

Impact of Working Memory and Cognitive functioning on Specific Language Impairment (SLI)

Abstract

Purpose: The main purpose of this research was to investigate the functioning of working memory of children with Speech and Language Impairment (SLI).

Method: Two groups of children were selected for the purpose; Children with Speech and Language impairment (SLI) and Typically Developing (TD) children. The SLI group consisted of 15 children (10 male and 5 female) with an age range of 75-154 months. The TD children consisted of 23 children (12 male and 11 female) with an age range of 48-190. All children were assessed on the intelligence test followed by a computerized assessment of Short Term Memory (STM) and Working Memory (WM). The assumption was that children with SLI would demonstrate impairments on tasks of working memory compared to typically developing children. Data was analyzed using MANCOVA and t-test by SPSS statistical package.

Results: The results indicate that the SLI group showed impairment on the verbal working memory tasks as there was no difference observed between the TD and SLI group on the visual-spatial working memory components.

Conclusion: The SLI group showed their weaknesses on tasks measuring phonological short term working memory; whereas no difference was noted on tasks of visual-spatial working memory. These findings may help in the application of intervention strategies for children with SLI.

Research Article

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Abbreviations: SLI: Speech and Language Impairment; TD: Typically Developing; WM: Working Memory; STM: Short Term Memory; TDC: Typically Developing Children; CA: Chronological Age

Introduction

Working memory (WM) refers to a process of simultaneous retention and manipulation of information and is considered to be essential for complex cognitive tasks of learning and reasoning [1] including language development. Speech and Language Impairment (SLI) is a complex phenomenon as many research studies conducted in this area have produced conflicting results to ascertain the underlying factors of this debilitating problem affecting 5 to 10% of children across the world. Research studies looking for the relationship between WM and SLI have produced inconsistent results. One of the reasons for the divergence in results could be the complexity and heterogeneity of the SLI as a group itself and the selection of instrument for measuring WM.

Studies which have indicated the implication of working memory in SLI group propose that children with SLI are limited in their capacity to simultaneously process and store information [2-9]. However, majority of these studies have relied on tasks that measure verbal and non verbal reasoning abilities rather than working memory skills. This could be due to the non availability of specific standardized instruments designed to measure working memory at the time. Albeit, there are studies that relied on the subtests of an assessment battery to measure working memory, such as non-word repetition to measure verbal working memory

[3,8,10-13]. Dollaghan & Campbell, as well as studies using more conventional verbal short term memory measures, such as serial recall of digits or words [14-16]. These results indicated age appropriate performance for SLI groups on visual storage tasks [14], and were found to have difficulties on working memory tasks involving the storage and processing of verbal but not visual-spatial tasks [14,17]. This dissociation has been explained in the light of evidence that performance decrements occur only when the task additionally taps the impaired phonological but not preserved visuospatial storage abilities [18].

Marton [19] examined executive functions and visuospatial processing working memory in children with SLI and typically developing children (TDC) and he found children with SLI performed very low on all visual-spatial working memory tasks compared to their age-matched peers. The SLI group also produced more preservative errors and more rule violations than their peers on tasks measuring executive functions. This experiment proposed that executive functions have a great impact on SLI children's working memory performance, regardless of domain. In another study, Briscoe & Rankin [20] studied children with SLI, and they concluded that a predominant feature of the working memory profile of SLI was a marked deficit on phonological loop tasks.

The main reason of the present research was to analyze comprehensively the functioning of verbal and visual spatial working memory of children by using specially designed battery of test measuring working memory in order to clarify some of the doubts created by the previous research.

Research Method

The aim of the present study was to explore the pattern of dysfunction of working memory in children with SLI and compare them with the typically developing children on a specifically designed instrument measuring verbal and visual-spatial working memory.

Selection of Sample

SLI children

15 SLI and 23 typically children participated in this investigation. Children in the SLI group were recruited from a community speech and language department residing in Munster region of the Republic of Ireland. They were attending special speech and language class for five days a week, especially designed for children with language difficulties. The criterion for selection for these children was that they should perform within the average range on the performance tasks of an IQ test and very low on the speech and language assessment. They were comprehensively assessed by the speech and language therapist on a battery of standardized assessment tools and they were found to be functioning from moderate to severe range on the receptive and expressive language indices. Children were excluded from the study if they had an additional diagnosis of attention deficit hyperactivity, ASD, or motor coordination disorder. Furthermore, two children who obtained a score within the mild range of intellectual difficulty were excluded from the study.

The SLI group had a mean chronological age (CA) of 98 months (range = 73.00 -154.00 months) and consisted of 10 boys and 05 girls. The mean FSIQ for the SLI group was 85.00 (range = 72.00 - 100.00). The mean VCI for the SLI group was 87.0 (range = 67.00 - 106.00). The PRI mean for the SLI group was 93.0 (range = 77.00 -108.00).

TD Children

Children for the normal group who participated in the study with typical development had average and above average intelligence. These children were selected from local schools that were reported to have no difficulties with their school work and were considered to function on par with their normally developing peers. The TD group had a mean chronological age (CA) of 123 month (range = 48.00 -190.00 months) and consisted of 12 boys and 11 girls. The mean FSIQ for the TD group was 100.0 (range = 80.00 - 122.00). The mean VCI for the TD group was 100.0 (range = 73.00 - 126.00). The PRI mean for the TD group was 99.0 (range = 79.00 - 127.00).

The parents and school were approached for their consent through a formal letter. All children, who participated in the study, were native English speakers and were residing in the Munster region of the Republic of Ireland.

Materials

Wechsler Intelligence Scale for Children (WISC-IV) (6-16 years)

WISC-IV [21] test comprises ten core subtests and five supplemental ones. These subtests then generate a Full Scale score (FSIQ) as well as four composite scores known as indices: Verbal Comprehension (VCI), Perceptual Reasoning (PRI), Processing Speed (PSI) and Working Memory (WMI). The WISC-

IV is considered to be highly reliable and valid instrument for measuring the IQ for children from 6 years to 16 years.

Automated working memory assessment (AWMA) - for age group from 4-22 (Alloway, 2007)

The AWMA (Alloway, 2007) battery consists of 4 sets of measures of memory which provides standardized scores, with a mean value of 100 and standard deviation of 15, for 4 to 22 year-olds (AWMA: Alloway, 2007). The test-retest reliability for this test in a normally-distributed sample is reported to be .64 [22]. The research has also established a good diagnostic validity of the test [23]. Prior to the commencement of each task, the child is presented with examples and practice items to familiarize him/her with the task. The AWMA includes the following measures and submeasures.

The Verbal Short term memory tasks include digit recall, word recall, and non word recall. The Verbal Working Memory includes the backward digit recall, listening recall and counting recall. The Visual Spatial STM includes, the block recall, Mazes and Dot Matrix. The Visual Spatial WM consists of Odd-one-Out, Mr X and Spatial Span subtests.

Procedure

The assessments were completed over two- to -three sessions in a quiet room mostly on one to one. Each assessment lasted for approximately four to five hours. A standardized procedure was adopted in the order of administration of tests. The Intelligence test was always used first in the sequence of administration, followed by a memory assessment with a gap of at least one day. There were 2 children in the SLI group who scored within the Intellectual Disability range therefore they were not included in the study.

Results

Table 1 presents the mean scores and the ranges of all the four groups. The sample of the TD children seems quite homogenous as can be seen by their scores falling almost in the same range of minimum and maximum on the memory tasks. The scores on the VCI, PRI and FSIQ of WISC-IV seem quite uniform for both TD and SLI groups.

The SLI group scores on the intelligence test ranges from borderline to average.

The results (Table 2) indicate implications of composite scores of the SLI group, i.e., Verbal STM/WM. These results suggest SLI performing on par with the typically developing children on the Visual Spatial STM and WM. Notwithstanding the low score of SLI on the Verbal STM, they have however, performed comparatively on Non-word tasks of the Verbal STM. Previous studies also expressed the skepticism about the non word test which was discussed in the introduction section. Though the SLI group has performed generally low on the Verbal WM, however, their performance is quite low on the Listening recall, as compared to the Digit and Counting recall. This result is according to the expectation as the Digit recall and counting recall tasks consist of numerics/digits while the listening recall relies mostly on word recall.

On the Visual Spatial WM, the difference is not significant as both groups have performed similarly except on Spatial Recall

subtest which has probably affected the score on the composite score of Visual Spatial WM. This would point towards SLI difficulties on specific tasks of spatial recall.

A MANCOVA was performed (Table 3) on the four composite memory subscales to find out whether the three major components of the intelligence i.e., PSI/PSQ, VIQ/VCI, and PIQ/PRI (for convenience these IQs would be referred as PSI, VCI and PRI respectively), with the PSI, PRI and VCI measure as covariate. The overall group term was non-significant on all the indexes. Hence, these results suggest that these indexes of the IQ are probably affecting the performance of SLI children on the memory tasks.

Performance of SLI and TD with matched IQ

An independent t-test analysis (Table 4) was conducted on the SLI and TD children while matching them on their IQ level. Children with the range of FSIQ 80-100 were included for this analysis, a score considered to be within the average range. Significant difference was observed on the Verbal STM Digit recall subcomponent as typically developing children performed better on the Digit recall than the SLI: Digit recall for SLI (M= 87.00, SD = 10.21) and for the TD children (M= 99.46, SD = 13.11); t (24) = 2.70, p = .01. There was significant difference observed on the Verbal WM Listening recall of the verbal WM subcomponent: (M=

81.54, SD= 17.38) for the SLI and for the TD children (M=95.54, SD = 12.47) t (24) = 2.33, p = .03. There is significant difference observed on the Block recall, a subcomponent of the Visual-Spatial STM. Children with SLI performed better than TD children with the following scores: (M= 106.92, SD = 12.15) and for the TD children (M= 92.77, SD = 19.32), t (24), p = .04. There was also significant difference observed on the Visual Spatial STM Composite Score, in favour of the SLI, which may have been due to the high score on the Block recall. The scores are for SLI (M= 104.15, SD=16.52), and for the TD children (M= 88.69, SD=16.67), t (24), p = .03. There were no significant results observed on any of the components of the visual-spatial WM between the SLI and TD children. These results suggest that children with SLI have very specific difficulties related to specific aspects of the verbal memory which is consistent with the previous research and with the present research assumption. The better performance by the SLI group over the typically developing children on the visual-spatial memory could be due to the specific intervention that these children availed of from their respective agencies. Majority of these children with SLI, prior to attending the SLI special class, had received intensive intervention which mostly focused on their memory and processing abilities. These factors may have contributed to their better performance over the typically developing children in this are

Table 1: Mean and standard deviation of demographic variable, intelligence test and memory test of the entire groups (n=38).

	TD (n=23) (m:12; f: 11)				SLI (n=15) (m: 10; f: 5)			
	Min	Max	M	SD	Min	Max	M	SD
Age (in Months)	48	190	123.97	46.93	73	154	98.2.	25.98
WISC-IV VCI	73	126	100.22	12.46	67	106	87.2	10
PRI	79	127	99.22	11.91	77	108	92.93	9.15
PSI	73	121	101.91	11.01	78	11200	91.27	10.1
FSIQ	80	122	99.83	11.2.	72	100	85	6.39
Verbal STM CS	65	127	100.57	18.44	64	103	84.6	13.09
Digit Recall	74	131	102.48	13.68	58	122	81.27	16.8
Word Recall	64	128	99.61	19.81	66	129	86.13	16.8
Non Word Recall	66	135	99.96	20.95	61	118	93	15.71
Verbal WM CS	72	131	103.48	16.85	61	107	83.53	13.2
Listening Recall	63	135	105.43	16.69	58	122	81.27	16.81
Counting Recall	63	125	96.96	16.11	66	129	86.13	16.8
Digit Recall	65	130	103.91	17.36	61	118	93	15.71
Vs-Spatial STM CS	64	129	94.83	17.31	72	128	101.27	17.54
Dot Matrix	66	128	96.91	15.73	75	126	97.4	13.1
Mazes Memory	64	137	94.43	18.43	61	135	101.53	23.38
Block Recall	61	123	97.96	16.47	77	125	103.86	14.09
s-Spatial M CS	63	132	102.17	17.51	59	136	90	18.3
Odd-One-Out	71	131	100.3	16.98	67	126	92.47	17.62
Mister X	71	131	102.43	15.51	70	130	92.8	17.75
Spatial Recall	64	135	101.43	16.43	57	129	87	20.61

VCI= Verbal Comprehension Index; PRI = Perceptual Reasoning Index; CS = Composite Score; STM = Short Term Memory; WM = Working Memory; Vs = Visual; TD= Typically Developing Children; Sp & Lang impairment = SLI.

Table 2: Comparison of SLI and TD children and their significance level.

	SLI (n=15)		TD (n=23)		t	P
	M	SD	M	SD		
Verbal STM Digit Recall	85.53	10.33	102.48	13.68	.781	.000
Verbal STM Word Recall	86.87	12.53	99.61	19.81	4.172	.033
Verbal STM Non Word Recall	90.47	19.51	99.96	20.95	.069	.170
Verbal STM Composite Score	84.60	13.10	100.57	18.44	2.13	.006
Verbal WM Listening Recall	81.27	16.81	105.43	16.69	.000	.000
Verbal WM Counting Recall	86.13	16.80	96.96	16.11	.054	.054
Verbal WM Digit Recall	93.00	15.701	103.91	17.36	.417	.057
Verbal WM CS Visual Spatial Short	83.53	13.20	103.48	16.85	1.658	.000
Term Memory Dot Matrix	97.40	13.10	96.91	15.73	1.066	.921
Visual Spatial Short Term Memory	101.53	23.38	94.43	18.43	1.296	.304
Mazes Memory Visual Spatial Short Term Memory Block Recall	103.87	14.09	97.96	16.47	.323	.261
Visual Spatial Short Term Memory Composite Score	101.27	17.54	94.83	17.31	.175	.272
Visual Spatial Working Memory Odd-One-Out	92.47	17.62	100.30	16.98	.001	.179
Visual Spatial Working Memory Mister X	92.80	17.75	102.43	15.51	.010	.085
Visual Spatial Working Memory Spatial Recall Visual Spatial	87.00	20.61	101.43	16.43	1.205	.022
Working Memory Composite Score	90.0000	18.30	102.17	17.51	.002	.047

Table 3: Mean scores of the two groups and the level of significance.

MANCOVA (n=38)									
Measure	PRI as Covariate			VCI as a Covariate			PSI as a Covariate		
	F	P	Pairwise Comparison	F	P	Pairwise Comparison	F	p	Pairwise Comparison
Verbal STM	.978	.331	NS	.289	.595	NS	.027	.870	NS
Verbal WM	.050	.825	NS	.030	.865	NS	1.082	.307	NS
Visuospatial TM	.000	.985	NS	.109	.744	NS	.094	.761	NS
Visuospatial WM	.192	.665	NS	.610	.442	NS	.978	.331	NS

Table 4: Mean differences between the IQ matched SLI and TD children and the level of significance.

	SLI n=13		TD n=13		t	P
	M	SD	M	SD		
Verbal STM CS	87.69	11.06	94.77	19.49	1.14	.27
Digit Recall	87.00	10.21	99.46	13.11	2.70	.01
Word Recall	90.46	8.85	91.46	18.98	.17	.86
Non Word Recall	93.08	19.59	96.77	21.47	.46	.65
Verbal WM CS	84.85	13.70	95.15	15.20	1.82	.08
Listening Recall	81.69	17.38	95.54	12.47	2.33	.03
Counting Recall	86.54	17.25	91.30	17.74	.70	.49
Digit Recall	95.31	15.29	97.69	18.20	.36	.72
Visual Spatial STM CS	104.15	16.52	88.69	16.67	2.38	.03
Dot Matrix	99.77	12.10	94.38	13.73	1.06	.30
Mazes Memory	103.15	24.25	87.77	17.35	1.86	.08
Block Recall	106.92	12.15	92.77	19.32	2.24	.04
Visual Spatial WM CS	91.00	19.37	95.23	18.66	.57	0.58
Odd-One-Out	93.85	18.29	94.08	16.76	.03	.97
Mister X	93.69	18.90	97.46	15.21	.56	.58
Spatial Recall	86.69	21.78	94.62	16.49	1.05	.31

(n=26; FSIQ= 80-100).

Performance of SLI with different range of IQ

There was no significant difference observed between the two IQ groups of SLI (group 1 = 72-84, group 2 = 85-100) on any of the component of AWMA.

General Discussion

The present study attempted to explore the profile of memory in children with SLI. For this purpose, a broad battery of computerized working/Short Term memory (AWMA) measure was used to assess Verbal and Visual-Spatial WM/STM.

While the previous findings have been mixed, the present research aimed at a direct comparison of children with SLI within a single study design by exploring a distinct pattern of working memory deficits within this population. This research also points in the direction of the important role of intellectual functioning and its strong relationship with memory as a construct. However, there are other factors that could also significantly influence not only memory but also the outcome of the cognitive measures such as attention, concentration, language skills. This observation is based on the present researcher’s experience while evaluating children with numerous developmental delays on developmental measures. There is a high risk of obtaining skewed results if a child presents problems in these areas. This view could be substantiated by the earlier stand that a core impairment associated with particular developmental disorder can have cascading effect on other cognitive skills.

These results of SLI performing low on the verbal STM/WM appear to be in agreement with the previous results. For example

Alloway et al. [24] also found SLI performing low when non-verbal IQ was taken into account. The reason for this low score could be because of the SLI group’s difficulties with both storing and processing of information. These results also point towards the complexity of the cognitive skills that contribute to these tasks, including language and vocabulary [14].

The results of the analysis of SLI scores indicate significantly low performance on both the verbal STM and WM composite scores when compared to the TD. And, there were no differences observed on the visual-spatial STM tasks. These results are consistent with the previous findings where SLI group were in general found to have impaired performance on the verbal memory tasks compared to visual-spatial memory tasks. Baddeley [25] suggested that short-term memory plays an important role in learning new words by generating a phonological representation of brief and novel speech events thereby mediating the creation of a phonological entry within the long-term lexical store. These results support the assumption that children with SLI perform low on the verbal memory tasks compared to TD children and no difference will be observed on the visual-spatial memory tasks between the two groups.

However, when children were matched on IQ and age, the difference between the performance of SLI and TD groups was restricted to a few memory subcomponents such as Digit recall of the verbal STM, Listening recall of the verbal WM and Block recall of the Visual-Spatial STM. Significant difference was also observed on the Visual-Spatial Composite Score. And, no significant difference was observed on the other subcomponent and composite scores of the memory test. These results suggest

that children with SLI present very specific difficulties related to particular aspects of the verbal memory rather than a general difficulty as reported in the earlier research. Of note is the better performance of SLI group on the word and non-word tasks which is contrary to the outcome of that of Gathercole et al. [3] study and supports the study of Van del Lely [26]. In Gathercole et al. [3] study, it was concluded that SLI children necessarily, have an impaired capacity for phonological storage as reflected by recall of non words. While on the other hand, there are researchers who consider non-word as not a true measure of working memory [11] and, when Van del Lely replicated his earlier study, he could not find the same outcome. Van der Lely [26] argued, in support of their work that probably Gathercole et al. [3] used an insensitive instrument for matching the group since a short version of BVPS was used at the time. However, this argument seems to have no basis, since for the present research and that of Van der Lely, children were comprehensively assessed for their difficulties with linguistic skills.

In the present study, despite the fact that a standardized assessment tool was used for the purpose, the word and non- word repetition may not have been probably very sensitive in tapping the deficits within SLI group compared to digit and counting recall. One of the other reasons could be that children in the age range of the present study had been in receipt of significant amount of intervention with a focus on enhancing their vocabulary bank to their optimum level. A look at some other factors which may have also contributed to word/non word repetition including input and output phonological process, [27,28], and pre-existing lexical knowledge [28,29], and that may have improved with the intervention, Hence, this may help in understanding the outcome of the present research in this domain.

A further close look at the outcome of the present study would indicate that, children's performance was mainly affected on the Digit recall of the STM and Listening recall of the working memory. Both of these tasks have been widely tested with an aim of measuring working memory. The Listening recall subtest creates an additional load on memory by remembering the last word of a sentence while processing the content of it. While numbers can be considered much more abstract carrying no similarity to each other and therefore can be considered as a very reliable instrument of measuring an aspect of memory. However, if we analyze these two tasks further, they are not putting any extra demand on the word production per se. Whereas there were many other tasks in the memory test which were highly demanding on word production such as word recall, non-word recall, and as such children did not show any significant difference on these tasks.

On the basis of this finding, it seems likely that the poor short term memory and working memory function in this group reflects single deficit rather than a parallel underlying disorder. In a recent study, it was found that children with a history of very poor short term memory that extended between 4 and 8 years of age and working memory skills in the low average range had age-appropriate language abilities four years later [30]. Second, and conversely, children with learning difficulties in reading and mathematics are typically characterized by poor working memory than verbal short term memory function [31,32]. This argument is in favour of parallel systems of working memory and Short term memory.

The data of this research, however, supports our hypothesis that SLI children would perform equally well on the visual-spatial memory tasks. The performance of the SLI matched age and IQ group with the TD showed no significant difference except their low performance on the Block recall, which is a subcomponent of the Visual-Spatial STM, and on the Visual-Spatial STM composite Score. This result on the Block recall could be an outcome of their difficulties with attention and concentration. The SLI group may have found this task highly demanding on the attention and concentration.

This finding supports Engle's [32] attention control theory to some extent since this was not the only task which required attention and concentration. Other tasks within the same domain, such as Mazes and Dot Matrix, are also equally demanding of attention and concentration skills. Albeit, none of the SLI children met the criterion for ADHD/ADD, yet, a number of these children were noted to have difficulties with sustained attention and concentration. The author suggests that many children with neurodevelopment difficulties show clinically significant level of attention and concentration difficulties.

This research, despite the use of a reliable and standardized instrument, measuring different subcomponents of memory could not find significant differences between the SLI and TD children, when they were matched on IQ. The only difference was observed on digit and counting recall. This outcome vindicates the earlier stand regarding the importance of IQ in memory functioning. SLI children in this sample were all functioning within the average range on the IQ tests, which has in the author's opinion certainly helped these children improve their performance.

Another reason for this outcome could be that majority of the children in this study were attending the specific special speech and language class. These classes comprise of approximately 7 children per group who get intervention from a speech and language therapist on a daily basis, that lays an emphasizes on their listening and attention alongside a focus on their linguistics/ including pragmatic skills. The curriculum also embraces word production, and vocabulary building, therefore the possibility of an enhanced performance of this group on the tasks involving words may make sense. However, this group of sample still presents with difficulties on tasks requiring memory skills such as digit recall and counting recall.

Another important consideration for the present outcome is the heterogeneity of the SLI sample, which could have accounted for the difference. With increasing research it is becoming evident that the population of SLI children is inherently diverse. Some subgroups have clearly differing linguistic characteristics, for example, "semantic- pragmatic SLI" children who have relatively fluent speech and good grammatical comprehension [33] versus children who exhibit grammatical deficits in both their comprehension and expression of language [26]. However, other subjects from the SLI population share some but not all linguistic characteristics (Gopnik & Crago's [34] group characterised by familial aggregation). The possibility that different groups of SLI children may have different characteristics in memory tasks and language abilities has important implications for the underlying cause of SLI in children. It would appear unlikely that a single underlying cause could account for the wide range of deficits found. At the same time, it is as yet unclear to what extent the

underlying cause of SLI in different groups of children who share some but not all linguistic characteristics may be related. Only further research with clearly defined subject groups may be explored for a possibility of establishing this notion.

Summary

Sample of children with SLI were not impaired in all aspects of STM and WM in comparison to younger language-matched control children. The SLI children were also found to be equally sensitive to remember words and non-words in sequence as their matched LA controls.

The interpretation of the data from this study partially agrees with many previous findings in which an impairment in immediate recall in SLI children has been attributed to defective STM or subcomponents of STM (e.g., Gathercole et al. [3]). Therefore, children with SLI are likely to be impaired relative to chronological age controls in STM tasks.

However, it is quite challenging to identify children with specific SLI as there appear to be varied forms and categories of SLI. Therefore, in future research, it would be ideal to match children by taking into account their level of language impairment, keeping in view the diversity within the SLI group.

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Key Points

There were research studies which have pointed towards the implications of working memory in Speech and Language Impairment.

- a. The present research however, used a valid and reliable instrument measuring working memory to look into the various aspects of working memory impairment within the SLI group.
- b. The results indicated that the SLI group showed impairment on the verbal working memory tasks and some aspects of visual-spatial working memory components.
- c. The SLI group showed their weaknesses on tasks measuring phonological short term working memory; whereas no difference was noted on tasks of visual-spatial working memory. These findings may help in the application of intervention strategies for children with SLI.

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