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Editorial

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Implicit Sequence Learning and Recursion Deficit in Children with Specific Language Impairment: A Neurocognitive Triad

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Abstract

Recursion is the process of having one's own output as its next input to make infinite sequences. Similarly, recursion in language applies to merging subtle language elements such as combining morphemes to make longer words in agglutinating languages and embedding of subordinate clauses to main clauses such as embeddedness. The present study proposes that recursion could be happening in unification gradient space (i.e., in inferior frontal cortex). Inferior frontal cortex also hosts procedural memory operations such as implicit sequence learning. Therefore, the present study predicts recursion deficits (merging and embeddedness) in children with SLI who are reported to manifest implicit sequence learning deficits. 22 SLI (specific language impairment) and 22 language age matched TD (typically developing) children were selected for the study. They were administered a sequence learning task to measure implicit sequence learning and a story narration task to measure recursiveness. Results showed that children with SLI were significantly poorer compared to TD children on sequence learning as well as on recursion measures. The correlation between sequence learning and recursion was present in TD group and was absent in SLI children. Discussion states that recursion in TD children is a procedural skill and recursion process could have been taken over by intact declarative system in children with SLI.

Keywords: unification, merging, embeddedness, specific language impairment, procedural memory, declarative memory

1. Introduction

1.1. Recursion in Language

Humans have multifold thought system. That is, we can have thoughts within a thought such as [[[thinking of a man who thinks of a man] who thinks of a man]] who thinks of the Christ]]]. Recursion is the process of having one's own output as its next input to make infinite sequences. However, in practice humans do not use such infinite sequences. By definition, recursion is a procedure that calls itself or a constituent that contains a constituent of the same kind (Pinker and Jackendoff, 2005).

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Pinker and Jackendoff adds that human language is as recursive as its thought. Chomsky (1995) in his minimalist program claims that human thought is generated by merge operations applied recursively. Simply, merging of words to each other (simple adjacent operation) and embedding clauses into main theme (long distance non-adjacent operations) involve recursion process (see Chomsky, 1995). The recursiveness or the ability to hierarchically organize the elements was reported to have played critical juncture in human language evolution (Hauser, Chomsky and Fitch, 2002). Hauser et al. (2002) in their hypothesis (famously known as HCF hypothesis) on language uniqueness stated that recursion is the only narrow language faculty. That is, recursion is the only cognitive component exclusively dedicated to language functioning. Fitch and Hauser (2004) provided empirical evidence to the hypothesis while they examined the parsing abilities of cotton-top tamarins (Saguinus Oedipus). The study showed that unlike humans, monkeys lacked the ability to hierarchically organize elements. Recursive process is specific to human beings, therefore, it is believed to have evolved at the latest in brain for language (see for review Sengottuvel and Prema, 2013b). Chomsky's idea about human expressive language (recursively added units) states that formation of language requires lexical items to be selected and merged according to the formal features of lexical items. Even though, the concept of linguistic recursion is sophisticated for the convenience of relating the recursion and well studied unification/procedural operations (explained later) in the present study we limit the recursion premise within two main components such as merging and embedding. In English, merging is adding a free morpheme to the root morpheme. For example, merging 'shoe' with 's' forms "shoes". In a language such as Kannada (a south Indian Dravidian agglutinating language), merging denotes agglutination, that is merging morphemes to root.

Example (1)
madu – tha – ida - ne
do - PRS- PROG -he
'He is doing'

Example 1 contains morphemes for tense and gender marker adhered, making it a well agglutinated unit.

In natural language, there is another level of recursion that governs conjoining of elements beyond adjacency called embeddedness. This non-adjacent embeddedness is hierarchical in nature and it requires merging at higher level (see Chomsky, 1995). Using hierarchical recursive process, noun phrases can be built from noun phrases. For instance, simple noun phrases such as 'the cat, the dog, the house, the tree' can create new noun phrases by placing the word 'behind' between any pair. Like 'the cat behind the house' and 'the dog behind the tree'. However, recursive constructions need not involve embedding of the same constituents. Recursion could also be used to embed phrases in a sentence (see self-embedding by Chomsky 1956, 1959). For example, two sentences such as 'Susan likes John' and 'Susan flies airplanes' could be embedded into 'Susan, who flies airplanes, likes John'. In sum, recursive components such as merging and embedding are essential for (complex) sentence making. Sengottuvel and Prema (2013b) states that the evolutionary nature of recursion leading to a suspicion that developmental language deficits that shows genetic mutation could be vulnerable to recursive deficits. Such developmental language conditions helped explore evolutionary neurobiological aspects of language. One such developmental language condition is specific language impairment (SLI) which is characterized by language impairments in the absence of any sensory deficit, neurological dysfunction, motor deficit, or mental retardation that would explain the language delay (Leonard, 1998).

Compared to age-peers, children with SLI display shorter utterances and are more likely to omit obligatory noun and verb inflections in spontaneous language (Bedore and Leonard, 1998). Language of children with SLI is not simply time-delayed compared to age-peers. They also omit grammatical inflections more often than younger, normally developing children who create sentences of similar length (Leonard, Bortolini, Caselli, McGregor, and Sabbadini, 1992). Overall, language profiles of children with SLI are characterized by marked difficulty with morpho-syntax, moderate difficulty with semantics, and unimpaired or mildly impaired phonology (Tomblin and Zhang, 1999). Children with SLI use fewer words and propositions in their description compared to TD children (e.g., Manhardt, Hansen, and Rescorla, 1995). Shorter, less cohesive syntactically simpler stories were reported in children with SLI (Liles, Duffy and Purcell, 1995; Norbury and Bishop, 2003). Leonard (2000) reports of considerably less embedding, conjunctions, and connectives in utterances of children with SLI. Children with SLI also make more errors in complex syntax than their age-peers (Gillam and Jonston, 1992; Scott and Windsor, 2000). Children with SLI produced utterances with fewer total words than their peers' complex sentences (Scott and Windsor, 2000). Norbury and Bishop (2003) claim the narrative utterances of children with SLI to be having frequent errors of syntax, semantics, and morphology. These syntactic delays persist into adolescence and adulthood (Mawhood, Howlin, and Rutter, 2000; Marinellie, 2004). As children grow, research highlights specific differences in use of complex syntax both over time and between children with and without language impairments. As school-age children without language impairment grow, their sentences exhibit increased clause density (Loban, 1976), increased mean length of T-unit, and more frequent use of relative clauses (Nippold, Hesketh, Duthie, and Mansfield, 2005). Compared to unimpaired peers in the same grade, school-age children with SLI used fewer complex sentences in conversation, and these complex sentences tended to have fewer clauses (Marinellie, 2004), and fewer total words (Scott and Windsor, 2000) than their peers' complex sentences. Marinellie (2004) also reported that children with SLI produced fewer complex utterances with fewer clauses in them and also produced some examples of most spoken complex sentence structures. Even though the proportion of complex syntax increased over time, the total proportion of complex syntax remained low for children with SLI compared to TD children (Arndt and Schuele, 2008). A microstructure analysis of sentence making in children with SLI was attempted by Gils (2010). Results of Gils' study showed that children with SLI produced significantly lower mean length of utterance in story retelling as well as story generation. Usage of conjunction, embedding in children with SLI were significantly poorer compared to TD children. Even though, children with SLI show sentence complexity deficits they maintain the essential ingredients of a story of keeping the main ideas arranged in appropriate sequence (Clifford, Reilly, and Wulfeck, 1995). Reilly et al. (2004) reports that like TD children, children with SLI also establish and maintain the story's theme. Moreover, children with SLI present theory of mind in their story description (Leonard, 2000; Liles, 1985). In general, children with SLI are reported to produce shorter sentence with less embeddings. Studies attributed the sentence making deficits in children with SLI to processing deficits in them (Coco, Garraffa, and Branigan, 2012; Gils, 2010; Montgomery and Windsor, 2007).In spite of the explicability, the processing and capacity limitations have on representative failures; they could be insufficient of explaining the sentence varieties human produce. Therefore, in the present study we relate sentence making difficulty in children with SLI to their poor recursive ability. The assumption is that if the central underlying hosting mechanisms such as unification and implicit sequence learning in sentence making are explored, the difficulty could be profiled neurobiologically and hence could be understood effectively.

1.2. Neurobiology of Recursion

The ability to learn hierarchical sequences (recursion) is reported to be located in Broca's area of left hemisphere (Friederici, 2004, Grodzinksy and Friederici, 2006, Hagoort, 2005). Further studies have shown that left Brodmann area 44 (Broca's area) is the neural correlate for computations regarding linguistic recursion i.e., processing embedded structures (for detailed review see Friederici, Bahlmann, Friedrich, and Makuuchi, 2011). In an elaborated model of unification under the memory unification control (MUC) framework proposed by Hagoort (2005), inferior frontal gyrus (Broca's area) contributes to merging the semantic units from medial temporal lobe. The unification in MUC could serve as a psychological realization for merging reported by Chomsky (1995). About the same time, Ullman and Pierpont (2005) proposed the procedural deficit hypothesis (PDH). Procedural memory system is a part of non-declarative memory system that enables learning of pattern and unconscious recall of learned patterns (e.g., Ullman and Pierpont, 2005). PDH originated from studies that consistently reported of implicit sequence learning deficits in children with developmental language impairment (e.g., Lum, Conti-Ramsden, Page, and Ullman, 2012). PDH claims that language elements retrieved from declarative memory located in medial temporal lobe need to be sequentially arranged based on specific rules. According to PDH, the arrangement of sequential linguistic elements transpires in inferior frontal gyrus, which also underlies implicit sequential skill learning (for details see Ullman and Pierpont, 2005; Sengottuvel and Prema, 2013b; 2013d). Broca's area is a significant portion of procedural memory circuit, which consists of basal ganglia and cerebellum to it in a loop (Ullman and Pierpont, 2005; Sengottuvel and Prema, 2012). Procedural memory also assists in learning the language patterns (probabilistic statistical learning) implicitly from spoken language, therefore helping the child to learn word boundaries in turn vocabulary learning (e.g., Saffran, Aslin, and Newport, 1996; Hsu and Bishop, 2011).We state that the process of linguistic recursion is believed to be in Broca's area of left frontal lobe overlapping on procedural memory functions (governing implicit sequence learning) and unification (see Hagoort, 2005; Ullman and Pierpont, 2005; Bolender, Erdeniz, and Keromoglu, 2008). In sum, children with SLI who tend to have poor sentence complexity could also demonstrate unification and procedural memory deficits.

1.3. Recursion, implicit sequence learning and SLI triad

In spite of studies consistently showing procedural memory deficits in language impairment, the relation between recursion and procedural learning has long been in proposal stage. Having found the relation between procedural learning and language, it is reasonable to state that recursion (a believed procedural skill) would also be affected in children with SLI. Moreover, there are proposals from various linguists that unique human nature to combine words taken from lexicon could be an implicit procedural skill (Bolender et al., 2008, Chomsky, 1995). Genetic evidence shows that the family members of language impaired children manifest mutation on FOXP2, which is a language gene (Fisher, 2005). FOXP2 is a commanding gene for language learning through which CNTNAP2 is monitored. The expression regions of CNTNAP2 (regulated by FOXP2) in developing brain is identical to procedural memory structures (Lai et al, 2003). Structural and functional brain imaging studies have shown that affected family members of language impaired have abnormalities in the caudate nuclei (basal ganglia) and dentate nucleus (cerebellum) as well as in Broca's area (frontal cortex) (Vargha-Khadem, Gadian, Copp, and Mishkin, 2005). Note that these anatomical, genetic, and psycholinguistic evidence show that recursion areas (Broca's area), procedural memory circuits and FOXP2 expression regions form a triad. The assumed triad intrigues us to propose that children with SLI would show procedural memory deficits associated with recursive deficits. The proposed link between language and procedural memory is evidenced from studies that showed consistent procedural learning deficit in children with SLI (Adi-Japha, Strulovich-Schwartz, and Julius, 2011; Hedenius et al., 2011; Sengottuvel and Prema, 2012, 2013a, d; Lum, Conti-Ramsden, Page, and Ullman, 2012; Lum, Gelgec, and Conti-Ramsden, 2010; Tomblin, Mainela-Arnold, and Zhang, 2007).

Procedural memory system (at least frontal structures in procedural memory system) could be compared to syntax unification structures reported by Hagoort (2005). In other words, recursion reported by Bolender et al., (2008) and Chomsky (1995) could be located in areas reported for unification by MUC (Hagoort, 2005) and for procedural memory for implicit sequences by PDH (Ullman and Pierpont, 2005), i.e., the left inferior frontal gyrus (of course other cortical connections). Therefore, the present study predicts that children with SLI should also exhibit recursive difficulties such as poor merging and embedding along with sequence learning difficulties. To summarize, the brain areas implicated for unification in MUC (see Hagoort, 2003;2005) are similar to brain areas implicated for implicit sequential learning in PDH (see Ullman andd Pierpont, 2005). Therefore, an instantaneous presentation of implicit sequence learning deficit and unification deficit (recursion) could be expected and predicted in children with SLI.

Even though, studies have reported of sequence learning and grammar deficits in SLI, none of the studies examined recursion and sequence learning relation in children with SLI. One study that got closer to examining the relation was by Sengottuvel and Prema (2013d). Sengottuvel and Prema examined the relation between sentence complexity measures of SLI and their sequence learning and reported no correlation between two tasks. Moreover, the study did not have language age matched groups. The study used t-unit measure and did not analyze the sample for its embeddedness, and agglutination (merging) quantity which could be reflective of recursive ability. Therefore, it is necessary to examine the relation between procedural learning and recursion measures specifically to answer the raised research questions such as

1. Do children with SLI show deficits in recursive grammar such as merge and embeddedness?
2. Is recursion a procedural skill?

In the present study we propose to examine the agglutination ability and embeddedness as a measure of recursion in participants using Kannada language. Kannada language is rich in agglutination and embeddedness (see for details of Kannada language Sridhar, 2007), therefore, to examine recursion, Kannada language would be appropriate.

2. Methodology

2.1. Participants

Twenty two children with SLI with the language age range of 8-10 years and 22 language age matched typically developing (TD) children participated in the study. The language ages (both TD and SLI) were tested using Linguistic Profile Test (LPT) by (Karanth, 1980). LPT is a test to quantify receptive language using judgment task. Table 1 shows participant details of TD and SLI group and their receptive language age scores of domains such as phonology, semantics and syntax. In each group (SLI and TD), 9 children with total language age of eight, 8 children with total language age of nine and 5 children with total language age of ten were selected. Parents of all participants signed a written consent to involve their children in the study. All the TD children were administered a WHO-ten disability questionnaire (Singhi, Kumar, Malhi, and Kumar, 2007) to rule out for any sensory and developmental complications. Children with SLI were included in the study based on Leonard's exclusionary criteria (1998). All the participants (TD and SLI) were right handed and were native speakers of Kannada (a Dravidian language spoken in southern India).

2.1.1. Diagnosis of SLI

The grand total language scores (receptive) on LPT was used to diagnose children with SLI based on Leonard's exclusionary criteria (1998). The receptive grand total language score is cumulative of phonology, semantics, and syntax scores. According to the Leonard's criteria, participants were included into SLI group, if their grand language total score was at least 1.25 SD lower than the standard language score for that chronological age. Language age scores on receptive tasks are given in Table 1. Other objectives of Leonard's exclusionary criteria for diagnosis of children with SLI such as no history of otitis media, neurological deficits, oro-motor dysfunction, and non-verbal IQ were also agreed upon. Non-verbal intelligence of SLI participants were examined using Gessell's drawing test (Venkatesan, 2002a) and children who scored less than 85 in IQ measure were excluded from the study. None of the 22 children with SLI included in the study was enrolled for formal speech language intervention at the time of study.

Groups	Mean	SD	Min	Max	Std. Error	LB	UB
C-age							
TD	8.95	.84	8.00	11.00	.19	8.55	9.35
SLI	11.68	.99	10.00	13.00	.19	11.28	12.07
Ph-age							
TD	9.40	.66	8.00	11.00	.18	9.04	9.77
SLI	11.68	.99	10.00	13.00	.18	11.31	12.04
Sem-age							
TD	9.04	.78	8.00	11.00	.20	8.62	9.46
SLI	11.31	1.12	9.00	13.00	.20	10.90	11.73
Syn-age							
TD	8.50	1.05	7.00	11.00	.23	8.02	8.97
SLI	6.72	1.16	5.00	9.00	.23	6.24	7.20
TL-age							
TD	8.81	.79	8.00	10.00	.16	8.47	9.16
SLI	8.81	.79	8.00	10.00	.16	8.47	9.16

Abb: C-age: chronological age, Ph-age: phonological age, Sem –age: semantic age, Syn-age: syntax age, TL-age: total language age, LB: lower bound, UB: upper bound.

Table 1. Descriptive scores of language domains (age in years) for TD and SLI groups

Overall, the SLI group were better significantly in phonology and semantics and poorer significantly in syntax when compared to TD group. Such greater chronological, phonological and semantic age to syntax age trade off was inevitable in matching TD and SLI groups on total language age (see table 2).

Dependent variable	Mean Sq	F(1,42)	Sig.	Partial η^2
Chronological age	81.81	96.18	.00	.69
Phonological age	56.81	79.30	.00	.65
Semantic age	56.81	60.06	.00	.58
Syntactic age	34.56	27.99	.00	.40
Total language age	.00	.00	1.00	.00

Table 2. F statistics for comparison between TD and SLI groups on various language ages

2.2. Stimuli and Procedure

2.2.1. Measuring Recursion

All the participants were given the picture in which the story was depicted in three sequences. The picture was pencil line drawing presented on a card with diameter 7.28”, 4.92”. A simple English narration of the picture would be “Two dogs are fighting for a bone. A puppy is watching it. Whilst the dogs fight, the puppy picks the bone and runs. The fighting dogs are famished and fooled by a cunning puppy” (see Figure 1). Participants were asked to describe the story in the picture in as much detail as possible.

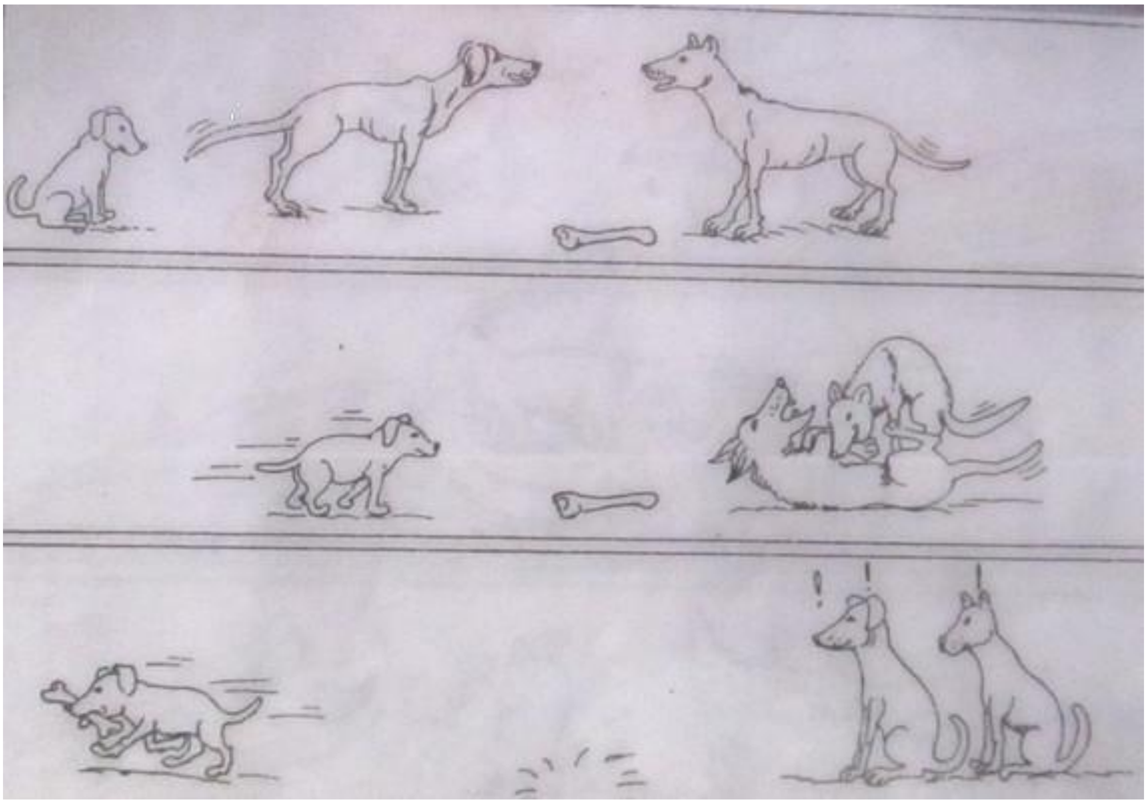

Fig 1. Story sequence used to elicit recursion (Source: Standardized pictures by Nagapoornima, 1990).

2.2.1.1. Analysis of data for recursion

Responses were recorded using digital audio recorder and broadly transcribed. Each participant’s recursive abilities were measured under embedding nature and agglutination. Embeddedness is an ability to accumulate clauses within a clause. Note that from our previous explanation recursion was described as a process by which several similar units could be included into a single unit. Therefore, embeddedness could give measure of recursion. Number of clauses per t-unit (CTU) measure quantified embeddedness in the present study. A main clause and its embedded (subordinate) clauses were considered a t-unit (Hunt, 1965) (see table 3). Agglutination of morphemes into a root is a main feature of sentence making in agglutinating language such as Kannada. The quantity of agglutination would demonstrate the participant’s ability to use merge operations (also a recursion measure). This measure is similar to MLU (mean length of utterances) measure, except where the total morphemes used were divided by total number of clauses (it is total number of utterances for MLU measure). Therefore, number of agglutinations in narration was calculated as illustrated in Table 4, 4a, 4b, and 4c. Because the objective of the present study is to examine the recursion and merge operations, calculation such as agglutination/clauses (AGC) would be more meaningful in quantifying merging ability.

Narrated phrase (transcribed)*	**Embeddedness measure**
//eraduna:yiiruthadhe/avemo:lekosakaradzagala a:dutha iruthadhe/ a:vaga ondhuchikkamarinoduthairuthadhe//	1 t unit (1 main clause and 2 embedded clause)
//iveraduna:yigaludzagala a:dubekadre/ i:chikkmari a mo:lenaethkondu o:dodubudathe//	1 t-unit (1 main clause and 1 embedded clause)
//iveraduna:yigalusapemariaginoduthairathe//	1 t-unit (1 main clause)

*for English translation of narration see measuring recursion section

Table 3. Analysis for embeddedness

Tables 4. Analysis for usage of agglutination (below)

eradu	na:yi	iru –tha- dhe	ave	mo:le-ga:gi
NA	*NA*	*iru-1+1*	*NA*	*mo:le-1*
dzagala	a:du-tha	iru-tha-dhe	a:vaga	ondhu
NA	*a:du-1*	*iru-1+1*	*NA*	*NA*
chikka	mari	nodu-tha- iru-tha-dhe	agglutinating morphemes	
NA	*NA*	*nodu-1+1+1+1*	*10*	

Table 4a. For the 1st t-unit

ive-radu	na:yi-galu	dzagala	a:du-bek-adre	i:-chikk-mari
ive-1	*na:yi-1*	*NA*	*a:du-1+1*	*i:-1+1*
a	mo:le-anu	eth-kondu	o:-dodu-buda-the	agglutinating morphemes
1	*mo:le-1*	*eth-1*	*o:1+1+1*	*12*

Table 4b. For the second t-unit

ive-radu	na:yi-galu	sapemari-agi	nodutha-irathe	agglutinating morphemes
ive-1	*na:yi-1*	*sapemari-1*	*nodu-1+1*	*5*

Table 4c. For third t-unit

From the example in tables (4a, 4b, and 4c, where "NA" means agglutinating morphemes not applicable to that root) we could see that there are 27 (12+10+5) agglutinating morphemes used by a participant (example of a TD child). Therefore, on an average he/she was using 4.5 agglutinating morphemes per clause (because the total clauses were 6 in this particular narration). Ten percent of the data were analyzed by two different speech language pathologists and the inter-rater agreement was 87% for clauses quantification and 91% for quantifying agglutinations.

2.2.2. Sequence learning measure

The study used an adapted serial reaction time task (AD-SRT) for measuring implicit motor sequence learning. Prior to administration of AD-SRT task all the participants were administered a simple visuo-motor attention task called two choice reaction time task (TCRT) from Cognispeed software version 1.21b (University of Turku, Finland). On TCRT task "1" or "2" appeared randomly with irregular intervals between two presentations. The participant's task was to press the left arrow when "1" appeared and press the down arrow when "2" appeared. The time gap between the appearance of stimulus and button press was measured in milliseconds. At the end of 40 trials, the accuracy as well as maximum, minimum, and mean reaction times for all 40 responses were measured (for schematic illustration of TCRT task see Sengottuvel and Prema, 2013c, 2013d, 2013a). Sengottuvel and Prema (2013c) showed that TCRT task is an adequate task for candidacy selection for AD-SRT task. In the present study, all SLI participants were given TCRT task and the comparison with TD group shows that SLI were in par with TD children's attention and motor speed.

Groups	TCRT mean		TCRT accuracy	
	Mean	SD	Mean	SD
TD	835.90	104.81	2.86	1.42
SLI	918.77	178.92	3.59	2.23
F statistics				
F(1,42)	3.51		1.65	
Mean Square	75530.20		5.81	
Sig	.06		.20	
Partial η^2	.07		.03	

Table 5. Mean, accuracy scores, and F statistics of TD and SLI groups on TCRT task

The procedure used to measure sequence learning (AD-SRT task) was identical to the one used in study by Sengottuvel and Prema (2013d). In AD-SRT task, the participants had to trace the spatial location of the picture which might appear in any of the four blocks using buttons in a game pad. The buttons were located in spatial correspondence to four boxes in screen where the picture (a dog) will appear at any of the boxes at a time. The picture disappears and appears in another box if the button press is correct. Instruction for the participant was to trace the dog using spatially related button as fast and as accurate as possible to get better scores. The time gap between appearance of stimulus and button press is measured in millisecond (ms) as reaction time. The task did not measure incorrect responses, alternatively the picture won't move to next box until the correct button is pressed. Therefore, it will eventually increase the RT for next response. AD-SRT task was designed and checked for its validity by

Sengottuvel and Prema, (2013c) in Indian population. AD-SRT measures sequence learning at three intervals such as SLavg1 (sequence learning average 1), SLavg2 (sequence learning average 2), and SLavg3 (sequence learning average 3) (see Figure 2 and Figure 3).

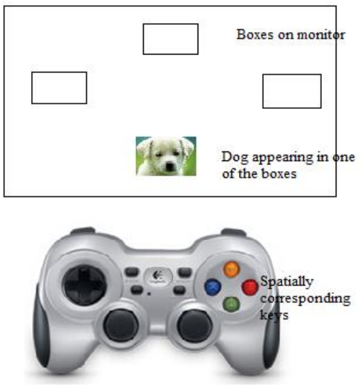

Fig 2. Instrumentation of AD-SRT task

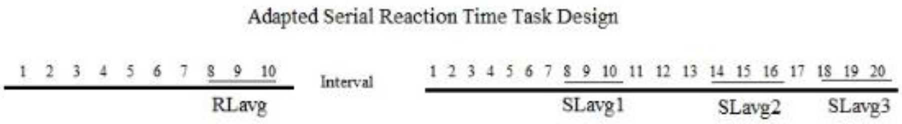

Fig 3. Schematic illustration of AD-SRT task (Source: Sengottuvel and Prema, 2013d)

Two types of trials were given during testing. Initially 100 random trials were presented during which the stimulus appeared in any of the box without any scope for sequence learning. After ten random sets (i.e., after 100 such presentations) the picture stimulus starts to appear in a pattern without participant's awareness ensuring sequence learning to take place. For, e.g., 1324214313 was the sequence set pattern that keeps repeating for 20 times in sequence trial condition. The assumption is that the participant with significant sequence learning will perform sequence trials faster than random trials. In other words, reaction times measured while performing sequence trials would be substantially lesser than reaction times measured while performing random trials.

2.2.2.1. Analysis of data for sequence learning

Final thirty RTs of random trials (random learning average/RLavg) and sequence trials from 80-100 (sequence learning average 1/SLavg1) were averaged separately. To measure the sequence learning quantity SLavg1 was subtracted from RLavg, and this value was called as index of sequence learning (ISL henceforth). To extract a meaningful data from the whole response any response which was lesser than 100 ms was removed from the analysis considering they were too short to be genuine responses. Similarly, towards the end of the trials, some of the RTs were too high (>2SD of mean of SLavg3) due to reactive inhibition (see Hull, 1951; Sengottuvel and Prema, 2013c,d) and such responses were excluded from the analysis. SLavg1 was most stable (free from reactive inhibition) among all SLavgs therefore, it was preferred for ISL calculation over Slavg2 and SLavg3.

3. Results

3.1. Measures of recursion

Comparison between TD and SLI groups on clauses/t-unit (CTU) and agglutination/clauses (AGC) showed that children with SLI were significantly poorer compared to TD children on both the measures (two way MANOVA) [for CTU, $F (1, 42) =139.77$, $p=0.00$, $\eta 2=0.76$; for AGC, $F (1, 42) =126.84$, $p=0.00$, $\eta 2=0.75$]. Table 6 and figure 4 shows the descriptive values of TD and SLI groups.

Parameters	Mean	SD	Std. error	LB*	UB*
CTU					
TD	3.32	0.468	0.088	3.14	3.50
SLI	1.84	0.351	0.088	1.66	2.02
AGC					
TD	4.32	0.563	0.107	4.11	4.54
SLI	2.62	0.431	0.107	2.40	2.83

Abb: CTU: clauses/t-unit; AGC: agglutination/clause; Std.error: standard error; LB: lower bound; UB: upper bound

Table 6. Descriptive statistics of TD and SLI groups on CTU and AGC scores

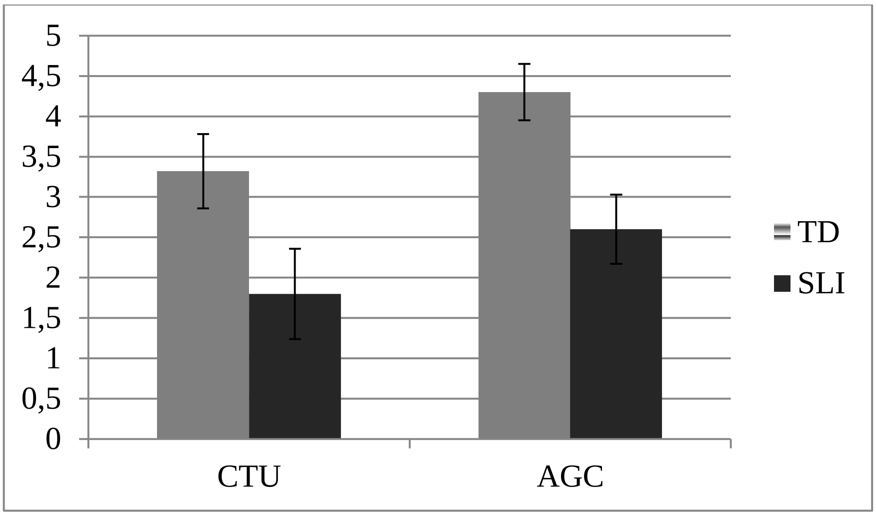

Abb: CTU: clauses/t-unit; AGC: agglutination/clause

Fig 4. Comparison of TD and SLI groups on CTU and AGC

3.1.1. Discussion

Children with SLI in the present study showed significant poor performance compared to TD children on measures of recursion such as embedding and agglutination. Poor embeddedness could be viewed as poor recursive ability (see Chomsky, 1956, 1959) therefore; poor embeddedness in children with SLI in the present study could be viewed as poor recursive ability in them.

Poor embeddedness in children with SLI has been reported earlier as poor sentence making (for studies on poor sentence making in SLI, see Liles, Duffy, Merritt, and Purcell, 1995; Norbury and Bishop, 2003). The findings showing poor embeddedness in the present study are in support of results reported by Leonard (2000). Leonard reported considerably less embedding using conjunctions, and connectives in utterances of children with SLI. Akin to present findings, lesser clause density (Loban, 1976), lesser mean length of t-unit, and less use of relative clauses (Nippold, Hesketh, Duthie, and Mansfield, 2005) were reported in children with SLI. However, agglutination alone was not tested in children with SLI. The present study is a first of its kind to examine agglutination quantity in children with SLI and compare it with TD children. Poor agglutination in children with SLI could be indicative of poor merging of elements into root word. This insufficiency in merging could be attributed to poor implicit sequencing in children with SLI. The present study showed that despite their sentence complexity deficits, children with SLI maintain the essential ingredients of a story of keeping the main ideas arranged in appropriate sequence (see also Clifford, Reilly, and Wulfeck, 1995; Reilly, Losh, Bellugi, and Wulfeck, 2004).

3.2. Results of sequence learning measure

Mixed ANOVA was done to see the performance of both the groups on measures of AD-SRT task such as RLavg, SLavg1, SLavg2, SLavg3, and ISL. As a whole, the main effect of RTs of RLavg and SLavgs (SLavg1, SLavg2, and SLavg3) were significant [$F(4,168) = 448.92$, $p=0.00$, $\eta 2=0.91$]. The interaction between group and AD-SRT task performance was also significant [$F(4,168) =29.03$, $p=0.00$, $\eta 2=0.40$). Therefore, within each group a repeated measure of ANOVA was performed. TD group showed that the difference between RTs of averages were significantly different [$F(1, 21) =355.04$, $p=0.00$, $\eta 2 =0.94$]. Comparison between averages showed that SLavg1 was significantly better (faster RT) than RLavg, $p=0.00$). In other words, TD children showed significant sequence learning in AD-SRT task. The SLavg2 scores in TD group was better than SLavg1, but the difference was not significant, $p=0.10$. The scores on sequence learning got significantly poorer as trials progressed (i.e., SLavg3 of TD group was significantly poorer than SLavg2, $p=0.00$). To summarize, TD children showed initial sequence learning followed by non-significant sequence learning, which ended up in regression of performance (see table 7and figure 4).

Repeated measures of ANOVA of SLI group showed that the difference between RTs of averages were significantly different [$F(1, 21) =318.54$, $p=.00$, $\eta 2 =.93$]. Comparison between averages showed that SLavg1 was not significantly different from RLavg ($p=.10$), in fact SLavg1 was non-significantly poorer than RLavg. The difference between SLavg2 and

SLavg1was not significant (p=.10). Like TD group, the difference between SLavg3 and SLavg2 was significant (SLavg3 poorer than SLavg2, p=0.00). To summarize, children with SLI did not show sequence learning in AD-SRT task, and they performed the trials throughout without any significant sequence learning (see table 7 and figure 5).

Parameters	Mean	SD	Std. error	LB*	UB*
RLavg					
TD	659.46	164.23	37.44	583.89	735.03
SLI	768.77	186.35	37.44	693.20	844.34
SLavg1					
TD	490.59	141.31	37.20	415.51	565.67
SLI	794.04	202.31	37.20	718.96	869.12
SLavg2					
TD	449.79	170.09	38.63	371.83	527.75
SLI	790.68	191.64	38.63	712.72	868.64
Slavg3					
TD	529.58	202.58	43.75	441.28	617.88
SLI	856.40	207.83	43.75	768.10	944.71
ISL					
TD	0.15	0.047	0.01	0.13	0.17
SLI	-0.01	0.043	0.01	-0.03	0.00

*95 % confidence level

Abb: Std.error: standard error; LB: lower bound; UB: upper bound

Table 7. Descriptive statistics of TD and SLI groups on parameters of AD-SRT task

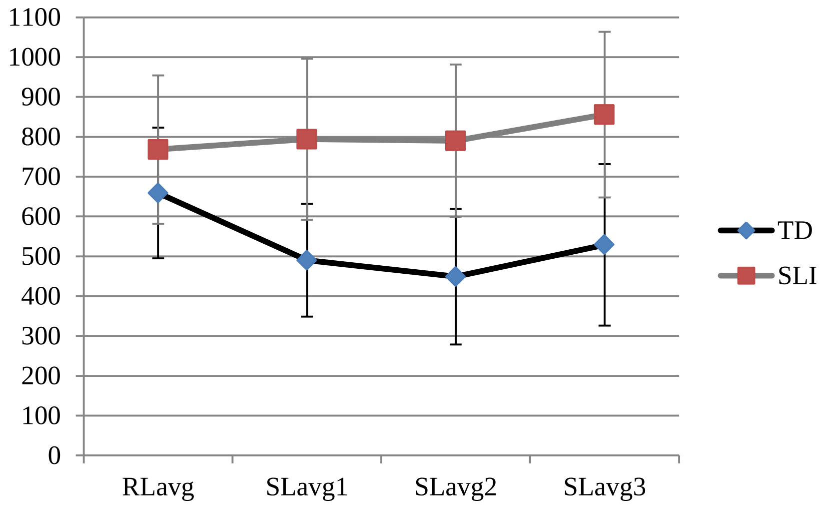

Fig 5. Comparison between TD and SLI groups on parameters of AD-SRT task parametes.

Parameters of AD-SRT task was compared between TD and SLI groups using two way MANOVA. Children with SLI performed significantly poorer compared to TD children on all the occasions [RLavg1: F(1,42)=4.260,p=0.04, η2=0.09; SLavg1: F(1,42)=33.26,p=0.00, η2=0.44; SLavg2: F(1,42)=38.93, p=0.00, η2=0.481; SLavg3: F(1,42)=27.89, p=0.00, η2=0.399; ISL: F(1,42)=140.277, p=0.00, η2=0.77]. Further, an Independent t-test was done for ISL value alone to compare the sequence learning quantities of TD and those of SLI groups. Results showed that SLI children had significantly poorer sequence learning quantity compared to TD children [t (42) =11.84, p=0.000]. Notice that the mean ISL value for SLI group is negative, in other words, their RTs during sequence learning were poorer than RTs during random trials (see figure 6).

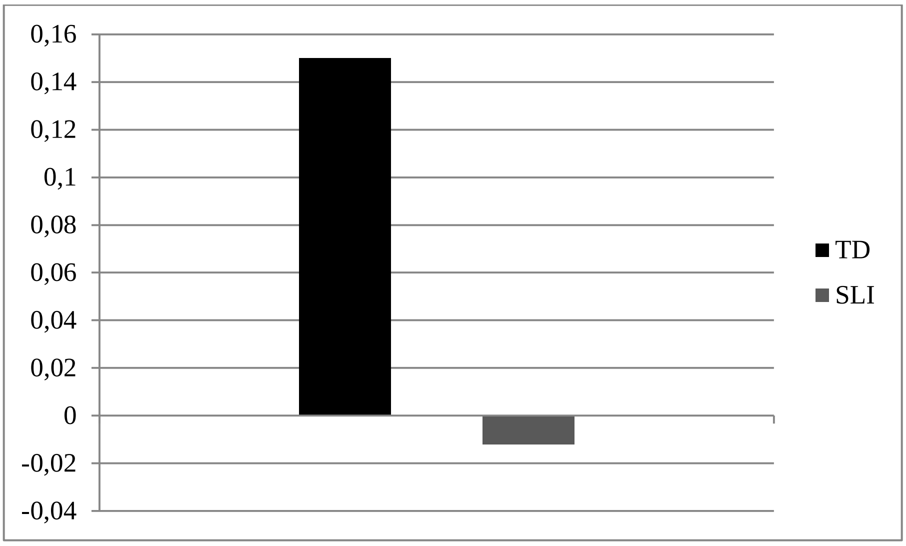

Fig 6. Comparison of ISL value of TD and SLI groups

3.2.1. Discussion

TD children in the present study showed substantial RT difference between SLavg1-RLavg showing significant sequence learning. On the other hand, in the SLI group RT difference between SLavg1 and RLavg was not significant showing poor sequence learning. The comparison of quantity of sequence learning (ISL) of SLI group was significantly poorer than TD group. The results of the present study showing poor sequence learning by SLI children were reported in past using AD-SRT task (see Sengottuvel and Prema, 2012;2013a, 2013d). Moreover, children with SLI are consistently shown to have affiliated sequence learning problems (e.g., Sengottuvel and Prema, 2013d: Lum et al., 2012). The findings are largely in support of procedural deficit hypothesis (PDH) proposed by Ullman and Pierpont (2005). PDH predicts that children with SLI have procedural memory deficits affiliated to language deficits. The explanation for poor sequence learning in children with SLI could be that they have genetic aberration of FOXP2 (a language commanding gene), which expresses on procedural memory structures in brain. Therefore, children with SLI lose the ability to predict (implicitly) the nth element in sequence of AD-SRT tasks which could be reflecting in their language ability also (see Sengottuvel and Prema, 2013b). In spite of absence of sequence learning both the groups showed poor performance towards the end of the task which could be attributed to reactive inhibition by participants when they learn repeated motor sequences several times. Note, that there were 200 trials sequences in the present design (for reactive inhibition in AD-SRT task see Sengottuvel and Prema, 2013c, d).

3.3. Correlation between sequence learning and recursion

In the TD group a positive correlation was observed between quantity of sequence learning (ISL) and CTU (r=0.629*). In TD group, within recursion measures CTU correlated positively with AGC measure (r=0.509*). On both the occasions, correlation was significant at .05 level of significance. In SLI group, none of the sequence learning measure correlated with scores on CTU or AGC (recursion measures). However, similar to TD group, within SLI group recursion measures correlated between them (r=0.639**, correlation was significant at .01 level of significance).

A correlation analysis was run between receptive language measures such as receptive semantics and syntax measures and CTU and AGC measures to report whether syntax or semantic scores correlated with recursive measures (in each group separately). Results showed that both semantic and syntax language scores correlated with AGC (but not with CTU) in TD group (for semantic and AGC: r=0.533*; for syntax and AGC: r=0.614*). On the other hand, in SLI group only semantic language scores correlated with both CTU and AGC (CTU: r=0.575*, AGC r=0.638**). Notice that semantic scores correlated with agglutination scores at .01 level of significance.

3.3.1. Discussion

None of the earlier studies attempted to relate sequence-learning skills to recursion measures in particular. In the present study, TD group showed correlation between sequence learning quantity and clauses per t-unit (recursion measure). On the other hand children with SLI did not show correlation between implicit sequence learning and any of the recursion measures. The study predicted a relation between sequence learning and recursion measure. The rationale behind predicting a correlation between sequence learning ability and language ability comes from PDH (Ullman and Pierpont, 2005). That is, when a participant performs well in sequence learning the performance would be reflected on his/her grammar scores (see also Sengottuvel and Prema, 2013d). Similar correlations between implicit sequence learning and grammar measure were reported in previous studies (e.g., Hedenius et al., 2011; Tomblin et al., 2007). The presence of correlation in TD group and absence of correlation in SLI could state that the recursion which is implicit in TD children would be mediated by different mechanisms in SLI. Further, specific correlation between semantic scores and recursion scores leading to suspicion that declarative system could be contributing to recursion scores in SLI. However, these statements could only be considered as a new line of research possibility since, TD also shows correlation between semantic and recursion scores (but only semantics and AGC in TS group).

4. General Discussions

The present study enumerated that recursion process is possible by unification of words and phrases into a main theme. The review justifies that unification gradient space is inferior frontal lobe, where the procedural memory function for implicit sequences also resides (see Hagoort, 2005; Ullman and Pierpont, 2005). Recursion is a narrow language faculty which evolved recently and children with SLI tend to have lack of evolution on this language specific cognitive faculty (see also Sengottuvel and Prema, 2013b). Therefore, the present study predicted that children with SLI would perform poorly in recursion as well as implicit sequence learning (possibly the unification gradient space). Present study used agglutinating quantity as measure of merging ability, clauses/t-unit as measure of embeddedness, and AD-SRT task as a measure of implicit sequence learning. Results of present study showed that children with SLI performed significantly poorer compared to TD children on implicit motor sequence learning task as well as on recursion measures. However, the correlation between sequencing abilities and recursion measures was present only in TD children. Further, in SLI group recursion measures such as merging and embeddedness correlated with semantic scores but not with syntax scores.

The comparison showed that children with SLI were poor on learning implicit sequences and using recursive rich expression. Children with SLI are slow in general motor speed (Miller, Kail, Leonard, and Tomblin, 2001; Windsor, Kohnert, Loxtercamp, and Kan, 2008) that is evident from significant difference between RLavgs of TD and SLI groups. However, TD children showed a significant progress in RT for sequence trials, which was absent in SLI children. Within group factors showed that the RT for SLI children did not improve, therefore, suggesting a lack of sequence learning despite circumventing the motor speed factors. Moreover, on TCRT task both groups were similar showing that their attention and vigilance to perform AD-SRT task was adequate. Hence we would rule out the factor of general motor speed on results and would attribute the absence of RT progress for sequence trials in SLI to poor sequence learning. A straightforward interpretation showing sequencing and recursion deficits (not including correlation findings) in the results of the present study could be that implicit sequencing skills (unification) underlines recursion process. In which case, the present data strengthens the proposal that recursion is a procedural skill. Considering the positive correlation between sequence learning quantity and recursion measure further scaffolds the implicit underlining of recursion. In other words, findings in TD children suggest that the prefrontal cortex responsible for unification and procedural memory also substrates recursion (see Bolender et al., 2008; Chomsky, 1995; Sengottuvel and Prema, 2013b).

Interpretation of results of SLI group in the present study is complex (i.e., no correlation between sequence learning and recursion). Firstly, the present study showing poor sequence learning in SLI is in support of PDH and several previous studies (e.g., Lum et al., 2010). In general poor sentence complexity in sentences of children with SLI has been reported (e.g., Marinellie, 2004). Studies examining merging, embedding and implicit sequencing in children with SLI are not available. However, a single study (Sengottuvel and Prema, 2013d) reported no correlation between grammar complexity and sequence learning in SLI. Sengottuvel and Prema included wide age range from 7-13 years and the narration was not analyzed for recursive measures specifically, rather a t-unit based complexity and length analysis was done. Though the analysis was gross the correlation results of Sengottuvel and Prema is in support to present study. If there is no correlation between recursion and implicit sequence learning variable how could a statement enunciating relation between sequence learning and recursion be accepted with present data. Nevertheless, because of the lack of correlation the direct relation between sequence learning and recursion could be confounded. Note that the correlation was present in TD group therefore; a possibility to accept the relation between implicit sequence (procedural) skill and recursion was substantiated during earlier discussions. The absence of correlation between procedural memory skills and recursion skills in SLI groups could be explained from different perspectives. One perspective could be that recursion is not a procedural skill in SLI group. In other words, children with SLI use operations beyond implicit sequence learning to make recursive sentences (if at all they use some recursion because analysis shows that they are poor in using recursion). Another possibility for children with SLI not showing correlation between sequence learning and recursion scores could be that, they are not using the automatic unification for recursion. As the sequence learning scores suggest, they are rather compromised in SLI children. Therefore, they could be utilizing a system that is intact or even hyper functioning for this recursion purpose. PDH proposes a see-saw effect between procedural and declarative memory system for the benefit of language acquisition (see Ullman and Pierpont, 2005). Implicating it in the present study where there is no relation between procedural system performances with recursion in children with SLI there could be a possibility that children with SLI have poor procedural memory system (as evident from poor sequence learning scores) and it is not influencing the recursion performance. Probably, an intact declarative system, which is identical to memory in MUC, could take over the job of combining words and even short phrases and storing it in declarative system as a compensatory strategy for automatic combination of words by procedural system. However, there is no specific data in the present study to strengthen the compensation hypothesis. Nevertheless, the correlation results showed a positive correlation between semantic scores and measures of recursion in SLI group. The semantics and recursion scores correlation could indirectly favor the discussed probable compensation by declarative system in SLI children. From PDH perspective, a declarative memory (or just memory in MUC) has stored the agglutinated words and even phrases in whole form. Therefore, making the procedural/unification system less vulnerable in constructing longer sentences (in present study at least). In sum, the recursion scores of SLI children in the present study were influenced by declarative (memory) system and not by procedural (unification) system. Evidence also emerging from studies such as Hedenius, Ullman, Alm, Jennische, and Persson (2013) which reports of enhanced declarative system in developmental dyslexics (a condition where procedural system is compromised). Further, SLI children were reported to produce fewer complex utterances with fewer clauses in them and produced some examples of most spoken complex sentence structure (Marinellie, 2004). Marinellie's study could be an example for our assumption of declarative system compensating for inadequacy of procedural system. Nevertheless, correlation analysis does not entail a causative proximity; therefore, the interpretations and views proposed here shall be considered only moderately. The present study also showed that in both TD and SLI children, the scores on agglutination correlated with scores on embeddedness. This could have an implication in language processing mechanisms. For instance, if the merging is assumed as a simple adjacent operation and embeddedness is considered as non-adjacent operations, we could interpret from our results that the operations underlining adjacent and non-adjacent constructions are similar. The present results could be in synchrony with the study by Udden, Ingvar, Hagoort, and Petersson (2012), who reported from their artificial grammar-learning task which examined mechanism behind learning various adjacent and non-adjacent dependencies. Udden et al, reported analogous acquisition process behind adjacent and non-adjacent relations. Still, there could be a possibility that non-adjacent operations would require greater sequencing skills compared to merging operations (for e.g., see Sengottuvel and Prema, 2013d). To summarize, based on the evidence from present study and discussion the raised research questions are answered as follows.

1. Do children with SLI show deficits in recursive grammar such as merge and embeddedness?

Yes. Children with SLI show recursion deficits such as poor agglutination and poor embeddedness when compared to TD children.

2. Is recursion a procedural skill?

Yes. Recursion is a procedural skill. Children with SLI could probably be adapting an alternative declarative system to compensate for poor procedural based recursion.

5. Conclusion

The present study examines the statement that recursion is a procedural skill. As a whole the evidence shows that recursion is a procedural skill and therefore, could be affected in children with SLI. Nevertheless, statements made in discussion such as a probable declarative system taking over the function of recursion need further studies. Moreover, though the groups were matched on language age, the measure used in LPT to test language ability in participants was receptive in nature in spite of recursive measure requiring expressive skills. Therefore, we insist a moderation of discussion of the findings. More direct investigations on the brain activity while the person is engaged in recursion as well as implicit sequence learning could give substantial evidence to present proposal. Furthermore, recursiveness measured as a relative variation in SNPs of FOXP2 could be a promising research, as this is believed to be the gene through which language specific cognition is expressed in humans. Overall, the present study could be an initiative to further studies relating recursive abilities to neurobiology.

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The effect of two learning methods on the initial second language lexical processing: Evidence from backward translation recognition study

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Abstract

The study presented in this paper aimed to examine the effect of two learning methods on young learners' processing of second language vocabulary. More specifically, we attempted to determine whether the direct access to the conceptual store is possible after single learning session and how different learning methods may affect the connections between lexical and conceptual representations in the bilingual mind. The performances of two learning groups (picture- and word-based) were compared on backward translation recognition study in which they had to decide whether the second word of a pair was a correct translation of the first. Three different types of word relations were examined: correct translations, semantically related and form related word pairs. The results showed that children from picture-based group experienced significant interference effect with semantically related pairs, whereas the performance of learners from word-based method proved to be affected by form manipulations.

Thus, our findings have provided evidence that the direct access to the conceptual store is possible after single learning session; more importantly, they have indicated that the strategy of L2 learning modulates initial connections in the bilingual lexicon. Accordingly, the acquisition of L2 lexis via L1 instruction appears to promote the establishment of strong associative links between L2 words and their L1 translations. As a consequence, the activation of L2 word is immediately followed by the activation of its L1 equivalent, rather than its conceptual node. In contrast, bilinguals who employ picture-based learning method prove to develop direct and more permanent links between L2 words and their conceptual representations. The results of this study were also discussed in reference with DRM and BIA models.

Keywords bilingualism, vocabulary learning methods, lexical access, translation recognition, interference effect, BIA model

1. Introduction

The organization of the second language learner's mental lexicon received much attention over the last few decades. Psycholinguists were especially interested in how learners who already have established system of words in their L1 accommodate new forms and meanings in an L2. More specifically, how the connection between a second language form and its concept is achieved, and how it may be affected by different variables.

In accordance with the Revised Hierarchical Model (Kroll & Stewart, 1994), the critical factor determining the direct access to the conceptual store from L2 words is proficiency. Still, some researchers (Altarriba & Mathis, 1997; Finkbeiner & Nicol, 2003; Sunderman & Kroll, 2006; Tonzar, Lotto, & Job, 2009; Comesana, Perea, Piñeiro, & Fraga, 2009) challenged this assumption

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and started to investigate other variables and their influences on the initial structure of the bilingual lexicon.

The first direction of research concerned the effect of age of acquisition on L2 lexical processing (Silverberg & Samuel, 2004; Ferre, Sánchez-Casas, & Guash, 2006). Other studies focused on examining the differences in processing different types of words (de Groot, 1992; de Groot, Dannenburg, & Van Hell, 1994).

The present study also contributes to this line of research by investigating the influence of learning strategy on early links between L2 words and the conceptual system. More specifically, we aimed to examine the impact of two different learning methods (picture-based method and word-based method) on the development of the initial bilingual lexical network in children.

The importance of this variable has been already recognized and addressed in a number of studies. For instance, in the variable interconnection hypothesis, developed in Cieślicka (2000), preferred learning strategy is one of the vital factors modulating the strength of connections in the bilingual's mental lexicon. Also, Jing (2000) in his psycholinguistic model of L2 vocabulary acquisition as one of the variables affecting lexical development indicated different teaching approaches, namely word association approach and contextualized approach.

More experimental evidence supporting the importance of learning method comes from research in Chen (1990), Lotto & de Groot (1998), Finkbeiner & Nicol (2003). The results of those studies have clearly indicated that the choice of learning method exerts a considerable influence on the structure of the bilingual lexicon. Unfortunately, that evidence mostly comes from studies in adults, child's L2 conceptual processing has been rather neglected area in the psycholinguistic literature. However, as it has been revealed by neuroimaging studies (Kim, Relkin, Lee, & Hirsh, 1997), children (early bilinguals) activate different cortical areas while processing L2 than adults (late bilinguals). Thus, empirical research examining child's L2 processing is crucial to developing a comprehensive picture of an L2 conceptual processing.

To our knowledge, only few studies were conducted in this area, i.e. Comesana et al. (2009), Tonzar et al. (2009), Comesana, Soares, Sánchez-Casas, & Lima (2012). Moreover, due to the lack of adequate control over the stimuli and methodology, those studies failed to find any significant effect of learning method on the early L2 conceptual processing. For instance, considering the research by Tonzar et al. (2009) and Comesana et al. (2012), as also indicated by Comesana et al. (2012), the use of cognates prevented the complete inhibition of L1, as a result, participant's first language remained, at least, at the same level of activation as his/her second language. At the same time, the difference between methods in structuring connections in mental lexicon was not significant. Also, regarding Comesana et al. (2009) study, the influence of the first language was not reduced to a minimum, as in a test both groups (word and picture) were supposed to provide L1 equivalents to already learnt L2 words.

Given all the above considerations, in our work we aimed to provide such experimental conditions for picture-method group that would promote larger L2 activation, inhibit the reliance on L1 and, consequently, ensure direct connections between L2 words and the conceptual store. First, the stimuli list composition, in our study, was restricted to non-cognates. Second significant methodological factor, that was controlled for, is the condition of a test. Contrary to Comesana et al. (2009) study, test condition was congruent with learning method, i.e. subjects from picture-based method were asked to match L2 words with pictures, not translate them. Additionally, during learning phase, participants were instructed to silently rehearse and memorize presented L2 words. That process of "subvocal rehearsal" was supposed to not only ensure the retention of newly learnt L2 words in the phonological store, but also increase their resting level of activation (parameter in BIA model that determines lexical retrieval) in comparison to their L1 equivalents in the competitive process of word retrieval. The increased dominance of second language, inhibited influence of first language and context availability - all these conditions provided by picture-based method, to our belief, promoted and strengthened direct links between newly learnt L2 words and the conceptual store. In contrast, the conditions provided in word-based method, i.e. large L1 reliance, lack of context - conceptual meaning available only via L1, were assumed to promote the establishment of strong associative links between L2 words and their translation equivalents.

Basing on this reasoning, we formulated the following hypotheses for the both groups of our participants: In the case of picture-based group, we hypothesized that they would be more sensitive to semantic manipulations. We expected them to make more errors with semantically related pairs than with form related ones. Thus, for word-based group, we expected the opposite pattern of results; i.e. more errors with form related words than with semantically related ones. Also, with respect to RT (response latency), if we consider results obtained in Comesana et al. (2012), word-based group was supposed to show faster responses than picture-based group.

2. Methodology

2.1. Participants

Fourteen primary school students whose first language was Polish and second one was English participated in our study. At the time of participation they were all beginners and their mean age was 11,2 years old (10-12 years old). None of them has intellectual or learning disabilities.

Subjects were also asked to complete a detailed questionnaire in order to collect information concerning their language history. As the questionnaire revealed most of our students began acquiring English, approximately, at the age of 6. Thus, at the time of testing each participant had been learning English for 5 years. The data has also shown that, apart from the Internet, games and movies, their learning mostly occurs via L1 instruction at school and in private lessons (received once a week). Furthermore, they have had no contact with native speakers of English or never lived in English-speaking country. Regarding the fact that it was rather homogeneous group with respect to proficiency and learning context, participants were randomly assigned to picture-based group or word-based group (7 children at each).

2.2. Stimuli

We selected ten nouns, ten verbs, and five adjectives from English lexicon to serve as primes in our study. All of the stimuli were of high frequency and with low level of difficulty, since our subjects were beginners. Each English word was paired with three types of Polish words: correct translation, semantically related and similar in form to Polish correct translation. For instance, the word "sad" was paired with Polish "smutny" (correct translation) "ponury" (semantically related), and "smukły" (form related to Polish translation). Thus, each list consisted of 75 pairs (25 correct translations, 25 semantically similar words, 25 form-related words). The additional 10 pairs were used as practice trials to ensure stable results.

The selection of the semantically related words was based on the feature generation task performed by our participants one month prior to the study. Children were asked to list features of things, emotions or actions designated by the words. Having analyzed the features, we chose the most commonly encountered ones and, on their basis, we selected semantically related words.

2.3. Procedure

Considering the fact that our participants were beginners and that semantic priming paradigm is the most adequate indicator of the conceptual processing, we decided to use backward translation recognition task in our study.

In order to test the effect of training paradigm on the lexical processing, the design of the experiment was composed of two stages: the acquisition of lexical items and translation recognition task.

The procedure of the former phase was as follows. Participants of both groups were presented with three sheets of paper. The first sheet contained 10 nouns, the second one contained 10 verbs and the third one contained 5 adjectives, all of them in L2. Still, in the picture-based group words were matched with colourful pictures, collected from Google images (www.google.images.com), while in the word-based group words were paired with their L1 translation equivalents. Subsequently, each group was asked to memorize all new L2 lexical items. However, as mentioned above, the word-based group was given direct instructions to learn new words by silently rehearsing each L2-L1 pair. In order to decrease the level of anxiety and stress, all subjects were given as much time as needed. Once all English words were learnt, the children were assessed on their comprehension. As indicated above, the test condition was congruent with the condition of acquisition. Only those participants who scored 80% or better were allowed to the next stage of the study. Due to this restriction, 2 children were excluded.

Having completed the acquisition stage, the children from both groups were asked to perform translation recognition task. They were seated in front of 17-inch computer screens in a quiet, well-lit room. The experimenter informed them that they would be shown pairs of English and Polish words and their task would be to indicate, by pressing one of two response buttons, whether the second word (L1) is a correct or incorrect translation of the first one (L2). The "yes" responses were made with the preferred hand.

The procedure was created using DMDX display software (Forster & Forster, 2003) and the complete sequence was as follows. An English word was displayed for 500 ms, and it was replaced by Polish word. Each item was presented in lowercase and was centered in the viewing screen. If no response was registered within 500 ms after the emergence of the Polish word, the following trial was initiated. This particular interval was chosen in order to ensure semantic processing, and not merely lexical recognition. Also, it shall be noted that each subject received 10 practice trials prior to the experiment to familiarize him/her with the procedure and ensure stable results. Moreover, during the practice, each subject received feedback on speed and accuracy in order to encourage all participants to be as quick and accurate as possible when performing the experiment.

3. Findings

Mean response latencies of correct answers and percentage of errors, calculated for both learning groups and for each type of prime-target pair, are shown in Table 1.

	Translations	Semantically related condition	Form related condition
Picture-based group RT	738,12 ms	892,07 ms	773,59 ms
Picture-based group % errors	7,2%	14,5%	8,6%
Word-based group RT	722,55 ms	844,75 ms	760,35 ms
Word-based group % errors	7,6%	10,7%	14,9%

Table1. Mean RTs and percentage of errors for all types of prime-target relations for picture and word-based group

We conducted an analysis of variance (ANOVA) on the mean response latencies and percentage of errors by both items and participants. Only the results that reached significance were presented.

The ANOVAs performed on RTs revealed the main effect of the group, $F(1,98)=4.28$, $p<0.05$ (by items), reflecting that participants from word-based group responded faster than participants from picture-based group, in both prime-target conditions. Also, there was a significant effect of the type of learning condition on the participants' RTs, in the case of semantically related word pairs, $F(1,48)=15.7$, $p<0.001$. Moreover, the results of two-way ANOVA revealed to be significant for the interaction between learning strategy and prime-target relation, as shown in Table 2.

	Sum of Squares	Degrees of freedom	Mean square	F	Critical Value for Significance
Prime-target relation	71646,2	1	71646,2	2,8	0,0997
Learning group	114934,6	1	114934,6	4,4	0,0379
Interaction	69599,9	1	69599,9	2,7	0,1046
Res. error	2489417,9	96	25931,4		

Table 2. The results of two-way ANOVA on RTs

Concerning error percentage, there was a significant effect of the group, i.e. participants from picture based group made more errors with semantically related pairs, $F(1,12)=4.92$, $p=0.05$ (by participants), while subjects from word-based group responded more erroneously to form related pairs, $F(1,48)=9.53$, $p<0.01$ (by items). Thus, two-way ANOVA revealed that the interaction between the type of learning method and prime-target relation reached significance, as presented in Table 3.

	Sum of squares	Degrees of freedom	Mean square	F	Critical Value for Significance
Prime-target relation	8,4	1	8,4	0,0	0,8929
Learning group	816,2	1	816,2	1,8	0,1851
Interaction	5513,1	1	5513,1	12,0	0,0008
Res.error	43980,3	96	458,1		

Table 3. The results of two-way ANOVA on error percentage

Considering the effect of the type of words, learning method proved to have insignificant influence on the processing of abstract words, reflecting that participants of both groups performed more or less similarly with the respect to emotion words. The advantage of picture-based group was not observed.

4. Conclusions

In sum, as the results of the experiment indicated, the participants from picture-based group took more time and made more errors rejecting target words that were semantically related to correct translations than words that were similar in form. Hence, they proved to be more sensitive to semantic manipulations and showed clear semantic interference effect, as it was predicted. In contrast, subjects from word-based group made more errors while responding to form related pairs than to semantically related ones. However, their response latencies were not affected by prime-target condition, since the differences between their mean RTs failed to reach statistical significance.

Still, error analyses provided sufficient support for the claim that learning strategy had an influence on the initial processing of L2 words.

5. Discussion

The present experiment was designed to examine the effect of two learning methods on the initial establishment of links between lexical items and their corresponding conceptual representations in the process of L2 acquisition. This question was addressed by comparing performances of two groups of beginning, primary school learners, in a backward translation recognition study.

The obtained results clearly demonstrated differences in the pattern of interference effect between picture-based and word-based group. In particular, considering semantic manipulations, the former group proved to be more sensitive to this variable by demonstrating significantly greater inhibitory effects in semantically related condition than the word-based group.

This effect could have been obtained in the following way. The presented L1 target activated its corresponding feature nodes at the conceptual level, but some of them must have already been activated by an L2 prime. Such co-activation of semantic features resulted in participants' incorrect "yes" responses to semantically related pairs.

At the same time, our findings constitute support for the Distributed Feature Model, developed by de Groot (1992). According to this model, the number of shared conceptual nodes between an L1 and L2 word is critical in determining cross-language activation. In other words, both L1 and L2 words must activate their shared features in the conceptual model for the semantic priming to occur between them. In our study, an L2 prime must have activated its corresponding semantic nodes, since the activation of semantically related L1 target was easily achieved.

The semantic interference effect for picture-based group was also observed in Comesana et al. (2009) study. Nevertheless, in this research, it reached to significance only in the delayed test, not immediately after single learning phase. From our point of view, this divergence of results may be partly due to the condition of the test used in Comesana et al. (2009) which not only increased L1's level of activation, but also strengthened the L2 and L1 lexical links and weakened the connection between L2 words and their conceptual representations. Only when this learnt L2-L1 lexical connection weakened with time, participants were able to rely more on the conceptual links while processing L2 words.

Considering the pattern of data obtained for the word-based group, we observed significant inhibitory effects only for form-related distracters. Participants from this group proved to have developed strong lexical L2-L1 connections. This may be a result of "subvocal rehearsal", explained in the introduction, that did not only lead to the automatization of this L2-L1 association, but also increased the activation level of an orthographic form of L1 target. As a result, as predicted by BIA model (Bilingual Interactive Activation model), target words similar in form to the correct translations were given "yes" responses. Accordingly, participants from this group proved to be largely insensitive to semantic manipulations, but strongly affected by form manipulations.

Nevertheless, it has to be taken into account that the difference between semantic and form interference effect was only obtained in error data, not in

response times. However, an interesting pattern of results emerged from the RTs analysis: The responses of the participants from word-based group were faster than the responses of the participants from picture-based group. Also, this pattern of results may be explained within the framework of BIA model. Since subjects from word-based group were already familiarized with orthographic forms of L2 words during acquisition phase, they managed to recognize them faster than participants from picture-based group.
To conclude, the findings obtained in this study have shown that even after single learning session learners may have an access to the conceptual store, in a word recognition process. More importantly, it has been demonstrated that the strategy of L2 vocabulary learning significantly influences the strengths of connections in the bilingual mental lexicon. That is, the bilinguals who employ picture-based learning method develop strong direct conceptual links, whereas participants from word-based learning group strengthen more the associative links between L1 and L2 words. At the same time, subjects from the former group access the conceptual level directly from L2 lexis, while for the children from the latter group it is only possible via L1 translation equivalents.
Since the bilingual mental lexicon is constantly being developed, longitudinal studies are needed in future to investigate how the strengths of connections in the mental lexicon change over the process of L2 acquisition. Moreover, it would be interesting to further explore how new concepts nonexistent in the L1 are developed and how old L1 concepts are restructured under the impact of second language.

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