Original Article

Working Memory in Specific Language Impairment

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ABSTRACT

Aim: To study the relation between working memory deficits and development of language in patients with Phonological programming Specific Language Impairment (SLI), Lexical syntactic SLI and Phonological syntactic SLI.

Patients and Methods: This study is a retrospective study conducted on a series of Specific Language Impairment children (n=94). Inclusion criteria: children age range between 2.5- 6.5 years, native Arabic speakers with history of speech and language delays and nonverbal IQ ≥ 85. Exclusion criteria: children with mental retardation, hearing impairment and any psychiatric disorders such as autism. Investigating working memory in SLI children was done and comparing the results with a control group (n=33).

Results: There was statistically significance difference between different types of SLI and the control group in verbal working memory (*P value< 0.001*).

Conclusion: Verbal working memory abilities and language development are associated especially to Lexical syntactic SLI, Phonological syntactic SLI rather than to Phonological programming SLI.

Key Words: Language, nonverbal, verbal, working memory.

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INTRODUCTION

Classification of Specific Language Impairment (SLI):

Several classification systems have classified children with Specific Language Impairment into homogeneous subgroups. Rapin and Allen[1] identified three subgroups of age-related disorders and six different types of language problems. They classified SLI according to linguistic analyses of morphosyntactic, pragmatic, phonological, or lexical capabilities into

1) Mixed expressive- receptive disorders which include

a) 'Verbal auditory agnosia': This condition occurs in epileptic aphasia and is sometimes accompanied by marked EEG abnormalities. Language comprehension and articulation are poor.

b) 'phonologic-syntactic deficit disorder': Comprehension is variable; Sometimes complex expressions are difficult to understand. Sentences are short with inaccurate syntax.

2) Expressive disorders which include

a) 'Verbal dyspraxia': Signs of oromotor dyspraxia may be present. Comprehension is adequate. Nevertheless, sentences are short with impaired phonology.

b) 'Phonologic- programming deficit disorder': Comprehension is adequate. Sentences are long, good syntax, yet grammatic markers may be omitted and poor phonology.

3) Higher order processing disorders which include

a) 'Lexical syntactic deficit disorder': There is insufficiency in comprehension of complex sentences. Syntax is immature rather than deviant. Nevertheless, phonology is good.

b) 'Semantic-pragmatic disorder': Comprehension is sometimes over-literal. The child responds to only one or even two words in a sentence. Sentences are well formed with good articulation. As regard expression the child may have echolalia. The child's use of language in social context is poor as manifested in turn taking.

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Working memory

Working memory is defined as the ability to store, maintain, and manipulate information in ongoing cognitive tasks[2]. Baddeley and Hitch[3] proposed the tripartite system that has an attentional controller, a central executive (CE), helped by two secondary systems that are: phonological or articulatory loop and the visuo-spatial sketchpad.

Working memory and language acquisition

There is no simple relation between language acquisition and working memory although of several studies tried to make a link between language deficits and deficits in specific memory systems[4,5]. Some researchers approved high association between WM capacity and language acquisition and functioning[6]. In addition, working memory (WM) deficits were documented in SLI children[7,8,9]. Differences in the language profile and performance of children with SLI may be due to neurodevelopmental factors that play an important role in SLI. SLI is believed to be a disorder not only caused by phonological short-term memory deficits but also by perception of auditory input[10], or more general processing or capacity limitation[11]. As pointed out by Bishop *et al*.[12] and Botten[13], this was supported by persistent phonological memory deficits in a group of children with SLI after solving language problems. Others consider working memory deficit to be a result more than a reason of language impairment[14]. Nevertheless, not all SLI children demonstrate WM limitations[15].

Models of working memory explaining language acquisition

Baddeley and Hitch's model of Working Memory[3]

According to Baddeley's model the phonological loop, central executive and previously learned language kept in long term memory (LTM) contribute to language acquisition. The model said that low working memory capacity limits language acquisition and vice versa.

Gupta & Tisdale[16] described bidirectional association between working memory and language over time, with varying degrees of influence. Gathercole[17] noted that dependence on phonological short term memory (PSTM) to acquire new words decreases as vocabulary increases. This is due to better backing from LTM stores to analyze and store new arriving phonological information. Hence, Working memory and long-term memory are correlated with one another, as evidenced by this as seen in (Figure 1). The shaded area in the figure marked "crystallized" to indicate its long-term character reveals how the initial tripartite working memory model has been altered to specify its interaction with long-term memory.

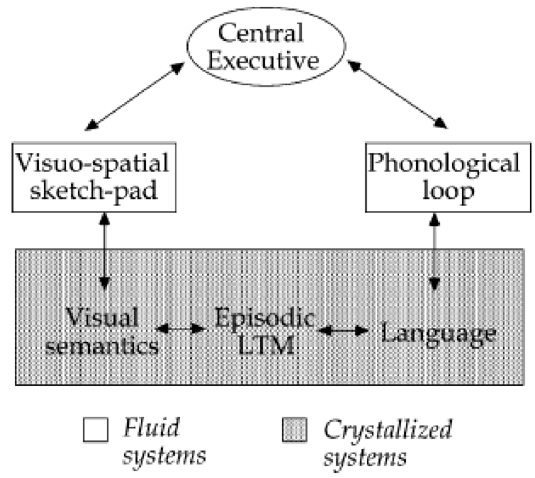

Fig. 1: The modified tripartite working memory model[6].

The working memory model proposed by Cowan.[18]

Cowan considered that the working memory is equivalent to the short term memory (STM) when it is used to do duty or deal with a problem. If a neuron's firing pattern is strong enough, it becomes responsive. Information stored in STM remains a trace of LTM even after a long period of time. Therefore, given the link between STM and LTM, it is understandable that language processing is limited by insufficient STM capacity. According to Cowan model, WM is the volume of information in LTM that is held in a readily accessible state for a brief period of time (STM) under CE's control and via a pattern of neuronal firing. The time it takes to encode new words into LTM will increase if a person's PSTM is constrained because they won't be able to simultaneously maintain many neurons in an active state.

Adams and Gathercole[19] noted that there is specific association between language development and phonological memory skills with little relationship with other components of working model such as visual-spatial sketchpad and central executive skills. However, the authors stated that there are inconsistent association between the latter components of working memory and language development, which preclude firm conclusions about the specificity of the relationship to the phonological domain.

Aim of the work

In this research, the authors aim to know the relation between working memory deficits and language development in children with Phonological programming SLI, Lexical syntactic SLI and Phonological syntactic SLI and which type of working memory that affect language development in those patients.

PATIENTS AND METHODS:

This study is a retrospective study conducted on a series of 94 children presented to the Phoniatric unit. Inclusion criteria: children age range between 2.5- 6.5 years, native Arabic speakers with history of speech and language, delays and nonverbal IQ ≥ 85. Exclusion criteria: mental retardation, hearing impairment and any psychiatric disorders such as autism. The cases were compared with a control group with normal language development (n=33). Evaluation of the language abilities using Arabic language test[20] and Intelligent Quotient (IQ) using Stanford Binet edition V[21] were done for the recruited children. Assessment of total working memory, verbal working memory and non verbal working memory was done by using Stanford Binet edition V for all children. Also audiological evaluation was done.

According to Rapin & Allen (1) classification, the cases (n=94) are divided into three groups; Phonological programming SLI (n=33), Lexical syntactic SLI (n=33), Phonological syntactic SLI (n=28). The cases are compared with a control group (n= 33) in Total working memory (TWM), Verbal Working memory (VWM) and Non-verbal working memory (NVWM) in the studied types of SLI.

Nonverbal Working Memory (NVWM)

1- Delayed Response (DR): Three cups are used to hide a duck-shaped toy; the child must eventually figure out which cup the duck is in.

2- Block Span (BS): It is a nonverbal equivalent of the forward and backward digit span tasks. The child is instructed to imitate tapping a block onto a row of four blocks, then two rows of eight blocks, with higher levels requiring the division of sequential taps into row-by-row tapping.

Verbal Working Memory (VWM)

1- Memory for Sentences (MFS): After the examiner finished speaking, the youngster was asked to repeat it. The task started with two or three word sentences and grew to longer sentences over time.

2- Last Word (LW): The young reader was given a variety of questions to read-the number of questions varied by level and ranged from one to nine. Each question was responded to by the youngster. He or she remembers the final phrase of each sentence afterward. As the task and the child's age increased, the questions grew longer.

Prior to the start of the research, the ethical committee's approval was obtained. Before the study began and following a discussion of its goals, all parents provided their written consent.

Statistics:

• Analysis of data was done using IBM SPSS Statistics for Windows version 20.0

• The mean, standard deviation, median and range was measured.

• The data were tested for normality using Shapiro-Wilk test. The nonparametric Kruskal–Wallis test with multiple pairwise comparisons was used for data which wasn't normally distributed.

• *P value* of 5% or less was deemed statistically significant.

RESULTS:

Descriptive statistics:

Ninety-four children have been included in this study; 64 males and 30 females. The children were subdivided into three types of SLI according to their language skills. The number of children, gender distribution and the mean age in each group have been shown in (Table 1).

Table 1: Descriptive statistics for the different studied types of SLI and the control group

	No. Total (94)	Sex distribution		Mean age in months (±SD)
		Males	Females	
Phonological programming SLI	33	21	12	51± 8
Lexical syntactic SLI	33	25	8	45± 7
Phonological syntactic SLI	28	18	10	51± 9
Control group	33	30	3	58+12

Total working memory:

There was statistically significance difference between different studied types of SLI (Phonological programming SLI, Lexical syntactic SLI, Phonological syntactic SLI) and the control group in total working memory (*p value< 0.001*). By comparing each type with the control group, there was no significant difference between phonological programming SLI and the control group (*P value < 0.307*) (see Table 2, Figure 2)

Table 2: Comparison between the studied groups and control group regarding total working memory.

	Phonological programming SLI (n= 33)	Lexical syntactic SLI (n= 33)	Phonological syntactic SLI (n= 28)	Control (n= 33)	*P value*
	P1 =0.307	P2 <0.001	P3 <0.009		
Total working memory Mean± S.D.	95.87 ± 10.95	81.1 ± 7.22	90.67 ± 8.09	97.18 ± 8.29	*<0.001*

P-value compared total working memory of all groups
p1 compared Phonological programming SLI and control group
p2 compared Lexical syntactic SLI and control group
p3 compared Phonological syntactic SLI and control group
P-value, P1, P2, and P3 were calculated by Kruskal Wallis test with multiple pairwise comparisons
P-value < 0.05 is statistically significant

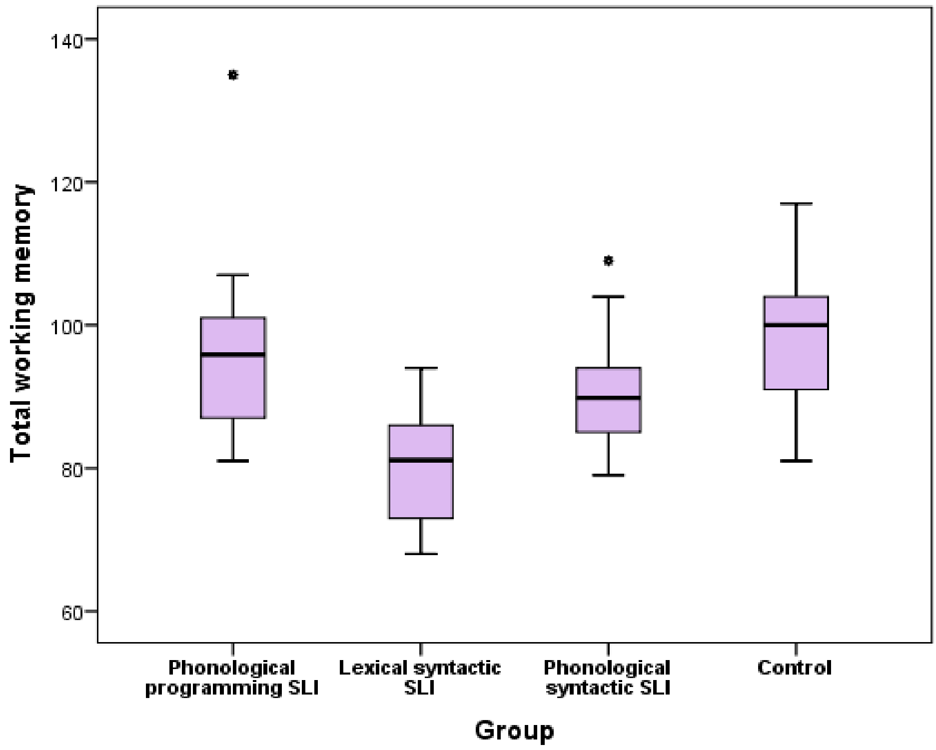

Fig. 2: Comparison between the studied groups regarding total working memory.

Verbal working memory:

There was statistically significance difference between different studied types of SLI (Phonological programming SLI, Lexical syntactic SLI, Phonological syntactic SLI) and the control group in verbal working memory (*P value< 0.001*). By comparing each type with the control group, there was no statistically significant difference between phonological programming SLI and the control group (*P value < 0.0231*) (see Table 3, Figure 3).

Table 3: Comparison between the studied groups and control group regarding verbal working memory.

	Phonological programming SLI (n= 33)	Lexical syntactic SLI (n= 33)	Phonological syntactic SLI (n= 28)	Control (n= 33)	*P value*
	P1 <0.231	P2 <0.001	P3 =0.012		
Verbal working memory Mean± S.D.	9.16 ± 2.66	5.03 ± 2.69	8.15 ± 2.29	9.85 ± 1.86	*<0.001*

P-value compared verbal working memory of all groups
p1 compared Phonological programming SLI and control group
p2 compared Lexical syntactic SLI and control group
p3 compared Phonological syntactic SLI and control group
P-value, P1, P2, and P3 were calculated by Kruskal Wallis test with multiple pairwise comparisons
P-value < 0.05 is statistically significant

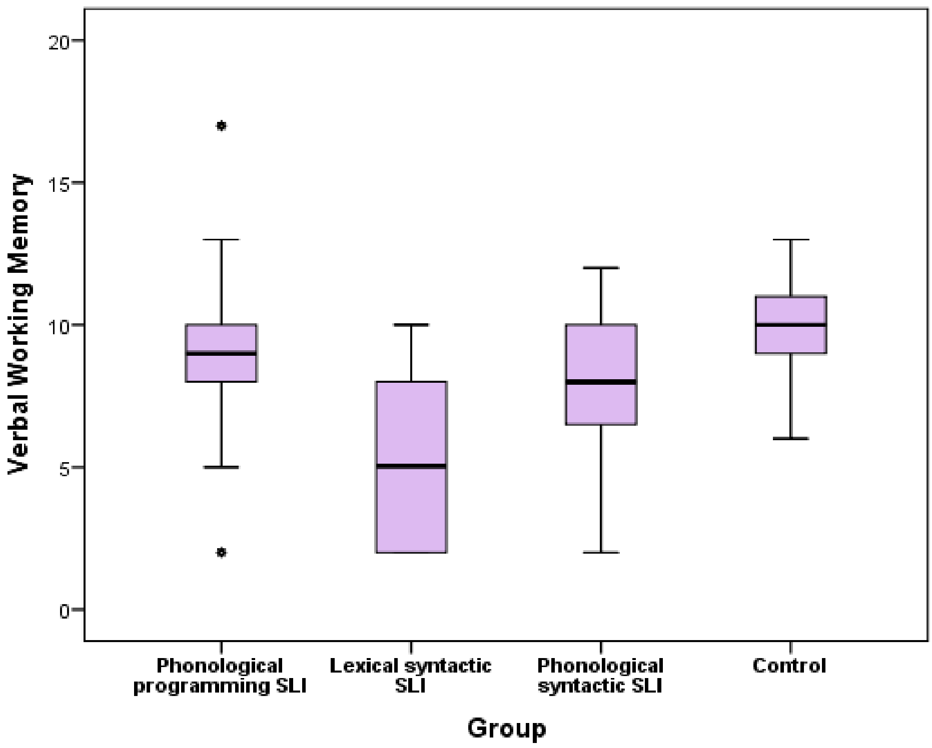

Fig. 3: Comparison of the studied groups in this regard verbal working memory.

Non verbal working memory:

There was no statistically significance difference between different studied types of SLI (Phonological programming SLI, Lexical syntactic SLI, Phonological syntactic SLI) and the control group in non verbal working memory (*P value= 0.073*) (see Table 4).

Table 4: Comparison of the studied groups in this regard non-verbal working memory.

	Group				*P-value*
	Phonological programming SLI (n= 33)	Lexical syntactic SLI (n= 33)	Phonological syntactic SLI (n= 28)	Control (n= 33)	
Non-verbal working memory Mean± S.D. Median (Range)	10.19 ± 2.47 10.19 (5 – 18)	9.18 ± 1.53 9 (7 – 14)	9.46 ± 1.88 9 (6 – 13)	10.15 ± 2.84 11 (0 – 15)	*0.073*

DISCUSSION

Specific language impairment (SLI) is a developmental disorder multifactorial in nature that has a high prevalence rate; it is known as risk factor for psychosocial and academic difficulties[22]. Specific language impairment (SLI) was ensured when children viewed language maturation, at least 12 months behind their chronological age with no sensory or intellectual deficits, no pervasive developmental disorders, no evident nervous damage, and tolerable social and emotional conditions[23]. Hence, hearing impaired, mental retarded children and children with any psychiatric disorders such as autism were excluded. In this study cases, only three types were studied; Lexical syntactic SLI, Phonological programming SLI, and Phonological syntactic SLI. Semantic pragmatic SLI and apraxia were excluded, as there was very limited number of cases that came to our unit during the period of the study. The Stanford Binet edition V[21] is suitable for evaluating kids' cognitive skills at various developmental stages and ages. Given that it has been standardised on children as young as 24 months, it is particularly useful for the early identification of developmental issues and other special needs[24]. Hence, in this study, it has been used to measure TWM, VWM and NVWM in SLI children.

Total working memory and Verbal working memory:

There was statistically significance difference between different studied types of SLI (Phonological programming SLI, Lexical syntactic SLI, Phonological syntactic SLI) and the control group in total working memory (*P value* < 0.001) and Verbal working memory (*P value* < 0.001) conforming the link between WM and language acquisition. Moreover, by comparing each group of SLI with the control group, statistically significance difference between Lexical syntactic SLI and typically developed language children in both total WM (*P value* <0.001) and verbal WM (*P value* <0.001) was found as Lexical syntactic SLI children had the worst performance. This can be taken to mean that someone with limited PSTM will take longer to code novel words to LTM and thus have difficulty acquiring new words[18,25]. Additionally, according to Adams and Gathercole[17], the length of utterances and productive vocabulary are related to phonological memory abilities. Evidence is present in typically developing (TD) children as moderate correlations between PSTM and vocabulary have been found[26, 27, 28]; however, it should not be assumed that PSTM and vocabulary acquisition are causally related[26, 29, 30]. Gray[31] surprisingly showed that a pSTM deficit does not limit the word learning of SLI children in a word-learning study, which surprised many people.

Statistically significance difference between Phonological syntactic SLI and typically developed language children in both total working memory (*P value* < 0.009) and verbal working memory (*P value* $= 0.012$). This can be interpreted that the phonological loop of the working memory model was identified to play a role in acquiring the phonological forms of morphosyntax[32, 33, 34]. Shorter utterances and a smaller variety of syntactic constructions would result from a limited range of syntactic models caused by poor phonological memory abilities. Speidel[35] proposed an interpretation in which the ability to imitate and short term retention of adult models of morphosyntactic constructions are ruled by phonological memory skills. The adult models of language are stored into a long-term memory of phonological representations. These adult syntactic models act as templates for spontaneous speech[35].

There was no significant difference between Phonological programming SLI, and typically developed language children in the Total Working memory (*P value* $=0.307$) and Verbal working memory (*P value* $=0.231$) indicating that working memory has no role in phonological development in children. Gathercole and Baddeley[36] studied a group of SLI children with no articulatory difficulties and they attributed the language delay in those children to the phonological loop of working memory.

In consistency of our results, Archibald and Gathercole[37] showed the SLI group performance in tasks having verbal storage was significantly worse than controls. According to the authors, a combination of a verbal-specific storage deficit and slower domain-general processing was to blame for the children's limited WM capacity. Incomplete or inaccurate representations of the speaker's input may be created as a result of poor processing. As Leonard *et al*.[38], poor ability to process input could lead to more extension of acquiring language, so for integration of words and language in the language system, children need more exposures to them.

Non verbal working memory:

No statistically significant difference between the different studied types of SLI in the nonverbal working memory. The tasks are presented with manipulatives (blocks, duck and cups), and brief oral directions, and responses involve gestures and manipulation. These results refute the notion that non-linguistic systems play a role in SLI[39]. Hence, nonverbal working memory tasks have lower language demands, although they are not entirely non-verbal. Nonverbal memory tasks are correlated to mathematics achievement[40] rather than language development.

Clinical implications

Because SLI children represent a heterogeneous population, we specify verbal WM training for only, Lexical syntactic SLI, Phonological syntactic SLI children. The reason of verbal WM training not only to enhance WM capacity but also to improve handling the dual demands of information processing and storage during different language - related activities. Training can be beneficial through some computerized programs or through rehearsal strategies. Using verbal WM, clinicians may broaden the scope of treatment if language-based approaches yield negligible results.

CONCLUSION

The findings show a significant correlation between verbal working memory abilities and language difficulties in SLI children. SLI children's verbal working memory capacities and language deficiencies are connected with the Lexical syntactic and Phonological syntactic SLI subtypes, rather than the Phonological programming SLI. As a result, language therapy aimed to improve children's WM functioning for SLI are recommended.

RECOMMENDATIONS FOR FUTURE WORK

The current study is regarded as a first step toward a better understanding the relation between working memory abilities and SLI. For an enhanced comprehension of nonverbal WM abilities, additional extensive research employing various psychometric testing, and the Working Memory Test Battery for Children, is strongly suggested.

CONFLICT OF INTEREST

There are no conflicts of interest.

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