls in our sample is unequal (more boys), and therefore we cannot draw reliable conclusions regarding sex differences. Given that SLI is a disorder that is significantly more prevalent in boys, it is difficult to equal gender distribution in this population. However, a significantly larger sample in a future studies would reduce the effect of this prevalence, allowing a more reliable examination of sex differences in children with SLI regarding everyday working memory performance.

CONCLUSION

Results of our study showed that a significant number of children with specific language impairment have difficulties in the area of behavioral aspect of working memory. These findings add to a growing body of evidence indicating that children with SLI exhibit working memory deficits and provide evidence that such difficulties manifest in everyday living. Children with SLI have already significant difficulties in academic achievement due to language difficulties, so difficulties in the area of cognitive abilities can make process of mastering academic skills even harder for these children. Accordingly, results of our study indicate the need for more extensive assessment of these children in preschool period.

Also, some developmental sex differences regarding behavioral aspect of working memory were observed. However, more detailed methodology is needed in future studies for reliable conclusions.

Also, future studies in this area should investigate the precise association between the behavioral aspect of working memory and the specific linguistic difficulties present in children with SLI. At the end, important issue should be focused to interventions/strategies that target executive abilities in natural context with SLI children.

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