RELATIONSHIP BETWEEN PROCEDURAL MEMORY DEFICITS AND SPECIFIC LANGUAGE IMPAIRMENT: AN EXPLORATORY STUDY

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to
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DECLARATION

I declare that this thesis entitled **"Relationship between Procedural Memory Deficits and Specific Language Impairment: An Exploratory Study"** which is submitted for the award of the degree of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysore, is the result of original work carried out by me at the All India Institute of Speech and Hearing, Mysore, under the supervision of Dr. K. S. Prema, Professor of Language Pathology, All India Institute of Speech and Hearing, Mysore. I further declare that the results of this work have not been previously submitted for any degree.

Place: Mysore **S. Kuppuraj**

Date:

April 2014

CERTIFICATE

This is to certify that the thesis entitled **"Relationship between Procedural Memory Deficits and Specific Language Impairment: An Exploratory Study"** submitted by Mr. S. Kuppuraj for the degree of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysore was carried out at the All India Institute of Speech and Hearing, Mysore.

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This is to certify that the thesis entitled **"Relationship between Procedural Memory Deficits and Specific Language Impairment: An Exploratory Study"** submitted by Mr. S. Kuppuraj for the degree of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysore, is the result of the original work rendered by him at All India Institute of Speech and Hearing, Mysore, under my guidance.

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Abstract

Background: Procedural deficit hypothesis (PDH) claims that children with specific language impairment (SLI) would show associated non-linguistic deficits such as poor sequence learning. Procedural deficits also cause statistical pattern learning deficits. The hypothesis proposes that both language (syntax in particular) and sequence learning are underlined by analogous fronto-basal ganglia-cerebellar structures. The present study examines in first place the procedural memory in children with SLI and relation between procedural memory and language computations in a Dravidian agglutinating language, Kannada.

Method and materials: Thirty one children with SLI and 33 typically developing (TD) children participated in this study. SLI children were in par with TD children on chronological age, motor speed, and semantics but lower on syntax and total language age compared to TD children. The study used an adapted serial reaction time task (AD-SRT) task to measure sequence learning and grammar stimuli to measure some grammatical functions such as ability to perform long-distant/non-adjacent (measured through inflectional morphemes), adjacent/derivational operations and make complex sentences (recursion) in SLI and TD children.

Results and discussion: Children with SLI performed significantly lower compared to TD children on both procedural learning as well as grammar tasks. Discriminant function analysis showed that SLI were clearly discriminable from TD on procedural learning and non-adjacent operations and sentence complexity measures but not on derivational operations. Principle component analysis showed that majority of significant markers was non-adjacent operations and sequence-learning parameters. Correlation in TD children showed that sequence learning correlated well with non-adjacent operations. Findings support the predictions that children with SLI show procedural learning deficit and procedural learning deficit could be a reason for their poor non-adjacent grammar performance (inflection marking problem). Further, procedural learning deficit would affect more the non-adjacent operations compared to adjacent operations. The present study is the first that attempts to understand the relation between specific aspects of grammar to sequence learning. Findings were discussed with principles of PDH, statistical learning mechanisms and possible compensatory role by declarative system.

Chapter 1
Introduction

Language is innate and majority of children learn language effortlessly. However, a considerable amount of children (7% as per ICD 10) find language learning effortful. Children who demonstrate language learning difficulties despite adequate nonverbal abilities are referred to as children with specific language impairment (SLI). Leonard (1998) defines SLI as a developmental condition in which a child fails to develop language at a typical rate despite normal general intellectual abilities, adequate exposure to language in the absence of hearing impairment, obvious neurological signs, inadequate motor skills, and socioeconomic deficits. Children with SLI have the greatest problems in syntax compared to semantics, while their acquisition of pragmatics is relatively spared (Leonard, 1998).

Several linguistic causative approaches have been proposed to explain the linguistic behavior of SLI. Significant ones are the agreement deficit account (Clahsen, Rothweiler, Woest, & Marcur, 1992), extended optional infinitive account (Rice, Wexler, & Cleave, 1995), agreement tense omission model (Schutze & Wexler, 1996) and surface account (Leonard, 1989). However, the linguistic hypotheses often do not cross language barriers and restricted to explain specific linguistic behaviors of SLI alone and fails to account for non-linguistic deficits of SLI (Ullman & Pierpont, 2005). Ullman (2001) in his declarative/procedural (DP) model proposes that human language is mediated by temporal-hippocampal based declarative memory system and frontal-basal ganglia-cerebellar based procedural memory system. DP model was a dual mechanism model which postulated that semantic associations of a word (abstract) is stored and retrieved from declarative memory system and rules of grammar are learned and retrieved from procedural memory system. Ullman also discriminates these two memory systems based on their learning speed and conscious retrievability. The learning speed of declarative memory system is rapid compared to procedural memory system where the learning is achieved after several exposures. The items stored in declarative memory system are consciously accessible whereas the items stored in procedural memory systems are not available for consciousness and are often rapidly accessed (Squire & Knowlton, 2000).

Based on DP model, Ullman and Pierpont (2005) proposed the procedural deficit hypothesis (PDH) to explain linguistic and non-linguistic behaviors of SLI. The PDH claims that children with SLI have problems beyond language in the memory system that mediates learning of motor and cognitive sequences. In other words, children with SLI would show associated motor (cognitive) sequencing problems along with language problems. PDH further justifies the pattern observed in children with SLI such as relatively intact semantics compared to syntax to relatively intact declarative system in them. PDH also assumes a compensatory declarative system, which could take over some functions of procedural systems by memorizing small phrases as single chunks and storing regular inflections as single words in declarative memory system (M. Ullman, personal communication, 7th October, 2013). Ullman and Pierpont's PDH also claims to account for heterogeneous and cross linguistic manifestations in SLI population (for details Ullman & Pierpont, 2005).

Two types of implicit learning underlined by procedural memory system have implications in language learning. First one is the memory of sequences which is predominantly non-verbal. However, it could also assist prediction of next element in an event such as speech (Mainela-Arnold & Evans, 2013). Second type is learning statistical information (or pattern) from input which is predominantly verbal (Hsu & Bishop, 2011). Research has used both these procedural memory functions to explain language behavior of children with SLI (Lum, Conti-Ramsden, Page, & Ullman, 2012, for sequence learning & SLI; Evans, Saffran, & Robe-Tores, 2009, for statistical learning & SLI).

Sequence learning ability is measured using serial reaction time (SRT) task and statistical learning is measured through artificial grammar task. The present study was carried out employing SRT task. SRT task is a visuo-motor task where in a participant has to trace the stimulus which could be appearing in any of the four boxes in the screen using a gamepad which has spatially corresponding buttons to the stimulus boxes (method section 3.2.1). Children with SLI are shown to have deficits in SRT task indicating instating that children with SLI do have procedural memory system deficits along with their language deficits (Lum et al., 2012). Evidence has also shown that sequence learning scores predict grammar better compared to vocabulary (Hedeinius et al., 2011; Tomblin, Mainela-Arnold,

& Zhang, 2007). These studies add evidence to the claims of PDH which proposes that procedural memory would be significant for rule learning than for abstract learning.

Though such gross relations were reported, earlier studies did not attempt to study the role of sequence learning to specific aspects of grammar such as adjacent operations (derivational grammar) and non-adjacent operations (inflectional/morpho-syntax). Proposals outside PDH, but with scope of procedural skill were also made in the present study. That is, the present study states that merge operation that binds the words to make longer sentences could be a procedural skill (Bolender, Erdeniz, & Kerimoglu, 2008; Chomsky, 1995).

The present study makes predictions for certain aspects of grammar such as derivational, inflectional / morpho-syntax and sentence complexity of children with SLI based on principles of PDH. Linguistic theories categorize inflectional/morpho-syntax operations as non-adjacent operations. In other words, the usage of an inflection morpheme (or morpho-syntax) would depend on several other words in that sentence that are distantly (non-adjacently) placed. The present study predicts with basic principles of PDH that non-adjacent operations would demand greater sequencing abilities. Therefore, non-adjacent operations would be of great difficulty for children with SLI who according to PDH would have sequencing problems. On the other hand, derivational morphemes operate in sentence like any other word in a sentence and hence would be relatively easy for children with SLI. Considering the statements of Bolender et al. (1998) and Chomsky (1995) we also predict that sentence complexity measures would also be affected in SLI (Kuppuraj & Prema, 2013b).

The present study examines the predictions using data from motor sequence learning and grammar task and attempts to explain the observations using procedural deficits in SLI. The study compares a group of Kannada speaking children with Specific Language Impairment (SLI) and Kannada speaking typically developing (TD) children on procedural learning skill. The study also compares the SLI and TD groups on grammatical operations. The ultimate aim of the study that is to study the relation between procedural learning and language learning /impairment is served by examining the correlation between procedural memory and grammar.

Chapter 2
Review of Literature

'Human brain has knowledge for language like any other species has skill for its own' (Rice, & Wexler, 1995, p. 216). Human language that governs structural aspects is overlaid on the brain systems previously implicated exclusively for implicit skill learning (Christiansen, 1994; Christiansen & Devlin, 1997; Kuppuraj & Prema, 2012a; 2013b). Therefore, causative explanation for language (syntax in particular) deficit could be better explained if the underlying phylogenetic substrates of syntax are considered (Kuppuraj & Prema, 2013b). Procedural deficit hypothesis (PDH) (Ullman & Pierpont, 2005) is a causative hypothesis to explain grammatical deficits in individuals who manifest language impairment with typical non-verbal intelligence. Procedural memory is an implicit non-declarative memory specialized in learning sequences irrespective of domain (Square & Knowlton, 2000). The hypothesis implicates deficits in implicit sequence learning skills as a cause for grammatical deficits in SLI. PDH states that grammar deficits in children with language impairments could co-occur with sequence learning deficits. Sequence learning is an implicit skill learning which happens through repetitive exposure to same stimuli. According to PDH, language learning is implicit skill learning; therefore, any language deficits in children with language impairment could be explained by procedural memory deficits (Kuppuraj & Prema, 2012a). PDH also claims that associative memory systems such as declarative memory systems could also be affected analogous to procedural system deficits in language-impaired children. Theories that assumed a straightforward general purpose learning mechanism has drawbacks in accounting for rapid syntax acquisition, specific linguistic deficits, and cross-linguistic variation in language impaired children. PDH on the other hand claims to have provision to explain specific linguistic, non-linguistic and cross-linguistic variations of language impaired children and among language impaired children. Therefore, there is every reason to assume that as per the claims of PDH, certain aspects of language (syntax) mature without our knowledge or attention to the input (Borer & Wexler, 1987). The implicit knowledge and its relation to various syntactical operations are examined in the present study by using tasks for implicit sequence learning and for syntax. The data was obtained on children who were known to have impairments specifically in language domain through clinical examinations and assessments.

Few children do not develop grammar at the same rate as that of typical children but show protracted period of language acquisition, in spite of no obvious neurological conditions. Terms such as developmental aphasia (Eisenson, 1968) and developmental dysphasia (Clahsen, 1989) were initially used in the literature for such children. Around 1980's researchers adapted the term Specific Language Impairment (SLI) to label children who show language deficits but otherwise perform similar to typically developing (TD) children on domains outside language. Currently the term SLI is used for such children who show deficits in language alone. Although, a variety of diagnostic labels appear in various diagnostic manuals and clinical settings (Leonard, 1998), claims challenging the views maintaining exclusive language specific deficits in SLI have emerged in the past decade (American Psychological Association, 2000; Ullman & Pierpont, 2005). Ullman and Pierpont (2005) through the procedural[1] deficit hypothesis (PDH) announced that deficits outside language domain could be compromised in children with SLI. PDH gathered evidences, which showed difficulties in sequencing cognitive and or motoric events in SLI children. PDH claims that procedural learning deficit may account for a wide range of SLI heterogeneity.

Specific Language Impairment is considered a relatively common developmental condition in which a child fails to develop language at the typical rate despite normal general intellectual abilities, adequate exposure to language, and in the absence of hearing impairment (Leonard, 1998). Eisenbeiss, Bartke, and Clahsen (2006) define SLI as a delayed or deviant language development in children in the absence of neurological trauma, cognitive impairment, psycho-emotional disturbance, or motor-articulatory disorders. SLI children have the greatest problems in learning word forms and the grammatical structure of language, with acquisition of semantics and pragmatics relatively spared (Bishop, 1997; Leonard, 1998).

[1]Procedural memory system is a memory system underlying implicit (unconscious) statistical/sequence learning.

2.1. Diagnostic Criteria for SLI

Children with SLI typically manifest impaired word knowledge such as delayed acquisition of first word (Trauner, Wulfeck, Tallal, & Hesselink, 1995), slow naming (Lahey & Edwards, 1996), weak verb learning (Watkins, Rice, & Molz, 1993), and grammatical knowledge impairment with particular difficulty in acquiring verb morphology (Rice, Wexler, & Cleave, 1995). One of the distinctive criteria for SLI is a discrepancy between age-appropriate non-verbal intelligence and delayed language development. The marked deficit in verbal domain is a common feature among children diagnosed as having SLI. American Psychiatric Association's diagnostic and statistical manual (DSM-IV, 1994) provided exclusionary diagnostic criteria for identifying children with SLI that excludes language or communication problems that may be related to any other identifiable causes. The causes needed to be excluded to consider an individual as SLI are autism, mental retardation, hearing impairment or other sensory deficits, a speech-motor deficit, severe environmental deprivation, or an acquired disorder. Leonard (1998) proposed a similar criteria for SLI which included a combination of normal intelligence (performance IQ greater than 85) and language impairment (a composite language measure falling more than 1.25 SD below the standard mean). Specific clinical exclusionary criteria (Bishop, 1989; Records & Tomblin, 1994) used to identify SLI considered children who failed a teacher/parent checklist for social interaction skills and a pure tone screening at conventional levels for diagnosis of SLI. The criteria excluded children who had head trauma or epilepsy, or had frank neurological signs, had delay of greater than 6 months in phonological development, and/or had known history of recurrent otitis media. The criteria excluded children who exhibited oro-motor or sensory anomalies, and who exhibited emotional or behavioural problems sufficient to employ intervention. Furthermore, children who perform more than one standard deviation (SD) below the mean for nonverbal IQ for their age were excluded from the diagnosis of SLI.

The World Health Organization's International Classification of Diseases (ICD-10, 1993) specifies that language skills to be at least one SD below non-verbal IQ. Traditionally, children who show a clear discrepancy between their performance on non-verbal assessments and language assessments, along with all other criteria for SLI outlined above, may be diagnosed as having SLI. This traditional criterion of nonverbal IQ and language discrepancy was questioned by one of the largest epidemiological study (Tomblin & Zhang, 1999) and a twin study (Bishop et al., 1999). Studies such as Tomblin (and Bishop) showed that language impaired children performed similarly on variety of measures despite their nonverbal IQ being above or below average range. However, there is widespread agreement, regarding the language test criteria to be employed in identifying SLI. Study by Records and Tomblin (1994) validated the use of composite language measures to identify children with SLI by comparing them with the judgement of experienced speech language pathologists on the presence of SLI. The results were that the clinicians agreed on the diagnosis of SLI for individuals scoring at least 1.25 SDs below the mean on composite language measures. Records and Tomblin used composite measures of language because it provides robust estimate of performance. Currently, many studies employ the criterion of scoring at least 1.25 SDs below the mean on two language measures to identify research participants with SLI (Bishop, Bright, James, Bishop, & van der Lely, 2000; Ellis Weismer et al., 2000).

A standardized diagnostic criteria for diagnosing children with SLI was attempted on more than 7000 kindergarten (age 5 years) children in the USA (Tomblin, Records, & Zhang, 1996). The results showed that the diagnostic sensitivity for SLI was the best when two or more composite scores of receptive and expressive language modality on semantic, syntactic, and narrative domains were 1.25 SDs below the mean. Tomblin and his colleagues also mentioned that children also had to meet the usual exclusionary criteria and perform within normal age limits on a measure of nonverbal intelligence. Using these criteria of Tomblin and colleagues 7.4% of the kindergarten children met the criteria for SLI.

2.2. Incidence and Prevalence

The incidence and prevalence of children with SLI is often a perplexing picture as SLI overlaps with similar other developmental conditions. For instance, late bloomers also manifest similar characteristics as SLI (Rescola, 1989). On an average up to 15% of children are late bloomers who show delay in uttering the first 50 words and word combinations by 2 years of time. Among the late bloomers 50% persisted with the problem (SLI) and rest catch up with the typical peers. Consequently, 7-8 % of preschool and school age children persist to have SLI without sustained and effective intervention (Leonard, 1991). Around 7% of children entering school are language impaired and the deficit is associated with later difficulties to reading (Bartlett, Porter, Borkakoti, & Thornton, 2002). Bishop et al. (2012) made a statement based on prevalence estimates provided by past studies (Haynes & Naidoo, 1991; Neligan & Prudham, 1969) on late talking and SLI children. She stated that in a population of 1000 children, there could be 100 late talkers. Among hundred late talkers, there could be 30 children with severe SLI.

Studies have shown that SLI runs in families (Benasich & Spitz, 1999). The incidence of SLI to run in family is estimated to be 20-40% (Choudhury & Benasich, 2003). 65% of SLI probands had history of speech, language or reading problems and remaining 35% were isolates (Tallal, Townsend, Curtiss, & Wulfeck, 1991). Tomblin and Buckwalter (1994) reported that among the 26 families tested, of the 42% of children diagnosed with language impaired (proband), at least one family member had speech language difficulties. Tallal et al. (1991) assessed direct testing to assess the rate of language impaired in proband and control families. Tallal and colleagues found that 52% of the proband children and 15.4% of control children had affected first-degree family members showing greater familial aggregation.

2.3. Differential Diagnosis of SLI

Differential diagnosis of SLI at very young age is justified by the greater need of long term language intervention for children with SLI. Differentiating children with SLI from other developmental conditions such as late bloomers, late talkers, autism, and semantic–pragmatic disorder is challenging. The difficulty in extracting morpho-syntax which gives significant markers about developmental disabilities could be the main reason for the challenge in differential diagnosis at young children. Late bloomers are group of children often embedded among late talkers who resemble SLI. Fischel, Whitehurst, Caulfield, and Debaryshe (1989) followed 26 two year old children who were reported to have good understanding but with only few one word utterances by their parents. Five months after initial assessment one third of children performed typically, one third had made some improvement and one third remained the same. Similar pattern of rapid growth in language after initial slump were reported by several studies (Rescorla & Schwartz, 1990; Thal, Tobias, & Morrison, 1991). Due to challenges posed by overlapping conditions linguistic and non-linguistic hereditary markers are studied in SLI and related conditions to differentiate children with SLI with high sensitivity. Bishop et al. (2012) conducted a longitudinal study to report on aspects which are predictive of persisting language problems. They followed 24 late talkers and 58 average talkers at the age of 20 months and followed them up after 4 years. Among the late talkers, 29 % (seven children) met the criteria for SLI at 4 years of age. In the group of average talkers, 14 % (eight children) met the criteria for SLI at 4 years. Follow up results showed that around three-quarters of late talkers outgrow language deficits like their typical peers at 4 years of age provided there was no family history of language impairment. Bishop and colleagues concluded that the best predictors of SLI at 20 months of age were family history of late talking, receptive language scores and parents' performance on a non-word repetition task.

Leyfer, Tager-Flusberg, Dowd, Tomblin, and Folstein (2008) reported of 41% overlap between SLI and autism on social and communication domains. The seminal study that investigated overlap between SLI and autism was by Bartak, Rutter, and Cox (1975). Bartak and colleagues compared 48 boys with autism or SLI matched on age and nonverbal IQ. The results showed that even though most individuals could be clearly differentiated easily by general observations, there were areas of overlap and five children exhibited characteristics of both disorders (Bartak, Rutter, & Cox, 1977). Cantwell, Baker, Rutter, and Mawhood, (1989) studied the same children when they were adolescents. Even though, the boys with SLI had improved communication skills, there was an increase in their use of stereotyped utterances. SLI children also showed greater social problems compared to earlier years such as difficulty making friends and joining group activities. On the other hand, the autism group had behaviours either improved or remained unchanged. Mawhood, Howlin, and Rutter (2000) re-examined same group of individuals at ages 23–24 and reported that some individuals continued to show social difficulties in the SLI group. In general, the studies followed SLI and autism group over years showed that the differences between the autism and SLI groups increase over time making the differential diagnosis easy and the differences were quantitative rather than qualitative in nature.

The overlap between form (like in SLI) and usage domain (like in autism) indicates that domains of language are interconnected and deficit specific to certain domain are not always prevalent in reality. Bishop (2003) called autism as "SLI plus" as she considered autism as a condition with additional features to language impairment. She also reported of intermediate condition between SLI and autism. Bishop stated that more family members of autism are identified to have SLI. Therefore, a causative link could be evident among conditions such as SLI and autism. The part of language module, which is compromised would accordingly implicate the language outcome of an individual. The language modules such as structural (morphology, syntax), content (semantics), usage module (pragmatics) could be solely or integrally compromised (Fodor, 1983). Therefore, resulting linguistic manifestation could be of various types leading to subtypes among children with SLI.

2.4. Subtypes of SLI

Attempts were made to cluster individuals with SLI based on their uniformity in clinical manifestations (cluster analysis approach by Aram & Nation, 1975; processing criteria such as expressive vs. receptive and/or clinically based models by Bishop & Rosenbloom, 1987). However, a widely agreed-upon grouping for heterogeneous SLI data is not available until date. When the cache of cognitive resources for a particular language module is disturbed, it results in disturbance of that module (for detailed review on modules of brain, Fodor, 1983). Deficit in certain module would result in deficit primarily pertaining to that aspect of language. Such specific modular deficits in lexical system (Dockrell & Messer, 2007), pragmatic system (Botting & Conti-Ransden, 2003), semantic and pragmatic systems (Rapin & Allen, 1983), and syntax system (van der Lely, Rosen, & McClelland, 1998; van der Lely, 2005) were documented in the past. SLI could also be classified into a group that resolves later and group that continues to have language deficits (Bishop, 1997). Some authors classified SLI as grammatical and non-grammatical deficits group (Bishop, Bright, James, Bishop, & van der Lely, 2000). School-aged children with SLI with syntactic deficit, but with normal lexical retrieval and phonological abilities were also documented (Friedmann & Novogrodsky, 2004 & 2007; Novogrodsky & Friedmann, 2006). There are evidences that a group of SLI exists with impaired phonology but with intact syntax (Gathercole, Tiffany, Briscoe, Thorn, & The ALSPAC team, 2005a; Hansson, Nettelbladt, & Nilholm, 2000). Alternatively, evidences also support the existence of SLI population with impaired syntax but intact phonology (Stokes, Wong, Fletcher, & Leonard, 2006). Coltheart (2005) in his work on psycholinguistics of SLI subgrouped SLI into five major subtypes. He grouped children who showed difficulty in producing speech sounds correctly with no apparent physical cause as phonological expressive impairment subtype. Children under this subgroup could have normal understanding of speech and they could be called as developmental verbal dyspraxics. Coltheart classified children who show specific difficulty in understanding spoken words despite normal hearing as verbal auditory agnosia subtype. He named children with SLI with lexical and grammar deficits as lexical-syntactic subtype. In Coltheart classification of SLI, children with obvious and persisting grammatical errors in comprehension and production were grouped under grammatical subtype of SLI. Coltheart also came across a group of language impaired children who had fluent speech with correct grammar and articulation yet their communication skills are severely hampered, he called such group as semantic-pragmatic subtype.

As explained earlier there are several modules in brain and few of them are specific for language computation (Fodor, 1983). Every module of language is prone to cognitive deficits. Nevertheless, the most prevalent modular deficit in SLI population is syntax module deficit (van der Lely, 1999). The high prevalence of syntax disturbance could be due to the vulnerability of syntax domain to disturbance compared to other domains. Novodgrodsky and Friedman (2006) name the group with predominant syntax deficit as Syntactical SLI. The similar condition was labelled as Grammatical SLI (G-SLI) (van der Lely, 2005). Children with G-SLI show exclusive syntax deficits that persists throughout. Linguistically, G-SLI children tend to consistently manipulate vital aspects of syntax, such as tense and agreement marking, assigning thematic values in passive sentences, errors on embedded phrases and clauses, assigning reference to pronouns or reflexives, and producing Wh-questions (van der Lely, 1998) (Table 2.1).

It is evident that while G-SLI children share many grammatical inflectional features with other SLI children (Bishop, 1997; Leonard, 1998), syntactic structural errors are more predominant in G-SLI children compared to other SLI children. Aspects of language beyond grammar, like pragmatic inference and verbal logical are intact in G-SLI (van der Lely, Rosen, & McClelland, 1998). For instance, G-SLI children show promising knowledge in determining conversational inferences and using pronouns in narratives to facilitate sentence comprehension (van der Lely & Stollwerck, 1997). Bishop et al. (2000) however, questioned the pure existence of G-SLI among SLI population. Bishop and colleagues conducted a study which aimed at assessing the validity of G-SLI as a grammatical subtype within the SLI population. Within the SLI population over 9 years old with persisting deficits and normal non-verbal abilities, the prevalence of G-SLI is around 10–20% (Bishop et al., 2000) which is two out of ten SLI children.

Table 2.1

Examples of syntax deficits in G-SLI

Example for	*in Kannada*	*Description*
Tense and agreement marking	*na:nu na:Le u:rinda* me tomorrow from home *bande* came ‘I came from home tomorrow’	Tense agreement deficit
Assigning thematic values in passive sentence	In a action of man eating fish the child would say	*mi:nu avanannua thinnutta: ide* fish him eating ‘The fish is eating him’ The thematic value is assigned erroneously; therefore, the sentence conveys inverse meaning
Errors on embedded phrases/clauses	*krishna ninne a: laDDu* Krishna yesterday that laddu *nange koDti:ni anta* to me give like that *he:Ltidda* was telling ‘Krishna was telling yesterday that he will give me that laddu’	G-SLI child says *krishna a: laDDu* Krishna that laddu *ninage koDutane anta he:Lutini* to you will give will tell incorrect embedding
Assigning reference to pronouns	*ra:ja oLLe huDuga* raja good boy *avanu oLLekelasavannu ma:Duta:ne* he good work does ‘Raja is a good boy and he does good job’	*ra:ja oLLe huDuga. adu oLLe* raja good boy that good *kelasa ma:Duta:ne* job will do reference has been assigned incorrectly ‘Raja is a good boy. That does good work’

In sum, SLI could manifest itself predominantly in any of the language domains, even though syntax deficits are the most prevalent among children with SLI. The term SLI in the current research work refers to children with difficulties pertaining to language domain and whose nonverbal intelligence is in level with typically developing (TD) children. The language deficits of the SLI children mentioned in the present study could be approximated to the "typical SLI" group proposed by Bishop (2004). The typical SLI children would show predominantly phonological and syntactical errors compared to semantic and pragmatic errors, however minimal semantics and pragmatics errors were reported in this subgroup (Leonard, 1998). Other labels that could match the SLI group in the present study are 'phonological-syntactic' type (Rapin & Allen, 1983) or the 'classic' SLI (Hynes & Naidoo, 1991).

2.5. Language Deficits in SLI

2.5.1. Early communication deficits. A child who is likely to be at risk for SLI may show signs of communication incompetency as young as 1 month old. Hamaguchi (2001) described few discrepancy patterns such as avoiding eye contact, limited or no imitation of sounds, no evidence of first true word, and unable to follow one step commands that children with SLI show when compared to typical peers during their early language development (1-18 months). Such patterns would indicate that the particular child would grow up to persist with SLI. Hamaguchi (2001) reported that significant signs to be noted from 0-12 months as indicators of risk for SLI are avoiding eye contact, rare babbling, not showing consistent response to whispered speech, showing little interest in waving "bye bye", imitating gestures, and crying often without showing pitch or intensity change. Further, extending the observation until 18 months showed that the communication features included avoiding eye contact, not saying "mama" or "dada", not showing body parts when asked, and showing difficulty in following a verbally given simple one-step command, unless accompanied by gesture. However, the study also gave a caution that the mentioned signs could also be risk indicators of autism and other developmental disabilities.

2.5.2. Phonological characteristics of SLI. A child is considered to have phonological disorder, if the speech utterances of the child show unintelligible predictable pattern of errors even after the time limit in which it subsides in TD children. Phonological process evident in children with SLI is similar to TD as a whole except some notable differences. Prevocalic voicing and deletion of word initial weak syllable may occur with greater frequency among SLI children. Leonard & Leonard (1985) documented that children with SLI produced unusual errors that are not associated with usual phonological process such as stopping of liquids and substituting liquids for glides. A substantial percentage of children with SLI show speech problems. In some cases, these speech problems could lead to language problem. For instance, difficulty in production of sounds such as /t/, /d/, /s/ or /z/ in English could reflect as morphological deficits as these sounds are used to indicate morphological markers for past tense, third person singular present tense, possession and plurals (Rescorla & Lee, 2001). PDH offers explanation for any phonological deficit since, it considers phonotactic rule learning as a procedural skill. For instance, a child who learns English language would form sentences that end with consonant as this is the rule for English language. The child exercises implicit learning skills using the probability knowledge of occurrences of preceding/consequent phonemes (sounds). Similarly, the implicit skills also help the child to divide/identify words in a continuous speech stream which is widely known as 'bootstrapping' (Gleitman, 1990).

2.5.3. Semantic problems in SLI. Deficits in semantic domain are documented in children with SLI (Brackenberry & Pye, 2005). Sheng and McGregor (2010) reported of semantic–lexical organization deficits in children with SLI. Delay in emergence of first word is often the clear indicator that a child could develop lexical-semantic language impairment in future (Bishop, 1997). One of the hypotheses that attempted to explain semantic deficits in SLI is the retrieval hypothesis, which states that children with SLI have semantic deficits because the algorithms or mechanisms that are used to access the word from lexicon are less efficient compared to the peers (Newman & German, 2002). At the age of two years, TD children produce 200 words, but a child with SLI could produce no more than 20 words (Paul, 1966; Rescorla, Roborts, & Dahlsgaard, 1997). Because of lack of vocabulary children with SLI use over extensions and under extensions of word meanings even after the age of 3 years (Nelson, 1993). Nouns dominate children's vocabulary as the ability to label concrete objects learned easily by typically developing children. At around two years, verbs are learnt and typically developing children begin to produce the first two word combinations (noun + verb). SLI acquire these early appearing word combinations, but much later than the typical children does. Children with SLI take much longer than typically developing children in understanding that this two word combinations convey variety of information apart from noun plus verb constructions (Kitty run), such as possession ("my kitty"), disappearance ("kitty gone") or rejection ("no kitty") (Hegde & Maul, 2006). The semantic domain related problems in SLI are reported to show greater differences compared to typically developing children (Lahey & Edwards, 1999). Children show this greater difficulty in semantic domain as academic incompetence as they find it difficult to expand their language skills to understand abstract concepts compared to TD children. The less severe semantic problems associated with procedural mechanism deficit could be explained by PDH using the involvement of some of the procedural mechanism structures in lexical retrieval. Furthermore, the lexical retrieval problems could also be explained by the extension of procedural mechanism structures into declarative regions of brain (i.e., storage areas of brain-temporal lobes). In other words, assuming a possible declarative memory deficit affiliated to associated with procedural deficit could explain semantic deficits in SLI if observed. Moreover, the prefrontal cortex that underlies procedural mechanism also partly enables word retrieval, which is an executive function. In sum, there could be several possibilities to explain semantic deficits from PDH.

2.5.4. Grammatical deficits in SLI. The consistent diagnostic feature in children with SLI is their syntactic and morphologic errors (Conti-Ramsden & Jones, 1997; Rescorla & Lee, 2001). They omit various grammatical morphemes even though the learning sequence is similar to TD children. Generally, children with SLI take longer time to learn grammatical morpheme or omit them throughout their life. The trait particularly holds good for G-SLI (van der Lely, 1999, 2005). Children with SLI use shorter, less complex, and less varied sentences. Children with SLI are less likely to use restrictive embedded classes. They find difficulty in manipulating sentences and transforming sentence types (such as active to passive). Children with SLI omit functional morphemes and prefer to retain content words in the speech resulting in telegraphic like speech utterances. One typical example of syntax alone deficit in SLI is given further. SLI child with syntax deficit alone knows in a sentence like *priya says prethi is pinching herself*, "herself" is female (knowledge of semantics) and knows that pronouns in general must be used for people who existed in conversation already (knowledge of pragmatics). However, does not understand that "herself" in the sentence is "preethi" and does not differentiate sentences like *priya says preethi is tickling herself* and *priya says preethi is tickling her* (poor syntax knowledge).

The linguistic competence of individuals depends on their ability to sequence content words from lexicon with the help of functional words/morphemes as per the rules of native language. Functional class morphemes are a closed set of words that do not posses complete lexical meaning, but have a functional or more often grammatical role. Functional class includes inflections, pronouns, articles, prepositions, conjunctions, comparatives, conditionals, and auxiliary verbs. On the other hand, the main role of content words is to convey semantic information and they are of open class system. Content words comprise nouns, main verbs, adverbs, adjectives and derived forms. Children with SLI show deficits predominantly in the usage of functional class morphemes (Leonard, 1998; Rice & Wexler, 1996; Schuele & Nicholls, 2001) where the content words (lexicon) appear near normal (Ullman & Pierpont, 2005).

2.5.4.1. Derivational morphology in SLI. Studies on derivational morphemes in SLI were less compared to studies on inflectional deficits. Nevertheless, studies reported of poor derivational morphological knowledge in SLI (Gopnik, 1999; Ravid, Levie, & Ben-Zvi, 2003; Windsor & Hwang, 1999). Derivational morphemic deficits in children with SLI could be explained by PDH that claims involvement of declarative memory systems along with procedural memory deficits. PDH assumes that derivational morphemes are handled by lexical retrieval operations of memory systems. Therefore, as per the PDH, involvement of declarative memory systems would explain poor lexical retrieval and associated derivational morphemic deficits. A recent study that examined the derivational morphemic usage in children with grammatical-SLI (G-SLI) came from Marshall and van der Lely (2007). Marshall and his colleague examined whether children with G-SLI omit derivational morphemes. They also examined whether the phonological and inflectional complexity linked to root word affect derivation. The results revealed that G-SLI children make very few derivational morphemic omissions compared to inflectional past tense suffixation omission. The high complexity of stimulus did not show any changes in the derivational morphemic performance. However, findings such as bare stem errors *(e.g. more/most)* in derivational morphology as well as semantic substitutions were observed in the performance of G-SLI suggesting the difficulty related to lexical retrieval. The derivational suffix as such was not affected in children with G-SLI. The findings are consistent with most dual route models that claim that operations such as derivations are lesser rule dependent and oriented towards lexicon of language (Gopnik, 1999).

2.5.4.2. Inflectional morphology in SLI. Children with SLI fail to make agreements with tense, number and gender in a sentence. Several studies have shown deficits in usage of inflectional morphology in children with SLI (Rice, Wexler, & Hershberger, 1998; Rice, Wexler, Marquis, & Hershberger, 2000; Rice, Tomblin, Hoffman, Richman, & Marquis, 2004). Major clinical markers of SLI are considered to be the deficits in inflectional morphemes such as, tense and agreement marking, which result in omission of third person singular */–s/, /be/*, */do/* and past tense */–ed/* (Rice & Wexler, 1996). Recent studies have shown that omission of these morphemes is optional in children with SLI, and when these morphemes are available they were used accurately (Ullman & Gopnik, 1999; van der Lely & Ullman, 2001). Several accounts predicted inflectional morpheme deficits in SLI (Extended Optional Infinitive Account by Rice et al., 1995; & Agreement Tense Omission Model by Wexler, 1998). However, all the accounts attributed the deficits to lack of maturation, even though that is not the case in children with SLI as they continue to show these problems throughout their life (Rice & Wexler, 1996b). Few hypotheses attributed the deficits to processing difficulties inside the system mimicking the surface structure of input language (Surface Account by Leonard, 1989; Morphological Richness Account by Leonard, 1989). The processing accounts predicted that deficits in children with SLI must improve with increased quantity and fidelity in input but that is not the case in most of children with SLI (Bishop & Edmundson, 1987; Leonard, 1998, 2000; Schwartz, 2009). On the other hand, one of the neurolinguistic accounts proposing procedural sequencing deficits (procedural deficit hypothesis, PDH henceforth) claims an alternative explanation as cause of inflectional deficits. PDH explains the verbal inflection deficit in English speaking SLI children as a deficit in long distance sequencing deficit. For instance, usage of reference in subject position of a sentence in English would necessitate occurrence of /–s/ with the verb. In the sentence "*he gives the orders*", "*he*" induces */-s/* in the following sequence. Sequence deficit in SLI as claimed by PDH would make the task difficult for them.

2.5.4.3. Morphosyntax in SLI. Morphosyntax is not a separate entity of grammar from inflectional morphology. Wexler (1996) in his work on development of inflection in a biological based theory of language acquisition demonstrates the inseparability between verbal inflection and morphosyntax such as preposition, conditionals and conjunctions of a sentence. The present work addresses these inflectional and morpho-syntax operations as non-adjacent or long-distance operations. In other words, these operations would require relation between words that are not adjacent to each other. For example, in a sentence "*na:Le (tomorrow) radza: idre (if holiday) avaru (he) pa:Ta (lesson) maDalla* (will not do), */idre/* decides the occurrence of event such as "to-do" (*maDalla*) or "not to do" (*ma:Dalla*) (conditional marker) which is placed after two adjacent words (therefore called long distance/non-adjacent). The non-adjacent operations such as predicting the appropriate long distant words based on earlier inflected word would require implicit sequencing skills. The appropriate usage and selection of preposition in sentence representation demand interaction between semantic and syntactic functions (Glera, Rashiti, & Soares, 2004). Studies on knowledge and performance of preposition in children with SLI showed inconsistent results. While Glera, Rashiti, & Soares (2004) reported affected performance, adequate performance was documented by Puglisi, Befi-Lopes, & Takiuchi (2005), and the same was also reported much earlier by Watkins & Rice (1991). Conjunctions usages among children with SLI in previous studies were elicited on narration task alone and significant poor performance was reported among children with SLI on conjunctions usage (Gonzalez, Caceres, Bento-Gaz, & Befi- Lopes, 2012). They also reported that both children with SLI and typically developing (TD) children used more coordinate than subordinate conjunctions and the usage of conjunctions decreased significantly in the discourse of children with SLI. Other closed class morphemes such as conditionals, were not studied in the previous studies among children with SLI.

Children with SLI are often identified using morpho-syntax clinical markers (Gardner, Froud, McClelland, & van Der Lely, 2006; Vicki, 2005). Clinical makers could be elicited from judgment or revision tasks (Rice, 2002). Research shows inflectional morphemes to be predominant linguistic clinical markers of SLI (tense and agreement markers Rice & Wexler, 1996; Prema et al., 2010). Prema et al. (2010) studied individual SLI clients in order to look for clinical markers. Study reported that plural markers, tenses, agreement markers, adjectival confusion were observed to be clinical markers in Kannada speaking SLI clients studied. Literature reports inflectional morphemes as prominent clinical markers of SLI. The general explanation offered by Rice, Wexler, and Redmond (1999) for clinical markers being inflectional morphemes was from their extended optional infinitive (EOI) hypothesis. The EOI offers explanation as weakness in judgments of finiteness omission. Some studies attribute inflectional and morph-syntax deficits to generalized slowing of processing in language-impaired children (Kail, 1994). According to this slow processing hypothesis inflectional marker, such as tense marker could be interpreted as localized consequences of more generalized, limited time-dependent processing of linguistic input (Miller, Kail, Leonard, & Tomblin, 2001). In the present study, an attempt would be made to find out the efficient markers of SLI from those measured adjacent and non-adjacent grammatical morphemes.

2.5.4.4. Sentence complexity in SLI. Children with SLI are reported to have difficulty in sentence complexity measures at various levels. Children with SLI used simpler, shorter utterances and also omitted obligatory noun and verb inflection in a study by Bedore & Leonard (1998) but produced utterances with fewer total words than their peers' complex sentences in the study by Scott & Windsor (2000). Marinellie (2004) also reported that children with SLI produced fewer complex utterances with fewer clauses in them and 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 & Schuele, 2008). PDH in its original form does not account for features such as lesser complex sentences in children with SLI. However, the genesis of PDH has explanation for it. According to Chomsky (1995), the ability to merge words to make phrases is a procedural skill (Bolender, Erdeniz, & Kerimoglu, 2008). Therefore, the derivation from PDH account for poor sentence complexity in children with SLI could be the poor merge operations governed by inadequate procedural memory in them.

2.5.5. Pragmatic deficits in SLI. Studies that examined pragmatic aspects of language in children with SLI reported good conversation initiation, turn taking, good response to clarifications and adequate requisition for clarifications (Fujiki & Brinton, 1991). Alternatively, a few other set of studies reported contradictory findings of preserved pragmatic module in children with SLI. Paul (1991) reported of joint attention difficulties in SLI children. SLI children are documented to initiate conversation more with adults;

meanwhile TD children initiated conversation more with their peers (Rice, Sell, & Hadley, 1991). Earlier, Fey, Leonard, & Wilcox (1981) observed that the children with SLI were found to talk more to language matched peers compared to age matched peers. Therefore, pragmatic deficits such as poor interaction with peers among SLI could be due to their deficits in other aspects of language (such as syntax and semantics). However, study by Bishop (2003) provided genetic evidence to suggest that pervasive developmental disorders and SLI could be caused substantially by similar genomic aberrations. In other words, there could be a specific group in SLI population who are prone to pragmatic deficits compared to other SLI peers because of genetic aberrations.

2.5.6. Long term difficulties following language impairment. During preschool years, children with SLI are perceived negatively because of their poor communication abilities (DeThorne & Watkins, 2001). Poor social skills are also reported in children with SLI who show persistent language difficulties (Conti-Ramsden & Botting, 2004). Many adolescents with SLI perceived themselves negatively and lesser independent than their peers (Conti-Ramsden & Perkin, 2008). Academic problems in children with SLI are widely reported (Conti-Ramsden & Botting, 2008; Miller, Leonard, & Finneran 2008; Wetherell, Botting, & Conti-Ramsden, 2007). Persistence of symptoms of SLI could result in language related reading difficulties such as rhyming, letter naming, and concepts related to print (Boudreau & Hedberg, 1999). SLI children exhibit slower and lower processing of both linguistic and non-linguistic material in elementary school (Miller, Kail, Leonard, & Tomblin, 2001). Long term data on SLI reveal that SLI children show academic difficulties especially related to language processing. For instance, at the age of 14, SLI children still exhibited slower reaction times on language tasks (Miller et al., 2006). During middle and high school, they encountered rejection and bullying due to reticence and extreme loneliness (Conti-Ramsden & Botting, 2004). Children with SLI are also known to have high incidence of dyslexia and other more global writing and reading disabilities (Bishop & Snowling, 2004; Tager-Flusberg & Cooper, 1999). Even though, the present study does not intend to relate long term academic problems with sequencing deficits, sequence learning deficits have been reported in both children (Jiménez-Fernández, Vaquero, Jiménez, & Defior, 2011) and adults with reading impairment (Howard, Howard, Japikse, & Eden, 2006). In sum, the early language difficulties could lead to literacy difficulties in older children with SLI and procedural memory deficits are prevalent in children with SLI and dyslexia.

2.6. Causes of SLI

Causes of SLI are difficult to narrow down as SLI population is diverse (Tomblin, 1991). Even though, every single child could demonstrate various causative anatomical loci or linguistic behaviour, few of the causes are well studied and accepted widely to explain larger SLI population. The review below is detailed with biological brain abnormalities and genetic causes followed by processing and specific linguistic accounts.

2.6.1. General biological factors. The real causative phenomenon of SLI goes beyond poor parenting, subtle brain damage during birth or transient hearing loss (Bishop, 2006). Language learning problems in SLI suggest a neurological disorder (Aram & Eisele, 1994). Neurological factors such as delayed myelinization and slow transmission of nerve impulses have been reported in SLI (Hynd, Marshall, & Gonzalez, 1991). Children with SLI show evidence of right hemisphere being relied upon for language processing, in contrast to TD children where left hemisphere is active in language processing. This was supported by brain imaging studies that revealed brain symmetry in language processing region (Ors et al., 2005). Results of MRI studies that examined children with SLI showed different pattern of functioning such as decreased activation in the brain areas critical for communication processing. Reduced activation pattern in decoding regions of parietal lobe and encoding regions of frontal lobe was also observed in children with SLI (Ellis Weismer, Plante, Jones, & Tomblin, 2005). Biological evidence shows subtle reduction in cognitive and language functions in children with SLI. However, relating biological evidence alone with behavioural observation in children with SLI could be inappropriate given the heterogeneous and cross-linguistic nature of disorder. Therefore, further sections attempt to approach characteristics of SLI from various perspectives such as genetics, processing and neuro-linguistics are detailed in the following section.

2.6.2. Genetic causes of SLI. SLI is one of the well studied developmental conditions for its genetic basis. Studies showing that SLI tends to run in families are suggestive of genetic influence but they are not watertight, because family members also share environments as well as genes. More compelling evidence comes from identical twin studies. Identical twins or monozygotic twins who resemble each other genetically also more closely resemble each other on language deficits than dizygotic twins, who have only 50% of their segregating genes in common (Bishop, 2002). Statistical analysis of twin data shows that the environment shared by the twins is relatively unimportant in causing SLI, whereas genes exert a significant effect, with heritability estimates[2] typically ranging from around 0.5 to 0.75 for school-aged children (Bishop, 2002). There is a remarkable three-generational KE family from London, England, that has been extensively studied by geneticists. The language disorder in KE family was inherited through an autosomal dominant genetic mutation (Gopnik & Crago, 1991; Pembrey, 1992). The affected family members showed grammatical difficulties (Gopnik & Crago, 1991) such as past tense marking difficulties (Gopnik, 1994d), plural inflection (Gillon & Gopnik, 1994) and derivational morphology (Gopnik & Crago, 1991). Further, all the affected members of KE family showed oral dyspraxia (Vargha-Khadem, Watkins, Alcock, Fletcher, & Passingham, 1995). The consistent language impairment in KE family is indicative of genetic origin of this language specific disorder.

The specific gene responsible for monitoring the language related function was first identified to be FOXP2 by Fisher (2005). Fisher (2005) reported that FOXP2 is one of the complex genomic puzzles for language functions which express itself on corticostriatal and olivocerebellar circuits in mammals. Fisher (2005) further claimed that the FOXP2 is not the single gene which could monitor speech language functions rather it is a commanding gene which regulates several other genes in downstream pathway for speech language functions which is yet to be studied. FOX gene family encodes a large group of transcription factors sharing common DNA binding domain of sequences called the forkhead. Several FOX family members are revealed to be involved in embryonic development and mutations in FOX genes have been implicated in human developmental disorders (Carlsson & Mahlapuu, 2002). FOXP subfamily members are members of FOX gene family. FOXP subfamily members contain a zinc finger domain and a leucine zipper motif as a feature in addition to fork head domain (Shu, Yang, Zhang, Lu, & Morrisey, 2001). Three FOXP subfamily

[2] The proportion of variance in a trait that is attributable to genetic factors

members are reported to be abundantly expressing in developing brain and the expression pattern of these genes are largely overlapping but distinctive at some regions. FOXP1, FOXP2, FOXP3 and FOXP4 are the genes of FOXP subfamily worth mentioning. Among these even though all the FOXP genes except FOXP3 (expressed in immune system) is reported to be expressing in brain, FOXP2 has been consistently marked as a critical gene for hereDidary form of speech and language disorders (Lai, Fisher, Hurst, Vargha-Khadem, & Monaco, 2001). Even though, the expression regions of FOXP1 and FOXP4 overlaps with FOXP2 expression regions, detailed analysis revealed distinct expression pattern for each member in some neuronal cell types, even though the expression is the expression is being in same anatomical regions. Other genes such as CNTNAP2 gene on chromosome 7q (Vernes et al., 2008) and the calcium-transporting ATPase 2C2 (ATP2C2) and c-MAF inducing protein (CMIP) genes both on chromosome 16q (SLI consortium, 2002) were other genes found to be involved in downstream pathway for speech language function monitored by FOXP2. Chromosome 7q31 in which FOXP2 is located which is implicated in SLI (O'Brien, Zhang, Nishimura, Tomblin, & Murray, 2003). FOXP proteins given their homo-heterodimerization required for DNA binding might regulate transcription of downstream target genes during brain development; therefore FOXP2 is a commanding gene through which several transcription activities of downstream genes could be monitored.

The spatio-temporal expression pattern of FOXP2 mRNA indicates that the basic neural network that subserves speech and language might include motor-related circuits such as cortico-striatal and/ or cortico-cerebellar circuits. FOXP2 expresses on developing brain regions such as cerebral cortex, striatum, thalamus, cerebellum, and spinal cord. The FOXP2 expression regions are implicated in procedural memory system (Lai, Gerrelli, Monaco, Fisher, & Copp, 2003; Ullman & Pierpont, 2005). One of the recent studies that related FOXP2 and sequence learning was attempted (Tomblin, Christiansen, Bjork, Iyengar, *&* Murray, www.uiowa.edu/~clrc/ppts/ASHGFoxP2-2.ppt)*.* Tomblin and colleagues studied genetic link between procedural memory circuits (implicated in motor sequence learning) and genomic variations in FOXP2. The results of the study revealed that the FOXP2 genotypic variants are associated with individual differences in the procedural learning. The strong genetic basis for procedural learning from FOXP2, a commanding language gene serves as a preliminary evidence for Procedural Deficit Hypothesis (PDH by Ullman &

Pierpont, 2005) which will be discussed in detail under sections for specific accounts of SLI. Kuppuraj and Prema (2013b) propose grammar deficits in children with SLI to have strong evolutionary and genetic component in it. They stated that implicit memory was phylogenetically significant for motor sequence learning which was then adapted for grammar learning in human. The process was overwhelmed by natural selection of FOXP2 for human language. The work further explains the common underlying genetic substrate for sequence learning and human grammar. The biological and genetic causes of SLI behaviours ought to relate the images or anthropological genesis of the disorder. However, they could be considered supplementary evidences. The true causative picture would not be complete without considering the observed processing and linguistic accounts of SLI.

2.6.3. General processing accounts. Apart from biological and genetic causes several domain general and domain specific approaches for explaining the cause of SLI are available. These domain general and domain specific approaches differ, as to the range of impairments they aim to cover. One broad theoretical perspective claims that SLI is caused by a non-linguistic processing deficit. In other words, non- linguistic/processing/domain general accounts assume that the ability to access universal grammar, in principle, intact however, reduced intake capacities are claimed to cause the problems in constructing grammar. These accounts claim that language deficits in SLI are due to the deficit that links language module and the pathway leading to it or sometimes the cognitive capacity itself. Some processing-deficit hypotheses claim that the problem is either at the processing rate or at the capacity to process information (Bishop, 1994; Leonard, McGregor, & Allen, 1992b; Norbury, Bishop, & Briscoe, 2001). Therefore, deficit of this nature could invariably affect all the aspects of language. Such general processing deficit accounts for some of the breadth of linguistic and non-linguistic impairments in SLI children. Specifically, this explains why children with SLI have difficulties processing rapidly presented/ short duration verbal and nonverbal stimuli. These accounts further explain problems in cognitive tasks such as word retrieval, simultaneous task execution, and phonological discrimination (Leonard, 1998). Few well studied processing and capacity limitation accounts of SLI are discussed in detail.

2.6.2.1. Auditory processing deficit in SLI. One of the most experimented processing views claims that the deficit in children with SLI is at the input level of auditory perception. Hypotheses implicating processing deficits propose that the input pathways are disturbed, therefore starving the brain system responsible for language for information to encode. The deficits in perception of auditory input more generally affect language as a whole (Tallal, Stark, & Mellits, 1985). Other researchers argued that the views proposed by Joanisse and Seidenberg (1998), on information processing deficit affecting phonology could account for perceptual or temporal processing impairment in children with SLI (Merzenich et al., 1996; Tallal, Miller, & Fitch, 1993; Tallal & Piercy, 1973b, 1974). The rationale behind processing deficit hypothesis argues that language comprehension requires capacity to decode a sophisticated, rapidly changing, and fast fading auditory signal. An impaired capacity to decode aspects of incoming auditory signal could, therefore, interfere with language learning. Poor categorical perception was also reported in children with SLI on tasks requiring phonological feature discrimination such as consonant voicing (/ba/ versus /pa/) and place of articulation (/ba/ versus /ga/) (Elliott, Hammer, & Scholl, 1990). Children with SLI find difficulty in auditory processing of stimuli with rapid and sequential information (Kraus et al., 1996; Tallal, 1990). Tallal (1990) further added that selective impairments in perceiving transient acoustic cues (less than 50 millisecond duration) such as voicing nature of stop consonants (/kit/ and /kid/) is typically erred by children with SLI in perceptual studies. She also predicts that speech sounds that use longer acoustic cues (longer than 100 milliseconds) such as vowels and fricatives should be unimpaired in children with SLI. Tallal's investigations have also identified impairments in perceiving rapid visual and tactile stimuli in children with SLI, suggesting deficits in rapid processing of stimuli extending beyond auditory domain. Some researchers reported of frequency discrimination deficits in children with SLI leading to their language learning symptoms (Hill, Hogben, & Bishop, 2005; McArthur & Bishop, 2004a; McArthur & Bishop, 2004b; McArthur & Bishop, 2005). Processing deficit account do not make any language specific predictions, rather a general learning difficulty could be predicted. Leonard (1998) from his cross linguistic studies reported that general processing deficit is inefficient in explaining language incompetencies exhibited by children with SLI. Leonard further stated that inconsistencies SLI children show in linguistic manifestation across language could not be explained by processing account. The next domain general hypothesis argues that the deficit in SLI is at the level of capacity to store the elements in short term memory.

2.6.2.2. Phonological short-term memory deficit in SLI. The phonological short term memory (PSTM) deficit in children with SLI claims that linguistic deficits in SLI are caused by deficits in the phonological loop comprising phonological store and a sub-vocalic rehearsal process that are the components of working memory architecture (Baddeley, 2003; Baddeley & Hitch, 1974; Gathercole & Baddeley, 1990). The phonological loop in working memory system is responsible for processing and storing novel sound combinations and it is thought to be impaired in children with SLI. Deficits in phonological loop can cause problems in assigning adequate phonological representations and learning novel words as the ability to store incoming phonetic strings and cumulate them for comprehension is essential for speech comprehension (Archibald & Gathercole, 2006a). PSTM deficit hypothesis received greater attention among investigators exploring causative factors for SLI. The hypothesis underlying PSTM deficit in SLI (Baddeley & Hitch, 1974) is that SLI children fail to store (temporarily) the internally generated phonological sequences as well as sequences of spoken stimuli, therefore manifesting as poor phonology and grammar learning performance. PSTM is measured using nonword repetition task (NWR) (repeating syllable sequences like "mimen"). The inaccurate NWR performance in children with SLI has been replicated over years by many studies (Botting & Conti-Ramsden, 2001; Conti-Ramsden, 2003). The PSTM hypothesis as causative account of SLI is further strengthened by its high heritability. Poor NWR is proposed as a phenotypic marker of SLI (Bishop, North, & Donlan, 1996). A chromosomal abnormality related directly with NWR impairments in SLI has been identified on chromosome 16q (SLI Consortium, 2002, 2004) thus strengthening PSTM as causative factor of SLI.

Some studies contradicted the general processing and capacity limitation views by producing results suggesting lack of direct relation between perception, memory capacity, and language. They revealed that, even though children with SLI performed poorly on speed related tasks compared to TD children no correlation was found between test scores and language impairment (Tallal, 1990). Rosen (1999) showed evidence of a particular subgroup of SLI (the grammatical SLI) who consistently performed like TD children on auditory temporal processing tasks. Norrelgen, Lacerda, & Forssberg (2002) found high variability and no difference in mean scores between SLI and control children on a computerized same–different task using brief tone stimuli with variable inter stimulus intervals. Recent evidences contrasting the general processing and capacity limitation account maintains that, even if the auditory processing deficits are targeted in rehabilitation to attain better language and reading skills, there was no improvement in language skill. Cohen et al. (2008) compared the language skills among group of children with SLI, who received fast forward training and another group of children with SLI who did not receive the training. Results showed that the group that received fast forward did no better than a control group receiving no fast forward intervention. Study by Given, Wasserman, Chari, Beattie, and Eden (2008) produced similar outcomes in children identified on the basis of difficulties in reading. The strongest evidence in support of the improvement on auditory deficits without any impact on a language comes from the recent study of McArthur, Ellis, Atkinson, & Coltheart, (2008). McArthur and colleagues explicitly trained a group of children with poor auditory skills, and dyslexia and / or SLI on a variety of auditory tasks. The authors concluded that although auditory processing deficits could be successfully ameliorated, it did not help them acquire new reading, spelling, or spoken language skills. Therefore, there appears to be no advantage of auditory training on the development of language and literacy, even when improved auditory functioning could be demonstrated. Work by Newbury, Bishop and Monaco (2005) stated that the auditory processing aspect is not genetically passed on, instead is environmentally influenced. The results of Newbury et al. further weaken the processing and language relation as their study showed that language component in SLI was highly heritable, but the processing component was not. Researchers have appreciated the PSTM deficit hypothesis in explaining the acquisition of phonological representation and sentence comprehension (Gopnik & Crago, 1991; Rice & Oetting, 1993; Ullman & Gopnik, 1999; van der Lely & Ullman, 2001). However, PSTM hypothesis failed to explain the rapidity at which the syntax is acquired despite conservative speech environment. The hypothesis necessitates the syntax system to learn all types of grammatical forms by literally exposing the system to them. This type of learning is virtually impossible as the child begins to utter novel sentences even before they hear them all (Oetting & Rice, 1993). Although, these hypotheses explain certain specific deficits exhibited by SLI, such as difficulties on tasks requiring working memory, phonological processing, or the perception of rapidly presented stimuli, it is not clear that most children with SLI show these problems at all (Bishop et al., 1999; Tallal et al., 1995; van der Lely & Howard, 1993). Moreover, short term memory is undoubtedly significant for learning fixed sequences (words or idioms). However, learning of highly variable patterns in language may require different kind of cognitive mechanisms (Conway & Christiansen, 2001).

Auditory processing deficits and PSTM accounts cannot explain specific pattern of spared and impaired linguistic and non-linguistic functions in SLI (Hill, 1998; Leonard, 1998; Ullman & Gopnik, 1999; van der Lely & Stollwerck, 1996; van der Lely & Ullman, 2001). Even though these hypotheses explain processing difficulties of rapidly presented verbal and nonverbal stimuli along with difficulty in cognitive tasks such as word retrieval, simultaneous task execution, and phonological discrimination many specific types of linguistic impairments n in SLI especially the grammar cannot be explained by these views (Gopnik & Crago, 1991; Leonard, 1998; Rice & Oetting, 1993; Ullman & Gopnik, 1999; van der Lely & Ullman 2001). Moreover, these hypotheses state that processing deficits are quite general and cannot explain the selective nature of non-linguistic impairments in SLI (Leonard, 1998). Finally, these limited processing capacity hypotheses do not lend itself to specific predictions or testable hypotheses, since any type of impairments could be potentially explained by processing limitations or generalized slowing. The next level of explanation among broad processing deficit considers the language surface texture in order to explain the poor perceptual display by children with SLI.

2.6.2.3. The surface hypothesis. The surface hypothesis or surface account (SA) proposed by Leonard (1989) emphasizes that the grammatical deficits in SLI is caused by neglecting less salient information from language input. The reason for such neglect according to SA could be partially due to auditory perceptual incapacities. The hypothesis is also called as the sparse morphology account (Leonard, 1992). The account further claims that in children with SLI the inability to perceive less salient input could be combined with processing demands required to form grammatical representation. Acquisition of target grammar requires appropriate perception and processing of the elements such as frequency, (non) syllabicity and syllable/morpheme duration. These elements (surface characteristics) in an input could be either weak or strong depending on a language. The general idea of this SA hypothesis is that a child with SLI would find language acquisition difficult in a language which has more weak surface characteristics than a language with strong surface characteristics. SA gathered support from studies that systematically compared between languages with varying phonetic substance for morphosyntactic markers. For instance, present tense marker */–s/* in English is non-syllabic that lacks stress. Successful acquisition of this agreement marker on the verb (he) "*walks*" is possible only by simultaneously perceiving and morphologically processing the morpheme *–s.* This process could be very demanding for an SLI child learning English resulting in omission (at least prolonged acquisition) of that morphological marker. On the other hand, Kannada has strong syllabic and stressed morphemes. For example, /*mara<u>gaLu</u>*/ *'trees'* where */–'gaLu'/* denotes the plural marker */-s/* that is syllabic and stressed in Kannada. Therefore, children with SLI from stressed morphemic languages (Kannada) would show lesser difficulty in morphemes compared to unstressed languages such as English. The SA apart from explaining cross linguistic language characteristics of SLI also makes language specific predictions such as why plural –s on noun is easier than agreement –s on verb. The explanation given was that the more the inflection has semantic correlates the more difficult would be inflectional rule learning (Leonard et al., 1992b; Rice & Oetting, 1993). Data from Inuktitut language of SLI child (a girl called LE) showed that she even omitted salient features and showed addition of morpheme which is not in congruent with SA account and its predictions (Hadley & Rice, 1996). The next level of processing explanation comes from accounts that claim that children with SLI have slower processing speed compared to TD children.

2.6.2.4. The generalized slowing hypothesis. The Generalized Slowing Hypothesis (GSH) (Kail, 1994; Miller, Kail, Leonard, & Tomblin, 2001; Windsor & Hwang, 1999) was one of the earliest attempts to specify processing limitations in SLI. The core idea of GSH maintains that the low performance in both linguistic and non-linguistic tasks of children with SLI is due to generalized limitation in processing capacity in them. Children with SLI are slow in general to take in linguistic input, store it in memory, and access them appropriately causing a general delay in language development compared to typically developing children. The incomplete and slower intake results in underspecified lexical representations. Explanation by GSH predicts a delay rather than a deviant profile in SLI since the theory claims that the intake processes just operate slower than TD children. On the other hand Montgomery (2002) proposed a process dependent slowness which played crucial role in language delay in children with SLI (i.e., inefficient processing of linguistic information) is more critical than processing of other types of data such as acoustic-phonetic information. Even though, GSH appears to explain the delay linguistic nature of children with SLI, arguments suggesting the imprecise nature of GSH in explaining cross linguistic errors of SLI were obvious (Windsor, Milbrath, Carney, & Rakowski, 2001). These general deficit hypotheses explains broad linguistic and non-linguistic impairments observed in SLI, even though specific testable predictions are hard to be found, because nearly any kind of impairment could be explained by processing limitations or generalized slowing (Leonard, 1998; Ullman & Gopnik, 1999; van der Lely & Ullman, 2001). These general deficit hypotheses explain difficulties in processing rapidly or briefly presented verbal and nonverbal stimuli. Moreover, problems with cognitive tasks such as simultaneous task execution, phonological discrimination, and word retrieval could be explained using these hypotheses (Leonard, 1998). Not all processing-deficit hypotheses claim a general deficit. Impairments of a specific cognitive or processing mechanism such as dysfunction of phonological working memory (Montgomery, 1995) or an information processing deficit particularly to phonology (Joanisse & Seidenberg, 1998), temporal processing impairment (Tallal et al., 1993) were also proposed. Even though, these domain general hypotheses can explain language deficits involving working memory, phonological processing, or the perception of rapidly presented stimuli, they cannot account for some specific pattern of impaired and spared linguistic and non-linguistic functions in SLI (Leonard, 1998; van der Lely & Ullman, 2001). Research has shown inconsistent data on processing deficits in SLI and therefore, it is unclear whether all children with SLI show these problems at all (Bishop et al., 1999; Tomblin et al., 1995; van der Lely & Howard, 1993). In sum, general processing and slowing accounts of SLI accounts for almost any behaviour manifested by a child with SLI. However, any specific predictions in the linguistic feature of SLI and other motoric weaknesses such as oral-dyspraxia could not be accounted by accounts such as these (Rice, 1996). In order to narrow down the explicability of processing and capacity limitation accounts, linguistic accounts are discussed in the following sections. Linguistic account approaches language from its universal computational nature and tend to give specific predictions for language behaviour in SLI.

2.6.3. Linguistic accounts. Linguistic accounts approach the causative phenomenon from top down pattern. Language domain specific representational accounts assume that the deficit is in universal grammar (UG), therefore, the resources to construct grammar should be different in SLI compared to TD children. One of the important differences between the two approaches (domain general/ processing versus domain specific/ linguistic) concerns the resources children with SLI may or may not rely on in order to construct their grammatical systems. Domain specific perspective proposes that certain group of SLI show deficits or delay specific to language domain, grammar in particular. The view posits that it is the mental capacity that underlies the rule-governed combination of words into complex structures which is affected in children with SLI. This view point is expressed in numerous flavours, that identify particular grammatical operations, mechanisms, or types of knowledge that are problematic for children with SLI. For instance impairment in establishing structural relationships such as agreement (Clahsen, 1989) or missing linguistic features (Gopnik & Crago, 1991) or failure to consistently mark tense in main clauses (Wexler, 1994; Rice et al., 1995). Another account claims that broad range of grammatical difficulties could be explained in children with SLI, by a representational deficit of grammatical relations (van der Lely, 1994). Few grammar-deficit hypotheses proposes that the difficulties in SLI is quite broad within grammar (not pertaining to particular grammatical function or operation such as agreement or tense-marking) which could be explained by a deficit in computation of implicit grammatical rules (Ullman & Gopnik, 1994).

2.6.3.1. The missing features hypothesis. The missing feature hypothesis was mainly proposed and promoted by Gopnik and colleagues (Gopnik, 1990; Gopnik & Crago, 1991; Ullman & Gopnik, 1999). The hypothesis was proposed to account for linguistic deficits in a famous KE family (English). The linguistic deficits of KE family were hereDidary and transmitted through autosomal dominant genetic factors (Gopnik, 1990). Affected members of KE family had significant difficulty in rule based structures (such as past tense *–ed*) or other regular plural inflections (Gopnik, 1990). Gopnik claims that some semantic-syntactic features such as number, person, and tense are missing from the grammar system of children with SLI. Children with SLI of KE family had difficulties in using regular inflections which was rule based and showed typical over regularization ability Ullman and Gopnik (1999). In other words KE family members lacked suffixation rules because they were missing from their language system and instead relied on associative memory (the dual route mechanism by Pinker, 1994). The main argument of missing feature account (the pure linguistic deficit) was refuted by studies that showed non-linguistic, motor and cognitive deficits in members of KE family (Shriberg et al., 2006; Vargha-Khadem, Watkins, Alcock, Fletcher, & Passingham, 1995). Moreover, large group of SLI children do manifest use of many linguistic rules (Rice et al., 1995), which was not predicted by the missing feature account. The missing feature hypothesis does not explain over regularization errors in children with SLI (Leonard, 1998). Apart from predicting inflectional rule deficits in general, the missing feature hypothesis could not explain cross-linguistic observations such as grammatical profile on Hebrew and Italian speaking SLI children (Bortolini, Caselli, Deevy, & Leonard, 2002, for Italian).This account, furthermore, cannot account for the common optionality n in grammar of children with SLI. For instance utterances such as *she likes* and *she like* (Bishop, 1994; Leonard, 1998). In other words, the missing feature hypothesis does not generalize adequately to cases outside KE family (Leonard, 1998).

2.6.3.2. The extended optional infinitive (EOI) hypothesis. Explanations to account for the morphosyntactic deficits in English speaking children with SLI an extended optional infinitive (EOI) hypothesis was developed by Rice, Wexler, and colleagues (Rice & Wexler, 1995; 1996b; Rice et al., 1995). EOI was developed to explain tense marking difficulties on finite verbs among English speaking SLI children which they never acquire (Rice & Wexler, 1996b). The EOI is based on optional infinitive (OI) stage of language acquisition in TD children (Wexler, 1994, 1998). OI theory claims that TD children go through a stage (until the age of 3 at least) where they show optional marking of finiteness in verbs. OI theory explains that it is not because of faulty learning children omit the finite marking but because this aspect of grammar matures with age (Borer & Wexler, 1992). The hypothesis assumes that finiteness in TD children is genetically determined and not influenced by learning factors, and apart from finiteness marking other aspects of grammar development are intact in children with SLI (Rice et al., 1998; Wexler, 2003). Wexler maintains that children in the OI stage have no problems in setting the appropriate parameter but they omit tense or agreement in their syntactic representation (problems in principles). This feature was explained in agreement tense omission model (ATOM), which gives another explanation for OI stage in children’s grammar (Schutze & Wexler, 1996). The nucleus of ATOM is the Unique Checking Constraint (UCC) (Wexler, 1998). According to

Wexler (1998), OI occurs because the child cannot perform feature checking acts such as the D-feature of the Determiner Phrase against the D-features on agreement and tense (Chomsky, 1995). According to EOI hypothesis for SLI, the grammatical deficits in SLI are expected to be very similar to that of unimpaired children. For instance, the grammatical rules are intact and in place with extended developmental phases, therefore delay is manifested in children with SLI. Wexler et al. (2004a) stated that some children with SLI are reported to have persistent errors throughout the life therefore, Wexler stated that the ability to grow pass this EOI stage is questionable in some SLI children. Support of EOI and ATOM comes from several Germanic languages reporting on higher rates of feature checking errors in SLI than in younger unimpaired controls. There are certain limitations for these accounts. The EOI account predicts intact agreement marking and affected tense marking, a claim that cannot be supported by cross linguistic evidence. For instance, in Greek and German, agreement and tense marking can be separated (unlike in English). Studies of SLI in German and Greek showed contrary results to predictions of EOI, where the tense marking was found to be almost error-free and the same children produced significantly higher error rates in subject-verb agreement marking (Clahsen et al., 1997; Clahsen & Dalalakis, 1999). According to EOI agreement errors should be absent in children with SLI. However, ATOM allows both agreement and tense errors (Wexler, Gavarro, & Torrens, 2004a). The hypothesis is difficult to falsify as there is no prediction made regarding the quantity of agreement and tense errors. Another critic comes from Dutch SLI data (Bol & Kuiken, 1988) used in the study of Wexler et al. (2004a). A closer look on the data revealed that only certain SLI children had deficits explained by EOI which brings the generalizability of the account into question.

2.6.3.3. The agreement deficit account. The Agreement Deficit (AD) Account (Clahsen, 2008) is a representational account addressing deficits in agreement in children with SLI. Missing Agreement Account was the earliest form of AD account (Clahsen, 1991), which claimed that the deficit in SLI is caused by Control-Agreement Principle (Gazdar, Klein, Pullum, & Sag, 1985). Missing agreement account offered explanation for a wide range of morphosyntactic difficulties in SLI children. For example, subject-verb agreement, object-verb agreement, gender and number agreement on determiners and adjectives, finite auxiliary forms, and structural case marking. In a later version, then called

AD account, Clahsen et al. (1997) defined the linguistic difficulties in SLI as a problem with 'uninterpretable features' in the sense of formal features in Chomsky's (1995) theory. Agreement features of verbs (and adjectives) are formal features in Chomsky's theory. These uninterpretable features of verb phrase need to be checked against the interpretable feature of the noun phrase, which is difficult for SLI, therefore children with SLI show agreement deficits. This version of AD account predicts that problems with interpretable feature such as tense or gender should be fewer. The latest version of the AD accounts by Clahsen (2008) claims that the abstract computational knowledge of agreement is not entirely absent in children with SLI. This version of AD account claims that SLI can be explained as an impairment of agreement that affects the lexicon resulting in poor morphological paradigm of subject-verb agreement. As a result, features on verbs taken from the lexicon are not fully specified (at least not always). On such assumptions of this version of AD account, productions of infinite forms and or incorrect agreement markings are to be expected (Clahsen, 2008). Overall, Clahsen's AD account is consistent with the major difficulties with verb agreement found in data from various Germanic languages, whereas it is less applicable in pronoun-dropping languages (Shaalan, 2010). Even though, the AD account predicts verb agreement errors, it fails to explain the variety of symptoms found in other functional domains. AD account did not provide a complete characterization of the wide range of grammatical difficulties in SLI that have been found by other researchers (van der Lely, 2005).

2.6.3.4. The representational deficit of dependency relations. The representational deficit of dependency relations (RDDR) (van der Lely, 1996, 1998) focuses on a particular group of children with SLI- Grammatical-SLI (G-SLI) children. According to RDDR the origin of language difficulties in G-SLI is from deficits in the computational syntactic system. Particularly, children with G-SLI are assumed to have optional movement rather than movement in grammar due to a selective impairment in establishing the structural relationship between dependent constituents. These children fail to move constituents of sentence to the correct syntactic domain for checking purposes; therefore, they exhibit optional phonological realizations of morphosyntactic markers. Van der Lely (2004, 2005) reformulated and expanded the RDDR hypothesis as a deficit in computational grammatical complexity (CGC) accounting for range of symptoms affecting the comprehension and production. The CGC account involved all the elements that mark syntactic dependency involved in phonology, morphology, and syntax (i.e., unlike Clahsen's earliest account, involving only agreement). Evidence for RDDR and CGC accounts of van der Lely comes from her own work on English G-SLI children which involved several comprehension and production studies. Van der Lely claims from her work on G-SLI children that these children manifest deviant grammars and their morphosyntactic rules never reach adult like state. Van der Lely maintains that RDDR and CGC could account for a wide range of grammatical difficulties in G-SLI. However, substantiation of this claim and its generalizability needs that the CGC hypothesis should preferably be tested in SLI children acquiring various languages apart from English.

The domain specific hypotheses have been quite successful in accounting for many of the grammatical impairments manifested by children with SLI. Domain specific hypotheses such as RDDR, AD account, and missing feature account could not explain a wide range of deficits with in and across languages (Leonard, 1996, 1998). In other words a purely grammar based hypothesis cannot account for word-finding difficulties and non-linguistic deficits often observed in SLI. Moreover, grammar oriented hypotheses may not entirely account for combination of phonological, morphological, and syntactic deficits in children with SLI (Ullman, 2004). Therefore, the specific linguistic and general non-linguistic (processing/ capacity limitation) accounts described above can individually capture specific aspects of the empirical data from SLI children. However, none of the accounts could readily account for range or variation of the particular impaired linguistic and non-linguistic functions found across SLI and within SLI subgroups. These purely functional explanations of SLI will have difficulty even accounting for the variety of impairments that occur within SLI individual (Ullman & Pierpont, 2005).

A causative hypothesis which is applicable to range of specific linguistic, non-linguistic deficits in SLI which also attempts to integrate the non-linguistic impairments in SLI to the neural abnormalities could be essential in order to explain a heterogeneous, cross linguistic SLI data. One such hypothesis is Procedural Deficit Hypothesis (PDH) (Ullman & Pierpont, 2005). PDH argues that a substantial number of children with SLI show poor procedural memory system leading to poor motor sequencing problems affiliated with language deficits. PDH according to Ullman and Pierpont (2005) can explain the neural abnormalities associated with linguistic and non-linguistic deficits in SLI. PDH claims that it could also account for much of the consistency and heterogeneity in the linguistic and non-linguistic difficulties prevalent among children with SLI, both within a SLI individual and across individuals and subgroups. Independent knowledge of these well studied brain structures and their functions associated to language and sequential cognition allows PDH to make testable predictions regarding SLI which would not be possible by more restricted explanatory accounts (Ullman & Pierpont, 2005).

The contribution of procedural learning system to language acquisition is not new. For instance, Reber (1967) reported of this in his first study on examining implicit learning. In a last decade, this idea has been examined by several child language researchers (Ashby & Waldron 1999; Maye et al., 2002; Saffran, 2001; Ullman, 1998). Cognitive theories have explained procedural learning in their own agenda. One such theory that resembles PDH is competition between verbal and implicit systems (COVIS) theory of category learning (Ashby et al., 1998; Ashby & Waldron 1999). The authors of COVIS postulate that a frontal based explicit system and basal ganglia based implicit system competes for accommodating incoming information (learning) for learning categories. The procedural learning based system is phylogenetically older and it can learn wide variety of category information but it learns in a slow incremental fashion and depends heavily on immediate reliable feedback. Different anatomical substrates are attributed for these two types of competing systems (Ashby & Valentin, 2005). Yet, the implicit information-integration type of learning explained by COVIS mechanism is driven primarily by basal ganglion that is responsible for procedural learning in procedural-declarative model proposed by Ullman (2001). A general theme of these studies was that with the emphasis on sequential structural learning, procedural memory could be more appropriate for explaining acquisition of phonology and grammar structure of language. The idea was more explicitly proposed in a form of a dual mechanism model called Declarative Procedural (DP) model for grammar (Ullman, 2001). The procedural deficit hypothesis (Ullman & Pierpont, 2005) is extension of DP model to explain the grammar deficits in SLI using the architecture of dual mechanism model.

2.7. The Declarative Procedural Model

The Declarative-Procedural (DP) model (Ullman, 2001) proposes that human capacity to use language depends on two capacities substrated by distinct brain structures. One capacity is to memorize words (mental lexicon) and the other capacity is to use the words in sequential and hierarchical order such as predictable structured words, phrase and sentence of a given language. The DP model proposes that mental lexicon (memorization of non-compositional, arbitrary form-meaning pairings) is driven by associative memory of distributed representations substrated by temporal-lobe circuits. In contrast, acquisition and use of grammatical rules (computational in nature) for symbol manipulation is substrated by frontal/basal-ganglia circuits. In other words associative memory underlying mental lexicon was previously implicated in memory of facts and events. Meanwhile implicit unconscious memory subserving rule learning was previously implicated in memory of motor and cognitive skills including habits. The model further considers that the implicit procedural system may be significant for computing sequences for motor as well as language components such as phonology, and grammar. DP model resembles other dual-mechanism model in assigning different memory systems for different language operations (declarative memory system for lexicon and procedural memory system for rule based computations). The model is domain independent model which assumes that two capacities mentioned could be subserved by domain independent computational mechanisms. The domain independency could be well understood after the discussion on computational properties of basal ganglia which is analogous to all inputs. Ullman (2001) examined the model using morphological analysis of unproductive (go-went) and highly productive (walk-walked) morphological operations and gathered positive evidence for DP model. DP model gathered support from studies that showed relation between poor grammar and lesion in basal-ganglia and other procedural memory circuits (Ullman, 1994; Ullman et al., 1997).

2.7.1. Evidence from SLI for DP model. Children with hereditary SLI (mostly evidence from KE family) showed deficits in producing novel regular forms and over-regularizations indicating that SLI children were unable to use the past tense suffix productively. Children with SLI also showed frequency effects for both regular and irregular past tense forms but TD children showed frequency effects only for irregulars suggesting that the children with SLI had difficulty learning grammatical rules, therefore opted to memorize regular as well as irregular forms and stored them in mental lexicon (Ullman & Gopnik, 1994; Ullman & Gopnik, 1999; van der Lely & Ullman, 1996). Moreover some subjects in SLI group also showed motor sequencing impairments (Hurst, Baraister, Auger, Graham, & Norell, 1990; Vargha-Khadem, Watkins, Alcock, Fletcher, & Passingham, 1995) which was associated with frontal and basal ganglia abnormalities (Vargha-Khadem et al., 1998). These findings yielded evidence that states that grammar impairment in SLI group is also associated with procedural memory system deficits leaving declarative/lexical memory relatively intact (Ullman & Gopnik, 1999). The DP model further derives evidence from children with Williams's syndrome who show typical syntactical abilities but compromised lexical abilities (Bellugi, Bihrle, Jernigan, Trauner, & Doherty, 1990; Clahsen & Almazan, 1998). The DP model shaped into procedural deficit hypothesis (PDH) (Ullman & Pierpont, 2005) to explain grammatical deficits in SLI. The basic anatomical and functional knowledge of procedural memory system is necessary prior to understanding the procedural deficit hypothesis and its assumptions for linguistic and non-linguistic deficits in SLI.

2.8. Procedural Memory System

The procedural memory system is a distinctive memory system in brain which underlies procedural memory functions. The procedural memory system is labelled to refer to one variety of implicit, nondeclarative memory system, (Squire & Knowlton, 2000), but not every non-declarative or implicit memory systems. The label further refers to entire system implicated in learning, representation and use of procedural skill not limited to system implicated in acquisition of procedural knowledge alone (Ullman, 2004). Procedural memory underlies learning of new, and control of well established, motor and cognitive skills, habits and other procedures such as riding a cycle (Squire & Knowlton, 2000). This implicit unconscious memory system underlies learning and performing skills involving sequences which are serial or abstract, or cognitive or sensory-motor (Aldridge & Berridge, 1998; Boecker et al., 2002) and is particularly significant for rule-learning (Knowlton, Mangels, & Squire, 1996; Poldrack et al., 1999). Procedures are acquired gradually after multiple exposures or trials, but the learned procedures are applied automatically and instantly. Priming task is an example of a task which entails procedural memory. During priming operation the unconscious trace of previous presentation speeds-up the response for following stimulus. This variety of non-declarative memory is contrasted with declarative memory system (Squire, Knowlton, & Muse, 1993). Declarative memory system binds different or arbitrarily related representations or perceptual experiences to form (Mayes et al., 2007; Squire, Stark, & Clark, 2004). The key neurological substrate for declarative memory (the memory for events, learning words etc., i.e. a conscious explicit memory) is the hippocampus, whereas the Frontal-Basal ganglia-Cerebellar (FBC)[3] loop derives the procedural memory systems.

2.8.1. Neuro anatomy of procedural memory system. Several interconnected brain networks within left hemisphere (Schluter et al., 2001) forms the procedural memory system (Rizzolatti, Fogassi, & Gallese, 2000). Within left hemisphere structures that play significant role in procedural learning are frontal/basal-ganglia circuits (Eichenbaum & Cohen, 2001; Schacter & Tulving, 1994; Squire & Zola, 1996). The main function of basal ganglia is to influence cortical function either by inhibiting or exciting the cortex. The basal ganglia (collection of subcortical nuclei) include the neostriatum (striatum in primates), globuspallidus, sub-thalamic nucleus, and substantia niagra. The striatum has putamen and caudate well developed in primates. The structures of basal ganglia are linked closely to cortical regions (particularly in frontal lobe) via parallel and functionally segregated channels/circuits/loops (Middleton & Strick, 2000a). Each channels receive projections from particular set of cortical (projections from frontal lobe) and subcortical regions at striatum (some at caudate and some at putamen level). Each channel then follows a specific path through internal connections within the basal ganglia, and then projects outside via the thalamus to a particular cortical region from where the channel received input from (Broca's area in frontal cortex). Depending on whether the channel takes direct or indirect pathway while running along basal ganglia, it could have different influencing effect on cortex (frontal cortex). The direct and indirect pathways have opposing effect on the basal ganglia's influence on frontal cortex. Using series of inhibitory and excitatory projections,

[3] FBC circuit is an abbreviation used in the study by (Kuppuraj and Prema, 2012a) while mentioning about procedural memory circuits explained by Ullman (2001). Although, the procedural memory system is centered at Fronto-Basal structures, loops primarily integrated along Frontal, Basal Ganglia and Cerebellum serving procedural learning was reported by Ullman and Pierpont (2005) while discussing PDH.

while the indirect pathway inhibits frontal cortical activity, the direct pathway disinhibits it. Imbalance amidst these basal ganglia pathways could result in excessive inhibition or disinhibition of functions depending on that particular frontal cortical regions to which the basal ganglia project (Young & Penney, 1993). This imbalance is used to explain hypo (inhibited/suppressed) and hyper (disinhibited/unsuppressed) motor and other behaviours found in Parkinson's disease, Tourette syndrome, Huntington's disease, Obsessive-Compulsive disorder (OCD), Attention Deficit Hyperactivity Disorder (ADHD), and other adult-onset and developmental disorders affecting basal ganglia (Bradshaw, 2001; Middleton & Strick, 2000a; Young & Penney, 1993).

The channels of basal ganglia are topographically organized (including direct and indirect pathways). A topographic organization is maintained from the neostriatum throughout the basal ganglia to the thalamus and frontal cortex. Distinct channels project to regions of frontal cortex such as primary motor cortex, ventral premotor cortex, the supplementary Motor Area (SMA), and dorsolateral prefrontal cortex, among other regions (Middleton & Strick, 2000a). The different basal ganglia channels project to a heterogeneous set of frontal regions, and subserve a heterogeneous set of functions. Each channel/ circuit underlies those functions that are associated with the cortical region to which the channel projects (Middleton & Strick, 2000a). For instance, the channel passing through putamen and projecting to primary motor cortex subserves motor functions, therefore, putamen plays particularly important role in movement. Pathways passing through Caudate and projecting to prefrontal cortex m to be especially important for aspects of cognition. However, findings have shown that both striatal structures (putamen & caudate) are likely to contribute for motor as well as cognitive functions (Alexander, DeLong, & Strick, 1986; Middleton & Strick, 2000a; Poldrack et al., 1999). The basal ganglia performs analogous computations (such as sensory or motor) that are compatible with different sets of information from different domains, depending on the particular set of input regions and frontal cortical output destinations of a given channel (Middleton & Strick, 2000b). The analogous computational nature of basal ganglia could be compatible with language acquisition as information from different domains is required for language acquisition.

Within frontal cortex pre-motor cortex (particularly the region of the Supplementary Motor Area; i.e., SMA and pre-SMA) and cortex within Broca's area especially part of inferior frontal cortex, i.e. BA 44 and 45 are the areas that play vital role in procedural memory (Amunts et al., 1999). Even though evidence suggests that Broca's area is critical for abstract, cognitive aspects of procedural memory, the region also subserves motor functions (Ullman, 2004). Because not all frontal regions are involved in procedural memory, it follows that not all topographically organized regions of the neostriatum should be involved in procedural memory function. In other words, structures in basal ganglia whose circuitry projects to regions in frontal lobe that subserve procedural memory are expected to play a significant role in procedural memory function.

Other areas such as parietal cortex (particularly the supramarginal gyrus), aspects of the superior temporal cortex (including the superior temporal sulcus) and the cerebellum, (including the dentate nucleus -one of the deep cerebellar nuclei, and an important output nucleus of the cerebellum) are reported to have contributions to procedural memory circuits (Jellama & Perrett, 2001; Martin et al., 2000; Rizzolatti et al., 2001). Cerebellum is similar to the basal ganglia in that functionally and anatomically topographical channels are maintained from the cerebellum through the thalamus to frontal cortex (Middleton & Strick, 2000a). Moreover, structures in cerebellum are linked closely to frontal lobe along with basal ganglia structures for the function of procedural memory. Several other structures also play significant role in procedural memory system. But, structures related to grammar and sequence learning such as those involved in procedural memory system that extends from frontal lobe to cerebellum through channels of basal ganglia [fronto-basal-cerebellar (FBC) circuit] are relevant for the present study are discussed.

Structures contributing to procedural memory system play computational, complementary and functional roles. For instance, basal ganglia are significant for learning new procedures, but are less important for normal processing of already-learned procedures (Ullman, 2003, 2004). On the other hand, Broca's area appears to be underlying both learning and processing of learned procedures (Ullman, 2004). Therefore, the nature of procedural memory impairment would vary depending on the structure impaired in procedural memory system. . The brain structures that constitute the procedural system not only subserve motor and cognitive skills, but also other functions including (but not limited to) grammar, lexical retrieval, dynamic mental imagery, working memory, and rapid temporal processing. Even though, procedural memory is directly related to some of these functions (grammar), its relation to others is still not clear (Ullman & Pierpont, 2005). The relation between procedural memory deficit and grammar is proposed by PDH, as a neurolinguistic causative hypothesis of SLI.

2.8.2. Procedural Deficit Hypothesis. The Procedural Deficit Hypothesis (Ullman & Pierpont, 2005), rooted in DP model for language representation proposes that many (if not all) individuals with SLI are affiliated with brain abnormalities in procedural memory system that result in grammatical impairments and/or lexical retrieval deficits (Gopnik, 1999; Paradis & Gopnik, 1997; Ullman & Gopnik, 1994, 1999). These children with SLI may be characterized as having Procedural Language Disorder, or PLD (Ullman & Pierpont, 2005). These individuals should also have impairments of the non-linguistic functions that depend on the affected brain structures of the procedural memory system such as motor sequencing and mental imagery. Using PDH and the underlying neural connectivity, several testable and falsifiable predictions could be made at both the population and individual level of SLI phenomenon. The procedural memory system underlies non-linguistic functions such as motor sequencing, and linguistic functions such as grammar and lexical retrieval skills; therefore, abnormalities of brain structures underlying procedural memory system would result in impairments of grammar, lexical retrieval, and the non-linguistic functions. The hypothesis further proposes that this profile should be manifested in children with SLI and other basal ganglia deficits such as Parkinson's disease. PDH assumes implicit sequencing deficits to explain parallel grammar deficits. For instance, like how a motor skill is broken and learned as sequences, grammar components of language could also be learnt with help of implicit sequences. The dysfunction of different structures with in procedural memory system (frontal-basal ganglia or cerebellum) should yield different behavioural phenotype. For instance, deficits in basal ganglia should result in acquisition of procedural knowledge, and deficits particularly in cerebellum should result in execution of procedural skills (Seidler, Alberts, & Stelmach, 2002). PDH claims that the heterogeneous community of children with SLI forming subgroups with variation across individuals with respect to structures that are affected and the degree of functional impairment could be explained based on the PDH.

The behavioural manifestation of procedural memory deficit in children with SLI could vary depending on the channel within which frontal-basal ganglia circuit is affected. For instance, multiple domains are generally impaired with analogous impairments in movement and grammar (Bradshaw, 2001). Huntington's disease patients show insuppressible movements and insuppressible grammatical rule use, whereas individuals with Parkinson's disease show the suppression of both movement and grammatical rule use (Ullman et al., 1997). The variability in grammar and movement data among Parkinson's and Huntington's disease reveal that it is unlikely that all individuals with particular frontal/basal-ganglia disorder have particular channel affected. Moreover, the correlations between motor and grammatical impairments of Parkinson's or Huntington's disease patients are not perfect (Ullman et al., 1997). Therefore, PDH claims that the variability in linguistic and non-linguistic deficits across individuals with SLI could be explained with combination of channels that are affected, and the severity of their dysfunction. The hypothesis further maintains that all channels of frontal-basal ganglia circuit have an unequal probability of being affected in SLI. In other words, certain channels could be more likely to be dysfunctional than others. Such claims of PDH is supported by evidence from well-studied basal ganglia disorders which suggested that in a given basal ganglia disorder specific portions of the circuitry are more problematic than others. For instance, Parkinson's disease affects circuits passing through the putamen, whereas Huntington's disease disturbs circuits going through the caudate nucleus (Jankovic & Tolosa, 1993).

Therefore, PDH for SLI predicts that grammatical and lexical retrieval deficits could be strongly associated with impairments other than language domain. Functions that rely on circuitry involving the caudate nucleus of striatum and Broca's area of frontal lobe are especially expected to be impaired. Hence, even though functional heterogeneity depends on the channels that are affected, certain degree of similarity between children/ individuals with SLI are expected. Despite the fact that any abnormality will not be restricted just specifically to grammar or lexical retrieval circuits of the frontal/basal-ganglia procedural system, such a circumscribed dysfunction specific to grammar or lexical retrieval alone is theoretically feasible by PDH. However, the deficit explained by PDH need not be limited to language alone, i.e. the idea of "pure SLI" is not supported by PDH. Christiansen (1994) discussed the role of procedural memory system from socio-cultural perspective of human cognition and language. He stated that human language evolved from procedural memory circuits, which was already in use for tool usage. Therefore, according to Christiansen those language deficits should co-occur with sequence learning deficit. Studies have shown that children with SLI show affiliated sequence learning problems (Lum et al., 2010).

2.8.2.1. Declarative compensatory mechanism. Procedural deficit hypothesis posits a compensatory mechanism to explain some of the improvement in language behaviour associated with maturity which is otherwise procedural (Leonard, 1998). In other words, by including a declarative compensatory mechanism to account for language learning through explicit mechanism PDH accounts for language learning through maturity and progress from intervention explicit language intervention techniques. The highly plastic nature of developing brain enables compensation by allowing the unaffected similar proximate tissue to take over its function (Merzenich et al., 1988). The functions are only compensated to an extent since the function is taken over by a system whose primary function is different. Similarly, other portions of these structures may compensate for abnormalities of specific portions of the fronto-striatal circuitry. That is, if there is more than one computational mechanism involved in performing a particular function, the compensation is likely to happen from the intact mechanism/ systems. Therefore, in procedural learning disorder (PLD) the declarative memory system (which is computationally approximated) can and will take over certain grammatical functions from the procedural memory system (Ullman, 2004; Ullman & Pierpont, 2005). For instance, complex structures that are computed by grammatical/procedural system (*walk* + *-ed*) in TD children may just be stored as chunks (*walked*) in lexical/declarative memory among individuals with PLD. Individuals with PLD should be able to compensate for their grammatical difficulties by learning explicit rules in declarative memory, such as “add /*-ed*/ at the end of a verb when the event has already happened”. Such declarative-memory compensation has been reported in normal adults who is learning second language (individuals who could be approximated to PLD as per Ullman, 2004) and also among persons with agrammatic aphasia (Ullman, 2001). With this compensatory explanation by PDH some of the improvement observed in SLI as child matures could be explained. The higher chances of resolving language deficits in individuals with greater lexical/declarative abilities could be an evidence for the compensatory mechanism happening between interactive systems. The PDH predicts that grammatical deficits should be less apparent over course of time in individuals with superior lexical/declarative abilities, because possibility of greater compensation to store grammar explicitly in them. However, the process assumed and explained by such compensatory mechanism with in the brain of an SLI child is more complex. Thomas (2005) theorized the possibility of such declarative compensation in children with SLI. He criticized over dependency nature in explaining SLI features using compensatory declarative mechanism and urged for empirical studies before nature and extension of such compensatory mechanism could be accepted.

2.8.2.2. Procedural memory for grammar acquisition. The relation between grammar and procedural memory disorder is explored using co-occurring deficits in grammar and sequence learning in children with SLI (Kuppuraj & Prema, 2013d). Understating of how procedural learning function aids in grammar acquisition needs thorough investigation of some of other non-declarative memory systems and their functions. The contribution of specific non-declarative mechanism is essential, since grammar learning and implicit skill learning relation is difficult to explain unless other non-declarative functions such as statistical learning and knowledge of predictive dependencies are considered. This section reviews implicit memory systems that are not particularly limited to sequential learning functions. The functional involvement of all non-declarative memory systems and their roles with reference to normal language acquisition and evidence from children with SLI are described in following sections.

Aspects of non-declarative memory including procedural memory system are illustrated in Figure 2.1. Skills mentioned inside white circles involve implicit memory. It could be observed that implicit learning is domain general involving verbal and nonverbal aspects. Implicit memory involving statistical learning is mentioned in dark grey circle. The learning of non-verbal sequences and artificial grammar learning is included under non-declarative memory components requiring statistical learning.

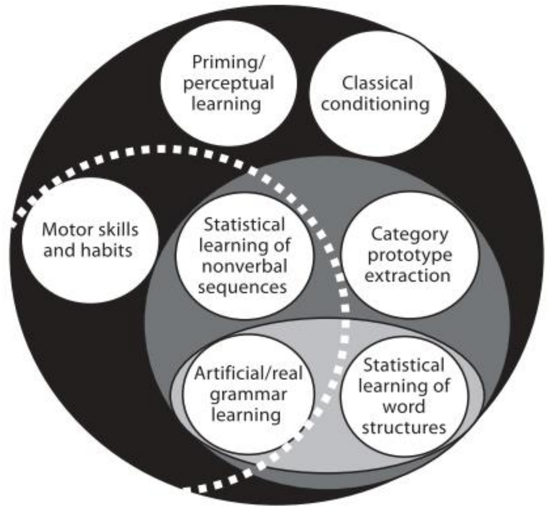

Figure 2.1 The schematic illustration of implicit, statistical and verbal sequence learning (Source: Hsu & Bishop, 2010)

The subset of implicit memory concerned with verbal learning is mentioned in light grey circle. Statistical learning of word structures and artificial grammar learning are involved in this verbal domain of implicit learning. According to PDH the skills bounded by the dotted line (all involving statistical sequence learning) are all postulated to be impaired. Statistical learning mechanism plays a significant role in finding word chunks in running speech (Saffran, 2003). The child learns the probability of co-occurrence of two sounds which would enable him to chunk the words in running speech as the probability of co-occurring of last sound of one word and first word of successive word is less, compared to sounds in a word through implicit learning mechanism . For instance, in English as the child is exposed to language he/she understands that the chances of */y/* and */b/* occurring in sequence are less compared to */ba/*, */by/*, or */my/* in sequences *my baby*. Views considering grammar as probabilistic knowledge rather than a system of symbolic rules are re-conceptualized in the recent times (Edelman & Waterfall, 2007). The probabilistic knowledge view is prompted by work contesting the poverty-of-stimulus argument (Redington, Chater, & Finch, 1998), and emphasizes on children's data-mining abilities when the input is filled with distributional regularities or patterns (Gómez & Gerken, 1999; Saffran, 2001). This view challenges the general view, which considered language impairment as downstream effect of poor non-linguistic deficits such as auditory processing, and poor phonological short-term memory (Bishop, 2006). The ability to segment words based on transitional probability and predict correct sequences in a sentence could be a vital implicit skill in language acquisition. There is evidence that children possess this implicit skill to segment words based on probabilistic knowledge very early in their life as young as 8 months.

Typical children, generally before 1 year of age, store incoming sentences in an exemplar-by-exemplar fashion. Children at this stage do not have knowledge on system-wide syntactic categories or schemas, and grammar gradually emerges as statistical generalizations that are created on these stored exemplars (Tomasello, 2000). Statistical learning of grammatical relations is studied using artificial grammar (languages). Artificial languages have scope to manipulate the transitional probabilities to give rise to structural dependencies of a certain artificial language. Children as young as 8-month old could utilize cues of higher transitional probabilities of adjacent syllables within words against the lower transitional probabilities of syllables across words to identify words in continuous speech (Aslin, Saffran, & Newport, 1998). Saffran, Aslin, and Newport (1996) further reported that such learning is rapid, involuntary, and domain general. Gómez and Gerken (1999) reported that 12-month-old infants could track the frequency of co-occurrence between two words to learn the orderings of words in sequences. Natural language on the other hand requires beyond just learning the adjacent relation, but long distance dependencies. For instance, in the sentence '*The house on the mountain is black*', it is the "*house*", rather than the "*mountain*", that is black. Therefore, the result of Gomez and Gerken's study cannot be applied instantly to natural language acquisition. Gomez (2002) examined the ability to learn non-adjacent dependencies. Non-adjacent dependency marking in natural language for instance is the ability to mark agreement. The assumption of Gomez (2002) was that closed functional sets such as auxiliaries are less in number forming a high transitional probability between them and open class words such as verbs and nouns are more in number; therefore, forming less transitional probabilities between them. When a sentence is formed, the open class words are merged by closed class morphemes. The lower transitional probability of adjacent open class words enables better detection of non-adjacent elements such as agreement. For example, in the sentence *There are few difficult problems,* /*are/* and */-s/* are closed group of words; therefore, it is easy to predict that when /*are/* appeared there is high chances that /*-s/* would follow with object. Because, the child knows words probability statistics it is easy for him/her to ignore the lower transitional probability words (open class words) to find the non-adjacent relation among closed class words. Gomez (2002) found positive evidence for her predictions for this type of non-adjacent learning of dependencies using typically developing adults and 18 month old infants. Her experiments further enunciated how learning could be dynamically guided by statistical structure. Saffran (2001) examined whether the statistical learning mechanisms can succeed in explaining the long distance relations required for grammar acquisition. The results of her study reported that statistical learning mechanism could be extended to explaining the hierarchically organized relationships in natural language. Saffran (2002) reported from her study on predictive dependencies that individuals learned the artificial language with more predictive dependencies better than artificial languages with less predictive dependencies. These findings led to the claim that learning mechanisms that are not specifically designed for language learning may have shaped the structure of human languages and human learning mechanisms themselves might have shaped the structure of human languages (Kuppuraj & Prema, 2013b; Saffran, 2003).

The role of procedural implicit memory is not restricted to learning statistical properties of language. The unconscious nature of knowledge also underlies in concatenating elements from lexicon to make phrases and clauses. Broca's area, particularly left inferior frontal gyrus (LIFG) is reported to play the role of combining words, the process long appreciated by dual mechanism models such as declarative procedural model (Ullman, 2001). Hagoort (2005) underscored the importance of unification process to human language. His work on role of Broca's area (LIFG in particular) in unification of words into sentences explores the Memory Unification and Control (MUC) framework for language comprehension and production. He claims that the memory component includes different types of language information stored in long term memory in the form of lexicons and retrieving operations. The unification component aids in integration of lexically retrieved information into a multi-word utterance. The control component relates language to action such as handling turn taking and language shift during conversation. Research evidences in other domains of cognition indicates that left prefrontal cortex has the necessary neurobiological characteristics for its involvement in the unification for language (Indefrey, 2004; Kaan & Swaab, 2002). Frontal lobe (Broca's area in particular) was highlighted as a crucial hub on neuro-anatomy of procedural memory system; therefore, apart from playing role in statistical learning for verbal and nonverbal sequences procedural memory could also play role in concatenating sentences. Hagoort further matched the unification process of MUC framework with merge process mentioned by Chomsky's minimalist program (1995). Bolender, Erdeniz, and Kerimoglu (2008) coated the significance of procedural memory in making recursive sentences. Bolender and colleagues proposed that the internal merge principle, which helps the computational system to hierarchically construct the sentence, is a procedural skill. The similar proposals linking sentence making with procedural skills has been proposed by Hauser, Chomsky, and Fisher (2002) in their hypothesis (HCF hypothesis henceforth). According to HCF hypothesis human language has two types of faculties offered by cognitive system such as broad and narrow faculty. Broad language faculties function for non-specific functions of language; however, recursion is the only narrow faculty offered by cognitive system. Therefore, in the process of evolution for language, recursion could have played a significant role, which is linked with procedural memory system closely (Kuppuraj & Prema, 2013b). Even though, PDH in its essence do not claim sentence making as a procedural skill, evidence offered by HCF (2002), Hagoort (2005) and Bolender et al., (2008) stated that the lack of procedural skill could explain poor sentence making as well. Therefore, it could be expected that children with poor procedural memory would also exhibit difficulty in making longer sentences.

Review on various causative accounts of SLI (both domain general and domain specific accounts) including explanations of procedural deficit hypothesis could be accounted for wide linguistic and non-linguistic deficits observed in children with SLI. Although there are studies that relate grammar and procedural memory in SLI (Tomblin et al., 2007), studies that have examined specific linguistic operations in relation to procedural memory deficit in children with SLI are very few. Studies that examined the relation between procedural memory deficit and language in children with SLI are discussed in detail.

Implicit memory system underlying grammar could have verbal and non-verbal domain of operations for learning (Hsu & Bishop, 2011). Therefore, to examine verbal and non-verbal domains of implicit/procedural skills, research paradigms with specified tasks are available. One of the widely used verbal implicit tasks is artificial grammar learning (AGL) task (Reber, 1967). In an AGL study, participants are asked to memorize a group of letter strings generated by a finite-state grammar. After initial memorization phase, participants are told that the strings follow particular rules (of a grammar). During the testing phase, participants are asked to classify new testing strings as grammatical or not. Typically, participants perform the task above chance despite not being able to verbally describe the procedure during testing phase. Therefore, Reber (1967) concluded AGL as an implicit task. Nissen and Bullemer (1987) introduced non-verbal testing paradigm for implicit learning in the form of sequence Learning (SL) task which taps on implicit sequential abilities of a participant. Sequence learning is usually measured using a visuo-motor task called serial reaction time (SRT) task (Nissen & Bullemer, 1987). In a typical sequence-learning task participants are asked to respond to the visual stimuli occurring in the monitor. Typically, the response is by selecting the spatially corresponding button in the gamepad to the stimulus on the screen. In a sequence learning task, order of stimuli is presented randomly followed by a pattern. Participants who show considerable sequence learning would perform substantially faster during pattern phase compared to random phase, as there is no scope for learning during random phase. Both AGL and SL tasks are tasks to examine implicit learning. Even though they appear in different modes, the underlying neural substrate that is active during testing is same (i.e. FBC circuit) (Squire & Knowlton, 2000; Amunts et al., 1999)

Ability to learn the transitional probability of adjacent sound sequences in SLI using AGL was studied by Evans, Saffran and Robe-Torres (2009). Evans et al. examined whether children with SLI can implicitly compute the transitional probabilities of adjacent sound sequences, and examined whether this ability is related to degree of exposure. The study also aimed to examine whether this probabilistic sequence implicit learning is domain specific or domain general and also whether the sequence learning ability is related to vocabulary. In the first experiment, 113 children (35 children with SLI and 78 TD children) participated and had six trisyllabic "words" (/*dutaba, tutibu, pidabu, patubi, bupada, babupu*/). The word of the language was designed to ensure that transitional probabilities between syllables with in word are higher than the transitional probabilities between syllables across word boundaries. Thirty children who participated in the first experiment were included after 6 months in a second experiment (2a). The stimuli and procedures for experiment 2a were identical to those of the first experiment, with the exception that the children listened to the same materials twice, without a break, for 42 continuous minutes**.** In a subsequent experiment (experiment 2b), the participants were given a stream which was constructed out of 11 pure tones. The tones were gathered into groups of three to make six tone words (GG#A, CC#D, D#ED, FCF#, DFE, & ADB). The results of experiment 1 indicated that after 21 min of exposure to a continuous speech stream, children with SLI were not able to use statistical information to implicitly discover word boundaries based on differences in transitional probabilities. In contrast, TD children were able to discover word boundaries after only 21 min of exposure, and their ability to use statistical information in the speech stream was also highly correlated with both expressive and receptive vocabulary. Children with SLI did show significant improvement in experiment 2a when the duration was increased to 42 minutes and also showed correlation with vocabulary knowledge. Results of experiment 2b (using tone combinations) also showed poor performance for SLI group compared to TD group. The finding of the study reported of implicit non-domain specific deficit in children with SLI.

Comparison between typical and SLI children on sensitivity to word order cues that signalled grammatical / non-grammatical word strings belonging to an artificial grammar was examined by Plante, Gomez, and Gerken (2002). The study included 16 adults with language learning disabilities (LLD) and 16 adults with no personal or family history of LLD. Practice phase was given in which the adults were asked to listen to a novel CVC words for 5 minutes. During the test phase, participants were asked to categorize heard strings as obeying or violating with practice grammar. LLD adults performed significantly lower compared to non-LLD participants, suggesting that children with LLD lacked this word order rules and hence performed poorly in natural language learning. The results of the study by Plante, Gomez and Gerken provide evidence for procedural deficit hypothesis.

The acquisition and consolidation of a grapho-motor symbol into long-term memory was examined by Adi-Japha, Strulovich-Schwartz, and Julius (2011). 5-year-old children with language impairment (LI) and TD children matched for age and visuo-motor integration skills participated in the study. All the participants (TD and LI) practised the production of a new symbol. Followed by initial practise phase, they were tested after 24 hours and two weeks for their acquisition and consolidation of new symbol (grapho-motor memory). 24 hours post practise showed that learning was slow in LI compared to TD children. Results of testing after 2 weeks showed that LI improved in performance and closed the gap in speed when compared to TD children, but the accuracy was compromised. In other words, the study showed that children with language impairment were slower in learning motor pattern and their speed of performance would increase only at the cost of accuracy of response. Authors used these findings of atypical and delayed acquisition in LI children to support the view that skill acquisition deficits in LI goes beyond the language system.

Studies used AGL examined the verbal implicit domain of implicit memory and has produced results supporting the role of unconscious memory in language operation. None of the statistical learning studies were attempted to support PDH, or PDH itself predict statistical learning deficit in particular among SLI children. Nevertheless, statistical learning is an essence of procedural memory system (Hsu & Bishop, 2011). Further section discusses in detail about the studies that used serial reaction time (SRT) task for measuring implicit sequence learning in SLI children. Results of studies examining sequence learning offers direct evidence to PDH, because it is the sequence learning that is measured through SRT task. SRT task uses visuomotor modality to measure the sequence learning of a participant. The task has several versions adapted for measuring sequence-learning skill of various age range and clinical conditions.

SRT task has sequences embedded within and the performance depends on the rate at which the creation of hierarchical relations and the prediction of future events are learnt over trials (Chafee & Ashe, 2007). The seminal SRT task introduced by Nissen and Bullemer (1987) used visuomotor modality where the participant had to spatially locate the four boxes on the screen using spatially corresponding buttons of a gamepad. Usually there are four boxes on the screen through which the stimulus (say a picture of dog) moves. The participant needs to press the spatially correct key as quickly as possible on the gamepad following each appearance of the stimulus (or each trial). The visual signal disappears upon the correct response and another signal appears at different position. Without the awareness of the participant the visual stimulus often follow a specific repeating sequence. For example, Nissen and Bullemer used 4 spatial positions, and named the positions as 1 to 4 from left to right, their sequence was 4-2-3-1-3-2-4-3-2-1(i.e. the visual signal moves from position 4 to 2 to 3 etc). The blocks following particular sequence is presented followed by a control block (random trials) and the difference between the reaction times between the sequence and the random blocks would give measure of sequence learning. Sequence learning cannot be measured by merely considering the improvement in the reaction time (RTs) across trials, because RT tends to improve, as participants get used to the non-sequential aspects of the task such as becoming more proficient with the stimulus-response mapping. Therefore, sequence learning is measured as the RT difference between a block of trials that follows the sequence and an adjacent control block (random trials) that does not follow the sequence. The resultant value is considered index of sequence learning (henceforth referred to as ISL). Imaging studies revealed that the sequence learning measured using SRT task is a valid measure of procedural memory skill (Keele, Ivry, Mayr, Hazeltine, & Heuer, 2003; Robertson, Tormos, Maeda, & Pascual-Leone**,** 2001). The neuroanatomical correlates underlying SRT performance conforms to anatomical substrates of implicit (procedural) memory. The SRT task substrates prefrontal cortex, striatum and dentate nucleus of Cerebellum, in other words the FBC circuit (prefrontal - Amunts et al., 1999, straitum - Eichenbaum & Cohen, 2001; Squire & Knowlton, 2000; cerebellum - Carey, Perretti, & Oram, 1997; Jellema & Perrett, 2001; Martin et al., 2000; Perrett et al., 1989; Perret, Mistlin, Harries, & Chitty, 1990; Rizzolatti et al., 2001). The brain areas that respond while performing on SRT task must theoretically be the same as the FBC circuit underlying the implicit sequence learning. Imaging studies have endorsed the reliability of SRT measure to implicit sequence learning by stating that the areas responsible for learning in SRT task is same as FBC circuit which is underlying neural region of implicit memory system (Pascual-Leone, Grafman, Clark, Stewart, & Massaquoi, 1993).

To date there are eleven research papers published that examined the PDH using SRT task. Eight of them are in favour of PDH (Gabriel et al., 2014; Hedenius et al., 2011; Kuppuraj & Prema, 2013a; Kuppuraj & Prema, 2013d; Lum, Gelgic, & Conti-Ramsden , 2010; Lum, Cont- Ramsden, Page, & Ullman, 2011;Tomblin, Mainela-Arnold, & Zhang, 2007; Tomblin et al., www.uiowa.edu/~clrc/ppts/ASHGFoxP2-2.ppt), while three of the studies refutes PDH (Gabriel, Maillart, Guillaume, Stefaniak, & Meulemans 2011; Gabriel, Stefaniak, Maillart , Schmitz, & Meulemans, 2012; Gabriel, Stefaniak, Maillart, Schmitz, & Meulemans, 2013).

Tomblin, Mainela-Arnold, and Zhang (2007) aimed to test the prediction of PDH using SRT task. The study specifically intended to examine the sequential learning among children with SLI compared to TD children. The study included 38 children with SLI (mean age 15) and 47 TD children (mean age 14.76). Since the study was concerned with whether individual differences in RTs is associated with individual differences in sequence learning rates, the SRT task used in this study was modelled after the SRT task used by Thomas and Nelson (2001b). The SRT task was designed and RTs for sequence trials were measured using E-prime software. The task had stimuli (a creature) appearing in one of the four boxes for 1000 milliseconds (ms) and disappearing for 500 ms and again appearing in another box. The participants completed four phases such as random phase 1, pattern[4] phase 1, pattern phase 2, and random phase 2. Stimuli in random phase did not follow any sequence and stimuli in pattern phase followed a specific sequence. The study aimed to report on sequential learning rates through a growth curve analysis of the obtained data. The authors used median values among 20 trial sequence of each phase as a sequence learning rate measure because the RTs were highly skewed. The initial results showed that the SLI group showed significantly greater RTs only during pattern phase suggesting slowed sequence learning in SLI group. The data revealed differences in rate and form of RT that declined in pattern learning between TD and SLI adolescents. The learning curve of TD group showed typical learning pattern of negative log function where the initial learning was rapid followed by gradual approach to asymptote. On the other hand, the learning curve of SLI group showed largely stable curve. The learning showed slow beginning followed by rapid learning but the curve never got asymptote (Figure 2.2). The study also found strong correlation between sequence learning ability and language ability of participants. This was one of the earliest studies that examined PDH and found results in favour of the hypothesis.

[4] Trials in pattern phase follows specific sequences.

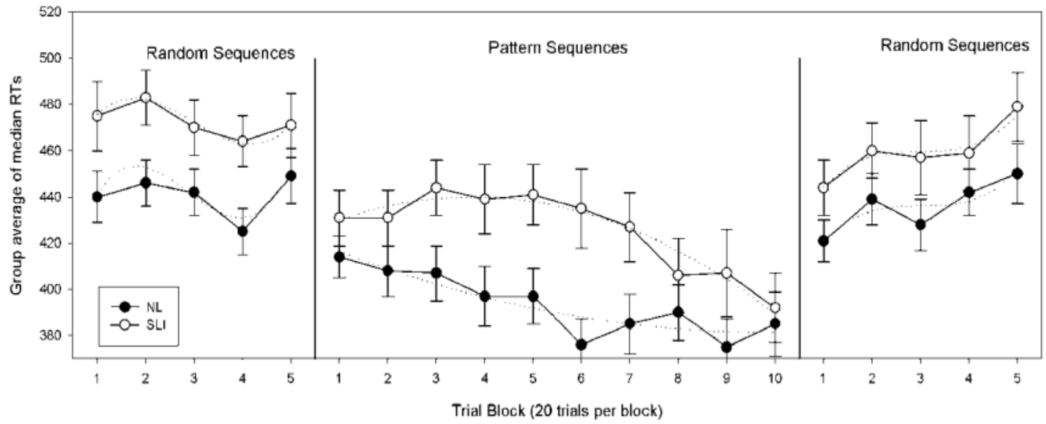

Figure 2.2 Change in reaction times over 20 trial blocks during Random Phase 1, Pattern Phases, and Random Phase 2 for the NL and SLI groups

(Source: Tomblin, Mainela-Arnold, & Zhang, 2007)

Lum, Gelgic, and Conti-Ramsden (2010) aimed to examine the lesser-known memory functions such as declarative and procedural memory functions in children with SLI through SRT tasks. 15 children with SLI and 15 TD children comparable to SLI in their age, gender, and handedness participated in the study. The study assessed procedural memory using SRT task along with verbal and visual declarative memory using paired associative task. The SRT task had 90 trials divided into 5 blocks. Like traditional SRT task, one of the blocks (5^{th} block) had random trials embedded. RTs on sequence block (4^{th} block) were subtracted from RTs of random block (5^{th} block) to arrive at quantity of procedural memory shown by two groups of participants. The study also examined for participant's explicit knowledge that could have possibly contributed to implicit performance and showed that none of the participants explicitly recalled 10-item sequence used. Therefore, the resulted sequence learning quantity was completely a procedural skill. Declarative memory for verbal information was assessed by word pair association task taken from Children's memory scale (WPCMS; Cohen, 1997). In this task participants were given 10 semantically unrelated word pairs (such as listen-magic) across three trials (the order of word pairs differed for three trials).The participant's task was to recall the associated word on the presentation of 1^{st} word. Declarative memory of verbal information is sub served by left temporal lobe. Paired associates learning (PAL) subtest from Cambridge automated neuropsychological test battery (Cambridge Cognition Ltd. 2006) assessed declarative memory for visual information. Declarative memory of visual information is sub served by right temporal lobe. The study used measures on motor screening test (MOT) from CANTAB[5] and a tapping task (Bishop, 2002) as a covariate to account for differences in motor speed between groups. The study also accounted for phonological short term memory using non-word repetition (NWR) task (Gathercole & Baddeley, 1996) and vocabulary using Peabody picture vocabulary test –Revised (Dunn & Dunn, 1981) as covariates. The motor speed measured using MOT and motor tapping task revealed no significant difference between SLI and TD groups suggesting that these two groups were comparable with respect to motor speed as independent variable. On the SRT task, SLI group was significantly lower than TD group suggesting poor sequence learning in them. This part of the result is in support for predictions of PDH. On the other hand visual declarative memory task showed no significant differences between SLI and TD groups; however, the verbal declarative memory was intact. Overall, the results showed that children with SLI show multiple memory system deficits. The authors concluded by proposing a possible future research question. They stated that language deficit in SLI could be at large due to working memory deficits because, all procedural and declarative memories are initially short-term representations to be processed in working memory.

The ability to consolidate and retain learned sequences in long-term memory in SLI children was studied by Hedenius et al. (2011). An alternating Serial Reaction Time (ASRT) task (Song et al., 2007) was used to examine initial as well as consolidation of sequence learning after three days. 31 children with SLI and 31 TD children participated in the study. An eight-item sequence of ten repetitions (i.e., 100 trails) was used as a stimulus. On the first day of testing (session 1), all the participants completed four epochs (20 blocks) for initial sequence learning. During the second session (i.e. 3 days later) a single epoch (5 blocks) was used to measure the consolidation and longer term sequence learning. The study also examined for possible explicit knowledge of the participant and results showed that

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[5] Cambridge Neuropsychological Test Automated Battery (CANTAB) is used assess neurocognitive performance in modeling studies of cognitive functions (Robbins & Sahakian, 1994). The CANTAB involves modules for neurocognitive functions and processes such as psychomotor and motor speed, attention and memory, and frontal, and hippocampal dysfunctions.

none of the participants could recall the 8 item pattern. When the groups were divided based on broader language skills the results on sequence learning showed that even though both groups showed consolidation, only TD group showed clear signs of long term sequence learning. Later the authors re-categorized participants in to grammar specific deficit group and non-grammar specific deficit group. The results after re-categorization showed that group with grammar deficits showed initial sequence learning similar to non-grammar deficits group, but the consolidation and longer term sequence learning was severely affected in grammar deficit group compared to non-grammar deficit group. The study was largely in support to the claims of PDH.

Lum et al. (2011) examined one of the proposals by PDH, which stated that brain structures associated with procedural memory also underlies working memory. Therefore, children with SLI with procedural memory deficits could also manifest working memory deficit. However, functions related to declarative memory must be unaffected as the structures underlying declarative memory are relatively independent of procedural memory structures. The objective was examined using 51 children with SLI and 51 children with TD with the mean age of 10. Working memory was assessed using working memory test battery for children (WMTB-C, Pickering & Gathercole, 2001). Procedural memory was assessed using visuo-spatial SRT task. The SRT task used consisted of five blocks each comprising of 90 stimulus presentations. From block 1 to block 4, the stimulus appeared in a pattern but not in the block 5. On the 5^{th} block stimulus appeared randomly. Each block had equal number of presentations at the end of task presentation. The declarative memory was measured using the children’s memory scales (CMS, Cohen, 1997), which gives measure of learning and retrieval of verbal and non-verbal information in declarative memory. Lexical and grammatical abilities were also measured. The results showed that SLI is affiliated with procedural memory deficits. Children with SLI showed intact declarative memory for visual and for verbal information even after controlling for working memory and language deficits. Working memory is adequate for visuo-spatial information, however, appears to be problematic in the verbal domain in children with SLI. Lexical abilities correlated at least in part to declarative memory in both TD and SLI groups. In TD children, grammatical abilities are related to procedural memory. In SLI, grammatical abilities appeared to be explained by procedural memory deficits and compensatory systems of intact declarative memory system. In summary, the study by Lum et al. (2011) offered evidence that memory systems interact in a complicated way for language. Furthermore, complements and compensations are possible among the memory systems. The findings are in support of compensatory principles proposed by PDH.

Kuppuraj and Prema (2013a) compared the performance of TD and SLI on learning speed and pattern of sequence learning using adapted serial reaction time (AD-SRT) task. The study used 34 TD and 22 SLI children in the age range of 7-13 years for the study. TD children of the study showed standard learning curve of rapid learning followed by slow approach towards asymptote. The learning pattern of SLI could be described as initial slow learning followed by earlier and prolonged asymptote. The total quantity of learning showed by SLI group was significantly lower than TD group, therefore, the findings strengthening the PDH. Kuppuraj and Prema (2013d) examined the aspects of grammar sensitive to procedural memory deficits in children with SLI. They examined sequence learning (using AD-SRT task) and grammar measures such as derivational, morpho-syntax, and sentence complexity measures in TD and SLI children. Results showed that children with SLI performed significantly lower compared to TD children on sequence learning task. Furthermore, the results showed that non-adjacent operations of grammar such as morph-syntax were affected as a cause of procedural mechanism deficit but not derivational morphemic deficits (which is declarative function). The authors used principles of PDH such as sequencing deficits affiliated to language deficits, statistical learning deficit, and compensatory mechanism by declarative memory system to explain the results.

The PDH is further strengthened by evidence that show strong relation between FOXP2 the commanding language gene and sequence learning measured through SRT task. Tomblin et al. *(*www.uiowa.edu/~clrc/ppts/ASHGFoxP2-2.ppt*)* studied the association of FOXP2 genetic markers with procedural learning and language. Results of the study provide the first direct evidence of an association between FOXP2 and procedural learning. Tomblin and his colleagues used a serial reaction time (SRT) task, for measuring procedural learning and associated learning rates. This was intended to whether the allelic variation among SNP markers within FOXP2 reflects on procedural memory variation. In other words, the proposal that procedural skill variations could be directly influenced by variation in FOXP2 (Liegeous, 2003; Ullman & Pierpont, 2005) was examined in this study.

The participants were eighth-grade students *(N=123).* Stimuli comprised sequences of images presented in both random and predictable order. Participants' responses were measured by reaction time, and learning was reflected in decreased reaction time on the patterned trials. Principal haplotype blocks within the FOXP2 gene was evaluated using six SNPs selected from genomic DNA of participants. Results showed that FOXP2 genotypic variants were reflected on individual differences in the procedural learning.

Studies employing SRT tasks also produced results in contrary to procedural deficit hypothesis that emphasize sequence learning deficits in children with SLI. Gabriel, Maillart, Guillaume, Stefaniak, and Meulemans (2011) examined procedural deficit hypothesis and also findings reported by which stated that sequence learning skills are more correlated to grammatical abilities than to lexical abilities (Tomblin et al., 2007). The study used a probabilistic rather than deterministic SRT paradigm to simulate language structures. The paradigms had irregularities inserted into sequences (non-deterministic) as contrast to previous SRT studies. The authors proposed that probabilistic sequences are more complex and mimic the natural statistical complexity of natural language more closely (Evans et al., 2009). Therefore, the results of such probabilistic SRT paradigm would apply more readily to language learning research. All the participants were given receptive and expressive vocabulary and grammar tests to extract lexical and grammatical measures (Gabriel et al., 2011). The SRT paradigm consisted of 13 blocks. One block consisted of an 8-element-long sequence repeated eight times, for a total of 64 trials by block and 832 for the whole task. 31432412 and 14234132 were the eight element learning sequences. Fifty percent of the participants were trained with the first sequence for block 1 to block 12 and with the second sequence for Block13 (the transfer block). The participants were asked to respond as fast and as accurately as possible to each stimulus by pressing the location on the touch screen. The task began after completing 20 randomly generated practice trials. Results regarding sequence learning speed and processing of probable and improbable sequences between groups were not significantly different from each other. More correct responses were provided for probable sequence as compared to improbable sequences as predicted for both the groups. Contrast to findings by Tomblin et al. (2007) the study by Gabriel et al. (2011) did not show any positive correlation between grammatical knowledge and SRT learning indices. The authors of the study postulated that the procedural mechanism responsible for language learning could be somewhat different from procedural mechanism for other motor sequencing functions. Overall, the results of the Gabriel et al. (2011) study is contrary to the results of studies that showed sequence learning deficits in SLI, thus refuting procedural deficit hypothesis.

Experiment that compared the response modes were completed by Gabriel et al. (2012). The experiment one used game pad and experiment two used touch screen as a response mode. The authors proposed that the touch screen mode would demand lesser cognitive load; therefore, would yield better sequence learning performance. The two experiments using different response modes were designed to examine the claim that that sequence learning deficits shown by traditional SRT task in children with SLI are due to the type of response mode used. For the experiment one 15 French-speaking children with SLI ages 6–12 years and 15 TD children were included. Two months later same participants were recruited for experiment two. The results showed that SLI group performed significantly slowly compared to TD group on response pad mode but not in touch screen mode. The results stated that poor sequence learning reported in SLI reported in previous studies could be attributed to response mode used and not to poor sequence learning. Therefore, refuting the procedural learning deficit as a reason for poor grammar performance in children with SLI. Gabriel et al. (2012) used artificial grammar tasks of visual stimuli and reported that children with SLI performed in par with TD children on sequence learning. Even though, studies by Gabriel and her colleagues show evidence to refute PDH, one of her recent studies, which compared the sequence complexity, gave support in favour of PDH.

The effects of sequence complexity on sequence learning tasks in children with SLI were examined by Gabriel et al. (2013). The results showed that type of sequence used (deterministic or probabilistic) could be a major factor that determines the performance of children with SLI. For instance, previous studies by Gabriel et al. used probabilistic sequences, which resembled natural languages. Even though, that does not directly explain the reason for difference between results it is obvious that language patterns could have contributed to the performance of sequence learning results in SLI. Moreover, Gabriel et al. used a touch screen node to examine sequence learning. Sequence learning is evidenced to be domain specific in recent times (Archibald & Joanisse, 2013); therefore, the response mode could have contributed to better performance in SRT tasks used by Gabriel et al. studies. In sum, studies examined the sequence learning performance in children with SLI showed results in favour and against PDH.

Studies reviewed on domain specific and domain general accounts of SLI highlighted the importance of procedural memory in language acquisition. Two components of procedural memory emerged with substantial evidence. The first component is the capacity to govern sequence-learning element, which predicts the successive elements in speech (Gomez, 2002, Kuppuraj & Prema, 2012a; 2013d; Mainela-Arnold & Evans, 2013). The second component of the procedural memory is the capacity to govern the statistical probability and regularity between speech elements. The significance of statistical learning in identifying word boundary in continuous speech stream (Evans, Saffran, & Robe – Torres, 2009; Kuppuraj & Prema, 2013d; Saffran, Aslin, & Newport, 1996) and for word learning (Lany & Saffran, 2010) was documented in the past. Hsu and Bishop, (2010), illustrate the existence of procedural learning system and statistical learning system amidst non-declarative memory system (Figure 1.1). To simplify, procedural memory system helps the child to identify word boundaries based on statistical probabilities and sequence-learning mechanism helps to find the successive elements in speech stream. Using statistical regularities these incoming exemplars form a representation or schema for language which is rich in regularities. This regularities formation is affected in children with SLI (Evans, Saffran, & Robe – Torres, 2009). The essence of PDH enables to infer that procedural memory system deficit in children with SLI disables them from the learning of probabilistic patterns and sequential dependencies, because of which they show deficits in learning implicit linguistic information that is most often required for syntax generation. The inference from opinions of Ullman and colleagues could be that the procedural learning deficit defies the grammar system to an extent that the regular inflections as per rule to be added to verb for agreement are turned effortful, resulting in morpho-syntax impairment. In other words, children with SLI make grammatical errors because their procedural system for sequence learning and statistical regularity learning is compromised. The unconscious nature of procedural learning is also believed to be underlying merging words to form clauses as per minimalist program proposed by Chomsky (1995). Minimalist program illustrates that words are combined conceptually through the merge principle which must be evolved specifically for human language (Hauser, Chomsky, & Fitch, 2002). Hagoort (2005) reported the significance of left inferior frontal gyrus in unification process which is similar to merge phenomenon (Bolender, Erdeniz, & Kerimoğlu, 2008). Therefore, deficit in procedural memory system in children with SLI could interfere with merge operations, which could result in lesser complex sentences. An incremental procedural grammar for sentence formulation also postulates the significance of implicit nature of procedural memory in sentence making (Kempen & Hoenkamp, 1987). Reports on procedural memory deficit in SLI are consistent in the literature (Hedenius et al., 2011; Lum et al., 2012; Lum et al., 2010; Plante et al., 2002; Tomblin et al., 2007). Even though, the relation between statistical and sequence learning is debated until date, agreement has been reached on the relevance of both the phenomenon for grammar acquisition (Hsu & Bishop, 2011; Kuppuraj & Prema, 2013d; Lum et al., 2010).

According to PDH, rule based operations would be more affected by sequence learning deficits. In view of the above, it could be said that agglutinating languages, which are highly inflectional (rule), would demand greater sequential cognition (Kuppuraj & Prema, manuscript submitted for publication). None of the previous studies examined the aspects of grammar particularly related to procedural memory, making a strong case for the such studies. The preliminary findings were extracted from an Indian study (Kuppuraj & Prema, 2013d) that related sequence learning in Kannada speaking children with SLI (an agglutinating language). The study examined the aspects of Kannada grammar sensitive to procedural memory deficits in children with SLI. Study showed that inflectional operations would be more vulnerable to sequence learning deficits compared to derivational deficits. Moreover, as per the relation between merge and procedural memory the participants of the study also performed sentence complexity with significantly greater difficulty compared to TD children. Another study by Kuppuraj & Prema particularly examined the hypothesis that agglutinating languages could have greater dependency for sequencing abilities since they are mostly inflectional. The study showed that children with SLI showed significantly high inflectional deficits compared to derivational deficits. The results were discussed from sequential cognition and statistical learning phenomenon both underlines by procedural memory.

2.9. Need for the study

Review illustrates the linguistic and non-linguistic explicability for children with SLI. Various linguistics explanations had drawbacks while owing for range (linguistic & non-linguistic) and cross-linguistic nature of SLI behaviour. Procedural memory deficit hypothesis was stated as a potential causative account to explain linguistic, non-linguistic, cross-linguistic, and heterogeneous SLI data. Further the components and dimensions of procedural memory such as sequence and statistical mechanisms that are discussed in a few sections of review offers evidence to state that children with SLI tend to show deficits both in sequencing as well as statistical mechanisms of procedural learning. The significance of procedural learning skills in grammar learning is also emphasized in the review (Kuppuraj & Prema, 2012a). The causal relation between procedural memory and grammar learning has been explored using paradigms examining artificial grammar learning and SRT performance in children with SLI. All the statistical regularity learning studies (using AGL) reported poor statistical learning in children with SLI (Aslin, Saffran, & Newport, 1998; Evans, Saffran, & Robe – Torres, 2009; Gomez, 2002; Gomez & Gerken, 1999; Plante, Gomez, & Gerken, 2002; Saffran, 2001; Saffran, 2002; Saffran, Aslin, & Newport, 1996). Studies examined sequence learning using SRT tasks and its variations were mostly in support of PDH (Hedenius et al. 2011; Lum et al., 2012; Lum et al., 2010; Plante et al., 2002; Tomblin et al., 2007, Tomblin et al., in preparation). These studies implied implicit learning mechanism to typical language acquisition. A general reason for inability to learn the transitional probabilities and non-adjacent relations in artificial language and motor sequence learning is underlined by a procedural memory deficit in SLI. However, few studies which used non-deterministic and differential mode of SRT design refuted the PDH (Gabriel et al., 2013). Studies have related grammar and vocabulary to sequence learning skills (Hedeinius et al., 2001; Lum et al., 2010; Tomblin et al., 2007). Study by Kuppuraj and Prema (2013d) reported that procedural memory could have various degree of relation to various language aspects in children with SLI. The procedural learning skills could be related differently to different grammar operations such as inflectional, derivational, morpho-syntax, and sentence complexity computations (Kuppuraj & Prema, 2013d). Moreover, agglutinating languages would have greater dependency for sequencing skills as they are highly inflectional (Kuppuraj & Prema, manuscript submitted for publication). The present study makes predictions based on PDH for grammatical deficits in SLI. The study also attempts to explain the grammatical features of SLI by applying the principles of PDH (including compensatory declarative mechanism) and other implicit skill-learning phenomenon such as statistical learning in an agglutinating language.

Predictions for inflectional deficits in a sentence based on the PDH are that the children with severe sequencing problems would show greater inflectional difficulties compared to children with lesser sequential problems. The assumption is that as they struggle with unconsciously predicting the next element in a motor sequence task they would also struggle making a sentence with all the items in proper sequence. The severity is expected to be greater in inflection because morphemes of this category modify words outside its word boundary. In other words, to mark agreement/tense/plural/case marker the participant need to relate two morpheme placed far in a sentence (non-adjacent elements), by applying sequential operations which is a procedural skill. For instance, in a sentence *"avanu (he) na:Le (tomorrow) barutta:ne (will come)"* modification on fourth element that is "*ne*" (*barutta:<u>ne</u>*) the agreement marker for gender and tense in Kannada would occur only if the first and second words are "*avanu"* (a masculine) and "*na:Le*" (future tense) in that sentence sequence. If the assumptions stating that more procedural influence on inflectional operations, one could expect the effect to be even greater in languages with lot of suffixation (as in agglutinating language). The errors in derivational morphemic operations would probably show limited relationship with motor sequential problems. As per PDH, an intact declarative system, which could manage appropriate supply of derivations from lexicon, would be sufficient for derivations. Therefore, the prediction of PDH for derivational morphemes is that the severity of sequential learning deficit would not reflect on the severity of derivational errors, as they are least dependent on procedural memory system. Some conditions such as associated lexical retrieval deficits in SLI leading to poor derivational morphemic performance could be accounted by PDH as a poor associated declarative memory system deficit. Sentence complexity measures are expected to be severely affected in children with SLI with implicit memory deficits. The prediction is that procedural memory system assists in merging the lexical items to make phrases and clauses as per Chomsky's minimalist program (Bolender et al., 2003; Hagoort, 2005). Children with SLI who lack procedural learning skill must also show lack of recursion, which is impeding them to make longer sentences by joining phrases. In sum, the explained predictions based on PDH and related principles could be applicable only if children with SLI show procedural memory deficit. Therefore, along with the necessity to experiment the proposed predictions, there is a need to examine if children with SLI show procedural memory deficits at all. Following are the objectives and specific research questions of the present study

1. Comparison of performance of Kannada speaking children with Specific Language Impairment (SLI) and typically developing (TD) children on procedural learning skill

   Statistical hypothesis. Children with SLI do not differ from TD children on procedural learning skill

   Research question. Do children with SLI differ in sequence learning and pattern compared to TD children?

2. Comparison of performance of Kannada speaking children with SLI and TD children on grammatical tasks

   Statistical hypothesis. Children with SLI do not differ from TD children on grammar performance

   Research questions Do children with SLI perform like TD children on grammatical operations? and what are the grammatical markers of SLI among extracted language measures in an agglutinating language?

3. To examine the relation between sequence learning skill and language in Kannada speaking children

   Statistical hypothesis. There is no relation between sequence learning skill and language

   Research question. Is language learning related to sequence learning skill/what are the aspects of grammar sensitive to procedural memory deficits?

Chapter 3
Method

The present study examines procedural deficit hypothesis in Kannada speaking children. The objectives were to compare group of children with SLI with typically developing children on sequence learning and on inflectional, derivational morphemes and sentence complexity measures. The present study therefore used a motor sequence-learning task and grammar task. Participants' details, nature of stimuli, procedure of administration of tasks, and scoring/analysis are explained in this section.

3.1. Participants

3.1.1. Language impaired group. Thirty-one children with language impairment in the age range of 8-13 years (i.e., >8.0 to ≤ 11.0 and >11.0 to ≤ 13.0) were included in the study (23 boys & 8 girls). The mean chronological age of language-impaired children was 10.1 and SD was 1.6. All the children with language impairment were reported by their parents to have had delay/history of delay in speech language skills. However, parents could not mention a reason for the delay in speech language skills of their children. All the children in language-impaired group were right handed which was determined based on handedness for daily routine activities (Oldfield, 1971)[6]. All the children included in this group showed normal hearing on Ling's six sound test (Ling & Ling, 1978) (Appendix A) and normal visual acuity on Snellen's visual chart (Snellen, 1862) (Appendix B). Children in this group had average or above average non-verbal IQ (Table 3.1). Language impaired participants were administered the linguistic profile test (LPT) (Karanth, 1980) to measure phonology, semantics, and syntax ability. LPT provides combined (receptive & expressive) age of phonology and receptive language age of semantics and syntax. LPT has norms developed for children age ranging from 7-13 years. Apart from providing individual language scores on phonology, semantics, and syntax LPT also provides a total language age. Total language age is the combination of raw scores on phonology, semantics, and syntax. The total language scores of every participant in this group was at least 1.25 SD

[6] Questions such as preferred hand for brushing, throwing, writing and opening a box were asked to decide on participant's handedness. According to Oldfield (1971) they were effective in determining the handedness of an individual.

lower than standard mean total language age score of that age group in LPT. Information regarding the acquisition of first word and family history was collected and mentioned in Table 3.1. All the participants in this group *(n=31)* were given the non-word repetition (NWR) task developed by Kuppuraj and Prema (2012b) to document the phonological short-term memory skills of each participant. The study by Kuppuraj and Prema revealed that syllable lengths 6, 7, and 8 were more sensitive in differentiating language impaired from TD participants at this age level (i.e., 7-13 years). The performance on NWR in the present study was considered poor (i.e., P) if the mean value of a participant on percentage of syllable correct (%SC) measure was at least 1 SD lower than group mean for TD children of that age group. The performance was called average (i.e., A) if it was within 1 SD of group mean for TD children of that age group (Table 3.1) (for stimuli from Kuppuraj & Prema, 2012b, scoring & TD mean for age groups 7-10 & 11-13 years, Appendix C).

3.1.1.1. Diagnosis of SLI. The diagnosis of children with SLI in the language impaired group was done using diagnostic (diagnosis by exclusion) criteria by Leonard (1998) (Appendix D), psycholinguistic marker (NWR scores), and developmental history of a participant. All the participants in SLI group agreed with Leonard's exclusionary criteria for diagnosis of SLI children (Leonard, 1998). In other words, all the participants in SLI group had at least 1.25 SD on total language mean compared to total language mean of TD children of that age group (based on LPT scores). Further, all the children showed average or above average nonverbal IQ scores. Parental details informed that all the children in language impaired group had no notable neurological complications, and social interaction issues. NWR repetition was a psycholinguistic task used in present study for measuring phonological short-term memory in children with language impairment and results showed that all the children in this group showed poor NWR repetition performance for NWR length of 6 and above syllable lengths. Poor NWR performance has been consistently reported in children with SLI (Edwards & Lahey, 1998; Ellis Weismer et al., 2000; Kuppuraj & Prema, 2012b). More than 60% of SLI participants in the present study had positive family history. Because the main criteria such as IQ and language abilities were considered even during initial inclusion into language impaired group all the participants *(n=31)* in language impaired group was eligible for SLI diagnosis in the present study. Therefore, all the participants in language-impaired group were labelled under SLI group and henceforth, the group would be addressed as group of children with SLI in the present study.

Table 3.1

Participants' information of SLI group

P.no	Demo graphic		Familial History*	Delayed acquisition (in months)	Non verbal IQ	NWR length			LPT scores			
	Age	Sex		1st Word		6	7	8	Pho	Sem	Syn	Tot
1	8	M	+VE	16	Avg	P	P	P	7	6	5	6
2	8	M	+VE	18	Avg	A	P	P	8	6	5	6
3	8	M	+ve	18	Avg	P	P	P	7	6	5	6
4	8	F	-ve	24	Avg	A	P	P	8	7	5	6
5	8	M	-ve	15	Avg	A	P	P	8	7	5	5
6	8	M	-ve	20	Avg	P	P	P	7	6	5	5
7	8	M	+VE	14	Avg	A	P	P	8	6	5	6
8	9	F	-ve	18	Avg	A	P	P	9	7	6	8
9	9	M	+VE	18	Abv Avg	A	P	P	8	7	6	7
10	9	F	+VE	18	Avg	A	P	P	9	8	5	6
11	9	M	-ve	24	Avg	P	P	P	8	6	5	7
12	9	M	-ve	20	Avg	P	P	P	8	7	6	6
13	9	M	+ve	18	Abv Avg	A	P	P	9	7	5	7
14	10	F	+ve	24	Avg	A	P	P	9	8	6	7
15	10	M	+VE	20	Avg	P	P	P	9	8	6	7
16	10	M	+VE	22	Avg	P	P	P	10	8	7	8
17	10	M	-ve	18	Avg	P	P	P	10	8	8	9
18	10	M	+VE	30	Avg	P	P	P	10	9	7	8
19	11	M	+ve	18	Avg	A	P	P	11	9	7	8
20	11	F	-ve	14	Avg	A	P	P	11	9	8	8
21	11	M	-ve	14	Avg	P	P	P	9	8	7	8

Table 3.1

Participants' information of SLI group (contd.)

P.no	Demo graphic		Familial History*	Delayed acquisition (in months)	Non verbal IQ	NWR length			LPT scores			
	Age	Sex		1st Word		6	7	8	Pho	Sem	Syn	Tot
22	11	M	+VE	30	Avg	A	P	P	10	9	7	9
23	11	F	-ve	24	Abv Avg	A	P	P	10	9	8	9
24	12	F	+ve	20	Avg	A	P	P	12	10	7	9
25	12	M	+VE	18	Avg	A	A	A	12	10	9	9
26	12	F	+VE	18	Avg	A	P	P	12	10	8	9
27	12	M	+ve	14	Avg	A	P	P	12	9	8	8
28	12	M	-ve	24	Avg	P	P	P	12	10	8	10
29	13	F	+VE	24	Avg	A	A	A	13	11	9	10
30	13	M	+ve	18	Avg	A	P	P	13	13	10	12
31	13	M	-ve	18	Avg	A	P	P	13	9	8	9
Mean	10.1								9.7	8.2	6.6	7.6
SD	1.6								1.9	1.7	1.5	1.6

* +VE- positive family history at first degree relation; +ve – positive family history at second degree relation second-degree relation.

Abb: P.no-participant number, P –poor performance and A-average performance, LPT-linguistic profile test, Pho-phonology, Sem- semantics, Syn-syntax, Tot-total language scores

3.1.2. TD group. Thirty three typically developing (TD) children in the age range of 8 to 13 years (18 boys & 15 girls) were included in the study. Information on TD participants and their scores on language domains such as phonology, semantics, and syntax as per LPT are mentioned in the Table 3.2. All the children in TD group were native speakers of Kannada[7] language. Kannada is a Dravidian agglutinating language spoken in Karnataka state of India. The language is rich in inflections. All TD children showed normal hearing sensitivity on Ling's six sound test (Ling & Ling, 1978) and normal visual acuity on

[7] Estimated speakers as per 2011 census were 37, 924,011 (Census of India, 2011)

Snellen's visual chart (Snellen, 1862). All the TD children were right handed and none of them showed any developmental disabilities on WHO screening questionnaire (Singhi, Kumar, Malhi, & Kumar, 2007) (Appendix E).

Table 3.2

Participants' details of TD group

P. no	CA	Sex	Language age (as per LPT)			
			Phonology	Semantics	Syntax	Total
1	8	M	8	8	7	7
2	8	M	7	7	7	7
3	8	M	7	7	5	6
4	8	F	9	7	7	7
5	8	F	7	6	5	6
6	8	F	9	8	7	8
7	9	M	9	8	8	8
8	9	M	10	9	7	9
9	9	F	10	8	8	9
10	9	F	8	8	8	8
11	9	F	10	9	8	9
12	9	M	9	8	6	7
13	10	M	10	8	10	9
14	10	M	11	9	10	10
15	10	M	11	10	10	10
16	10	F	9	8	8	8
17	10	F	10	9	9	9
18	11	F	11	10	11	11
19	11	F	11	11	11	11
20	11	M	11	12	11	10
21	11	M	11	12	10	10
22	11	M	11	12	10	10

Table 3.2

Participants' details of TD group (contd.)

P. no	CA	Sex	Language age (as per LPT)			
			Phonology	Semantics	Syntax	Total
23	11	M	11	11	11	11
24	12	F	12	12	12	12
25	12	F	12	12	11	11
26	12	M	12	12	10	11
27	12	M	12	12	12	12
28	12	M	12	10	10	11
29	13	M	13	12	10	12
30	13	M	13	12	12	12
31	13	F	13	10	11	11
32	13	F	13	11	11	11
33	13	F	13	12	12	12
Mean	10.39		10.45	9.69	9.24	9.51
SD	1.7		1.82	1.97	2.26	2.01

Comparison between SLI and TD on their chronological and language ages revealed that except for the chronological age and phonological language age scores, children with SLI were significantly lesser compared to TD children (Table 3.3).

Inclusion of children with SLI in the present study was based on language scores, Leonard's exclusionary criteria (normal non-verbal IQ), performance on NWR, and on par performance with TD on attention and vigilance on two choice reaction time task (TCRT) (explained below). TD children for the present study were selected based on WHO checklist and normal language scores on LPT.

Table 3.3

Comparison between SLI and TD on their chronological and language ages

Ages	Wilk's λ[F(5,58)=14.59,p=.000, η^2=.557]			
	Mean square	F(1,62)	Sig.	η2
Chronological	1.12	0.383	0.18	0.02
Phonology	6.178	10.617	0.13	0.14
Semantics	36.22	28.565	0.00	0.31
Syntax	105.33	16.013	0.00	0.21
Total	53.98	0.383	0.00	0.01

3.1.3. SLI versus TD group on two choice reaction time (TCRT) tasks. The two choice reaction time task (TCRT) used in this study was a vigilance and attention task taken from Cognispeed software, version- 1.21b developed by University of Turku, Finland. Vigilance and attention were among the nine subsections of cognitive skills assessed by Cognispeed software. TCRT task in the present study was used for measuring baseline attention via the procedure that is compatible with actual experimental visuo-motor serial reaction time task (Kuppuraj & Prema, 2013c).

Task description. TCRT is a task for assessing attention and vigilance skills. On TCRT task, one box of 6"x 4" appears on a special inlet window on the monitor. The stimulus is either '1' or '2' which appears randomly without particular interval between two presentations for forty times (Figure 3.1). The administration of TCRT task took about maximum of 5 minutes per participant.

Procedure and instruction. The time gap between the appearance of stimulus and button press was measured in milliseconds. At the end of forty trials mean reaction time for forty responses, minimum and maximum reaction times (in milliseconds/ms) for a button press, and number of correct responses among the forty responses (accuracy of response) were measured. The children are instructed to press the left arrow on the keyboard when '1' appears and press the down arrow on the keyboard when '2' appears (Figure 3.1).

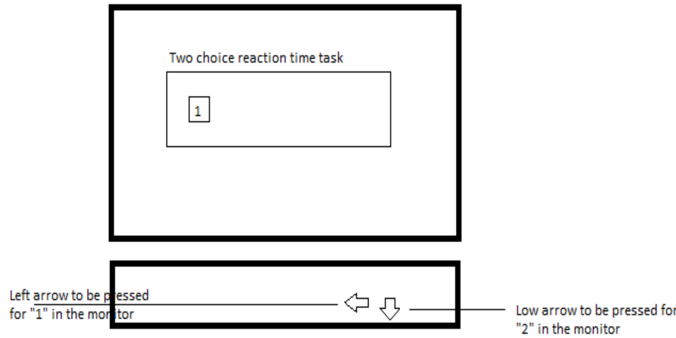


Figure 3.1 Schematic representation of TCRT task. The monitor shows window for TCRT task and two arrows to be pressed depending on the digit in the monitor (Source: Kuppuraj & Prema, 2013c)

Comparison between SLI and TD groups showed that SLI children did not differ on performance of TCRT task when compared to TD children. For TD group the mean value of TCRT mean was 821.30ms and SD was 176.36ms. For SLI group the mean value of TCRT mean was 877.61ms and SD was 134.48. The incorrect responses mean for TD group was 2.6 and SD was 1.6. The incorrect responses mean for TD group was 3.1 and SD was 1.9. SLI group did not differ from TD in mean and incorrect responses in two way MANOVA [for mean TCRT: $F(1,62)=2.04$, $p=0.16$, $\eta^2=0.03$; for incorrect responses $F(1,62)=1.19$, $p=0.28$, $\eta^2=0.02$]. Therefore, children with SLI in the present study did not differ from TD children on attention and vigilance scores. In other words, the SLI group of the present study could be compared to TD group in visuo-motor speed and accuracy (Kuppuraj & Prema, 2013a; 2013c; 2013d)

3.2. Experimental Tasks

The present study administered a visuo-motor sequence-learning task (AD-SRT task) and a grammatical task. The grammatical task consisted of a story to be described for certain measures of sentence complexity in order to achieve the main objective of examining the relation between procedural memory and grammar in SLI. SLI group was comparable to TD group on visuo-motor speed and attention as they did not vary from TD counterparts in visuo-motor speed and accuracy (section 3.1.3). The materials used for the study are displayed in Figure 3.2.

Figure 3.2 AD-SRT task and grammatical stimuli material

3.2.1. Adapted serial reaction time task

Task description. The adapted serial reaction time (AD-SRT) task used in the present study was the one used in the study by Kuppuraj and Prema, (2013a; 2013c; 2013d). The AD-SRT task has provision to measure sequence learning and sequence learning pattern (progress/regress) over trials. The AD-SRT task was used on 98 Indian children from the age range of 7-13 years and found valid for measuring sequence learning and its pattern by Kuppuraj and Prema, (2013c).

Instrumentation. A personal computer and a Logitech gamepad were interfaced (Figure 3.2). The AD-SRT task was designed using visual basic program V unlike conventional serial reaction time task, which is designed using e-prime software (Lum et al., 2010). The system provides the stimuli and the program measures the time gap from appearance of stimuli to response.

Procedure. Four boxes appeared in the computer screen. The response pad (A Logitech game pad) had keys in spatial correspondence to the boxes on the computer screen. A picture of dog appeared in any of the four boxes one at a time (which is the stimulus) (Figure 3.3). The dog stimulus appeared until the spatially corresponding correct response button was pressed in the gamepad. If the wrong response button was pressed, the stimuli did not move to appear in another box (therefore, increasing the response time). If the correct response button was pressed then the dog appears in next box. The reaction time (RT)[8] the participant consumed to press the key was measured. Figure 3.3 illustrates the schematic representation of the instrumentation for AD-SRT. The monitor shows four boxes for appearance of stimuli (i.e., picture of a dog).

Instruction. Participants were asked to chase the dog that appears on the screen as fast as possible using the game pad. In order to complete the task faster the participants were instructed to reduce number of incorrect button presses, because incorrect button presses do not cause the dog to move. Participants were told that the faster the chase is completed the better will be the score.

Figure 3.3 Schematic representation of AD-SRT task instrumentation (A Logitech gamepad connected to CPU of computer)

Construction of the AD-SRT task. The procedure used two types of trials to measure the sequence learning skill. First types of trials were random trials where the trial set[9] did not follow any specific pattern. Random trial sets did not have any regularity in the occurrence of numbers. For instance, two trial sets appeared as 1432423142 and 342341323. There were 10 random trial sets, each set comprising of 10 stimuli. Therefore, total number of random trials provided for each participant were WAS hundred (10 trial sets with 10 stimuli

[8] RTs mentioned in the study as extracted from AD-SRT task are in milliseconds (ms).
[9] Trial set is a group of trials (10 trials form a trial set)

per set= 100 stimuli) (Figure 3.4). Since there was no particular sequence followed in the stimuli of the random trial set, even at the end of several random trial sets, the reaction time was likely to remain the same. For instance, if the average reaction time was measured for random trial sets 8, 9, and 10, the resulting average reaction time was not likely to be different from the average reaction time for beginning random trial sets 4, 5, and 6. The participant was likely to perform at the same speed in pressing the right response button even towards the end of random trial sets indicating absence of any learning. The second type of trials used was the sequence trials where the trials follow a specific pattern. A total of 20 sequence trial sets were given (making it 200 trials) (Figure 3.4). For instance, 1324124324 and 1324124324 were two trial sets following a same sequence. Since there is a pattern, the participant reacts faster in pressing the button as the trial set increases. For instance, if the average reaction time is measured for sequence trial sets 14, 15, and 16 the resulting average reaction time will be lesser than average reaction time for sequence trial sets 8, 9, and 10. The participant was likely to perform faster in pressing the right response button towards the end of sequence trial sets if there was any sequence learning. Initially 25 random trials were presented as a practise items for which the reaction time was not measured. The random practise items were given for the participant to get hand-eye coordination for spatial motion between picture in screen and button in gamepad, followed by 100 random trials (10 x10 trials). After completion of hundred random trials a break of 2-3 minutes was given following which 200 sequences trials (20x10 trials) appeared. Examiner had no control over appearance of stimuli except for setting the task in motion. However, the break time between random and sequence trials were monitored by the examiner (maximum of 3 minutes only). The administration of AD-SRT task took about 15-20 minutes on an average to complete.

Measuring sequence learning. The average RT of final three random trial sets was noted as random learning average (RLavg). The final thirty random trials were considered for RLavg calculation because if there was any general motor learning and familiarization of the task to be achieved, it was assumed such learning and familiarization would have happened by then. The average RT for sequential trials was made at three interims during the sequential trial administration. The average was made once at trial sets 8, 9, and 10 (noted as sequence learning average 1, i.e., SLavg1), again at trial sets 14, 15, and 16 (noted as sequence learning average 2, i.e., SLavg2) and finally at trial sets 18, 19, and 20 (noted as sequence learning average 3, i.e., SLavg3). The sequence trials were averaged three times at different interims to track the course of learning during sequence learning task. In other words, pattern (progress/regress) in sequence learning. The final score that would demonstrate the presence and effectiveness of sequence learning is index of sequence learning (ISL) which is calculated by subtracting SLavg1 from RLavg (i.e., index of sequence learning = RLavg –SLavg1). The formula for index of sequence learning was generated on the basis of the study by Nissen and Bullemer (1987) and Cleeremans and Jiménez (1998) which suggested that sequence learning on sequence trials would be significantly better after adequate successive trials compared to random trials. They also stated that the reaction time for random trials would be higher than that of sequence trials. Further, if there were sequence learning, then the SLavg1 would be lower than RLavg (for complete descriptions of original AD-SRT task Kuppuraj & Prema, 2013c). To minimize the baseline reaction-time differences between participants, a sequence specific learning effect was calculated using a proportional measure of magnitude comparing the difference between random and sequence RTs, i.e., ISL=RLavg-SLavg1/RLavg+SLavg1 (Cherry & Stadler, 1995; Meulemans et al., 1998). Extracted values such as RLavg, SLavg1, SLavg2, SLavg3, and ISL for TD children and children with SLI were analyzed to investigate their sequence learning skills.

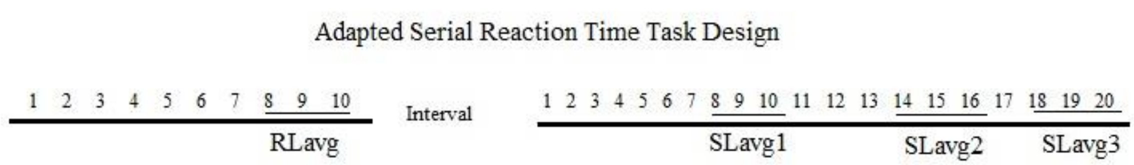


Figure 3.4 The design of AD-SRT task (source: Kuppuraj & Prema, 2013d)

3.2.2 Grammatical tasks (Grammatical aspects of Kannada). Grammatical stimuli used in the present study were in Kannada language. Two native Kannada speakers who are also speech language pathologists constructed sentences with target morphemes used correctly or incorrectly. Wherever the target morpheme was used incorrectly, another sentence was created to present in forced binary choice condition (if the participant failed to revise, explanation under section 3.2.2.2). The stimuli were then scrutinized by a Linguist for its appropriateness. Initially, Kannada morphemes (derivational, inflectional, morpho-syntax) were picked from the book Modern Kannada Language (Sridhar, 2007). Further, morphemes that are acquired were achieved by typical children by the age of 7 (as per Devaki, 1989) were used to develop the stimuli for the study. Kannada is an agglutinating language where inflection operations are significant and require greater relation between words in a sentence.

Example a: Function of inflections relies on knowledge of words/inflections placed further in a word.

ava*nu* na:Le u:rinda barutta:*ne* (/nu/ agree with /ne/, /na:Le/ agree with /ta/)

he tomorrow from home will come

'He will come from home tomorrow'

Example b: The derivations in Kannada would operate less dependent on other words in a sentence like a word from lexicon

avanudzeya:shali ja:gida:ne

he victorious is

'He is victorious'

/dzeyasha:li/ is a derived word from /dzeya/ and it is relatively independent of rest of words.

Grammatical tasks were employed to examine the grammatical knowledge of participants on comprehension/usage of derivational, inflectional and morpho-syntax aspects. Grammatical tasks were divided into stimuli for judgment only and stimuli for judgment and revision for the convenience of analysis. Table 3.4 shows the morphemes from each category used to develop the stimuli sentences for the present study.

Table 3.4

Morphemes used to develop the grammatical stimuli

Der	Morphemes	Inf	Morphemes	MS	Morphemic items
N/N	-ga:ra, -a:, -u, -iga, & -vanta	Pl	-gaLu	Pre	keLage, pakka, orage-, dzote, a:dame:le
N/V	o:, -u, -pu, -aNe, -o:Ne, & -ike	CM	annu, -lli, -a, ige, -ike	C/C/C	-idre, -mattu, -a:dare, -atava, -o:, :iladidre, -ginda
V/N	-isu	AG	-Dida[10]-, -ho:da, -bi:Lutta:		*n=12*
V/V	–a:Du		*n=9*		
Adj/N	-maya, -i:ya, & -ka:ra	A total of 37 morphemes were used to construct the stimuli with 64 sentences. Out of 64, 19 sentences were incorrect and required revision.			
	n=16				

Abb: N/N-noun derived from noun, N/V-noun derived from verb, V/N-verb derived from noun, V/V-verb derived from verb, Adj/N-adjectives derived from noun, Der-derivational morphemes, Inf-inflectional morphemes, MS-morpho-syntax. (See Appendix F for complete stimuli)

Sixty-four sentences were developed for the grammatical test material. The entire stimuli consisted of thirty derivational morphemes (six with judgment and revision), twenty-one inflectional morphemes (nine for judgment and revision) and thirteen morpho-syntax elements (three for judgment and revision). Stimuli[11] for judgment only were grammatically correct sentences embedded randomly in the test material. Stimuli for judgment and revision occurred as catching trial, in other words the stimuli that required revision along with judgment were always grammatically incorrect. Overall, among total sixty-four stimuli, eighteen stimuli needed revision after judgment (incorrect sentences).

A binary forced choice was introduced during administration of stimuli for revision. The binary forced choice (BFC) was used if a participant either failed to judge or revise the stimuli that needed judgment and revision. In the BFC, two sentences were given among

[10] -Dita/-Dida/-ita/-ida has been used interchangeably in the running text. Similarly some allophonic variations of same morphemes are used.

[11] By word stimuli we mean sentences used for testing the knowledge or usage of certain morpheme

which one had the target morpheme used correctly and other had had the target morpheme used incorrectly. The BFC was required to present the target morpheme in both correct and incorrect sentence frame. It gave an opportunity to check if the participant had the representation of that target morpheme. The participants' task was to judge the most appropriate usage of the morpheme by selecting the correct sentence among two. For the complete stimuli used for examining grammatical knowledge, see Appendix F (section 1). A picture description task of a sequential pictures was used to measure the sentence complexity ability of a participant using T-unit measures (Appendix F, section 2).

3.2.2.1. ***Stimuli for judgment***

Procedure. The examiner presented the stimulus orally, as many times as the participant demanded. In case of stimulus with judgment alone, the examiner moved on to the next stimulus when the participant provided a response. A score of "1" was given for judging the sentence as correct and no score "0" was given for judging the stimuli incorrectly (Table 3.5).

Table 3.5

Example of task administration of grammatical judgment

Presentation of stimulus	Participant judgment	Scoring
maguvannu sha:lege karedukonDu child to school take with you	Correct judgment	1
ho:gu ("annu" is used correctly) go 'Take the child with you to school'	Incorrect judgment	0

3.2.2.2 ***Stimuli for judgment and revision***

Procedure. In case of stimulus for revision the presentation was similar to the judgment only condition, where the examiner presented the stimulus orally and repeated ("n" repetitions) on participants' demand. Stimuli for revision were re-presented randomly after completion of presentation of routine stimuli. The random re-presentation was done to rule out any presentation bias. There was a chance of he/she guessing the correct one if a stimuli was repeated twice (i.e., BFC) instantly after his/her initial response.

Participant got the score of "4" if he judged and revised correctly without BFC. The re-presentation of that particular stimulus was not required for such participants. Instances where the participant had judged the stimulus correctly (i.e., judging as incorrect) but failed to revise correctly, the target morpheme was introduced in BFC frame. Participants judging correctly after BFC were given the score of "3". Participants got score of "2" if they judged incorrectly in BFC, provided the judgment was correct for stimuli[12]. A score of "1" was given for judging the stimulus incorrectly but judging it correctly while presented in BFC. In case of incorrect performance on both stimuli judging and BFC condition participants were given no score (Table 3.6).

Table 3.6

Example of administration and scoring of grammatical judgment and revision task

Presentation of stimulus	Participant's Response	Scoring
nanage ti: a:dare ka:fi koDi me tea but coffee give 'Give me tea but coffee' "a:dare" is used incorrectly, therefore revision is required after judgment	Judges and revises correctly	4
Binary forced choice (BFC) *(Which one is more appropriate)*	Judges the stimuli correctly but no attempt to revise or incorrect revision & *correct judgment BFC*	3
nanage te: a:dare kofi koDi me tea or coffee give give me tea or coffee	Judges the stimuli correctly & *incorrect judgment in BFC*	2
(or)	Judges incorrectly & *correct judgment in BFC*	1
nanage te: atava kofi koDi me tea or coffee give	Judges incorrectly & *judges incorrectly in BFC*	0

3.2.3. Grammatical complexity task. Sentence complexity and length of production in the present study was measured using t-unit measures. T-unit has been reported to be an adequate measure of sentence complexity (Hunt, 1964). The T-unit, or minimal terminable unit of language, was intended to measure the smallest word group that could be considered

[12] In such instances it could be a chance factor, therefore, a lower weightage for scoring is given compared to "3".

a grammatical sentence, regardless of how it was punctuated (Hunt, 1964). Sentence complexity measures such as number of T-units and number of clauses per T-unit was measured along with length of production measures such as number of words per t-unit and number of words per clause was used in the present study. Table 3.7 shows the analysis and scoring for various sentence complexity measures followed in the present study.

Table 3.7

Scoring for grammatical complexity task

Utterance transcribed (of a single participant describing the story)	Complexity		Length of production
eraDu na:yi ide adu mo:Lego:skra jagaLa a:Dta ide two dog there they bone fighting for 'Two dogs are there and they are fighting for bone'	1- t unit	2- clauses	No. of words= 22; No. of words / t-unit= 22/4=5.5; No. of words/ clause=22/6=3.6; No. of clauses/t unit=6/4=1.5
ondu chikkamari no:Dta: ide one puppy looking 'One puppy is looking at them'	1- t unit	1- clause	
iveraDu na:yigaLu jagaLa a:Dtidda:ga i: these two dogs when fight chikka mari mu:Leyannu this puppy bone togonDuho:gbiDatte grab the and run 'When these dogs fight, the pully grab the bone and runs'	1- t unit	2- clauses	
iveraDu na:yigaLu sappemari a:gho:gate these two dogs disappointed 'These two dogs get disappointed'	1- t unit	1- clause	
Total	4	6	

At the end of analysis number of t-units, number of words, number of clauses, number of words/t-unit, number of words/clause, and number of clauses/t-unit calculations were used to assess grammatical complexity of a participant (Lu, 2010).

3.3. Analysis of data

The examiner analyzed the responses while he replayed the recorded audio samples of participants and scored as mentioned under sections 3.2.2.1 & 3.2.2.2. Responses on picture narration were transcribed broadly and analyzed for sentence complexity measures (section 3.2.3). The items in different categories (within and across tasks of derivation and inflection) were not equal therefore, an average measure was always considered for statistical analysis. Tables 3.8, 3.9, 3.10, 3.11, 3.12, 3.13, 3.14, & 3.15 show the pattern followed for analysis of grammar aspects and sentence complexity measure. This section also illustrates the terms such as individual judgment, average judgment, individual revision, and average revision that would be used in results section. All the examples show exerted data from five children with SLI who were 8 years old (i.e., from SLI1 group).

Table 3.8

Individual and average judgment of derivational morphemes

P. No	Nouns derived				Verbs derived			Adj derived			Adv derived			**ADJ**
	N	V	Adj	%	N	V	*%*	N	Adj	*%*	N	V	*%*	
	(7)	(4)	(2)		(2)	(2)		(3)	(1)		(2)	(1)		
1	5	2	1	*61.5*	1	2	*75*	2	1	*75*	2	1	*100*	***77.75***
2	5	2	2	*69.2*	1	1	*50*	2	1	*75*	2	1	*100*	***73.55***
3	6	3	2	*84.6*	2	2	*100*	3	1	*100*	2	1	*100*	***96.15***
4	5	3	1	*69.2*	2	1	*75*	3	1	*100*	2	0	*66*	***77.55***
5	5	4	2	*84.6*	2	1	*75*	3	1	*100*	2	1	*100*	***89.9***

Abb: P.No-participant number, N-nouns, V-verbs, Adj-adjectives, Adv-adverbs. ADJ-average derivational judgment.

Italicized are individual derivational judgment scores. ADJ is an average derivational judgment, which comprises average of individual derivational items judged. The maximum values in each category are shown inside the bracket in row two (Table 3.8). For instance, the term “noun” means it is average of scores of nouns derived from nouns, verbs and adjectives (italicized section on left most –nouns derived). Therefore, 61.5% is the score on noun, 75% is the score on verb for the first participant. The average derivational judgment comprises the average scores calculated from scores of derived nouns, verbs, adjectives, and adverbs (Table 3.8)

Table 3.9

Individual and average revision of derivational morphemes (analysis after BFC)

P .No	noun from noun -ga:ra					noun from noun -iga					noun from noun -vanta						ADR*
	+j +r	+j +c	+j -c	-j +c	%	+j +r	+j +c	+j -c	-j +c	%	+j +r	+j +c	+j -c	-j +c	%	Similarly for -pu, -ige, & -ka:ra	
1	-	-	2	-	*50*	-	3	-	-	*75*	-	3	-	-	*75*		***62.5***
2	-	-	-	1	*25*	-	3	-	-	*75*	-	3	-	-	*75*		***50***
3	-	3	-	-	*75*	4	-	-	-	*100*	-	-	2	-	*50*		***62.5***
4	-	-	-	1	*25*	-	3	-	-	*75*	-	-	-	1	*25*		***45.8***
5	-	-	-	1	*25*	4	-	-	-	*100*	-	3	-	-	*75*		***66.6***

Abb: ADR- average derivational revision

ADR in the Table 3.9 comprises of average scores of –ga:ra, -iga, -vanta, -pu, -ige, & -ka:ra. Due to space constrains only revision of three morphemes are shown. Individual derivational revision[13] indicates the percentage score on each individual derivation revised (italicized sections in Table 3.9). The term average derivational revision (ADR) indicates an average of revision scores on all individual derivational revisions.

Table 3.10

Individual and average judgment of inflectional morphemes

P No.	*Plural* (3)	*%*	*Case marker* (5)	*%*	*Tense* (4)	*%*	***AIJ***
1	3	*100*	1	*20*	2	*50*	***50***
2	3	*100*	2	*40*	3	*75*	***66.6***
3	3	*100*	1	*20*	1	*25*	***41.6***
4	2	*66.6*	1	*20*	1	*25*	***33.3***
5	3	*100*	3	*60*	2	*50*	***66.6***

Abb: AIJ-average inflectional judgment

[13]In all the revision tables +j indicates judged correctly, -j indicates judged incorrectly, +c indicates correct response after clue, -c indicates incorrect response after clue.

In the result section individual inflectional judgment indicates the percentage score on plurals, case markers and tenses judged. Average inflectional judgment (AIJ) indicates averaged scores on all three inflections (plurals, case markers, & tenses) (Table 3.10).The revision under inflection was divided into case marker revision and agreement revision (Table 3.11 & 3.12)

Table 3.11

Individual and average case marker revision

P No.	*-a*					*-annu*					*-ige*						***ACMR***
	+j +r	+j +c	+j -c	-j +c	%	+j +r	+j +c	+j –c	-j +c	%	+j +r	+j +c	+j -c	-j +c	%	Similarly for -ige, & -ike, -lli (included for AIJ)	
1	-	-	-	1	*25*	-	-	-	1	*25*	-	-	-	1	*25*		***20***
2	-	-	-	-	*0*	-	-	-	1	*25*	-	-	-	1	*25*		***20***
3	-	-	-	1	*25*	-	3	-	-	*75*	-	-	-	1	*25*		***50***
4	-	-	-	-	*0*	-	-	-	-	*0*	-	-	-	-	*0*		***0***
5	-	3	-	-	*75*	-	-	2	-	*50*	-	3	-	-	*75*		***70***

ACMR- average case marker revision.

The italicized ones are individual case marker revision items. The term average case marker revision indicates average scores of individual case marker revision scores (Table 3.11).

Table 3.12

Individual and average agreement revision

P No.	*-ita(idane)*					*-o:daru/-avaru*						***AAGR***
	+j +r	+j +c	+j -c	-j +c	%	+j +r	+j +c	+j -c	-j+c	%	Similarly for –gaLu and -bi:Lutha	
1	4	-	-	-	*100*	-	-	-	1	*25*		***50***
2	-	3	-	-	*75*	-	-	-	-	*0*		***37.5***
3	-	3	-	-	*75*	-	-	-	1	*25*		***50***
4	-	3	-	-	*75*	-	-	-	1	*25*		***50***
5	4	-	-	-	*100*	-	-	2	-	*50*		***87.5***

Abb: AAGR-average agreement revision

The italicized ones are individual agreement revision items. The term average agreement revisions indicates average scores of individual agreement revision scores (Table 3.12)

Table 3.13

Individual and average morpho-syntax judgment

P. No	*Pre* (3)	*%*	*Con* (4)	*%*	*C/C* (1)	*%*	***AMSJ***
1	3	*100*	2	*50*	0	*0*	***66.6***
2	2	*66.6*	2	*50*	1	*100*	***66.6***
3	3	*100*	3	*75*	1	*100*	***88.8***
4	2	*66.6*	2	*50*	1	*100*	***66.6***
5	3	*100*	4	*100*	1	*100*	***100***

Abb: Pre-preposition, Conj-conjunctions, C/C-comparatives & conditionals, AMSJ-average morpho-syntax judgment

In the result section, the term individual morpho-syntax judgment indicates percentage scores on judgment of each morpho-syntax examined such as preposition, conjunctions and comparatives. Average morpho-syntax judgment indicates average scores of individual morpho-syntax judged correctly (Table 3.13).

Table 3.14

Individual and average morpho-syntax revision

P. No	*olage*					*a:dare*						***AMSR***
	+j +r	+j +c	+j -c	-j+c	*%*	+j +r	+j +c	+j -c	-j+c	*%*		
1	4	-	-	-	*100*	-	-	2	-	*50*	Similarly for –mele & -athava	***68.7***
2	4	-	-	-	*100*	-	-	-	1	*25*		***62.5***
3	4	-	-	-	*100*	-	-	-	-	*0*		***50***
4	4	-	-	-	*100*	-	-	2	-	*50*		***68.7***
5	4	-	-	-	*100*	-	-	-	-	*0*		***50***

Abb: AMSR-average morpho-syntax revision

The italicized ones in Table 3.14 show individual morpho-syntax revision scores in percentage. The average morpho-syntax revision indicates the average scores of all individual morpho-syntax revised (Table 3.14).

Table 3.15

Excerpts from analysis of sentence complexity measures

P. No	T -units	clauses	words	words/ clauses	clauses/ t unit	words/t unit
1	3	4	21	5.2	1.3	7
2	3	6	28	4.6	2	9.3
3	4	7	30	4.28	1.75	7.5
4	2	3	18	6	1.5	9
5	3	5	24	4.8	1.6	8

Table 3.15 shows analyzed narration for sentence complexity measures. In the Table 3.15, it shall be noticed that only t-units, clauses and words were analyzed values (extracted from sample) and rest of the values were calculated values.

After converting the responses in to numerical values appropriate statistical analysis were carried out using SPSS (version 17) to compare between TD and SLI participants on sequence learning and grammatical tasks. Initially to account for chronological age difference, data was divided based on age groups in TD (TD1- >8.0 to ≤ 11.0 years & TD2 - >11.0 to ≤ 13.0 years) and SLI (SLI1 - >8.0 to ≤ 11.0 years & SLI2 - >11.0 to ≤ 13.0 years) group. Even though, the study does not intend to study developmental pattern, the division was made therefore, a reasonable interpretation could be derived keeping in mind the vast age range of participants. If the analysis did not show group and chronological age interaction, they were combined and made a single TD and SLI group. Statistical procedures such as descriptive, analysis of variance, multiple analysis of variance, correlation, discriminant analysis, and factor (principal components) analysis were carried out and results are discussed.

To rule out the examiner bias 10% of the total data was reanalyzed by two other judges (excluding the examiner). Analyzed data was correlated using Chronbach's alpha (α) for reporting on agreement (reliability) between examiners data analysis. Results showed that for the morphemic analysis correlation was good (>.7 at lest), and for grammatical complexity analysis the correlation was acceptable (>.6 at least). The comparatively lower correlation for grammatical complexity analysis could be explained by the agglutinating nature of the language which could have contributed to differential segmentation for various measures by different judges. Over all, the reliability between the judges was good to acceptable (Table 3.16 for "α" correlation values for all the variables)

Table 3.16

Cronbach's alpha correlation between 3 judges

Non-adjacent operations	α	Adjacent operations	α	Sentence complexity	α
plurals	.93	nouns	.76	t-units	.76
case markers	.95	verbs	.92	Clauses	.69
tenses	.91	adjectives	.87	Words	.65
AIJ	.86	adverbs	.89	word/ Clause	.63
-a	.94	ADJ	.86	Clauses/t-unit	.62
-nnu	.97	-ga:ra	.82	Words/t-unit	.60
-ige	.73	-i:ga	.81	α >.7 is good and	
-lli	.93	-vanta	.75	α >.6 is acceptable	
-ike	.81	-pu	.71	(George & Mallery,	
ACMR	.81	-ige	.85	2003; p.231)	
-gaLu	.80	-ka:ra	.86		
-ita	.84	ADR	.71		
-bi:Luta	.72				
AAGR	.78				
prepositions	.90	10% of data was analyzed by 2 SLPs apart from			
conjunctions	.90	the examiner (examiner/judge 1, judge 2 and			
C/C	.82	judge 3 contributed to reliability measures)			
AMSJ	.87				
-me:le	.74				
-olage	.85				
-a:dare	.89				
-atava	.92				
AMSR	.73				

Abb: Average inflections judged, ACMR-average case markers revised, AAGR-average agreements revised, AMSJ-average morpho-syntax judged, AMSR-average morpho-syntax revised, ADJ-average derivations judged, ADR-average derivations revised.

3.4. Modifications after pilot study. The AD-SRT task and grammatical test material were put in to test on five TD children in the age range of 8-13 years (Kuppuraj & Prema, 2012a). The attempt was made to pilot the developed test material. During the pilot study, we observed that participants were not attempting to revise the incorrect stimuli. Therefore, a binary forced choice (BFC) discussed in section 3.2.2.2 was implemented to provide the participants with clue. The AD-SRT task was administered on 98 TD children in the age range of 7-13 years and it was proven that AD-SRT task does measure sequence learning and its progress effectively (Kuppuraj & Prema, 2013c). The study also reported that TCRT task could be used to measure attention and vigilance baseline prior to AD-SRT task administration. The study further showed SLavg1 (but not SLavg2 or SLavg3) was the consistent measure to use for calculating ISL because towards the end of the trials the reactive inhibition interferes with the actual sequence learning. A personal discussion with Dr. Jarrad Lum helped us to calculate the proportional ISL rather than mere difference between RLavg and SLavg1 as a measure of sequence learning quantity (J. Lum[14], personal communication, January 12, 2012). This proportional calculation could moderate motor speed differences among participants. The proportional ISL calculation procedure was proven effective in moderating SDs of RTs in studies that compared sequence-learning quantity of TD and SLI (Kuppuraj & Prema, 2013a).

Part of pilot study intended to check if the faster reaction times among sequence trials followed by random trials were due to accomplishment in general motor learning. In that case, the observed faster performance could not be attributed to sequence learning. To confirm that the faster reaction times observed during sequence trials was procedural and not motoric; an alternative paradigm compared to AD-SRT task was attempted during pilot. During pilot, 10 TD[15] participants were given 100 random trials (named as random learning average 2 or RLavg2) after 200 sequence trials (i.e., 100 random–200 sequence– 100 random). Because, the program of AD-SRT task was not tailored for this type of presentation, a complete presentation was run again after 10 minutes (approx, minimum of at least 7 min) interval. Only RLavg1 and RLavg2 were considered for the analysis. Analysis showed that RTs of random trials (RLavg2, trials $n = 100$) presented after 200 sequence trials were not significantly different from RLavg1 (i.e., first 100 random trials) suggesting that general motor learning achieved ceiling during first 100 random trials and further decrease in RT was due to sequence learning (mean RLavg1 = 687.79, SD = 183.56, mean RLavg2 = 683.64, SD = 189.65, $z=-0.83$, $p = 0.37$).

[14]Dr. Jarrad Lum is a Senior Lecturer in Psychology at Deakin University, Australia. He has conducted several studies using SRT tasks to measure procedural learning in children with SLI (http://www.deakin.edu.au/health/staffprofiles/index.php?username=jarralum).

[15] 1)10 years, male; 2) 8 years, male; 3) 11 years, male; 4) 10 years, male; 5) 9 years, female; 6) 8 years, male; 7) 9 years, male; 8) 10 years, female; 9)12 years, female; 10) 10 years, male (N=10, Mean age: 9.7;SD:1.25).

Chapter 4

Results and Discussion

Procedural deficit hypothesis (PDH) states that children with SLI show sequence learning problems along with language deficits. The present study predicts that certain grammar (non-adjacent) aspects would be in great demand of sequence learning compared to others (like adjacent). Data on sequence learning and various grammar aspects such as derivational (adjacent), inflectional/morpho-syntax (non-adjacent), and sentence complexity measures were taken from 33 TD children and 31 SLI children and analyzed using appropriate statistical procedures for serving the following objectives and research questions

1. Comparison of performance of a group of typically developing (TD) children and children with Specific Language Impairment (SLI) on procedural learning skill

Research question

a) Do children with SLI differ in sequence learning and pattern compared to TD children?

2. Comparison of performance of SLI and TD groups on grammatical tasks

Research questions

a. Do children with SLI perform like TD children on grammatical operations?
b. What are the grammatical markers of SLI among extracted language measures in an agglutinating language?

3. To examine the relation between sequence learning skill and language

Research question

a. Is language learning related to sequence learning skill/what are the aspects of grammar sensitive to procedural memory deficits

4.1. Objective 1: Comparison of performance of a group of children with specific language impairment (SLI) and typically developing (TD) children on procedural learning skill.

The data of both SLI and TD groups were analyzed to study developmental changes, if any, that would have contributed to motor sequence learning. Study by Kuppuraj and Prema (2013c) in which AD-SRT task was standardized on Indian children from 7-13 years showed that chronological age plays a significant role in speed of performance in AD-SRT task. They reported that the performance of children who are above 10 years was significantly faster than those of below 10 years. Therefore, in the present study participants in each group were grouped into two groups of TD1 and SLI1 (chronological age between >8.0 to ≤ 11.0 years in TD and SLI groups) respectively and TD2 and SLI2 (chronological age between >11.0 to ≤ 13.0 years in TD and SLI groups) respectively.

Results on AD-SRT task are discussed under sequence learning quantity and sequence learning pattern. Comparison of ISL (i.e., sequence learning quantity) between TD and SLI groups was made to discuss the, sequence learning quantity of TD versus SLI group. Comparison of the measures of AD-SRT task such as RLavg, SLavg1, SLavg2, and SLavg3 between TD and SLI groups was made to discuss the sequence learning pattern in TD and SLI groups. .

4.1.1. Sequence learning quantity (ISL). The ISL was a calculated proportional score using the RLavg and SLavg1 (for information on measuring sequence learning, method section 3.2.1). Analysis showed that the standard deviations (henceforth referred to as SDs or SD) of ISL were very high. Therefore, median values were included in the results. See Table 4.1.1 for mean, SD, and median of ISL for groups and chronological ages. Comparison of ISL between groups and chronological age was done using Mann-Whitney U test (non-parametric (test) in view of high SD (Table 4.1.1).

Table 4.1.1

Mean, SD, and median of ISL for SLI and TD groups

Par	SLI group						TD group					
	SLI1 (n=18)			SLI2 (n=13)			TD1 (n=17)			TD2 (n=16)		
ISL	M	SD	Med	M	SD	Med	M	SD	Med	M	SD	Med
	0.003	0.03	0.005	0.03	0.04	0.02	0.09	0.08	0.09	0.11	0.07	0.12

Abb: Par-parameter, ISL-index of sequence learning, M-Mean, Med- Median

Results on Mann-Whitney U test showed that ISL of SLI group was significantly lower than that of TD group, (z=-4.49, p=0.00). Comparison of chronological age between groups revealed that the ISL was significantly lower between TD1 and SLI1 (SLI<TD1), (z=-3.53, p =0.00) as well as between TD2 and SLI2 (SLI2<TD2) (z=-2.83, p=0.00). Significant difference was also seen for ISL between SLI1 and SLI2 (SLI2 > SLI1; z=-2.00, p=0.04) but, no significant difference was observed between TD1 and TD2 (z=-0.84, p=0.39) (Figure 4.1.1).

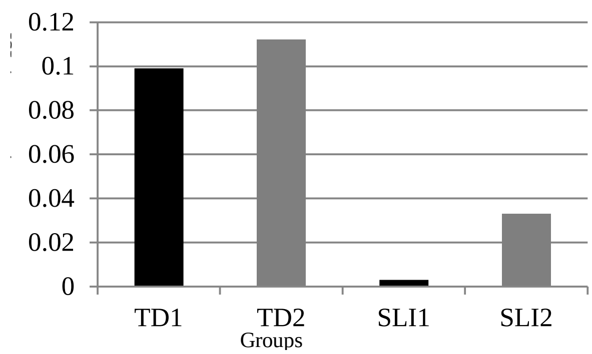


Figure 4.1.1 Mean scores of ISL for TD1, TD2, SLI1, and SLI2 groups

4.1.2. Sequence learning pattern: This section compares the performance of AD-SRT task between SLI and TD groups using MANOVA. The variables are the averages on AD-SRT task and chronological age and groups.

4.1.2.1. Performance on AD-SRT task by TD and SLI groups. The mean and SD of parameters from AD-SRT task is given in Table 4.1.2 & 4.1.3. Both RLavg [F (1, 60) =

8.13, p=0.01] and SLavg1 [F (1, 60) =29.569, p=0.00] for SLI was significantly higher[16] (indicating faster performance) compared to TD group in MANOVA. SLavg2 for SLI was significantly higher than TD group, [F (1, 60) = 39.70, p=0.00]. SLavg3 was significantly higher for SLI group compared to TD group, [F (1, 60) = 32.65, p=0.00]. All the averages such as RLavg, SLavg1, SLavg2, and SLavg3 were significantly different for chronological ages, i.e., >11.0 to $\leq$ 13.0 years were faster than >8.0 to $\leq$ 11.0, [RLavg (F (1, 60) = 7.09, p=0.01; SLavg1 (F (1, 60) = 10.763, p=0.00; SLavg2 (F (1, 60) = 8.321, p=0.01; SLavg3 (F (1, 60) =7.319, p=0.01)] (Table 4.1.2 & 4.1.3). In sum, all the parameters of AD-SRT task were significant for groups and chronological ages (in MANOVA) (Figure 4.1.2, 4.1.2. a-d).

The main effect of group was significant for RTs of AD-SRT task in within subjects [F (3, 180) = 16.29, p=0.00]. The main effect of age was not significant for RTs of AD-SRT task performance, [F (3, 180) =0.69, p=0.56]. Interaction effect between group and RTs of AD-SRT task was significant, [F (3, 180) = 19.59, p=0.00] in results of mixed ANOVA. Between subjects effects showed that SLI group was significantly lower compared to TD group on RTs of AD-SRT task [F (1, 60) =30.68, p=0.00]. RTs on chronological age >11.0 to $\leq$ 13.0 years were significantly better (faster performance/lesser values) compared to RTs on chronological age >8.0 to $\leq$ 11.0 years irrespective of groups, [F (1, 60) =9.47, p=0.00]. Meanwhile, no interaction between group and chronological age (group*age) on RTs of AD-SRT task was demonstrated in between subjects effects [F (1, 60) = 1.696, p=0.19].

Table 4.1.2

Mean and SD of AD-SRT averages for SLI and TD groups

Parameter	SLI group				TD group			
	SLI1 (n=18)		SLI2 (n=13)		TD1 (n=17)		TD2 (n=16)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RLavg	847.0	135.5	723.9	143.5	716.6	187.4	635.7	133.2
SLavg1	850.1	155.9	678.6	145.4	594.4	176.7	510.0	134.6
SLavg2	882.5	195.6	697.0	148.2	546.3	186.4	477.3	156.8
SLavg3	966.5	266.8	739.8	137.1	584.6	189.6	532.3	183.1

[16] Higher RT suggesting slower performance.

Table 4.1.3

Total mean and SD for groups and chronological age

Parameters	Group total (n=64)				Chronological age Total (n=64)			
	SLI (n=31)		TD (n=33)		>8.0 to < 11.0 yrs (n=35)		>11.0 to < 13.0yrs (n=29)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RLavg	795.42	149.90	677.42	166.05	783.74	173.47	675.25	142.57
SLavg1	778.22	172.17	553.55	161.08	725.96	208.97	585.62	161.39
SLavg2	804.72	197.84	512.86	173.59	719.21	254.08	575.81	186.99
SLavg3	871.48	246.60	559.27	185.51	781.05	300.08	625.34	192.50

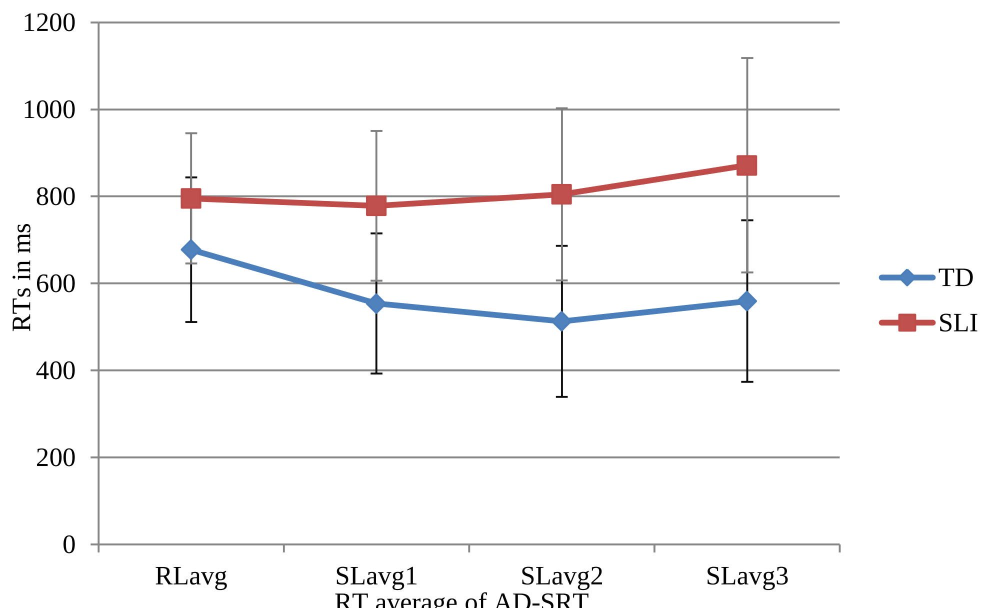


Figure 4.1.2 Comparison between SLI and TD groups on AD-SRT averages

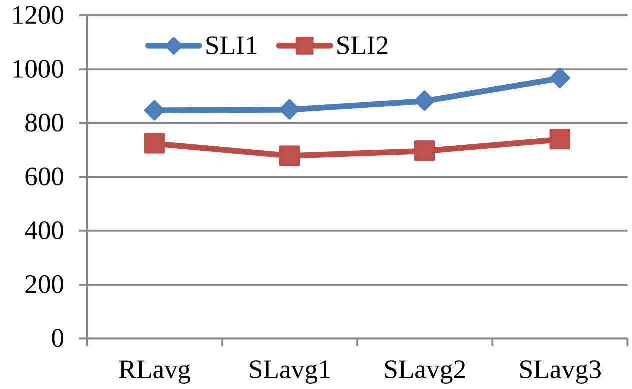


Figure 4.1.2 a Comparison between SLI1 and SLI2 on AD-SRT averages

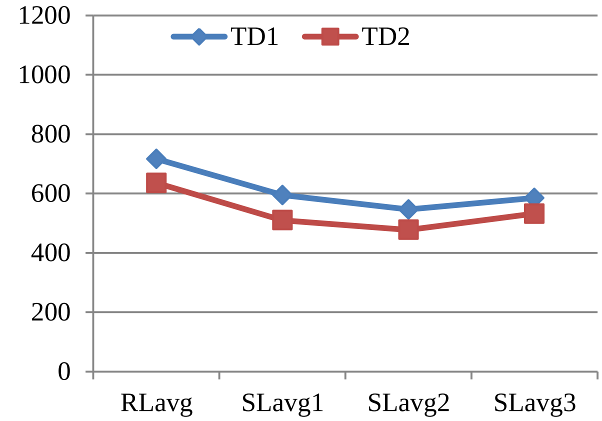


Figure 4.1.2 b Comparison between TD1 and TD2 on AD-SRT averages

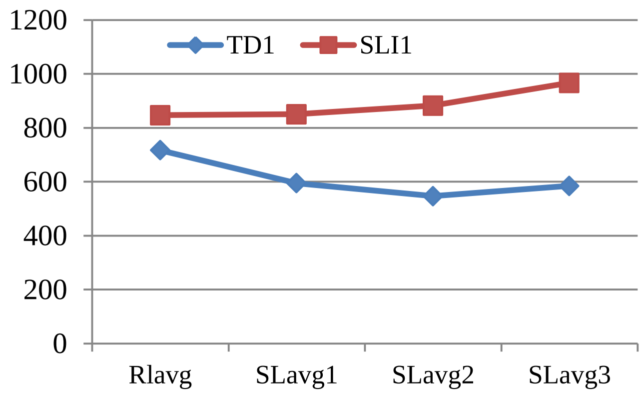


Figure 4.1.2 c Comparison between SLI1 and TD1 on AD-SRT averages

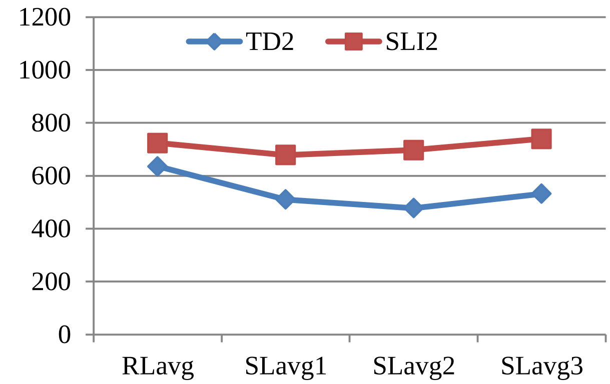


Figure 4.1.2 d Comparison between SLI2 and TD2 on AD-SRT averages

To study the pattern of sequence learning within each chronological age of TD and SLI group, one way repeated measures ANOVA was done.

4.1.2.3. Performance on AD-SRT task within SLI group. Within the SLI group, for SLI1 (age group >8.0 to $\leq$ 11.0 years) difference was seen on AD-SRT average, [F(3, 51) = 7.12, p=0.00]. Pair-wise comparison revealed no difference between the RLavg (Mean: 847.07) and SLavg1 (Mean: 850.17) (p=1.00), even though SLavg2 (Mean: 882.51) and SLavg3 (Mean: 966.56) were different from RLavg values. SLavg3 was lower than SLavg2 (p=0.116) indicating that sequence learning has not taken place immediately unlike TD group of >8.0 to $\leq$ 11.0 years (Table 4.1.3). However, the mean score shows that SLavg2 and SLavg3 were lower than SLavg1 suggesting that the sequence learning has not taken place in SLI1.

For SLI2 (age group >11.0 to $\leq$ 13.0 years) no difference was seen on AD-SRT average [F (3, 36) = 2.12, p=0.114]. Pairwise comparisons revealed that only SLavg1 (Mean: 678.60) was lower than RLavg (Mean: 723.90). However, SLavg2 (Mean: 697.01) and SLavg3 (Mean: 739.83) were not different from RLavg value. Results of this pattern suggest that learning happened initially like TD children; however, it declined as trials progressed. A closer look at the results shows that the decline happened even before SLavg2 in SLI2 (where as the decline began at SLavg3 in TD). For the SLI1 group, the SLavg1 (Mean= 850.1) was not different from RLavg (Mean= 847.0). Further progress in trials did not bring any improvement in RTs, rather it declined with trials (SLavg2, mean =882.51 & SLavg3, mean= 966.56). SLavg3 (Mean= 966.5) did not show any difference compared to SLavg2 for SLI1 group.

4.1.2.2. Performance on AD-SRT task within TD group. For the chronological age group >8.0 to $\leq$ 11.0 years (TD1), AD-SRT averages differed significantly from each other, [F(3,48)=15.04, p=0.00]. Pair wise comparisons revealed that SLavg1, SLavg2, and SLavg3 were significantly better than RLavg in TD1. For the chronological age group >11.0 to $\leq$ 13.0 years (TD2), AD-SRT averages were significantly different from each other, [F(3,45)= 20.42, p=0.00]. Pair wise comparisons revealed that SLavg1, SLavg2, and SLavg3 were significantly better than RLavg in TD2. For the TD1 group SLavg1 (Mean=594.4) was significantly better (faster in this case) than RLavg (Mean=716.6) showing significant initial sequence learning (p=0.00). As the trials progressed the sequence learning diminished in this group, i.e., SLavg2 (Mean=546.3) was not significantly better than SLavg1 (Mean=594.4, p=0.13), even though SLavg2 was better than SLavg1 (without statistical significance). Similarly, SLavg3 (Mean=584.6) was not significantly different (p=0.29) when compared to SLavg2 (Mean= 546.3). It could be noted that SLavg3 value has declined (increased in RT) compared to SLavg2. Therefore, in summary, TD1 group showed significant initial sequence learning followed by insignificant learning which ended in declining of sequence learning performance. In the TD2 group, SLavg1 (Mean=510.0) was significantly faster than RLavg (Mean=635.7 & p=0.00) suggesting that initial sequence learning was present substantially in this age group of TD children as well. SLavg2 (Mean= 477.3) of TD2, got better than SLavg1 however, the improvement was not significant (p=0.18). Unlike TD1, TD2 group showed significant worsening of SLavg3 (Mean=532) compared to SLavg2 (Mean= 477.3, p=0.04). To sum up, both the TD groups showed significant initial sequence learning, followed by decline in learning. The decline was non-significant in TD1 and significant in TD2.

To summarize, the sequence-learning pattern of SLI group was slightly different compared to TD group. The SLI1 (>8.0 to $\leq$ 11.0 years) group did not show any sequence learning with increase in the number of trials. Moreover, the RT declined with increase in trials. SLI2 (>11.0 to $\leq$ 13.0 years) group did show significant improvement in SLavg1 (Mean= 678.6) compared to RLavg (Mean=723.9, p=0.03) suggesting the likelihood of beginning of the sequence learning. However, the results on sequence learning quantity showed that it was significantly lower in SLI2 than TD2 (poor sequence learning quantity). In the SLI2 group after SLavg1, the learning declined through SLavg2 (Mean= 697.0) till SLavg3 (Mean= 739.8) (note the difference was not significant). To summarize, SLI1 did not show any sequence learning throughout the SRT task and the performance also declined as the trials progressed. The SLI2 group showed initial sequence learning, like their chronological age counter parts (TD2), but as the trials progressed, they showed pattern similar to SLI1. It should be noted that the improvement in performance for SLavg1 compared to RLavg in SLI2 should not be interpreted as adequate sequence learning since the ISL (measure of sequence learning) for SLI2 was significantly lower compared to TD2 (section 4.1.1).

The scores on sequence learning measure such as SLavg1, SLavg2, SLavg3, and ISL of all four groups (SLI1, SLI2, TD1, & TD2) were subjected to discriminant function analysis. RLavg values were not included, as they do not signify sequence learning. 92.3% of the variables of AD-SRT task were loaded into first discriminant function (DF1) [Wilks' λ = 0.439, $\chi 2(12) = 48.5$, p = 0.00], 6% into second discriminant function (DF2) [Wilks' λ = 0.196, $\chi 2(6) = 5.184$, p = 0.52], and only 1.7% into third discriminant function [Wilks' λ = 0.980, $\chi 2(2) = 1.186$, p = 0.55]. Tables 4.1.4 a, b, & c show standardized canonical discriminant function coefficients, structure matrix coefficients, and functions at group centroids of sequence learning performance respectively.

Table 4.1.4

Discriminant function analysis for AD-SRT task

4.1.4.a

Standardized Canonical Discriminant Function Coefficients

Measure	Function		
	1	2	3
SLavg1	-.10	1.95	-.72
SLavg2	.46	-1.06	-.66
SLavg3	.36	-.16	1.75
ISL	-.46	.64	.36

4.1.4.b

Structure Matrix Coefficients (correlation <0.3 was not considered)

Measure	Function		
	1	2	3
SLavg2	.91*	.23	.04
SLavg3	.84*	.25	.46
SLavg1	.82*	.56	-.07
ISL	-.75*	.31	.42

Table 4.1.4.c

Functions at Group Cendroids of sequence learning performance

Measure	Function		
	1	2	3
SLavg1	-0.75	0.30	-0.12
SLavg2	-1.08	-0.14	0.17
SLavg3	1.39	0.13	0.08
ISL	0.37	-0.39	-0.16

The correlation between variables and discriminant functions revealed that all the variables were loaded into DF1 starting from SLavg2 (r=0.91), SLavg3 (r=0.84), SLavg1(r=0.82), & ISL (r=-0.75). DF2 and DF3 did not have any variables loaded to them. Discrimination function plot shows that DF1 clearly discriminated SLI and TD groups with the highest loading factor (92.3%). Classification results based on discriminant functions revealed that 59.4% of the participants were correctly grouped. 66.7% of participants in SLI1, 61.5% of participants in SLI2, 41.2% of participants in TD1, and 68.8% of participants in TD2, showed predicted group membership. To summarize, the discriminant function analysis shows differentiation between groups at least through one function, the discrimination through other function was not clear for AD-SRT task between SLI and TD groups (Figure 4.1.3).

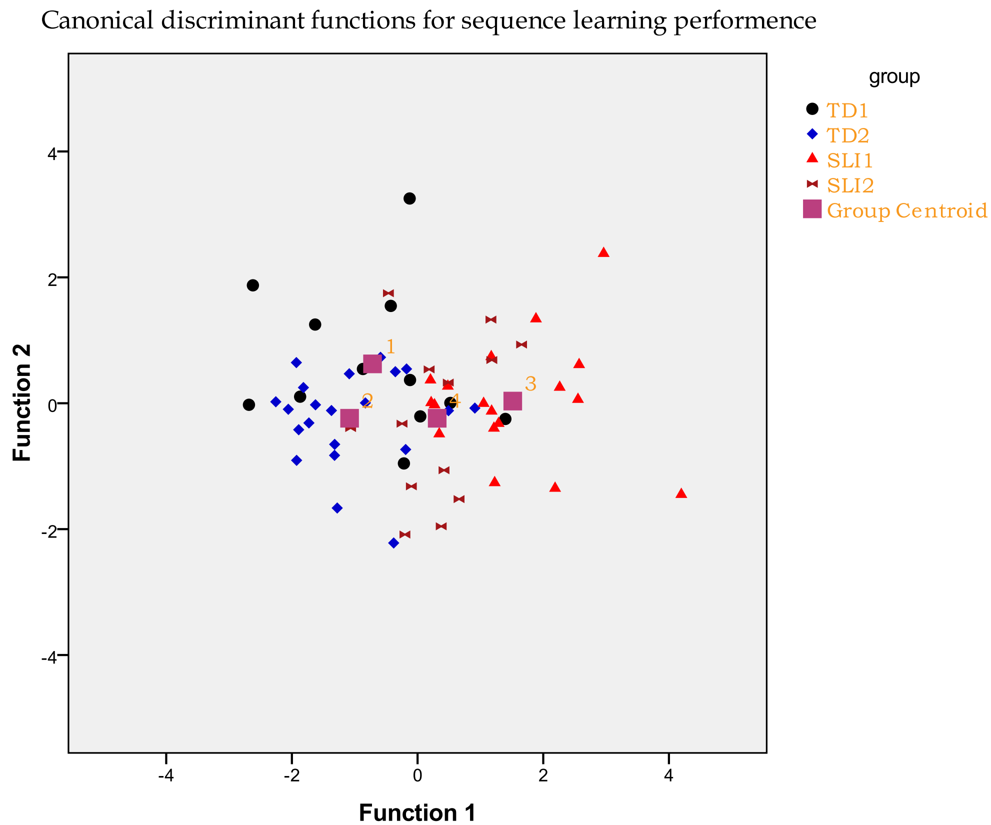


Figure 4.1.3 Combined group plot for canonical discriminant functions of sequence learning performance

4.1.3. Discussion

4.1.3.1. Sequence learning performance (quantity). Within the TD group, the sequence learning quantity was similar for both the chronological age groups. However, SLI group showed improvement in ISL quantity with increase in age, i.e., SLI2 > SLI1. This is consistent with the improvement SLI2 participants showed in SLavg1 compared to RLavg. Kuppuraj and Prema (2013c) while standardizing the AD-SRT task reported that TD children over ten years of age perform better compared to children lower than ten years of age on sequence learning measures of AD-SRT task. Findings on TD children in the present study are in contrast to the study by Kuppuraj and Prema (2013c). This could be due to the methodological differences between the present doctoral study and study by Kuppuraj and Prema (2013c) in calculating the ISL. In their earlier study, Kuppuraj and Prema used a mere difference between SLavg1 and RLavg for deriving ISL, where as in the doctoral study a proportional value[17] was considered which could have reduced the variations in ISL (Kuppuraj & Prema, 2013d; 2013a). Stanger & Gridina (1999) claim that maturation must play an important role in sequence learning performance during early adolescence. However, the results on TD children of the present study showed evidence against it. The reason could be that, the task was relatively easy compared to traditional SRT task (Nissen & Bullemer, 1967), since AD-SRT task is a simple eight digit sequence appearing several times (unlike in traditional SRT task where the sequences are merged amidst random trials). Therefore, even TD1 participants could perform on SRT task with the mean score reaching the maximum scores. In the SLI group, SLI2 participants showed better performance compared to SLI1. This suggests that the task SLI children could vary in their performance on AD-SRT task. In other words, the task showed scope for improvement in sequence learning quantity among SLI groups. In spite of older SLI participants (SLI2) performing better than younger SLI participants (SLI1) both the age groups of SLI (SLI1 & SLI2) were significantly lower than TD group (TD1 & TD2) in sequence learning quantity indicating poor sequence learning performance by children with SLI.

The results of present study are in consonance with procedural deficit hypothesis (Ullman & Pierpont, 2005), which states that children with SLI exhibit sequence learning problems. Poor sequence learning in children with SLI have been reported by several other studies using variations of SRT tasks (e.g., Lum et al., 2010, 2012; Tomblin et al., 2007; Hedenius et al., 2011, Kuppuraj & Prema, 2013d). The results of the present study suggesting sequence learning skill differences between TD and SLI group is in contrast with the findings reported by Gabriel et al. (2011), Gabriel et al. (2012) and Gabriel et al. (2013).

The contrasting results of the present study and studies that reported evidence in favor of PDH with studies by Gabriel and colleagues could be differences in the test paradigms used to measure sequence learning. Gabriel's study used a probabilistic rather than deterministic SRT paradigm to simulate natural language structures. The sequences

[17] ISL=RLavg-SLavg1/RLavg+SLavg1

were lesser in number and the response mode was touch screen in Gabriel's study (unlike usual SRT task where the response mode is through gamepad). The cognitive load required for performance of sequence learning task in Gabriel et al. study could have been nullified (at least minimalised) by the lesser sequences to learn and easier response mode. Gabriel et al. (2013) also mentioned about such differences contributing to differences in SRT studies. Furthermore, Lum, Conti-Ramsden, Morgan, and Ullman (2013) conducted a meta-analysis of studies that used SRT task to report on the reason behind various test findings on SRT task in children with SLI. Lum and colleagues concluded that the larger number of trials, higher age of participants and smaller effect sizes were the reason why some studies did not show sequence learning problems in SLI. In sum, the results on AD-SRT task of present study are in favour of procedural deficit hypothesis proposed by Ullman and Pierpont (2005).

4.1.3.2. Sequence learning pattern. As discussed earlier both the SLI groups showed significantly poor sequence learning quantity compared to their TD counterparts. TD children (both TD1 & TD2) demonstrated similar pattern in AD-SRT task that is significant initial sequence learning followed by decline. SLI1 >8.0 to ≤ 11.0 years group) showed no trace of sequence learning, however, SLI2 produced pattern similar to TD group (only the pattern, not the quantity). The sequence learning pattern observed in the present study could be compared to learning pattern studied by Tomblin et al. (2007). Tomblin and colleagues studied sequence learning pattern in adolescents with TD and SLI. TD adolescents showed typical learning pattern of a log function where the learning was rapid initially followed by gradual increment towards asymptote. SLI participants in Tomblin's study showed initial slowness in sequence learning followed by rapid learning and their learning never approached asymptote. General conclusion on Tomblin's study was that adolescents with SLI exhibited slow sequence learning compared to TD adolescents in initial phases. In the present study, the SLI1 showed no sequence learning and SLI2 group showed pattern similar to TD counterparts. In other words, as the SLI children got older they begin to show sequence-learning pattern similar to TD children in AD-SRT task; even though, the quantity was not on par with TD counterparts. Kuppuraj and Prema (2013a) compared performance of TD and SLI children on sequence learning pattern using AD-SRT task and reported that sequence learning in TD children progressed rapidly and significantly till SLavg2 (till 160th trial) and learning started to decline and reached an asymptote towards the end. The sequence learning of SLI group began slower than their TD counterparts and it reached asymptote sooner than TD children did. To simplify, Tomblin et al. (2007) reported of very slow sequence learning in children with SLI, but Kuppuraj and Prema reported that children with SLI showed slow and less progress in sequence learning. Kuppuraj and Prema attributed the differential pattern of SLI children to lack of complacency in the procedural system. The results of SLI1 group of present study could be compared to SLI group's performance reported in an earlier study by Kuppuraj and Prema (2013a) but in contrast to Tomblin et al. (2007). Similarly, SLI2 group of present study showed similarity to Tomblin et al. (2007), that was in contrast to Kuppuraj and Prema (2013a). Another interesting finding was that that needs to be explored further was that the performance reached maximum by SLavg2, but showed a decline instead of a plateau until SLavg3 in both TD and SLI2. This observation could be reasoned from psychomotor phenomenon called reactive inhibition (Hull, 1951). Reactive inhibition reduces the non-reinforced motor performance after repeated trials, which could happen when the participants repeat the same motor pattern several times as in AD-SRT task. Kuppuraj & Prema (2013c) reported of such reactive inhibition in AD-SRT task. The fact that sequence learning has not taken place in children with SLI could also be explained using absence of reactive inhibition in them. That is, the performance was worsening even before SLavg3 was calculated. To summarize, the present study provides evidence that sequence learning pattern is deviant at least for SLI1 compared to sequence learning pattern of TD1. With increase in age, the SLI participants begin to show the pattern similar to TD counterparts, yet performing lower than TD children.

4.2. Objective 2: Comparison of SLI and TD participants on grammatical abilities.

Grammatical (morphemic) operations such as adjacent (derivational) and non-adjacent operations (inflectional & morpho-syntax) along with sentence complexity measures were analyzed to compare between SLI and TD groups on their grammar abilities. Results are discussed from procedural memory deficits (see discussion). Further a factor analysis (principal component analysis) was carried out to derive (if any) specific clinical marker/s for SLI.

4.2.1. Performance on adjacent operations (derivational morphemes). Derivational operations in Kannada are adjacent operations where they do not require greater relation between words in a sentence. Results on derivational task in the present study are reported under two sections. The first section reports results for derivational morphemes that require judgment only and the second section reports results for derivations that require judgment and revisions.

The groups were made into two chronological age groups in each group of SLI & TD (>8.0 to $\leq$ 11.0 & >11.0 to $\leq$ 13.0 years) to report on any developmental changes that could be contributing to performance on grammatical abilities. The analysis was conducted for individual derivations judged (two way ANOVA), individual derivations revised (cross tabs), average derivational judgment (two way ANOVA) and average derivational revision (two way ANOVA). Table 4.2.1 shows the derivational morphemes used in calculating average derivation judged and revised.

Table 4.2.1

Particulars of abbreviations/clarifications in derivational morpheme section

Abbreviation	Expansion	Description
ADJ	Average Derivational Judgment	Average scores of judgment on noun, verb, adjective and adverb derivations
ADR	Average Derivational Revision	Average scores of revision of *–ga:ra, –iga, –vanta, –pu, –ige,* & *–ka:ra*

4.2.1.1. Judging derivations.

Individual derivational judgment (judging derivational morphemes). Table 4.2.2 & 4.2.3 shows the Mean and SDs of SLI and TD groups for derived morphemes given for judgment.

Table 4.2.2

Mean and SD for derivations judged by SLI groups

Derivation	SLI1 (n=18)					SLI2 (n=13)				
of	Mean	SD	Std.Er	LB	UB	Mean	SD	Std.Er	LB	UB
Noun	77.75	9.10	2.45	73.00	82.84	82.82	12.23	2.94	77.15	88.96
Verb	87.50	17.67	2.98	81.86	93.84	92.30	15.76	3.58	85.03	99.41
Adj	87.50	12.86	2.54	82.42	92.65	94.23	10.96	3.05	88.86	101.13
Adv	94.33	13.03	2.14	90.29	98.90	94.76	12.76	2.57	88.79	99.12

Table 4.2.3

Mean and SD for derivations judged by TD groups

Derivation	TD1 (n=17)					TD2 (n=16)				
of	Mean	SD	Std.Er	LB	UB	Mean	SD	Std.Er	LB	UB
Noun	92.75	12.012	2.50	88.12	98.19	96.15	6.88	2.58	90.78	101.16
Verb	96.07	11.09	3.05	90.15	102.41	100.00	0.00	3.14	93.68	106.31
Adj	97.05	8.30	2.60	91.98	102.45	96.87	8.53	2.68	91.55	102.33
Adv	100.00	0.00	2.19	95.59	104.40	100.00	0.00	2.26	95.46	104.54

Abb: Std.Err-standard error, Adj-adjective, Adv-adverb, LB-lower bound, UB-upper bound

Comparison between SLI and TD groups on judging derivational morphemes was done by two way MANOVA (Table 4.2.4). Wilk's λ for group had significant effect in judging derivational morphemes [λ=0.590, F (8, 98) = 3.700, p=0.001, η^2 =0.232]. However, chronological age did not show significance in judging derivational morphemes [λ=0.621, F (16, 150.335) = 1.587, p=0.079, η^2 =0.112]. Further, the group and age interaction (group*age) was absent in judging derivational morphemes [λ=0.825, F (16, 150.33) = 0.508, p=0.872, η^2 =0.047]. Children with SLI performed significantly lower compared to TD group on judging all the derivatives except on adverb derivation [noun: F(2,52)=14.85, p=0.00; verb: F(2,52) = 3.27, p=0.04; adjective: F(2,52)= 3.63, p=0.03; adverb: F (2,52)=3.10, p=0.05]. Chronological age did not show significant difference on any of the derivational judgments except for verb derivation with >8.0 to $\leq$ 11.0 years performing lower than >11.0 to $\leq$ 13.0 years [F (2, 52)= 2.68, p=0.04]. Interaction between group and chronological age was absent for all derivational judgments (Table 4.2.4). To summarize, children with SLI performed significantly lower compared to TD children on judging majority of derivational morphemes (except for adverb derivation).

Table 4.2.4

Comparison between SLI and TD groups on individual derivational judgment (F- values of two way MANOVA)

Derivations judged		df, 52	Mean square	F	Sig	η^2
Group	Noun	2	1578.46	14.85	0.00	0.36
	Verb	2	516.17	3.27	0.04	0.11
	Adj	2	417.63	3.63	0.03	0.12
	Adv	2	252.14	3.10	0.05	0.10
CA	Noun	4	145.60	1.37	0.25	0.09
	Verb	4	422.37	2.68	0.04	0.17
	Adj	4	97.33	0.84	0.50	0.06
	Adv	4	80.67	0.99	0.42	0.07
Group & CA*	Noun	4	30.15	0.28	0.88	0.02
	Verb	4	91.31	0.58	0.67	0.04
	Adj	4	28.22	0.24	0.91	0.02
	Adv	4	80.67	0.99	0.42	0.07

Abb: Adj-adjective, Adv-adverb, CA-chronological age

Average derivational judgment. Comparison between SLI and TD groups on averaged derivational judgment performance was done by two way ANOVA. Results are displayed in Table 4.2.5 and Figure 4.2.1. Results showed that children with SLI performed significantly lower compared to TD group on average derivational judgment [F (2, 52) = 13.178, p=0.000, η^2=0.33]. Chronological age had no significant effect [F (4, 52) = 1.179, P=0.331, η^2=0.08] and group/age interaction was absent [F (4, 52) = 0.168, p=0.954, η^2=0.01] (Table 4.2.5).

Table 4.2.5

Comparison of SLI and TD groups on average derivational judgment (F-values of two way ANOVA)

Groups	Mean	SD	Std.Er	LB	UB	Group SLI<TD	CA	Group & CA*
SLI1	82.84	9.98	1.98	79.15	87.12	F(2,52)=	F(4,52)=	F(4,52)=
SLI2	87.79	8.24	2.38	83.15	92.71	13.178,	1.179,	0.168,
TD1	95.07	7.85	2.03	91.27	99.42	p=0.00,	P=0.33,	p=0.954,
TD2	96.86	5.80	2.09	92.63	101.04	η^2=0.33	η^2=0.08	η^2=0.01

Abb: Std. Er-standard error, LB-lower bound, UB-Upper bound, CA-chronological age

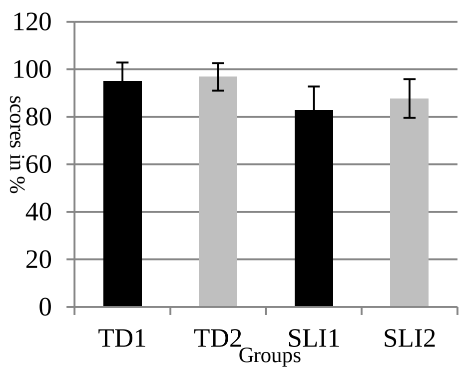


Figure 4.2.1 Comparison of SLI and TD groups on average derivational judgment

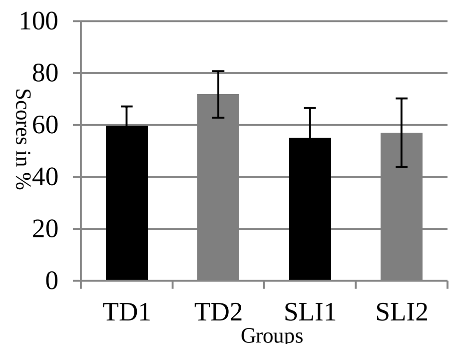


Figure 4.2.2 Comparison of SLI and TD groups on average derivational revision

4.2.1.2 Revising derivations

Average derivational revision. Scores of all the morphemes required revision were averaged (average derivation revised) and compared between groups and chronological ages using two way ANOVA. The descriptive values and F statistics of average derivative revisions are shown in Table 4.2.6.

Table 4.2.6

Descriptive and F values of average derivational revision for SLI and TD groups

Groups	Mean	SD	Std.Er	LB	UB	Group SLI<TD	CA	Group & CA*
SLI1	55.06	11.48	2.512	49.980	60.061	F(2,52)	F(4,52)	F(4,52)
SLI2	57.01	13.21	3.014	50.771	62.865	=8.095,	=1.004,	=.376,
TD1	59.76	7.35	2.570	54.851	65.165	p=.001,	P=.414,	p=.825,
TD2	71.80	8.93	2.649	66.655	77.287	η^2=.237	η^2=.072	η^2=.028

Abb: Std. Er-standard error, LB-lower bound, UB-upper bound, CA-chronological age

Between subjects effects showed that group was significant for average derivations revised, that is SLI was significantly lower compared to TD in revising derivations [F(2,52) =8.095, p =0.001, η^2 = 0.237]. Chronological age had no significant effect [F (4, 52) =1.004, P=0.414, η^2=0.072]. The interaction between group and chronological age (group * age) was absent [F (4, 52) = 0.376, p=0.825, η^2=0.028]. The Figure 4.2.2 shows the difference between SLI and TD groups on average derivational revision.

Individual derivations revised. Frequency of distribution using crosstabs was calculated for every derivational morpheme that required revision. As reported earlier (under the section 4.2.1.2) when the average was taken derivational revisions did not show chronological age wise difference; therefore, for individual derivational revisions groups were merged and single TD (n=33) and SLI (n=31) group was considered. On the x-axis of the Figure 4.2.3 a till 4.2.3 f, marks on “0” indicate number of participants neither revised nor judged even after the clue (binary forced choice in method section 3.2.2.2, Table 3.6) in each group. Mark on “25” indicates number of participants who did not judge the stimulus but revised after clue in each group. Mark on “50” indicates number of participants who judged the stimulus but did not revise after clue in each group. Mark on “75” indicates number of participants who judged (on their own) and also revised with clue in each group (for explanation on clue see two choice judgment frame in method section 3.2.2.2, Table 3.6). Marks on “100” indicates number of participants judged and revised on their own in each group. The results are displayed in Figure 4.2.3 (a-f).

Results show that no difference between SLI and TD was observed for revision of –*ga:ra*. Both the groups found difficulty in revising it. None of the participants from either TD or SLI scored 100, and both the groups peaked at 25 (Figure 4.2.3 a). On revising –*iga*, number of TD children scored 100 were compared to SLI children, otherwise a similar pattern between TD and SLI was observed in deriving –*iga* (Figure 4.2.3 b). SLI has more participants at 25 for –*vanta* compared to TD. Whereas TD has peaks at 75 and 100, suggesting a clear distinction in revision performance between SLI and TD on revision of –*vanta* (Figure 4.2.3 c). Revision of –*pu* did not show major difference between SLI and TD participants. However, TD had more participants scored 100 compared to SLI (Figure 4.2.3 d). Revision of –*ige* was similar to –*vanta* where more SLI participants scored 25, with more TD participants scored either 75 or 100 (Figure 4.2.3 e). Performance of –*ka:ra* showed that children with SLI performed towards 25 and TD performed towards 50. While deriving –*ka:ra*, none of the participants from either of the groups scored 100, suggesting that it was difficult for both SLI and TD participants (Figure 4.2.3 f). Except for –*vanta* (Figure 4.2.3 c) and –*ige* (Figure 4.2.3 d) none of the derivational morphemic revision of SLI children showed clear discriminant pattern from TD children (Figure 4.2.3 a, b, e, & f). For revision of –*vanta* and –*ige* children with SLI show peak early, which means that more participants in SLI group revised only with clue. In other words, they did not revise –*vanta* and –*ige* at all, rather they judged with the help of examiner (with two choice judgment frame). To summarize, results showed that SLI and TD groups were overlapping in their revision performance of derivational morphemes (except for –*vanta & -ige*). In other words, only some revisions of derivational morphemes were difficult for SLI participants.

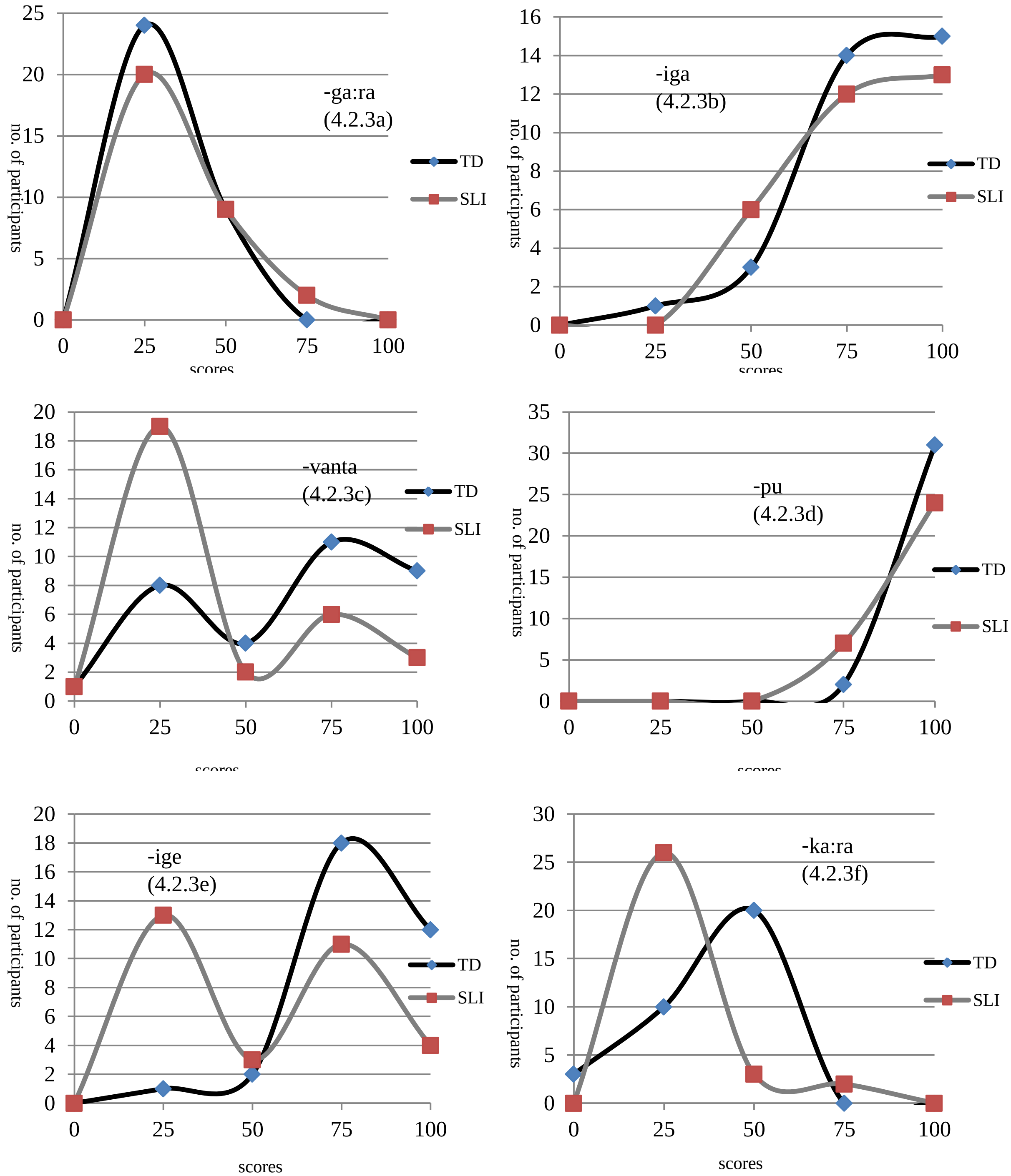


Figure 4.2.3 (a –f). Frequency of distribution of SLI and TD groups on revising *–ga:ra* , *–iga* , *–vanta*, *–pu* ,–ige, & *–ka:ra*

The chronological age-wise division in both the groups (SLI & TD) did not show significant difference; therefore, the chronological ages were combined and formed a single TD and single SLI group and analysis was run (see below). The total number of participants in TD group was 33 and SLI group was 31 for this section of analysis. Scores on noun, verb, adjective, and adverb derivations along with average revision and judgment scores of derivational morphemes of both the groups were analyzed using one way ANOVA. Table 4.2.7 and Figure 4.2.4 show the descriptive scores for SLI and TD groups.

Results of one way ANOVA that compared SLI and TD group are given in Table 4.2.8. Results show that all the derivations were significantly lower for SLI group compared to TD group [noun: $F(1, 62)=32.06$, $p=.000$; verb: $F(1,62) = 6.71$, $p=0.012$; adjective: $F(1, 62)=6.44$, $p=0.014$; adverb: $F(1,62)=6.14$, $p=0.000$]. Similarly, average derivations judged [$F(1, 62) =28.56$, $p=0.000$] and average derivations revised [$F(1, 62) =12.27$, $p=0.001$] were also significantly lower for SLI group compared to TD group (Table 4.2.8).

Table 4.2.7

Descriptive scores for SLI and TD groups for derivational morphemes

Derivation of	Group	Mean	SD	Std. Err	LB	UB	Min	Max
Noun	SLI	79.88	10.64	1.91	75.97	83.78	61.50	100
	TD	94.40	9.86	1.71	90.90	97.89	61.50	100
Verb	SLI	89.51	16.80	3.01	83.35	95.67	50.00	100
	TD	97.97	8.09	1.40	95.10	100.84	66.60	100
Adjective	SLI	90.32	12.37	2.22	85.78	94.86	75.00	100
	TD	96.96	8.28	1.44	94.03	99.90	75.00	100
Adverb	SLI	94.51	12.71	2.28	89.85	99.17	66.00	100
	TD	100	0.00	0.00	100	100	100	100
ADJ	SLI	84.91	9.48	1.70	81.44	88.39	62.50	100
	TD	95.94	6.88	1.19	93.49	98.38	79.10	100
ADR	SLI	55.88	12.06	2.16	51.45	60.30	37.50	87.50
	TD	65.60	10.09	1.75	62.02	69.18	41.60	83.30

Abb: ADJ-average derivational judgment, ADR-average derivational revision

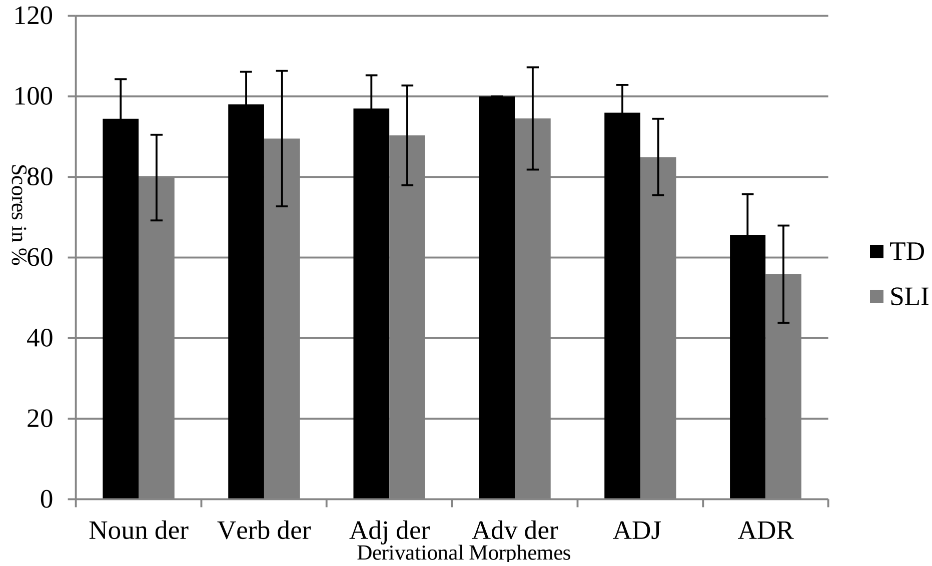


Figure 4.2.4 Comparison of means and SDs of SLI and TD groups on derivational morphemes

Abb: der-derived, Adj-adjective, Adv-adverb, ADJ-average derivations judged, ADR-average derivations revised

Table 4.2.8

Comparison between SLI and TD on derivational morphemes (one way ANOVA)

Derivation of	Mean square	F(1,62)	p
Noun	3369.69	32.06	0.000
Verb	1143.92	6.71	0.012
Adjective	706.25	6.44	0.014
Adverb	480.69	6.14	0.016
ADJ	1942.23	28.56	0.000
ADR	1510.91	12.27	0.001

Abb: ADJ- average derivational revision, ADR-average derivational revision

Derivational measures such as noun, verb, adjective, and adverb derivations along with average derivational measures such as average derivational judgment and average derivational revision and other individual revision scores were considered variables for discriminant function analysis. 68.1% of the derivational morphemes were loaded in to first discriminant function (DF1) [Wilks' λ = 0.300, $\chi2(36)$ = 66.169, p=0.002], 28.2% were loaded into second discriminant function (DF2) [Wilks' λ = 0.641, $\chi 2(22)$ = 24.49, p= 0.322], only 3.7% was loaded into third discriminant function (DF3) [Wilks' λ = 0.941, $\chi 2(10)$ = 3.318, p =0.973]. Tables 4.2.9 a, b, & c show standardized canonical discriminant function coefficients, structure matrix coefficients, and functions at group Cendroids coefficients respectively for derivational morphemes.

Table 4.2.9

Discriminant function analysis for derivational morphemes

a. *Standardized Canonical Discriminant Function Coefficients for derivational morphemes*

Derivations	Function 1	2	3
nouns	1.29	0.17	-0.67
verbs	0.54	0.58	-0.20
adjectives	0.352	0.21	0.46
adverbs	0.38	-.017	-0.20
ADJ	-1.13	-0.90	0.97
-ga:ra	-0.33	0.99	0.49
-iga	-0.28	1.05	0.21
-vanta	0.42	1.39	0.23
-pu	0.17	0.36	0.43
-ige	0.35	1.11	0.48
-ka:ra	0.03	0.08	-0.16
ADR	-0.02	-2.19	-1.31

b. *Structure Matrix Coefficients for derivational morphemes* (correlation <0.3 was not considered)

Derivations	Function 1	2	3
nouns	0.71*	0.01	0.12
ADJ	0.68*	-0.02	0.32
-ige	0.59*	0.22	-0.05
ADR	0.51*	0.49	-0.34
verb	0.34*	0.09	0.21
adverb	0.29*	-0.08	-0.13
-pu	0.26*	0.14	0.25
-ga:ra	-0.06	0.63*	0.02
-vanta	0.42	0.46*	-0.39
-iga	0.09	0.42*	-0.22
adjective	0.34	-0.05	0.68*
-ka:ra	0.19	-0.20	-0.37*

Abb: ADJ-average derivational judgment, ADR-average derivational revision

c. *Functions at group Centroids Coefficients*

Groups	Function 1	2	3
SLI1	-1.270	.014	-.246
SLI2	-.701	.277	.438
TD1	.755	-.990	.016
TD2	1.196	.811	-.096

The correlation between variables and discriminant functions revealed that noun derivation (r=0.71), average derivational judgment (r=0.68), revision of –ige (r=0.59), average derivational revision (r=0.51), and verb derivation (r=0.34) loaded heavily on DF1.

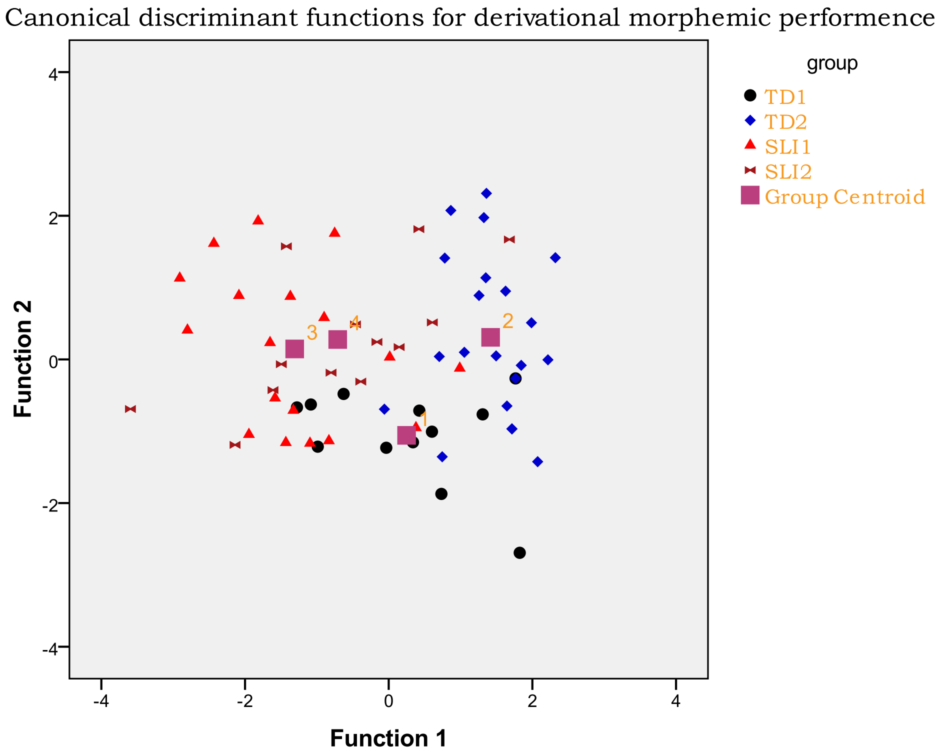


Figure 4.2.5 Discrimination function plot for groups on derivational morphemic performance

Revision of *–ga:ra* (r=0.63), revision of *–vanta* (r=0.46), and revision of *–iga* (r=0.42) loaded heavily on DF2. Adjective derivations (r=.68) and revision of *–ka:ra* (r=.37) loaded more on DF3 compared to other functions (Table 4.2.9 b). Discrimination function plot shows that function 1 discriminated the groups SLI1 and SLI2 relatively better than TD1 and TD2. Function 2 appears to be discriminating between TD1 and TD2, but not between SLI1 and SLI2. SLI1 and SLI2 are overlapping on function 2 (Figure 4.2.5). The classification results based on discriminant functions revealed that 75% of the participants were correctly grouped. In TD1 83.4%, in TD2 81.3%, in SLI1 72.2%, and in SLI2 61.5% of the participants showed predicted group membership. To summarize, the discriminant analysis did not show clear distinction between SLI and TD groups on derivational morphemes. Further, DF1 discriminated SLI and TD well and the function was loaded with derivational judgment (Table 4.2.9 b).

4.2.1.3. Discussion. Children with SLI performed significantly lower compared to TD children on judging majority of derivational morphemes, but not on adverb derivations. Children with SLI performed significantly lower compared to TD children on average derivational judgment and average derivational revisions. Chronological age wise division did not show any significant difference between the groups (TD or SLI). While revising individual morphemes SLI children performed like TD children on revision of *–ga:ra*, *-iga*, and *–pu* (both the groups revised with same difficulty, scores are around 75% to 100%). However, the performance of SLI was towards 25% or 50% for revision of *–vanta*, *-ige*, and *–ka:ra* (i.e., not revised until clue was given). Discriminant analysis did not differentiate well between performances of TD and SLI groups on derivational morphemes.

General derivational morphemic deficits were reported in children with SLI (Dalalakis, 1994; Gopnik, 1999; Piggott & Kessler Robb, 1999; Ravid, Levie, & Ben-Zvi, 2003; Windsor & Hwang, 1999). Therefore, as a whole the poor performance in derivational morphemes in SLI group of the present study is in support of previous studies that reported of poor derivational morphemes in children with SLI. According to PDH, it was hypothesized (see introduction) that sequence learning would not be essential for derivational functions. Therefore, children with procedural memory deficits (SLI group in the present study) should not show deficits in derivational operations. However, the results of present study on derivational morphemes are in contrast. An alternative explanation within the realm of procedural memory deficit could explain the poor derivational morphemic performance. Such an explanation would be more relevant to the present research work, which aims to explain SLI manifestations from procedural deficit perspective. Derivational morphemes are stored in lexicon and they make their way to sentence just like any other abstract words from lexicon (Dietrich et al., 2001; Ullman, 2004, 2005, 2006a, 2006b; Ullman & Pierpont, 2005). Therefore, deficits in lexical knowledge and retrieval could affect derivational performance. However, the declarative/procedural model (the seminal model for PDH) claims dissociation between declarative memory driven lexicons and procedural memory driven grammar. In other words, according to the dissociation between memory systems of PDH, procedural memory deficits should not affect derivational morphemic performance (i.e., poor lexical performance). However, the dissociation is somewhat complicated by the fact that certain brain structures underlying the procedural memory system also play particular roles related to declarative memory. For instance, ventro-lateral pre-frontal cortex (an asset in procedural system), sub serves the encoding of new declarative memories and the selection or retrieval of declarative knowledge (Buckner & Wheeler, 2001). Similarly, evidences show that regions of basal ganglia and cerebellum (structures of procedural memory system) are simultaneously involved in selecting, retrieving or searching for declarative memories (Ivry & Fiez, 2000; Ullman, 2004). Therefore, declarative functions such as selection, retrieval or search for lexical knowledge could also be affected analogously with procedural mechanism deficit in turn leading to poor derivational morphemic performance though not adversely in the present study (Ullman, 2004).

The derivational morphemic profile of SLI children in the present study is complex. For instance, children with SLI performed significantly poorly in all but one of derivational judgment task compared to TD. This poor performance could be explained using neurophysiological intertwining between declarative and procedural memory structures (Ullman, 2004). Study by Kuppuraj and Prema (2013d) attributed the poor derivational judgment to involvement of declarative memory system in the processing of derivational morphemes. An alternative explanation for the poor performance on derivational morphemes by children with SLI could be from another perspective of implicit (procedural) learning, such as learning deficit in statistical mechanism (Hsu & Bishop, 2011). The significance of statistical mechanism functions (introduction) for adequate word recognition and detection of word boundaries have been reported (Aslin, Saffran, & Newport, 1998; Gómez & Gerken, 1999; Saffran, 2001; Saffran, 2003). That is, using implicit statistical knowledge an individual calculates the transitional probabilities between syllables to find the word boundaries, alternatively termed as bootstrapping (Ronald & Langacker, 1999). This phenomenon could be applicable to the present judgment task used to elicit derivational morphemic knowledge. Poor derivational judgment from statistical learning could be because the statistical knowledge is a procedural skill (e.g., Hsu & Bishop, 2011, Kuppuraj & Prema, 2013b; Kuppuraj & Prema, 2012a; Kuppuraj & Prema, 2013d) and therefore, children with procedural deficits (SLI group in the present study) would invariably find the detection of word boundaries and morphemic detection difficult. Hence, the performance of the children with SLI in the present study was poor compared to TD children even in derivational morphemic judgment. Kuppuraj and Prema (2013d) also stated such statistical mechanism deficit followed by procedural deficit as a reason for poor derivational judgment in SLI children. The explanation from statistical phenomenon is free of non-adjacent relation predicted earlier for inflectional morphemic performance which was pertaining to sequencing perspective of procedural mechanism. Both sequence learning and statistical learning are under the shade of a single wing called implicit phenomenon (Kuppuraj & Prema, 2012a, Kuppuraj & Prema, 2013c, Perruchet & Pacton, 2006; Kuppuraj & Prema, 2013d).

While revising the derivational morphemes children with SLI performed closer to TD in revising most of individual derivational morphemes (SLI similar to TD on *–ga:ra, -iga, -pu,* & *-ka:ra*); SLI lower than TD on *–vanta & -ige*). However, on average derivational revision scores SLI group performed lower compared to TD group. In other words, though children with SLI performed closer to TD on revising individual derivational morphemes as a whole they did show retrieval deficits for derivational morphemes. Poor derivational morphemic revision could be attributed to poor declarative memory and associated lexical retrieval problems in them. The statement is in consonance with claim of PDH which states that children with SLI would show declarative memory deficits associated with procedural memory deficit due to its close anatomical proximity (Lum et al., 2011; Kuppuraj & Prema, 2013d). SLI children in the present study showed that when the two choice judgments were given for revision they performed accurately. Behaviour such as this was reported in SLI children when they were offered derivational morpheme to select from (Loeb & Leonard, 1991; Marshall & van der Lely, 2007; Oetting & Horohov, 1997; Ullman & Gopnik, 1999; van der Lely & Ullman, 2001). While revising individual derivational morphemes almost all (except for *–vanta*, & *-ige*) derivational morphemes were revised (using proper word retrieval) without clue just like TD participants. This result indicate that children with SLI had lexical retrieval system that was adequate to retrieve some of derivational morphemes. Lum et al. (2011) in their work on studying the interaction between various memory systems in SLI such as working memory, declarative, and procedural memory reported that children with SLI tend to struggle with their verbal declarative memory mainly because interaction of anatomical structure between declarative and procedural memory. Study by Kuppuraj & Prema (2013d) examined grammar aspects more sensitive to procedural memory deficits. Even though, they predicted derivational morphemes to be intact in children with SLI, the participants with SLI showed considerable deficits in derivational morphemes as well. Kuppuraj and Prema attributed the derivational deficits to possible declarative memory system deficits secondary to procedural memory deficits in SLI. The derivational deficits in present study could be in consonance with results reported by Kuppuraj and Prema. Results of discriminant function analysis where complete data (judgment and revision) on derivational morphemes were considered showed that SLI and TD groups were not differentiated well. It supports our hypothesis that performance on derivational morphemes of children with SLI would be closer to performance of TD children, because they do not rely on long distance (non-adjacent) relation between words in a sentence. To summarize, the present study attempts to explain the declarative memory deficits in SLI using specific ideas from PDH. Overall performance of SLI children on derivational morphemes is in favour of major claims of PDH. However, to account for association between memory (declarative/ procedural) and statistical learning further studies are required on judgment and retrieval skills of morphemes by children with SLI.

4.2.2. Results of non-adjacent operations (Inflectional morphemes). Non-adjacent operations are grammatical operations that require relation among words, which are placed further in a sentence (see introduction section). Operations such as inflection and morpho-syntax are non-adjacent operations and therefore, reported under the broad heading of non-adjacent operations. First major section under non-adjacent operations reports the results of inflectional morphemic performance of SLI and TD groups.

Table 4.2.2.1

Particulars of abbreviations for inflectional morpheme

Averages	Abbreviations	Morphemes included
Average Inflectional Judgment	AIJ	plurals, tenses, case markers
Average case marker Revision	AI cm R	average of revision scores of -annu, -lli, -a, ige, -ike
Average agreement Revision	AI agr R	average of revision scores of -Dida-, -o:daru, -Lutha

4.2.2.1. Inflectional judgment. Analysis for observations on inflectional task will be reported under two sections. The first section reports results for inflectional morphemes that require judgment only and the second section reports results for inflections that require judgment as well as revision. . There were two chronological age groups in each group (SLI & TD) such as >8.0 to $\leq$ 11.0 and >11.0 to $\leq$ 13.0 years. This division was done to report any developmental changes that could be contributing to interpretation of results. Mean and SD of inflectional morphemes judged is given in t Table 4.2.2.2 and 4.2.2.3

Two way MANOVA was done to check for significant difference between groups and chronological ages on judging inflectional morphemes. Wilks' Lambda (λ) showed that judgment ability for inflectional morphemes was significantly lower for SLI group compared to TD group [λ= 0.283, F (6, 52) = 14.662, p=0.000, η^2=0.468]. Whereas neither of the groups showed significant effect for chronological age on inflection judgment task [λ= 0.732, F (12, 52) = 1.382, p=0.182, η^2=0.099].

Table 4.2.2.2

Mean and SD of SLI1 and SLI2 groups for judging inflectional morphemes

JIM	SLI1 (n=18)					SLI2 (n=13)				
	Mean	SD	Std.Er	LB	UB	Mean	SD	Std.Er	LB	UB
Plurals	94.43	12.80	1.63	91.42	97.97	100.00	.00	1.95	96.07	103.92
CM	41.11	18.75	4.50	32.83	50.91	50.76	17.54	5.40	41.15	62.84
Tenses	47.22	20.80	4.08	38.46	54.87	53.84	22.46	4.90	45.71	65.39

Abb: JIM-judging inflectional morphemes, CM-case markers, Std.Er-standard error, LB-lower bound, UB-upper bound, CA-chronological age.

Table 4.2.2.3

Mean and SD of TD1 and TD 2 groups for judging inflectional morphemes

JIM	TD1 (n=17)					TD2 (n=16)				
	Mean	SD	Std.Er	LB	UB	Mean	SD	Std.Er	LB	UB
Plurals	100	.00	1.66	96.65	103.34	100.0	.00	1.72	96.54	103.45
CM	87.05	22.29	4.60	78.30	96.80	93.75	17.46	4.75	83.80	102.86
Tenses	95.58	13.21	4.18	87.43	104.22	96.87	8.53	4.31	88.01	105.31

Abb: JIM-judging inflectional morphemes, CM-case markers, Std.Er-standard error, LB-lower bound, UB-upper bound, CA-chronological age.

The interaction effect between group and chronological age was also not significant for inflection judgment task [λ= 0.846, F (12, 52) = 0.723, p=0.727, η^2=0.054]. Tests of between subjects effects showed that among the inflectional morphemes given for judgment of case markers and tenses were significantly lower for SLI group compared to TD group [CM: F(2,52)=41.62, p=0.00, η^2 =.62; Tenses :F(2,52)=55.14, p=0.00,η^2 = 0.68]. Plurals were not affected significantly for SLI group compared to TD group [F (2, 52)=2.58,p=0.08, η^2 =0.09]. None of the inflectional morphemes judged were significantly different within TD or SLI. In other words, chronological age had no significant effect for judging inflectional morphemes (interaction effect between groups and age was also absent for judging inflectional morphemes Table 4.2.2.4).

Average inflectional judgment. An average was taken from individual inflections judged and they were compared between SLI and TD groups. The scores were called average inflectional judgment scores. Two way ANOVA was run on average inflectional judgment scores of SLI and TD for comparison. Table 4.2.2.5 shows comparison between SLI and TD on average inflectional judgment scores. The result shows that children with SLI performed significantly lower compared to TD children [F (2, 52)=55.27,p=0.000, η^2=0.680]. Chronological age did not show significant effect, and the interaction of group with chronological age was non-significant (Table 4.2.2.5 & Figure 4.2.2.1).

Table 4.2.2.4

Comparison of SLI and TD groups on inflectional judgment (two way MANOVA)

Judged inflections		df, 52	Mean square	F	Sig.	η^2
Group	Plu	2	121.28	2.58	0.08	0.09
	CM	2	14918.93	41.62	0.00	0.62
	Tense	2	16281.50	55.14	0.00	0.68
CA	Plu	4	43.11	0.91	0.46	0.07
	CM	4	829.56	2.31	0.07	0.15
	Tense	4	257.61	0.87	0.48	0.06
Group * CA	Plu	4	43.11	0.91	0.46	0.06
	CM	4	61.50	0.17	0.95	0.01
	Tense	4	263.25	0.89	0.47	0.06

Abb: Plu-plurals, CM-case markers, CA-chronological age

Table 4.2.2.5

Comparison of SLI and TD groups on average inflectional judgment (two way ANOVA values)

Groups	Mean	SD	Std.Er	LB	UB	Group TD>SLI	CA	Group and CA*
SLI1	55.98	14.51	3.08	49.96	62.35	F(2,52)=	F(4,52)=	F(4,52)=
SLI2	64.06	14.18	3.70	57.71	72.58	55.27,	1.634,	0.360,
TD1	93.12	12.58	3.15	87.07	99.75	p=0.000,	P=0.180,	p=0.836,
TD2	96.35	10.09	3.25	89.57	102.64	ƞ2=0.680	ƞ2=0.112	ƞ2=0.027

*interaction, Abb: Std.Er-standard error, LB-lower bound, Ub-upper bound, CA-chronological age

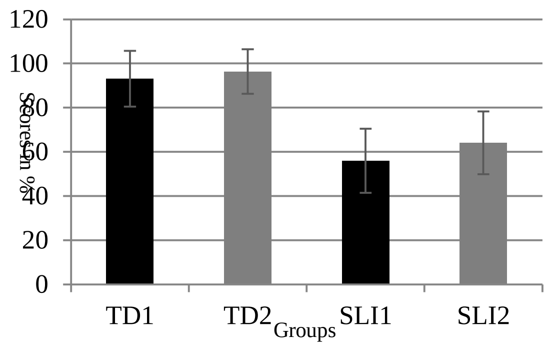


Figure 4.2.2.1 Comparison of SLI and TD groups on average inflectional judgment

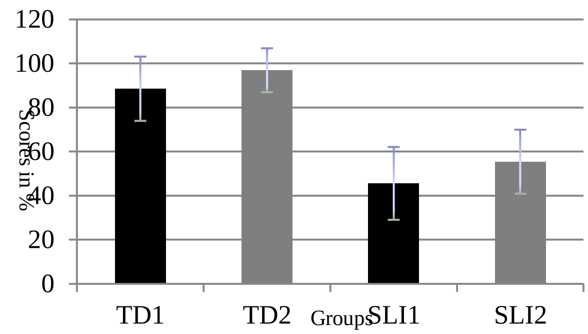


Figure 4.2.2.2 Comparison of SLI and TD groups on average case marker revision

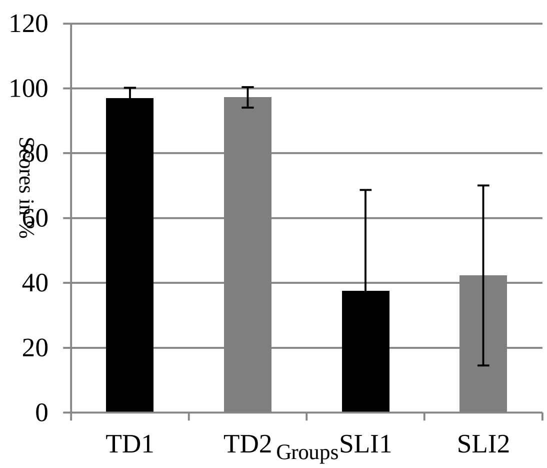


Figure 4.2.2.3 Comparison of SLI and TD on revising agreement inflections

4.2.2.1. Inflectional revision. Average of inflectional case markers revised and inflectional agreement markers revised were calculated separately from individual revisions made under respective categories. Inflectional morphemes that required revision was analyzed for case markers and agreement markers separately.

Average case marker revision. Average case marker revisions between SLI and TD groups were compared using two way ANOVA (Table 4.2.2.6). Children with SLI performed significantly lower compared to TD children on revising case markers as a whole [F (2, 52) = 66.14, p=0.000, η^2=0.718]. The chronological age was not significant across groups [F (4, 52) = 1.50, P=0.215, η^2=0.104]. The interaction effect between group and chronological age was absent [F (4, 52) =0.196, p=0.941, η^2=0.015]. Figure 4.2.2.2 shows the comparison of SLI and TD groups on average case marker revision scores.

Table 4.2.2.6

Comparison of SLI and TD on average case marker revision (two way ANOVA-F values)

Groups	Mean	SD	Std.Err	LB	UB	Group TD>SLI	CA	Group and CA*
SLI1	45.55	16.52	3.41	39.36	53.07	F(2,52)=	F(4,52)=	F(4,52)=
SLI2	55.38	14.50	4.09	47.77	64.22	66.14,	1.50,	0.196,
TD1	88.52	14.65	3.49	81.93	95.95	p=0.000,	P=0.215,	p=0.941,
TD2	96.87	9.97	3.60	89.54	104.00	η^2=0.718	η^2=0.104	η^2=0.015

Abb: Std.Err-standard error, LB-lower bound, UB-upper bound, CA- chronological age

Average agreement revision. Average agreement revision between SLI and TD group was analyzed using two way ANOVA and results are reported in Table 4.2.2.7. Children with SLI performed significantly lower compared to TD children on revising agreement inflections[F (2, 52)=51.89, p=0.00, η^2=0.67]. Chronological age was not significant across groups, [F (4, 52)=0.172, P=0.952, η^2=0.013]. The interaction effect between group and chronological age (group * age) was not significant, [F(4,52)=0.081, p=0.988, η^2=0.006] (Table 4.2.2.6). Figure 4.2.2.3 shows the comparison of SLI and TD on revising agreement inflections.

Table 4.2.2.7

Comparison of SLI and TD on average agreement revision

Groups	Mean	SD	Std.Er	LB	UB	Group TD>SLI	CA	Group and CA*
SLI1	37.50	31.21	5.28	27.41	48.61	F(2,52)	F(4,52)=	F(4,52)=
SLI2	42.30	27.73	6.33	29.50	54.93	=	.172,	.081,
TD1	97.03	3.24	5.40	86.28	107.97	51.89,	P=0.952,	p=0.988,
TD2	97.24	3.22	5.57	86.09	108.44	p=0.00,η^2=0.6	η^2=0.013	η^2=0.006

Abb: Std.Er-standard error, LB-lower bound, UB-upper bound, CA- chronological age

The chronological age group wise analysis did not show any significant interaction between chronological age and groups. Therefore, the chronological age groups were merged to make a single SLI and TD group and comparisons were made and results are reported. Results of combined group (SLI1+SLI2=SLI; TD1+TD2=TD) performance on inflectional morpehems are reporetd in this section. Scores on plurals, case markers, agreement markers, average inflectional judgment, average case markers revision, and average agreement revision were analyzed between SLI and TD groups using one way ANOVA. The results of descriptive statistics of SLI and TD groups are reported in Table 4.2.2.8 and Figure 4.2.2.4.

Table 4.2.2.8

Descriptive results of SLI and TD groups on inflectonal tasks

Parameters	Group	Mean	SD	Std.Er	LB	UB	Min	Max
Plu	SLI	96.76	10.03	1.80	93.08	100.44	66.60	100
	TD	100.00	0.00	0.00	100.00	100.00	100.00	100
CM	SLI	45.16	18.59	3.33	38.34	51.98	20.00	80
	TD	90.30	20.07	3.49	83.18	97.42	40.00	100
Tenses	SLI	50.00	21.40	3.84	42.14	57.85	25.00	100
	TD	96.21	11.04	1.92	92.29	100.12	50.00	100
AIJ	SLI	59.37	14.70	2.64	53.98	64.77	33.30	91.6
	TD	94.69	11.38	1.98	90.65	98.72	58.30	100
AI cm R	SLI	49.67	16.22	2.91	43.72	55.62	20.00	80
	TD	92.57	13.11	2.28	87.92	97.22	40.00	100
AI agr R	SLI	39.51	29.42	5.28	28.72	50.30	0.00	100
	TD	97.13	3.18	.55	96.00	98.26	93.70	100

Abb:Plu-plurals, CM-case markers, AIJ-average inflectional judgment, AI cm R-average case marker revision, AI agr R-average agreement revision, Std.Er- standard error, LB-lower bound, UB-upper bound.

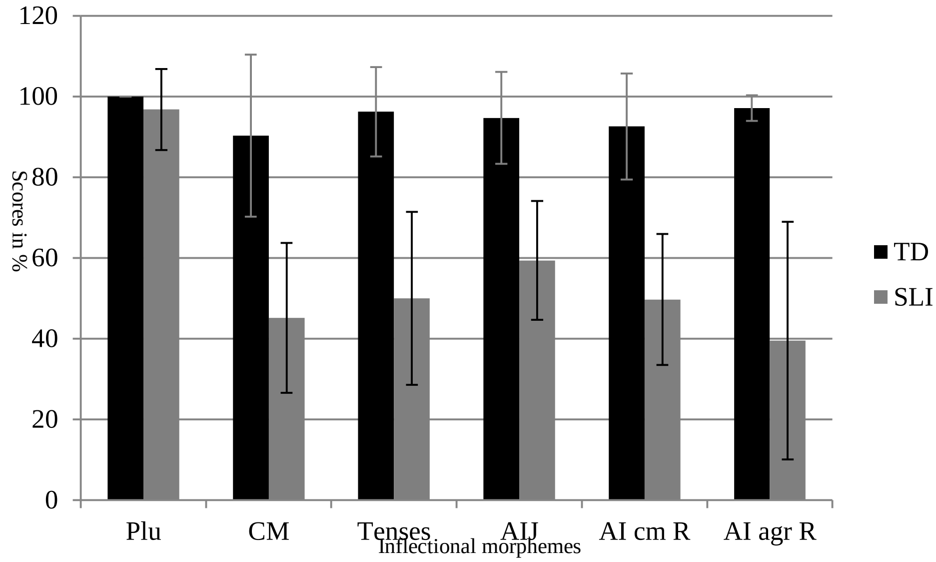


Figure 4.2.2.4 Comparison of SLI and TD on inflectional morphemes
Abb: Plu-plurals, CM-case markers, AIJ-average inflectional judgment, AI cm R-average inflectional case marker revision, AI agr R-average inflectional agreement revision

Results of one way ANOVA that compared inflectional task performance between SLI and TD groups are reported in Table 4.2.2.9. Results show that except for plurals children with SLI performed significantly lower compared to TD on all inflectional morphemic measures [CM: $F(1,62)=86.8$, $p=0.00$;tenses:$F(1,62)=119.899$, $p=0.00$;AIJ :$F(1,62)=116.170$, $p=0.00$;AI cm R: $F(1,62)=136.073$, $p=0.00$; AI agr R :$F(1,62)=125.142$, $p=0.00$].

Table 4.2.2.9

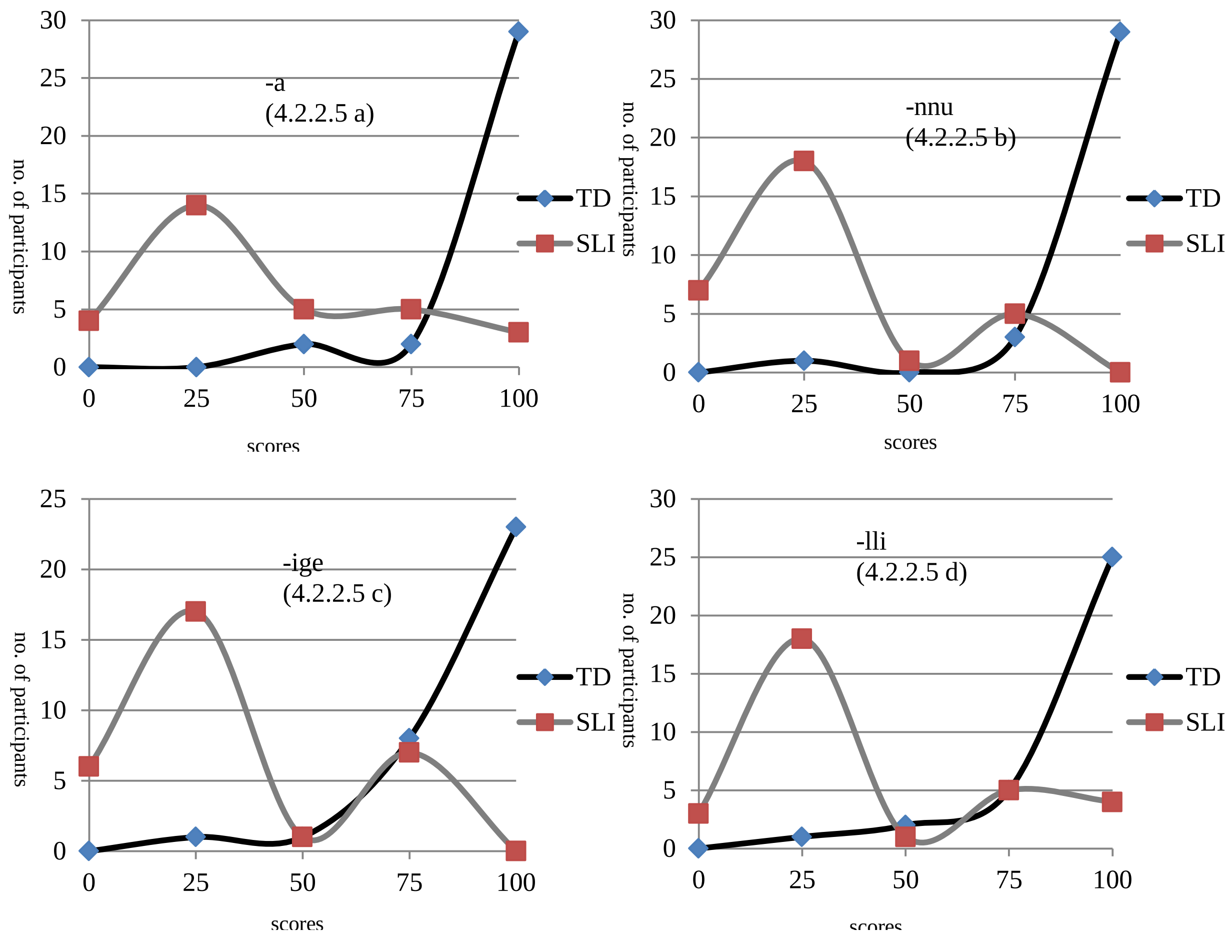
Comparison between SLI and TD groups on inflectional tasks (one way ANOVA)

Inflections	Mean square	F(1,62)	P
Plu	166.99	3.42	0.069
CM	32572.58	86.78	0.000
Tenses	34135.59	119.89	0.000
AIJ	19933.19	116.17	0.000
AI cm R	29415.52	136.07	0.000
AI agr R	53069.58	125.14	0.000

Abb: Plu-plurals, CM-case markers, AIJ-average inflectional judgment, AI cm R-average inflectional case marker revision, AI agr R-average inflectional agreement revision

Individual case marker revision between SLI and TD groups. Frequency of distribution was calculated using cross tabs for each SLI and TD participant to compare and report the performance on inflectional case markers revision. Since the chronological age and group interaction was absent for average inflectional revision performance the chronological age groups were merged to made a single SLI and TD groups. On the x-axis of the Figures, marks on "0" indicate number of participants neither revised nor judged even after the clue in each group. Mark on "25" indicates number of participants who failed to judge the stimulus but managed to revise after clue in each group. Mark on "50" indicates number of participants who judged the stimulus but did not revise after clue in each group. Mark on "75" indicates number of participants judged (on their own) and revised with clue in each group (for explanation on clue see binary forced choice in method section 3.2.2.2, Table 3.6). Marks on "100" indicates number of participants judged and revised on their own in each group. Figure 4.2.2.5 (a-e) shows frequency of distribution for case marker revision of SLI and TD participants

Revision of *–a* was performed with 100 % by almost all TD participants. However, SLI participants mostly scored 25% followed by some participants from SLI group scoring 50, 75 and 100 percentages (Figure 4.2.2.5 a). The similar pattern was also observed for revision of *–nnu* where almost all TD participants scored 100% with SLI participants performances distributed from 25% to 100% (Figure 4.2.2.5 b). However, like *–a*, *-nnu* also had more SLI participants scoring 25%. *–ige* is no different from *-a* and *–nnu*. However, while revising *–ige* some of TD participants scoring 75% which was slightly different from previous patterns for *–a*, and *–nnu* (Figure 4.2.2.5 c). Revision of *–lli* and *–ike* showed similar pattern to *–ige* (Figure 4.2.2.5 d & e). To summarize, children with SLI revised all the case markers with clue (i.e., with binary forced choice) where TD children revised all the case markers with ease.



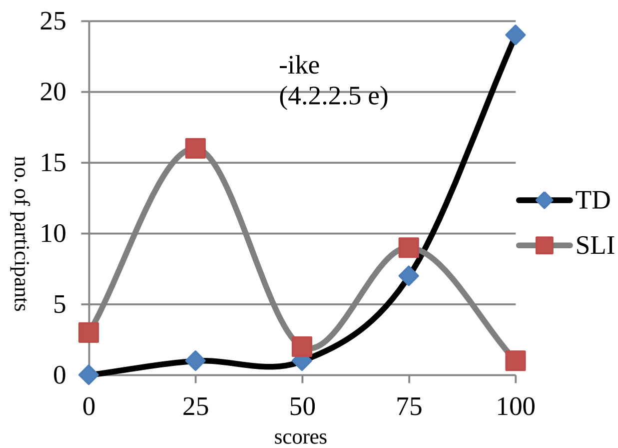


Figure 4.2.2.5 (a-e) Frequency of distribution for SLI and TD on revision of –*a, –nnu, –ige, -lli,& -ike*

Individual agreement revision between SLI and TD groups. Frequency of distribution was calculated using cross tabs for each SLI and TD participant to compare and report the performance on individual revision of inflectional agreement markers. Figure 4.2.2.6 (a-d) shows frequency of distribution for individual agreement revision of SLI and TD participants.

While revising inflectional agreement *–gaLu* all the TD participants revised with 100% accuracy. Where majority of SLI participants revised with 50% scores (Figure 4.2.2.6 a). Revision of *–ita* showed that all the participants from TD group performed with 100% score. However, some of children with SLI performed with 75% scores in revising *–ita* (Figure 4.2.2.6 b). Revision of *–o:daru* was distributed from 75% to 100% for TD children, where as it was distributed from 25% to 100% for SLI children (Figure 4.2.2.6 c). Revision of *–bi:Luta* was performed with 100% by almost all TD participants, but children with SLI had major performance at 25% and from there on it was distributed until 75% (Figure 4.2.2.6 d). To summarize, children with SLI performed agreement revision with clue (i.e., binary forced choice) while TD children revised agreements with relative ease.

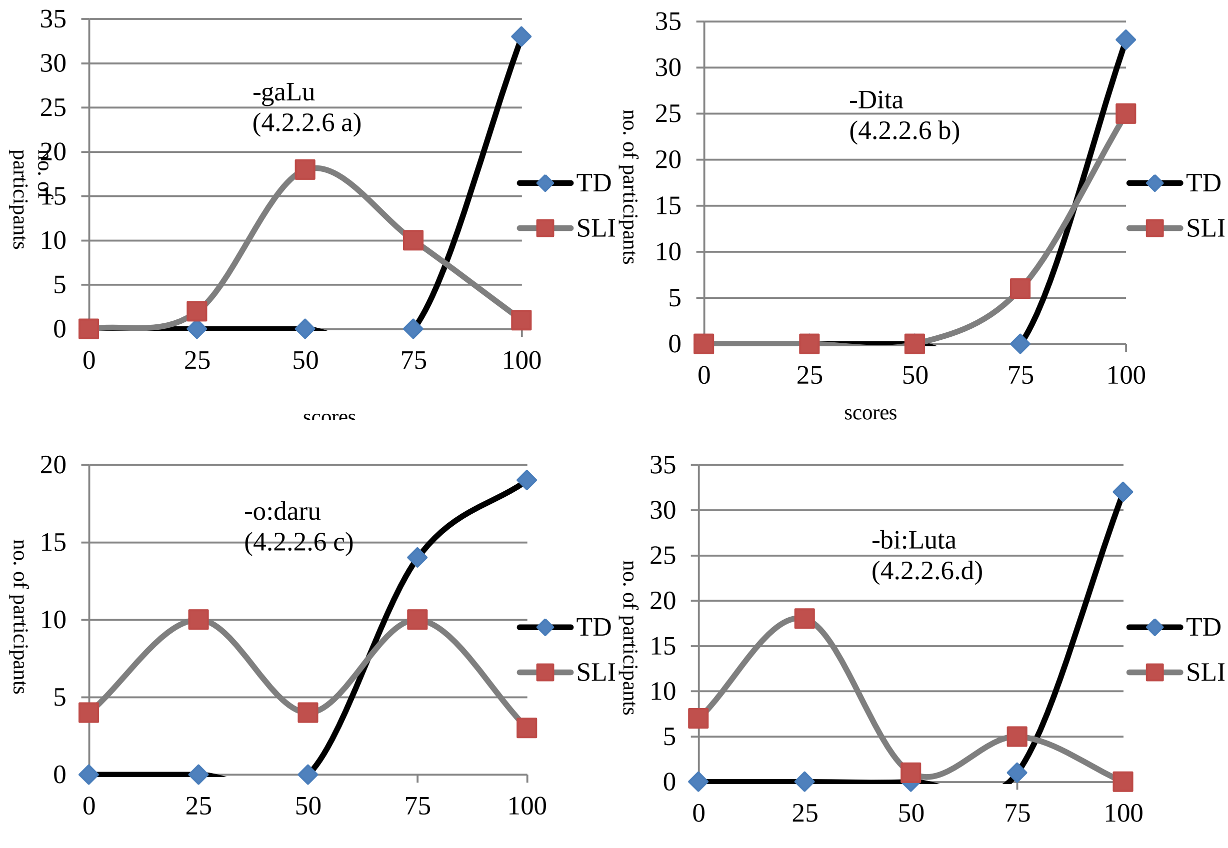


Figure 4.2.2.6 (a-d) Frequency of distribution for SLI and TD on revision of *–gaLu, -Dita,-o:daru, & –bi:Luta*

4.2.3. Results of non-adjacent operations (Morpho-syntax). Analysis for observations on morpho-syntax task will be reported under two sections. The first section reports results for morpho-syntax elements needing judgment only and the second section reports results for morpho-syntax structures needing revisions also. The groups were divided into two chronological age groups such as >8.0 to ≤ 11.0 and >11.0 to ≤ 13.0 years in each group. This division was done to report any developmental changes that could be contributing to interpretation of results.

Table 4.2.3.1

Details of morpho-syntax units included in averaging

Averages	Abbreviations	Morphemes* included
Average Morpho-Syntax Judged	AMSJ	average scores of *keLage, pakka, orage, dzote, a:dame:le, -idre, -mattu, -a:dare, -atava, -o:, :iladidare, -ginda*
Average Morpho-Syntax Revised	AMSR	average scores of *–me:le, -olage, -a:dare, & -atava*

*some dialectal variations of same morpheme units are used interchangeably in the text

4.2.3.1. Morpho-Syntax Judgment. Two way MANOVA was done to compare the performance of morpho-syntax elements that needed judgments. Table 4.2.3.2 & 4.2.3.2 show mean and SDs for morpho-syntax stimulus, which required judgment only (such as preposition, conjunctions, and comparative/conditionals).

Wilks' lambda shows that only group had significant effect in judging morpho-syntax [λ=0.240, F (6, 52) =17.37, p=0.000, η2=0.510]. Chronological age did not show any significance [λ=0.813, F (12, 52) =0.900, p=0.549, η2=0.067]. The group and chronological age interaction was absent [λ=0.814, F (12, 52) =0.892, p=0.557, η2=0.066].

Table 4.2.3.2

Descriptive results of SLI groups on morpho-syntax judgment

Morpho-syntax	SLI1 (n=18)					SLI2 (n=13)				
	Mean	SD	Std.Er	LB	UB	Mean	SD	Std.Er	LB	UB
Pre	40.27	33.36	5.43	29.52	51.34	51.92	33.01	6.52	41.90	68.09
Conj	36.11	27.41	8.30	19.41	52.72	53.84	28.58	9.95	35.57	75.53
C/C	38.61	24.95	4.26	30.56	47.67	45.76	20.90	5.11	35.84	56.37

Abb: pre: Prepositions, Conj: Conjunctions, C/C: Comparatives/Conditionals, LB: Lower bound, UB: Upper bound, Std. Er: Standard error. LB and UB significant at 95%confidence level

Table 4.2.3.3

Descriptive results of TD groups on morpho-syntax judgment

Morpho-syntax	TD1 (n=17)					TD2 (n=16)				
	Mean	SD	Std.Er	LB	UB	Mean	SD	Std.Er	LB	UB
Pre	100.0	0.0	5.5	88.8	111.1	100.0	0.0	5.7	88.4	111.5
Conj	75.0	39.5	8.4	58.2	92.3	85.9	34.1	8.7	68.5	103.6
C/C	97.0	12.1	4.3	88.4	105.9	100.0	0.0	4.4	90.9	109.0

Abb: pre: Prepositions, Conj: Conjunctions, C/C: Comparatives/Conditionals, LB: Lower bound, UB: Upper bound, Std. Er: Standard error. LB and UB significant at 95%confidence level

Tests of between subject effects showed that all the morpho-syntax elements were significantly different between groups (i.e., SLI <TD) [preposition: $F(2,52)=42.725$, $p=0.000$, $\eta^2=0.622$; Conj: $F(2,52)=8.106$, $p=0.001$, $\eta^2=0.238$; C/C-$F(2,52)=76.659$, $p=0.000$, $\eta^2=0.747$]. None of the morphosyntax elements showed chronological age difference in judgment. No interaction was shown between group and chronological age for any of the morpho-syntax judgment (Table 4.2.3.4).

Average morpho-syntax judged. A two way ANOVA was done on scores of average morpho-syntax judged from TD and SLI children and results are reported in Table 4.2.3.5 and Figure 4.2.3.1. It shows that average morpho-syntax judged by SLI children was significantly lower compared to TD children [$F(2, 52)=31.52$, $p=0.000$, $\eta^2=0.548$].

Chronological age did not have any significance in performance of morpho-syntax judgment irrespective of group [F (4, 52) =0.677, P=0.611, η^2=0.050]. Interaction between group and chronological age (group * age) was absent [F (4, 52) =0.432, p=0785, η^2=0.032].

Table 4.2.3.4

F *statistics for morpho-syntax judgment between SLI and TD (two way MANOVA)*

Judged morpho-syntax		df, 52	Mean square	F	Sig.	η^2
Group	Pre	2	22318.65	42.725	0.000	0.622
	Conj	2	9864.69	8.106	0.001	0.238
	C/C	2	24619.93	76.659	0.000	0.747
CA	Pre	4	665.39	1.274	0.292	0.089
	Conj	4	202.69	0.167	0.954	0.013
	C/C	4	270.81	0.843	0.504	0.061
Group * CA	Pre	4	665.39	1.274	0.292	0.089
	Conj	4	266.73	0.219	0.927	0.017
	C/C	4	111.12	0.346	0.846	0.026

Abb: pre: Prepositions, Conj: Conjunctions, C/C: Comparatives/Conditionals, LB: Lower bound, UB: Upper bound, Std. Er: Standard error

Table 4.2.3.5

Descriptive and F statistics for comparison between SLI and TD groups on average morpho-syntax judgment (two way ANOVA)

Groups	Mean	SD	Std.Er	LB	UB	Group SLI<TD	CA	Group and CA*
SLI1	38.30	26.47	5.39	27.68	49.33	F(2,52)=	F(4,52)=	F(4,52)=
SLI2	50.49	24.92	6.47	39.22	65.18	31.52,	0.677,	0.432,
TD1	86.90	19.36	5.51	76.06	98.21	p=0.000,	P=0.611,	p=0.785,
TD2	93.73	15.18	5.68	82.40	105.22	η^2=0.548	η^2=0.050	η^2=0.032

Abb:LB-lower bound, UB-upper bound, CA-chronological age.

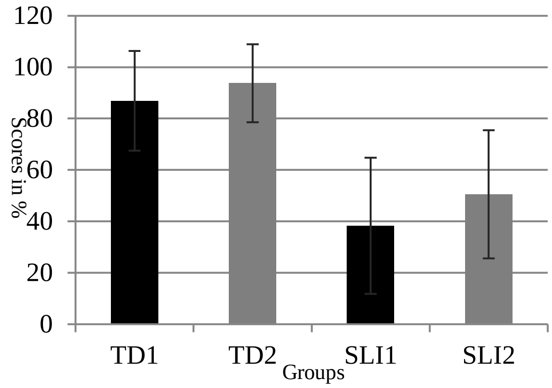


Figure 4.2.3.1 Comparison of SLI and TD groups on average morpho-syntax judgment

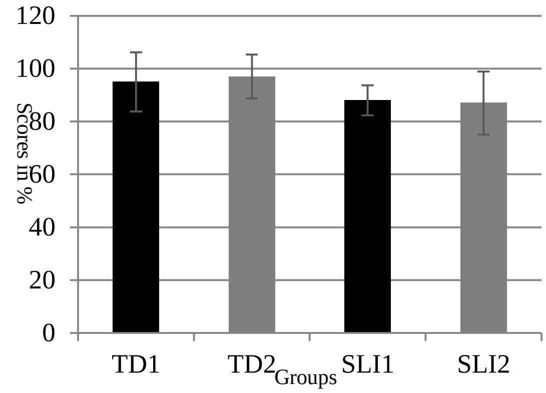


Figure 4.2.3.2 Comparison of SLI and TD groups on average morpho-syntax revision

4.2.3.2. Morpho-syntax revision

Average morpho-syntax revision. A two way ANOVA was done on average morpho-syntax revision scores of SLI and TD groups and results are reported in Table 4.2.3.6 and Figure 4.2.3.2. Results show that children with SLI performed significantly lower compared to TD children on revising morpho-syntax (F (2,52)=9.751,p=0.000,η^2=0.273). Chronological age did not show any significance difference in revising morpho-syntax (F (4, 52) =2.108, p=0.093, η^2=0.140). The interaction between group and chronological age was present (F (4, 52) =3.629, p=0.01, η^2=0.218). Therefore, the individual morpho-syntax element that was revised was reported separately using cross tabs for this group. However, a combined result also reported in further section.

Table 4.2.3.6

Descriptive and F-statistics for comparison of SLI and TD on average morpho-syntax revision (two way ANOVA)

Groups	Mean	SD	Std. Er	LB	UB	Group TD>SLI	CA	Group and CA*
SLI1	88.52	5.76	2.03	84.30	92.48	F(2,52)=	F(4,52)=	F(4,52)=
SLI2	87.48	11.95	2.44	80.91	90.72	9.751,	2.108,	3.629,
TD1	95.33	11.22	2.08	91.41	99.77	p=0.00,	P=0.093,	p=0.01,
TD2	97.51	8.39	2.14	93.41	102.03	η^2=0.273	η^2=0.140	η^2=0.22

Abb: LB-lower bound, UB-upper bound, CA-chronological age.

Because there was interaction between group and chronological age in average morpho-syntax, revision an independent sample t-test was administered to report on combinations that are significant for group and chronological age. Results of independent sample t-tests showed that both SLI1 & SLI2 were not significant between them (t (29) =0.321, p=0.750). However, within TD group the chronological ages (TD1 & TD2) were not significantly different (t (31)=-0.629, p=0.534). Comparison irrespective of groups (SLI1 &TD1) showed that TD1 was significantly better than SLI1 (t (33) =2.27, p= 0.029). Similarly, comparison between TD2 and SLI2 showed that TD2 had significantly better scores compared to SLI2 (t (27) =2.65, p=0.013).

Individual morpho-syntax element revision. This section discusses the individual morpho-syntax element revised for all chronological ages and groups accounting for chronological age and group interaction. Frequency of distribution of SLI and TD participants based on their revision performance was calculated using cross-tabulation. Result of each morpheme is reported in following Figure 4.2.3.3 (a-d). On the x-axis of the Figures, marks on "0" indicate number of participants neither revised nor judged even after the clue in each group. Mark on "25" indicates number of participants who failed to judge but managed to revise after clue in each group. Mark on "50" indicates number of participants who managed to judge but failed to revise after clue in each group. Mark on "75" indicates number of participants who managed to judge (on their own) and revise with clue in each group (for explanation on clue see binary forced choice in method section 3.2.2.2, Table 3.6). Marks on "100" indicates number of participants managed to judge and revise on their own in each group.

While revising *–me:le* all the four groups revised similarly. Most TD and SLI participants revised *–me:le* with 100% scores (Figure 4.2.3.3 a). While revising *–olage* all the TD (TD1 & TD2) scored 100% but SLI (SLI1 & SLI2) participants scored from 25% till 75 % (Figure 4.2.3.3 b). On revision of *–a:dare* most TD (TD1 & TD2) participants scored around 75% with most SLI (SLI & SLI2) participants peaked on 50% (Figure 4.2.3.3 c). On revision of *–atava* most TD (TD1 & TD2) participants showed peak around 75 % scores and most SLI (SLI1 & SLI2) participants peaked around 25% scores (Figure 4.2.3.3 d). To summarize, though average morpho-syntax revision scores showed age and group interaction, individual revision performances of all chronological ages (SLI1& SLI2; TD1 &

TD2) performed without difference. These individual morpho-syntax revision performances on cross tabs resemble the independent t-test results for average morph-syntax revision performance (independent t-test result on average morpho-syntax revision section).

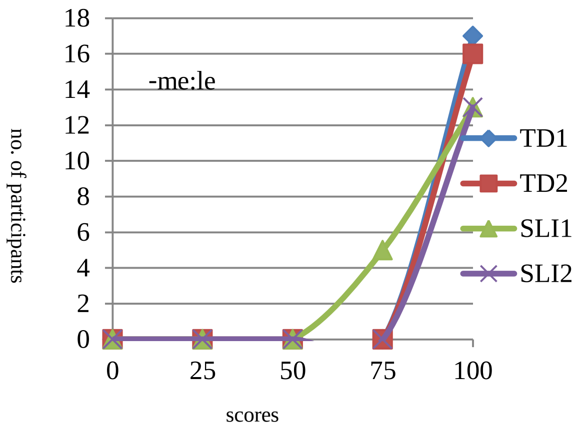


Figure 4.2.3.3 a Revision of *–me:le* by SLI1, SLI2, TD1, & TD2 participants

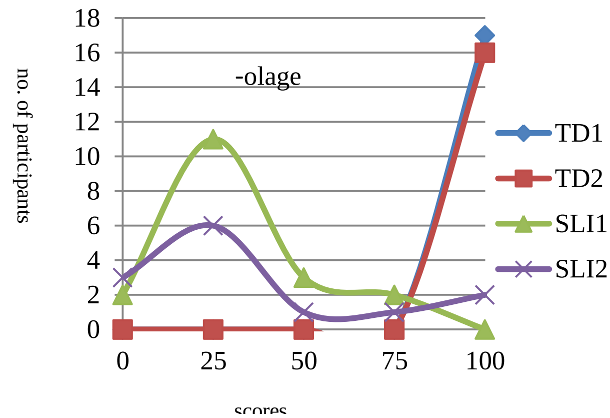


Figure 4.2.3.3 b Revision of *–olage* by SLI1, SLI2, TD1, & TD2 participants

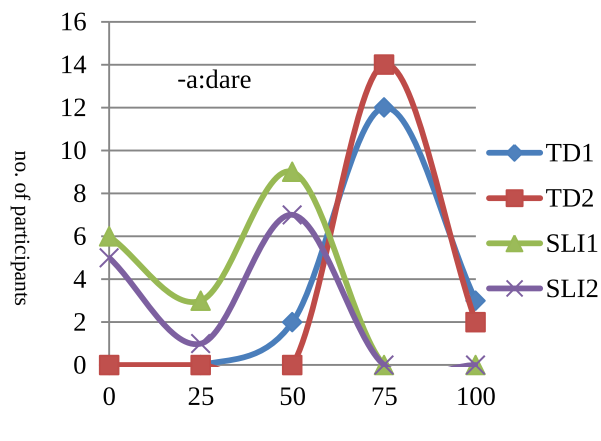


Figure 4.2.3.3 c Revision of *–a:dare* for SLI1, SLI2, TD1, & TD2 participants

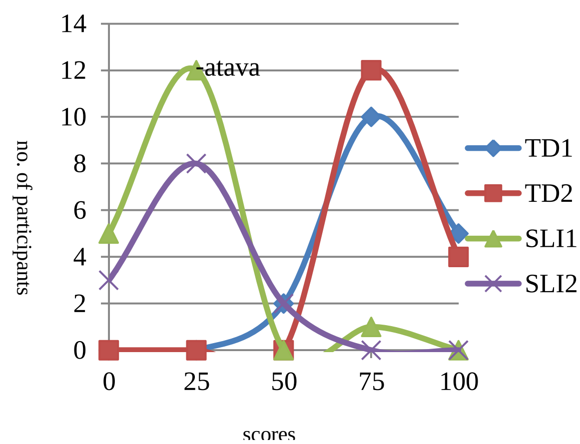


Figure 4.2.3.3 d Revision of *–atava* for SLI1, SLI2, TD1, & TD2 participants

Chronological age wise comparison showed that all the morpho-syntax elements and average judgment showed no interaction effect between group and age. However, average morpho-syntax revision showed interaction effect between group and age. Therefore, the combined analysis results apply for preposition, conjunction, comparatives/conditionals, and average morpho-syntax judgment and not for average morpho-syntax revision. Table 4.2.3.7

shows the descriptive results of SLI and TD groups on morpho-syntax performance (also Figure 4.2.3.4)

Table 4.2.3.7

Descriptive results of morpho-syntax performance of SLI and TD groups

MS	Group	Mean	SD	Std. Er	LB	UB	Min	Max
Pre	SLI	45.16	33.17	5.95	32.99	57.33	.00	100.00
	TD	100.00	.00	.00	100.00	100.00	100.00	100.00
Conj	SLI	43.54	28.84	5.18	32.96	54.12	.00	100.00
	TD	80.30	36.84	6.41	67.23	93.36	.00	100.00
C/C	SLI	41.61	23.25	4.17	33.08	50.14	.00	85.00
	TD	98.48	8.70	1.51	95.39	101.57	50.00	100.00
AMSJ	SLI	43.41	26.13	4.69	33.82	52.99	.00	86.60
	TD	90.21	17.53	3.05	83.99	96.43	55.50	100.00
AMSR*	SLI	88.08	8.73	1.56	84.88	91.29	50.00	100.00
	TD	96.39	9.86	1.71	92.89	99.89	66.60	100.00

Abb: MS-morpho-syntax, pre: Prepositions, Conj: Conjunctions, C/C: Comparatives/Conditionals, LB: Lower bound, UB: Upper bound, Std. Er: Standard error, AMSJ-average morpho-syntax judgment, AMSR-average morpho-syntax revision.

*showed interaction effect for group and age while analyzed after dividing into two age groups.

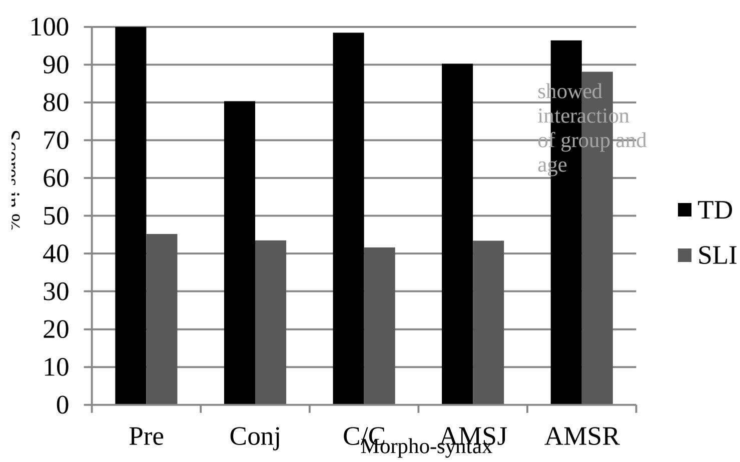


Figure 4.2.3.4 Comparison of SLI and TD groups on morpho-syntax performance

One way ANOVA was done to compare the performance of SLI and TD group on morpho-syntax skills (Table 4.2.3.8). Results showed that all the morpho-syntax scores were significantly lower for SLI group compared to TD group [pre: $F(1,62)=90.24, p=0.000$; Conj: $F(1,62)=19.57$, $p=0.000$; C/C: $F(1,62)=171.93$, $p=0.000$; AMSJ: $F(1,62)=71.57$, $p=0.000$].

Table 4.2.3.8
Comparison of SLI and TD groups on morpho-syntax performance (*one way ANOVA)*

Morpho-syntax	Mean square	F(1,62)	p
Pre	48069.556	90.246	0.000
Conj	21593.353	19.571	0.000
C/C	51700.153	171.931	0.000
AMSJ	35017.515	71.575	0.000
AMSR	1102.980	12.656	0.001

Individual morpho-syntax revision performance. Individual morpho-syntax revision performance of participants from SLI and TD groups were analyzed using crossbars and results are reported in Figure 4.2.3.5 (a-d). Chronological ages were combined within group and it could be justified as neither SLI nor TD showed chronological age differences within group (section on independent sample t-test under average morpho-syntax revision results)

While revising the morphemic element *–me:le* all the TD participants showed 100% performance, while 26 of SLI participants scored 100% and 5 SLI participants scored 75%. Therefore, it could be stated that SLI participants revised *–me:le* a locative morpho-syntax element almost like TD participants (Figure 4.2.3.5 a). All the TD participants revised *–olage* with 100% score, but SLI participants mostly scored 25% (n=17) and rest of SLI participants were scattered over 0%, 50%, 75%, and 100% (Figure 4.2.3.5 b). Similar pattern was observed for revision of *–a:dare*. TD peaks on 75% for most and few had peaks on 100% for revision of *–a:dare*. Whereas, SLI had peaks on 50% with some of participants scoring 25% and 0% (Figure 4.2.3.5 c). Revision of *–atava* showed clear distinction between SLI and TD because most TD participants peaked at 75% and some at 100%, but most SLI peaked at 25%, with only few SLI participants scoring 50% (Figure 4.2.3.5 d).

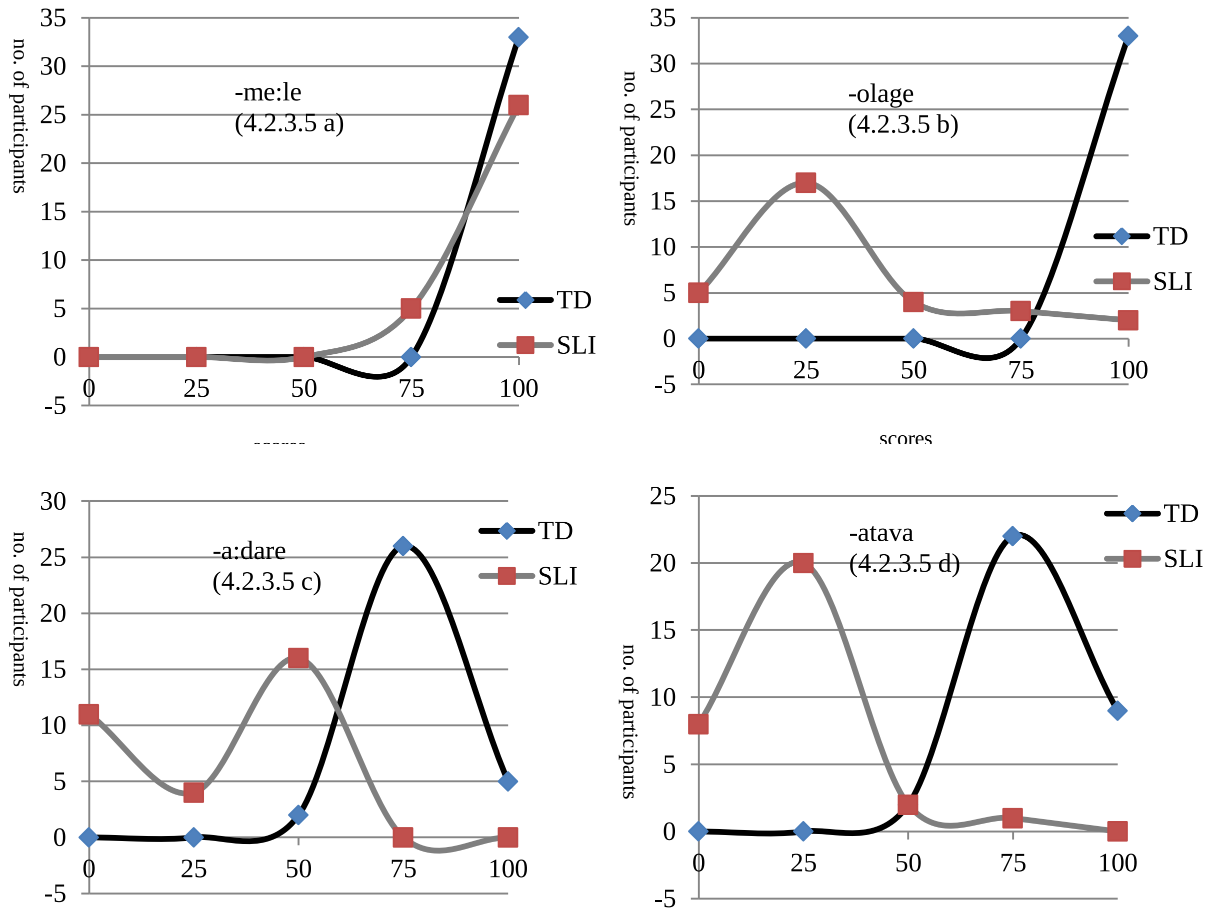


Figure 4.2.3.5 (a-d) Comparison between SLI and TD groups on revision of *–me:le, –olage, –a:dare,–atava*

Discriminant function analysis of non-adjacent operations. Non-adjacent operations such as judgment and revision scores from inflectional and morpho-syntax sections were considered variables and included for discriminant function analysis. The analysis revealed that 97.8% variables loaded in to the first discriminant function (DF1) [Wilks' λ = 0.009, $\chi2(72)$ = 232.92, p = 0.000], 1.5 % variables were loaded into the second discriminant function (DF2) [Wilks' λ = 0.423, $\chi2(46)$ = 42.115, p =0.636], and 0.7% loaded into third discriminant function (DF3) [Wilks' λ = .743, $\chi2(22)$ = 14.528, p =0.882]. Tables 4.2.3.9 a-c show standardized canonical discriminant function coefficients, structure matrix

Coefficients, and Functions at group Cendroids coefficients respectively for derivational morphemes.

The correlation between variables and discriminant functions revealed that only revision of –bi:Luta (r=.30) loaded heavily to DF1. Other several variables though were correlated they were not heavy (the value was <.3, Table 4.2.3.7 b) Variables such as revision of –ita (r=0.51), revision of me:le (r=0.45), revision of –ige (r=0.37), and revision of –ike (r=0.32). Revision of –ige (r=-.42) and average case marker revision (r=-.32) were loaded heavily in to DF3. Discriminant function plot shows that function 1 discriminated the SLI and TD groups clearly. Function 2 did not discriminate TD1 and TD2, but function 2 discriminated SLI1 and SLI2 very clearly (Figure 4.2.3.6). The classification results based on Discriminant functions revealed that 76.6% of the participants were correctly grouped. In TD1 70.6%, in TD2 81.3%, in SLI1 77.8%, and in SLI2 76.9% of the participants showed predicted group membership. In sum, non-adjacent operations clearly discriminated between SLI and TD groups.

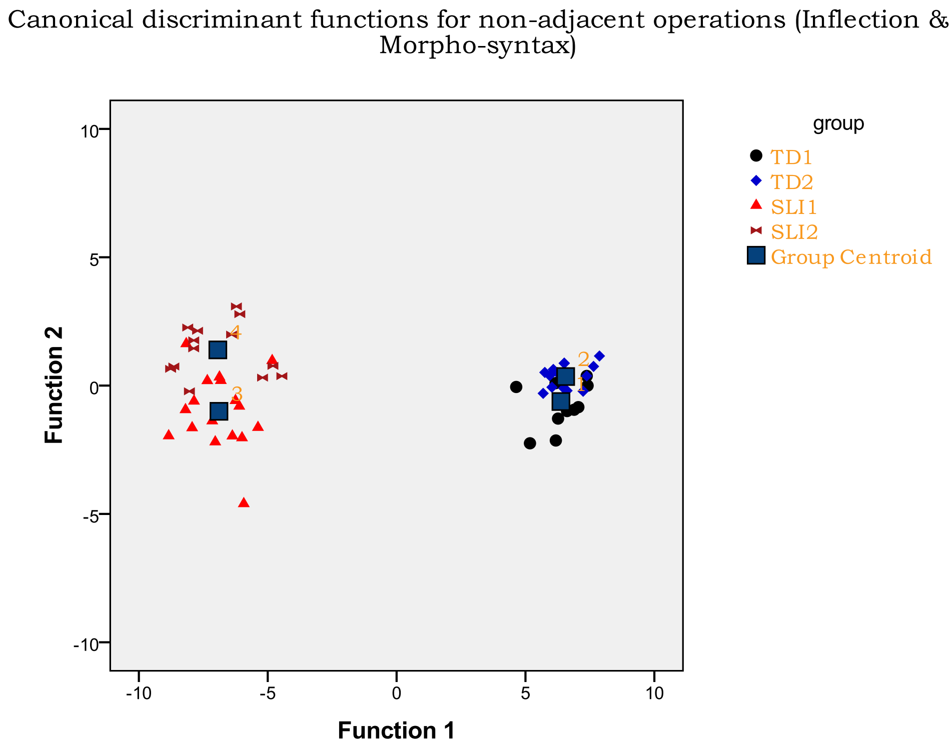


Figure 4.2.3.6. Discrimination of groups based on non-adjacent operations (inflection & morpho-syntax)

Table 4.2.3.9

Discriminant Function scores for non-adjacent operations

Non-adjacent elements (inflection & Morpho-syntax Included)	4.2.3.9.a *Standardized Canonical Discriminant Function Coefficients*			4.2.3.9.b *Structure Matrix* (correlation <0.3 was not considered)			
	Function			*Function*			
	1	*2*	*3*		*1*	*2*	*3*
plurals	-.34	.66	.11	-bi:Luta	.30*	-.18	.01
case markers	-1.20	-.02	.19	-athava	.28*	.01	-.02
tenses	-1.63	.03	.93	-gaLu	.27*	.17	.05
AIJ	2.43	.12	-.11	-olage	.25*	.05	.05
-a	.15	-.57	.94	-nnu	.25*	-.15	-.23
-nnu	-.00	-.09	-.99	C/C	.24*	.12	-.05
-ige	-.24	-.25	-1.13	AAGR	.20*	.06	.03
-lli	.49	.65	-.59	tenses	.20*	.12	-.01
-ike	-.89	-.09	.53	-a:dare	.19*	-.03	-.01
ACMR	.78	.18	-.36	-a	.17*	.01	-.03
-gaLu	.89	.07	-.68	-o:daru	.12*	.02	.04
-Dita	.456	.46	-.84	-Dita	.05	.51*	.001
-ho:daru	-.30	.01	-.43	-me:le	.05	.45*	.001
-bi:Luta	.59	-.67	.81	-ike	.16	.37*	-.13
AAGR	-.15	-.40	.90	-lu	.03	.32*	.001
prepositions	.01	.27	1.52	-lli	.15	.27*	-.19
conjunctions	3.87	2.73	.99	AIJ	.20	.22*	-.12
C/C	3.18	1.94	-.47	conjunctions	.08	.20*	-.19
AMSJ	-6.26	-4.03	-2.18	AMSJ	.16	.20*	-.16
-me:le	-.56	.24	.83	prepositions	.17	.17*	.03
-olage	1.14	.21	.05	-ige	.20	-.02	-.42*
-a:dare	1.02	-.15	-.21	ACMR	.22	.24	-.32*
-athava	.10	.34	.439	case markers	.17	.17	-.18*
AMSR	-.10	-.07	.31	AMSR	.06	-.05	-.13*

4.2.3.9.c *Functions at group centroids for non-adjacent elements*

Groups	Function		
	1	*2*	*3*
SLI1	-7.089	-1.011	-.001
SLI2	-6.702	1.440	-.023
TD1	6.350	.000	.778
TD2	6.674	-.032	-.807

4.2.3.3. Discussion. Inflections and morpho-syntax operations are integral in a language. For instance, Wexler (1996) in his work on development of inflection in a biological based theory of language acquisition demonstrates the inseparability between verbal inflection and morpho-syntax such as preposition, conditionals, and conjunctions of a sentence. In the context of present work, since both the operations necessitates non-adjacent (long distance) relation between the words in a sentence results on inflectional and morpho-syntax will be addressed as non-adjacent operations and discussed under a same section. Moreover, the explanation offered for both the operations from procedural memory system and its contribution for language is ambiguous.

On the inflectional judgment task, children with SLI performed significantly lower compared to TD children on case marker and agreement judgments but not on plural judgment. On average inflectional judgment performance, SLI children performed significantly lower compared to TD children. The same significant poor performance applied to comparison on average case marker revision (inflection) and average agreement revision (inflection). The same results apply to morpho-syntax judgment and revision, where SLI performed significantly lower compared to TD on all morpho-syntax judgment and revision tasks. Continuation with their good performance in judging plurals, children with SLI performed similar to TD on revising plural using marker *–gaLu*. On the individual revisions of morpho-syntax elements children with SLI always performed under 50%, with most participants scoring 25%. Overall, on revising individual inflectional/morpho-syntax items children with SLI always performed lower than 50% (i.e., mostly peaking around 25%).

The poor performance of SLI children on case and tense marking has been reported earlier (Rice et al., 2004; Rice et al., 1998; Rice et al., 2000; Kuppuraj & Prema 2012a, Kuppuraj & Prema, 2013d). Rice and her colleagues attributed the lack of agreement in grammar of SLI children to their tendency to mark the root morphemes optionally (for more details of the phenomenon extended optional infinitives hypothesis by Rice et al., 1995). Studies by Kuppuraj and Prema (2012a) discussed the poor inflection from poor sequence learning perspective and concluded this non-adjacent aspect of language operation require greater demand from procedural memory system. Therefore, children with SLI show greater inflectional deficits affiliated to sequence learning deficits. Children with SLI in the present study showed poor performance on morpho-syntax judgment and revision. Studies examined prepositional performance in children with SLI reported of mixed results (intact prepositional usage by Puglisi, et al., 2005; Watkins & Rice, 1991; affected prepositional usage by Glera et al., 2004). Prepositions like other inflections require greater relation between words in a sentence (Tomasello, 1987). Therefore, it could be difficult for children with SLI. Children with SLI performed significantly lower compared to TD children on conjunctions in the present study. Study by Gonzalez, Caceres, Bento-Gaz, and befi- Lopes, (2012) reported of poor conjunction performance in children with SLI that is in support to the findings of the present study. Even though, no specific study is found for performance of SLI on comparatives/conditionals it is obvious that these operations require greater relation from non-adjacent words in a sentence. Therefore, the explanation of poor sequence learning as a reason for poor performance in comparatives/conditionals will be appropriate. Study by Kuppuraj and Prema (2013d) used morpho-syntax in their study together with inflection and reported together to show the relation between these language aspects and sequence learning. Even though, morpho-syntax operations in the present study was analyzed separately the results on morpho-syntax are comparable to inflectional operations in the present study. The reason for poor performance could be due to its non-adjacent dependency nature in language just like inflections. Specific explanations from implicit phenomenon pertaining to non-adjacent operational deficits are given in the following section.

Even though, any language deficit could be explained by generalized processing and capacity limitations (Leonard et al., 2007), the present study ought to explain the language deficits from the functions of procedural mechanism. We predicted based on PDH that the non-adjacent operations such as inflections and morpho-syntax would be difficult for children with SLI. The non-adjacent marking difficulty in the grammar of children with SLI could be related to their poor performance in serial reaction time task (an Adapted-SRT task in the present study).

In a SRT task, participants are required to predict successive elements based on previous elements. Similarly, to mark an inflection (tense marking) using proper inflectional suffix the participant need to predict the suffix using first few elements in a sentence. As illustrated in Figure 4.2.3.7, children with SLI who lack the predicting ability in their sequential cognition, also fail to predict elements both in motor sequence as well as in sentence sequence that is, grammar (Knutson, 2006; Kuppuraj & Prema 2012a). Conway, Bauernschmidt, Huang, and Pisoni (2008) reported the relation between sequence learning and word predictability. Conway and others reported that speech perception is fostered by ability to predict elements of speech, which has direct correlation with sequential cognition. The results of present study conform to results of Conway and colleagues in explaining the relation between sequence learning and non-adjacent operations in language. Figure 4.2.3.7 provides a hypothetical illustration of how a motor sequence learning task could resemble the sequential grammar operation.

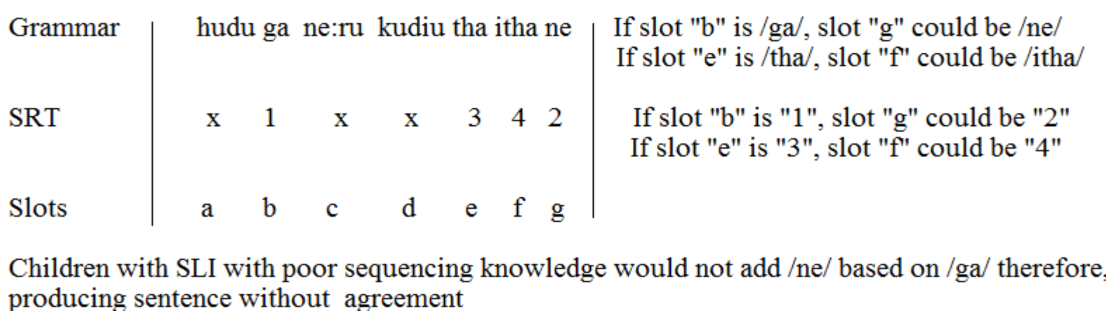


Figure 4.2.3.7 Hypothetical illustration to equal sequence learning (SRT) and inflectional grammar

Another explanation for poor performance in inflectional morphemes among children with SLI could come from statistical learning mechanism. Statistical learning is an integral part of non-declarative implicit learning, which aids in calculating the statistical probabilities (Aslin, Saffran, & Newport, 1998) of occurrence for successive elements in a speech string (or any non-verbal stimulus). The knowledge of transitional probabilities in a language could be handy in determining the word boundaries (Saffran, 2003) which in turn boosts the word learning (Tomasello, 2000). In the present study, stimuli for judgment were given orally and all the inflections in Kannada were attached (the phonotactics of Kannada) at the word ending. Inappropriate statistical learning driven by procedural memory system in children with SLI could have led to poor detection of inflectional/morpho-syntax elements and its errors in the present study. Kuppuraj and Prema (2013d) proposed similar reasons for their SLI children's poor performance in non-adjacent operations such as inflection and morpho-syntax. In summary, the judgment deficits on non-adjacent operations of children with SLI in the present study could be explained by sequential and statistical phenomenon of procedural mechanism.

Results on revision performance needs two levels of discussion as the task itself had several folds of scoring. Firstly, if participants were to revise at the first instance (i.e., score of 100%) they required greater lexical retrieval. Only few children with SLI in the present study scored 100% in non-adjacent revision (in plurals only). Therefore, the poor lexical retrieval in children with SLI should be prioritized drawing support from procedural deficit hypothesis followed by the performance on the revision task ranging from 25% to 50% range complemented with judging procedure that was a binary forced choice. In other words, they did not even revise but judged which would have required statistical knowledge, but with lesser cognitive load (with clue). Studies examined inflectional /morpho-syntax revision performance showed similar results to present study. They showed that when children with SLI were asked to revise on their own, they struggle, but when the morphemes were available, they used them correctly (Ullman & Gopnik, 1999; van der Lely & Ullman, 2001). The performance of SLI group in the present study is in continuation with the past results. Studies in the past have not explained any of the morphemic revisions particularly in relation with sequence learning mechanism. At first level, to explain poor lexical retrieval we ought to include the association between declarative and procedural memory in language operations. The association between procedural and declarative memory in some of declarative functions such as word retrieval could be a reason for the poor retrieval in the present study. The stimulus presentation design of the present study was such that when the participants failed revising the choices were given through binary forced choice. That is two sentences were given orally again from which the correct sentence need to be judged. Therefore, the second level of explanation for poor revision performance is drawn from to the statistical knowledge of participants. To judge effectively statistical knowledge is essential that is affected in children with SLI. Since statistical knowledge is a procedural skill (Hsu & Bishop, 2010; Kuppuraj & Prema, 2013d) the lack of awareness for identifying word boundaries could have impeded SLI children from choosing the correct response even in revision tasks.

It is worth mentioning the seesaw effect between two of the not so differentiated memory systems. The compensation between these systems could be used to explain the variance in performance between individuals. For instance, an individual with well-equipped declarative system could manage to perform grammar explicitly to an extent. This could be a major reason why children with SLI performed plurals like TD children. The relatively less number of plural markers in a language could have made it an easy candidate to be learned through declarative system. For instance, the declarative memory system could adapt an abstract definition for usages of plural such as ‘whenever there is more than one number, add –*gaLu* with the object’.

Results on derivational morphemes and non-adjacent operations were both shown to be affected in children with SLI. Procedural mechanism and associated declarative mechanism, statistical learning and seesaw effects were used to explain the derivational and non-adjacent judgment and revision performance of children with SLI. To report on most adversely affected grammar operation between adjacent and non-adjacent a within group comparison between derivational and non-adjacent average scores were done. Within group analysis for SLI and TD on derivational and non-adjacent operations (judgment and revision performance) would give additional evidence to the quest of finding the relation between procedural mechanism and most dependent language functions (please note that a specific correlation analysis is reported in section 3.3.1 for this objective). Average judgments for inflection and morpho-syntax were averaged and single scores were obtained (considered as non-adjacent) and compared against average derivational judgment scores. The average of three non-adjacent revisions (average case marker revision, average agreement revision and average morpho-syntax revision) were made and compared against average derivational revision scores.

4.2.3.4. Comparison of morphemic performance on morphemes within group. Comparison between inflection judgment and derivational judgment in TD group showed that they were not significantly different [t (32) =1.925, p=0.06)]. While comparing between inflectional revision versus derivational revision children with typical language showed that their inflectional revision was significantly better than their derivational revisions [(t(32)=-19.713,p=0.000)].Comparison between inflectional judgment and derivational judgment in SLI group showed that children with SLI performed derivational judgments significantly better compared to inflectional judgment [t(30)=11.83,p=0.000)]. Revision scores between inflection and derivation in children with SLI showed that they revised inflectional revisions significantly better compared to derivational revisions [t (30) =-7.51, p=0.000] (Table 4.2.3.10 & Figure 4.2.3.8).

Table 4.2.3.10

Mean *and SD of judgment and revision performance within SLI and TD groups*

Parameters	SLI (n=31)		TD (n=33)	
	Mean	SD	Mean	SD
Inf/Ms Jud	51.39	18.56	92.45	11.79
Der Jud	84.91	9.48	95.94	6.88
Inf/Ms Rev	68.88	9.05	95.36	7.19
Der Rev	55.88	12.06	65.60	10.09

Abb:Inf/Ms Jud-Inflection and Morpho-syntax judgment, Der jud-Derivational Judgment, Inf/Ms Rev-Inflectional and morpho-syntax revision, Der Rev-derivational revision.

In sum, comparisons between inflections and derivations within group showed that TD children judged inflections and derivations without significant difference. However, SLI performed derivation judgment significantly better than inflectional judgment. During revision was both SLI and TD groups showed that their inflectional revisions were significantly better than derivational revisions.

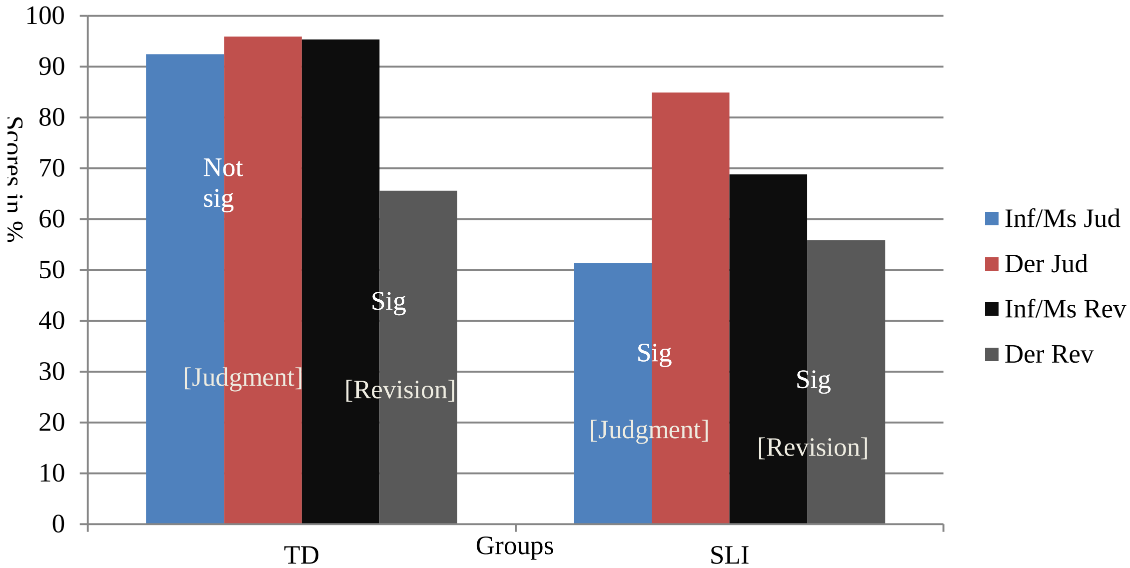


Figure 4.2.3.8 Comparison of judgment and revision performance within group

Abb: Not sig- the means were not different significantly, Sig-the means were different significantly. Inf/Ms Jud-Inflection and Morpho-syntax judgment, Der jud-Derivational Judgment, Inf/Ms Rev- Inflectional and morpho-syntax revision, Der Rev-derivational revision.

Discussion. The striking finding was obvious in judgment task where TD children performed both non-adjacent and derivational morphemes with equal ease. However, SLI performed non-adjacent judgment operations significantly lower compared to derivational operations. This finding reveals that inflectional operations required clear identification of word boundaries, predicting ability, and relation between words (even at far distance) more so compared to derivational operations. On the other hand, derivations mostly stand alone leading to better judgment even by children with SLI. The finding is added evidence to our proposed hypothesis that non-adjacent operations would require greater sequencing skills (procedural knowledge) compared to adjacent operations. Study by Kuppuraj and Prema (in preparation) found similar findings to the present study, where children with SLI performed the inflectional morphemes with greater difficulty. It could also be stated that sequencing difficulties do not affect derivations as adversely as it does the inflection performance. Severe inflectional deficits compared to derivational deficits were reported in the past (e.g., Kuppuraj & Prema, 2012a; Kuppuraj & Prema, 2013d; Marshall & van der Lely, 2007). The results of present study showing greater deficits on rule based operations by SLI support the

PDH which proposed that rule based operations were essentially related to procedural memory system. Comparison of revision results within group of SLI showed that the performance pattern of children with SLI for derivational and non-adjacent revisions was similar to TD children (inflectional revision better than derivational revision). The contribution of declarative memory system in word retrieval and lesser cognitive load that was offered during clue condition of the present study could have helped children with SLI from procedural dependency and therefore, producing indifference in revision of both adjacent and non-adjacent tasks.

4.2.3. Results of sentence complexity measure. To compare the performance of children with SLI and TD children on sentence complexity measures, number of t-units, number of clauses, number of words, Words/Clauses, Clauses/t-unit and words/t-unit were analyzed using two way MANOVA for all four age groups (SLI1, SLI2, TD1, &TD2). Descriptive results for sentence complexity measures are reported in Table 4.2.4.1, Table 4.2.4.2, and Figure 4.2.4.1.

Table 4.2.4.1

Descriptive statistics for SLI groups on sentence complexity measure

SC measure	SLI1					SLI2				
	Mean	SD	Std.Er	LB	UB	Mean	SD	Std.Er	LB	UB
t-units	3.00	0.90	0.23	2.54	3.50	3.15	0.37	0.28	2.56	3.70
Clauses	5.27	1.12	0.31	4.68	5.93	5.46	0.66	0.37	4.74	6.23
Words	24.88	5.14	1.63	21.69	28.26	22.69	2.81	1.96	18.75	26.62
Words/Clauses	3.83	0.75	0.19	3.45	4.22	3.56	0.58	0.23	3.03	3.95
Clauses/t-unit	1.13	0.20	0.05	1.02	1.23	1.09	0.15	0.06	0.95	1.20
Words/t-unit	5.81	1.07	0.32	5.15	6.47	5.60	0.84	0.39	4.85	6.43

Table 4.2.4.2

Descriptive statistics for TD groups on sentence complexity measure

SC measure	TD1					TD2				
	Mean	SD	Std.Er	UL	LL	Mean	SD	Std.Er	UL	LL
t-units	3.82	1.13	0.24	3.32	4.30	5.62	1.36	0.25	5.14	6.14
Clauses	6.00	1.62	0.31	5.36	6.63	7.81	1.47	0.32	7.18	8.50
Words	28.88	8.58	1.67	25.44	32.15	41.93	9.20	1.72	38.53	45.46
Words/Clauses	4.84	0.70	0.19	4.43	5.23	5.38	1.01	0.20	4.95	5.77
Clauses/t-unit	1.59	0.30	0.05	1.49	1.70	1.40	0.19	0.05	1.29	1.52
Words/t-unit	7.66	0.98	0.33	6.99	8.34	7.21	2.08	0.34	6.48	7.87

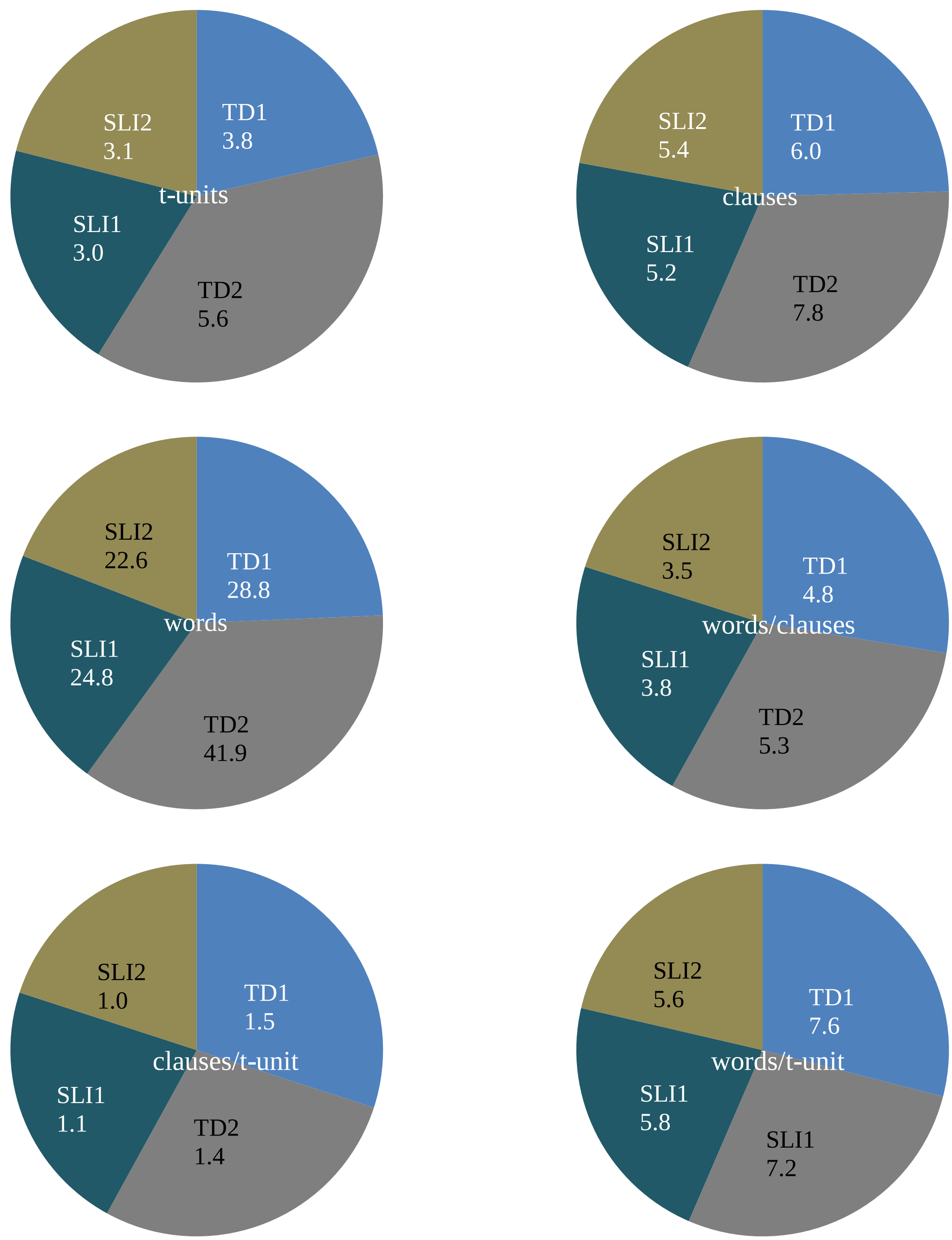


Figure 4.2.4.1 Comparison of SLI1, SLI2, TD1, and TD2 on sentence complexity measures

Wilk's λ for group showed that groups were significantly different from each other on all sentence complexity measures [λ=0.101, F (12, 94) =16.779, p=0.00, η^2=0.682]. Wilk's λ for chronological age was not significant [λ=0.682, F (24,165.17) =0.797, p=0.737,

η^2=0.091]. Group and chronological age interaction (group * age) was also not significant [λ=0.687, F (24,165.17) =0.783, p=0.754, η^2=0.090] (Table 4.2.4.3).

Table 4.2.4.3

F values for group, chronological age and group CA interaction between groups (two way MANOVA)

Parameters		df, 52	Mean square	F	Sig.	η^2
Group	t-units	2	24.50	24.41	0.00	0.48
	Clauses	2	21.27	12.51	0.00	0.32
	Words	2	1353.86	28.63	0.00	0.52
	Words/Clause	2	16.42	25.01	0.00	0.49
	Clauses/t-unit	2	1.32	26.39	0.00	0.50
	Words/t-unit	2	22.96	12.08	0.00	0.32
CA	t-units	4	2.05	2.04	0.10	0.14
	Clauses	4	2.31	1.36	0.26	0.09
	Words	4	74.48	1.57	0.19	0.11
	Words/Clause	4	0.15	0.23	0.91	0.02
	Clauses/t-unit	4	0.06	1.28	0.28	0.09
	Words/t-unit	4	1.23	0.64	0.63	0.05
Group * CA	t-units	4	0.67	0.67	0.61	0.05
	Clauses	4	0.57	0.33	0.85	0.03
	Words	4	44.04	0.93	0.45	0.07
	Words/Clause	4	0.61	0.93	0.45	0.07
	Clauses/t-unit	4	0.04	0.82	0.51	0.06
	Words/t-unit	4	1.31	0.68	0.60	0.05

Abb: CA-chronological age

Since there was no significant interaction between groups and age, different chronological ages were merged (for both SLI and TD). One way ANOVA was done to compare between SLI (n=31) and TD (n=33) groups on sentence complexity measures. Table 4.2.4.4 and 4.2.4.5 show the descriptive measures (Figure 4.2.4.2) and Table 4.2.3.6 reports F value of one way ANOVA.

Table 4.2.4.4

Descriptive statistics of SLI children on sentence complexity

SC measure	SLI (n=31)						
	Mean	SD	Std.Er	LB	UB	Min	Max
t-units	3.06	0.72	0.13	2.79	3.33	2.0	4.0
Clauses	5.35	0.95	0.17	5	5.70	3.0	7.0
Words	23.96	4.40	0.79	22.35	25.58	16.00	32.00
Words/Clauses	3.72	0.69	0.12	3.46	3.97	2.20	5.00
Clauses/t-unit	1.11	0.18	0.03	1.05	1.18	0.80	1.40
Words/t-unit	5.73	0.977	0.175	5.37	6.08	4.00	8.30

Table 4.2.4.5

Descriptive statistics of TD children on sentence complexity

SC measure	TD (n=33)						
	Mean	SD	Std.Er	LB	UB	Min	Max
t-units	4.69	1.53	0.26	4.15	5.23	2.0	8.0
Clauses	6.87	1.78	0.31	6.24	7.51	3.0	11
Words	35.21	10.97	1.91	31.32	39.10	18.00	57.00
Words/Clauses	5.10	0.89	0.15	4.78	5.42	3.60	7.60
Clauses/t-unit	1.50	0.26	0.04	1.40	1.59	1.12	2.50
Words/t-unit	7.44	1.60	0.27	6.87	8.01	1.30	10.40

Abb: Std.Er-standard error, LB-lower bound, UB-upper bound, Min-minimum, Max-Maximum

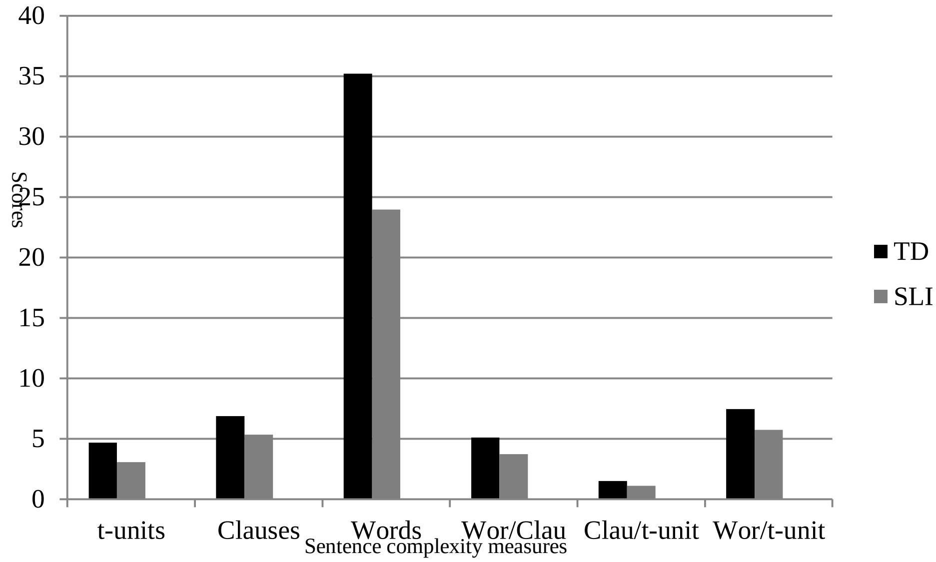


Figure 4.2.4.2 Comparison of SLI and TD on sentence complexity measure
Abb: Wor/clau-words per clauses, Clau/t-unit-Clauses per t-unit, Wor/t-unit-words per t-unit

Table 4.2.4.6

Comparison of SLI and TD groups on sentence complexity measures (one way ANOVA)

SC measures	Mean Square	F(1,62)	p
t-units	42.597	29.073	0.00
Clauses	37.122	17.896	0.00
Words	2021.001	28.244	0.00
Words/Clause	30.651	47.557	0.00
Clauses/t-unit	2.334	43.577	0.00
Words/t-unit	47.088	26.236	0.00

Table 4.2.4.6 shows that all the sentence complexity measures were significantly lower for SLI group compared to TD group [t-units, $F(1,62)= 29.07, p=0.00$;Clauses, $F(1,62)=17.89$, $p=0.00$; Words, $F(1,62)=28.24$, $p=0.00$; Words/Clause, $F(1,62)=47.55$, $p=0.00$; Clauses/t-unit, $F(1,62)=43.57$, $p=0.00$; Words/t-unit, $F(1,62)=26.23$, $p=0.00$).

4.2.3.1. Discriminant function analysis for sentence complexity measures. Sentence complexity measures such as t-units, words, clauses, words/t-unit, clauses /t-units and words/clauses were considered as variables and analyzed using discriminant function analysis. 90.3% of the total group variables are loaded into the first discriminant function (DF1) [Wilks' λ = 0.097, $\chi 2$ (18) = 135.13, p=0.00], 7.7% into second discriminant function (DF2) [Wilks' λ = 0.614, $\chi 2$ (10) = 28.25, p=0.002], and 2.1% into third discriminant function (DF3) [Wilks' λ = 0.892, $\chi 2(4)$ = 6.627, p =0.157]. Tables 4.2.4.7 a-c show Standardized Canonical Discriminant Function Coefficients, Structure Matrix Coefficients, and Functions at group Centroids coefficients respectively for derivational morphemes.

Table 4.2.4.7

D*iscriminant function analysis for sentence complexity measures*

	4.2.4.7.a *Standardized Canonical Discriminant Function Coefficients*			4.2.4.7.b *Structure Matrix (correlation <0.3 was not considered)*			
	Function				Function		
Parameters	1	2	3		1	2	3
t-units	1.552	.143	.691	word/ Clause	.406*	-.192	-.314
Clauses	-.242	-.151	1.647	words	.393	-.849*	-.243
Words	-.620	-.794	-2.134	t-units	.388	-.787*	.222
word/ Clause	.695	.191	.282	clauses	.290	-.638*	.199
Clauses/t-unit	.871	.584	-.658	Clauses/t-unit	.360	.623*	-.225
Words/t-unit	.442	.050	.827	Words/t-unit	.260	.299*	-.073

Table 4.2.4.7.c

Functions at group Centroids for sentence complexity measures

Group	Function		
	1	2	3
SLI1	-2.256	-.114	-.413
SLI2	-2.318	-.058	.567
TD1	1.738	.956	-.012
TD2	2.575	-.840	.017

Canonical discriminant functions for sentence complexity measures

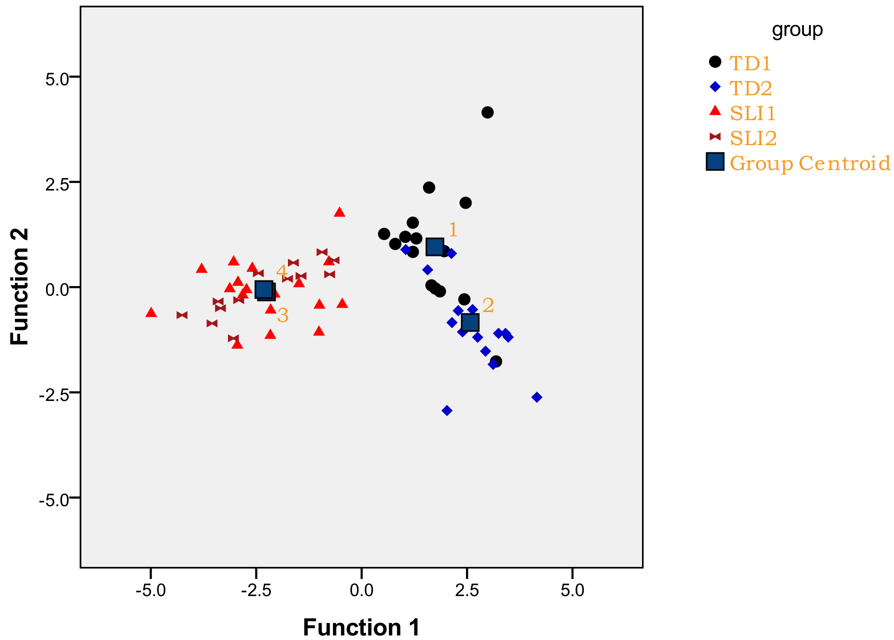


Figure 4.2.4.2 Distinction among groups based on sentence complexity measures

The correlation between variables and discriminant functions revealed that words/ clauses (r=.406) was loaded heavily to DF1. Words (r=-.849), t-units (r=-.787), clauses (r=-.638), and clauses/t-unit (r=.623) were loaded into DF2.The classification results based on Discriminant functions revealed that 73.4% of the participants were grouped correctly. In TD1 82.4%, in TD2 75%, in SLI1 66.7%, and in SLI2 69.2% of the participants showed predicted group membership. In sum, discriminant function plot shows that sentence complexity measures discriminated between TD and SLI groups clearly (Figure 4.2.4.2).

4.3.2.2. Discussion. Results on sentence complexity measures revealed that all the parameters measured were significantly lower for SLI group compared to TD group. Neither TD nor SLI groups showed chronological age difference in sentence complexity measure. Literature reported of simple sentences in children with SLI (Bedore & Leonard, 1998; Marinellie, 2004; Arndt & Schuele, 2008), which is in support for findings from this study. Chomsky (1995) proposes that syntactic structure is built from the bottom up process via a single operation called Merge. Chomsky (1995) consolidated the role of merge in making sentence in his explanations on minimalist operations, which maintains that lexical items are combined recursively by merge to make a complete syntactic structure. Bolender et al. (2008) reported that merge operation could be a procedural skill. The present data in which children with SLI who showed poor sentence making affiliated to poor procedural learning could be in support of claim by Bolender et al. (2008) and Chomsky, (1995). Procedural memory difficulties in SLI group could have resulted in drop in number of words and t-units resulting in reduction in all the other measures. Even though, poor sentence making abilities are not claimed by PDH in its original form, the relation was derived from Bolender's proposal of procedural memory and merge (for complete reviews, Bolender et al., 2008). Study by Kuppuraj and Prema (2013d) consolidated the idea by Bolender and colleagues to hypothesize that poor procedural learning could be the cause of poor sentence making in children with SLI. Kuppuraj and Prema (2013d) strengthened the relation between procedural memory and sentence making through various sentence complexity measures compared between TD and SLI children. Kuppuraj and Prema (2012a) also reported a link between sequence (procedural) learning and sentence making abilities. The results of present study are in consonance with Kuppuraj and Prema (2012a, 2013d), which in turn strengthens the proposed hypothesis. That is the results on sentence complexity measures of the present study are in favor of the proposed hypothesis, which states that procedural memory deficits would be reflected as poor sentence making in language-impaired children. The findings suggesting poor sentence making in children with SLI who showed poor procedural skill also is in support of previous hypothesis such as an incremental procedural grammar for sentence formulation (Kempen & Hoenkamp, 1987). Incremental procedural grammar claims that procedural memory forms the base of grammar operation by implicitly merging the segments.

Even though, the merge and procedural memory explanation could be accepted considering the substantiality of present data, how a direct relation between procedural memory and a merging operation could be accepted. Unlike for explaining grammatical operations (e.g., non-adjacent) implementing phenomenon such as sequence learning and statistical learning would not satisfy the relation between sentence making and sequence learning. To explain poor sentence making from procedural memory perspective, in spite of our peripheral knowledge on such relation phenomenon, we would like to come out with convincing evidence from recursion and related neuro-anatomical and psycholinguistic studies. Recursion (ability to repeat similar structure implicitly by merging) in language has been considered a narrow language faculty (Hauser, Chomsky, & Fitch, 2002). In other words, the ability to join phrase in a sentence could be the only evolved cognitive tool for language in human that differentiates them from ancestors (Hauser et al., 2002). Uniquely human grammar could have been underlined by specific anatomical distinction particular to human. Human brain has large quantity of white matter peduncle that runs from prefrontal to cerebellum (procedural memory structures), which is specific to human alone (for experiments on pre-frontal white matter peduncles, Alexander et al. 1986; Middleton & Strick, 2000a; Shimamura, 1995). Presence of such anatomical uniqueness across human brains intrigued researchers and they related the presence of distinct prefrontal white matter peduncle to modern syntax (Middleton & Strick, 2000b; Shimamura, 1995). In summary, the results of present study are largely in support of the proposed claim that sentence making ability could be influenced by procedural knowledge. Even though, the sentence making results could not be readily explained by the essence of PDH, evidences were gathered from recursion related neuro anatomical and psycholinguistics studies to relate procedural memory and sentence making.

4.2.4. Results of factor analysis. The data from children with SLI were analyzed using principal components analysis (PCA-a data reduction procedure) to delineate the components that are explaining the most of the variance in the SLI data. This was done to see the major variables contributing to the total variance of the SLI data. In other words, clinical markers of SLI from sequence learning measures and examined morphemes. Thirteen principal components were extracted (Table 4.2.5.1). First component explained 30% of variance with second and third components explaining 8.7 % and 7.8 % of total variance in data respectively. Cumulative percentage showed that these thirteen components extracted could explain 88% of total variance in SLI data (Table 4.2.5.1).

Table 4.2.5.1.

Percentage of variance and cumulative percentages accounted by the components extracted

Component	Initial Eigen values		
	Total	% of Variance	Cum %
1	14.04	30.53	30.53
2	4.03	8.76	39.29
3	3.62	7.87	47.17
4	3.12	6.79	53.96
5	2.97	6.46	60.43
6	2.31	5.02	65.46
7	2.10	4.57	70.04
8	1.87	4.07	74.11
9	1.80	3.92	78.04
10	1.44	3.14	81.18
11	1.17	2.55	83.74
12	1.10	2.40	86.15
13	1.04	2.26	88.41

Abb: Cum-cumulative

Rotated component matrix revealed that component one and two could explain maximum amount of variance; therefore, the variables contributing significantly (>.6 in extraction score) to these components were extracted and considered as clinical markers of SLI (Table 4.2.5.2)

Table 4.2.5.2 shows that all significant markers are non-adjacent components and three out of four moderate markers are non-adjacent components. Only noun derivations were shown to be moderate marker among derivational morphemes. Average inflectional judgments, tense judgment, revision of –*gaLu*, average case marker revision, judging case markers, average MS judgment, judging conjunctions and revision of case markers such as –*ike* are significant markers of SLI children.

Table 4.2.5.2

Variables with extraction scores for first two components

Variable (Italized are non-adjacent variables)	Component 1 (significant markers)	Component 2 (moderate markers)
Avg Inf (Jud)(Plu+Ten+CM)	.931	-
Tense (Inf jud)	.878	-
-gaLu (Inf rev)	.798	-
Avg Case marker (rev)	.787	-
CM (jud)	.690	-
Avg MS (jud)	.647	-
conj (jud)	.644	-
-ike (CM rev)	.638	-
-olage (MS rev)	-	.902
pre (MS jud)	-	.657
-lli (Inf rev)	-	.649
Deriving nouns (rev)	-	.625
SLavg1		.806
SLavg2		.800
SLavg3		.663

Abb: Avg-average, Inf-inflection, Jud-judged/judgment, CM-case marker, MS-morpho-syntax, conj-conjunctions, rev-revision (note: italicized are non-adjacent and bolded are sequence learning variables).

Further, revision of morpho-syntax such as *–olage*, judging prepositions, inflectional revisions of *–lli*, and deriving nouns are moderate markers of SLI children in the present study. Among the type of task, principle component shows that 50% of the markers were judgment tasks and 50% of them were revision tasks. This shows that type of ask did not influence the marker. Analysis showed that sequence learning measure could be a moderate clinical marker of SLI. Among the parameters of AD-SRT task, SLavg1 contributed more to group variability followed by SLavg2 and SLavg3. In summary, principal component analysis showed that non-adjacent operations irrespective of judgment or revision to be significant clinical markers of SLI in the present study.

4.2.4. 1. Discussion. Present study shows inflectional morphemes and morpho-syntax units to be significant clinical markers of SLI. Finding clinical markers was not the major objective of the present study; therefore, the stimulus did not focus on such objective. Hence, the clinical markers reported were only the evolved markers from whatever morphemes assessed in the present study. Similar to present study grammatical morphology has been reported as clinical markers of SLI (Bishop et al., 2004; Vicki, 2005; Gardner, Froud, McClelland, & ven Der Lely (2006). Rice and Wexler (1996) reported tense marking to be clinical marker of SLI, which is in coherence with the result of preset study, which showed tense to be a significant clinical marker of SLI. However, Rice and Wexler's study did not report agreement as clinical marker of SLI, which is in contrast to the present results, which showed agreement also to be significant marker. The present study showed that derivational morphemes were not significant contributor for being marker in clinics. The results were consistent with the research, where none of the past studies showed derivational morphemes as clinical marker of SLI. The present study reported markers from both judgment and revision tasks. A result such as these stating invariable markers from judgment and revision task has been reported earlier (e.g., Rice, 2002).

The general explanation offered by Rice, Wexler, and Redmond (1999) for clinical markers being inflectional morphemes was from their extended optional infinitive (EOI) hypothesis. The EOI offers explanation as weakness in judgments of finiteness omission. Kail (1994) provides contrasting hypothesis from his theory stating generalized slowing of processing in language-impaired children. According to this slow processing hypothesis inflectional marker, such as tense marker could be interpreted as localized consequences of more generalized, limited time-dependent processing of linguistic input (Miller, Kail, Leonard, & Tomblin, 2001). In order to discuss the results from PDH, which is the core of the present study, the results on clinical markers are interpreted from sequence learning perspective. That is, 73.3 % (11 out of 15) markers were from non-adjacent operations, indicating a dominance of sequence learning in deciding the clinical markers of SLI. In other words, if a child shows predominantly inflectional/morpho-syntax deficits he/she could be suspected to have procedural memory deficits affiliated with language deficits. Not surprisingly, the parameters of sequence learning were shown to be moderate markers of SLI. SLavg1 being more robust markers among parameters of AD-SRT task which is in line with study by Kuppuraj & Prema (2013c). Kuppuraj & Prema showed that SLavg1 is the most reliable measure of sequence learning because SLavg2 and SLavg3 are prone to reactive inhibitions (method section 3.4). The results could be considered first of this sort that compared the inflectional/morpho-syntax with derivational morphemes for evolving markers of SLI.

4.3. Objective 3: Relation between Sequence Learning and Language

Pearson's correlation was done among measures of sequence learning such as SLavg1, SLavg2, SLavg3 and ISL and average language measures such as average derivational judgment, average derivational revision, average inflectional judgment, average case marker revision, average agreement revision, average morpho-syntax judgment, and average morpho-syntax revision. Individual judgment or revision measures that had several "0" responses were not included for correlation analysis. Sentence complexity measures such as number of t-units, clauses, words, words per clause, clauses per t-unit, and words per t-unit were also correlated with sequence learning measures.

4.3.1. Correlation between sequence learning and language in SLI children.

Table 4.3.1

Correlation between sequence learning and language performance in SLI children

Between	Specific pairs	n	r	p	Correlation
Derivation & SL	ISL & ADJ	31	0.391*	0.029	Positive
Inflection & SL	ISL & rev-lli	31	0.385*	0.032	Positive
Morpho-syntax & SL	ISL & C/C	31	0.365*	0.043	Positive
Morpho-syntax & SL	ISL & AMSR	31	-0.426*	0.017	Negative
Sentence complexity	ISL & W/Cla	31	-0.449*	0.011	Negative
& SL	ISL & W/t-unit	31	0.358*	0.048	Positive

*correlation significance at <.05 level of significance
Abb: ADJ-average derivational judgment, rev-revision, C/C-comparative/conditional, AMSR-average morpho-syntax revision, W/Cla-words/clauses, W/t-unit- words per t-unit.

In the SLI group, index of sequence learning (ISL) correlated with most of the language measures. ISL correlated positively with average adjective derivation in SLI children (r=0.391, n=31, p=0.029). ISL correlated positively with revision scores of locative inflectional morpheme *–lli* (r=0.385, n=31, p=0.031). ISL value of SLI correlated positively with C/C (comparative/conditional) score of morpho-syntax performance (r=0.365, n=31, p=0.043). ISL value correlated negatively with average morpho-syntax revision (r=-0.426, n=31, p=0.017). Because, in a broad statistical model (two way MANOVA) group and chronological age interaction was present (section 4.2.3.2), each age group in SLI (SLI1 & SLI2) was analyzed separately. Results showed that among the SLI1, ISL value correlated with revision scores of *–a:dare* (r=-0.485, n=18, p=0.041) and none of sequence learning and language pairs correlated in SLI2 group (not shown in Table 4.3.1). ISL correlated negatively with words/clauses measure of sentence complexity in SLI group (r=-0.449, n=31, p=0.011). Index of sequence learning correlated positively with words/t-unit measure of sentence complexity in SLI group (r=0.358, n=31, p=0.048).

4.3.2. Correlation between sequence learning and language performance in TD children

Table 4.3.2

Correlation between sequence learning and language measure in TD children (showing only the pair that showed correlation)

Between	Specific pairs	n	r	p	Correlation
Derivation & SL	*All pairs*	*33*	-	-	*Absent*
Inflection	SLavg1 & rev-ige	33	-0.477**	0.005	High negative
& SL	SLavg2 & rev-ige	33	-0.452**	0.008	High negative
Morpho-syntax	SLavg2 &C/C	33	-0.348*	0.047	Negative
& SL	SLavg2 & AMSJ	33	-0.388*	0.026	Negative
	ISL & AMSJ	*33*	*0.403**	*0.020*	*Positive*
Sentence complexity	SLavg1 &W/t-unit	33	-0.441*	0.010	Negative
& SL	SLavg2 &W/t-unit	33	-0.451**	0.008	High negative
	SLavg3 &W/t-unit	33	-0.459**	0.007	High negative
	ISL &W/t-unit	*33*	*0.344**	*0.050*	*Positive*

*correlation significance at <.05 level of significance, ** correlation significance at <.01 level of significance
Abb: SL-sequence learning, rev-revision, C/C-comparatives/conditionals, AMSJ-average morpho-syntax judgment, W/t-unit-words/t-unit.

In the TD group, none of the derivational morpheme measures correlated with sequence learning measure. On the inflectional morpheme, revision performance of *-ige* had high negative correlation with sequence learning measures such as SLavg1(r=-0.477**, n=33, p=0.005) and SLavg2 (r=-0.452**, n=33, p=0.008). Rest of the inflectional morphemes in TD group did not correlate with measures of sequence learning. Morpho-syntax measures such as C/C (comparatives/conditionals) negatively correlated with SLavg1 (r=-.0452*, n=33, p=0.047). SLavg2 correlated negatively to average morpho-syntax judgment performance of TD children (r=-0.388*, n=33, p.026). Index of sequence learning (ISL) showed positive correlation with average morpho-syntax judgment scores in TD children (r=0.403*, n=33, p-0.020). Since, morpho-syntax performance showed chronological age difference, specific chronological age groups TD1 and TD2 were correlated separately with sequence learning measures. SLavg2 of TD1 correlated negatively with average morpho-syntax judgment (r=-0.497*, n=17, p=0.043). None of the morpho-syntax scores and sequence learning scores correlated in TD2. All the measures of sequence learning correlated negatively with words/t-unit measure of TD children. SLavg1 correlated negatively with words/t-unit measure (r=-0.441*, n=33, p=0.010). SLavg2 showed high negative correlation with words/t-unit measure(r=-0.451**, n=33, p=0.008). SLavg3 showed high negative correlation with words/t-unit measure (r=-0.459**, n=.33, p=0.007). The index of sequence learning showed positive correlation with words/t-unit measure (r=0.344*, n=33, p=0.050).

4.3.3. Discussion. TD group as a whole showed a pattern in correlation. All the averages (if the correlation was present) showed negative correlation with the language variable. It means that, as the performance got faster in sequence learning (less reaction time – reduction in value) the grammar scores improved (more value). Therefore, the reaction time in sequence learning and grammar measure were reciprocal. The same explanation could be extended to the positive correlation observed between ISL and other grammar variables in TD population. As one would recall, more the ISL value better is the quantity of sequence learning. When the ISL value increased the grammar performance also increased in TD group (i.e., both the variables are related positively). In the TD group, no correlation between derivational morphemes and sequence learning scores were shown. Among inflectional morphemes, revision of *–ige* correlated highly negatively with SLavg1 & SLavg2. SLavg1 & SLavg2 correlated negatively with C/C & average morpho-syntax revision. Positive correlation between ISL and average morpho-syntax revision was observed. Words/t-unit measure in sentence complexity measure correlated negatively with SLavg1, SLavg2, & SLavg3 and positively with ISL.

If there was any correlation grammar scores of SLI group showed with sequence learning, it was with ISL value. In the SLI group, ISL correlated positively with average derivation judgment, revision of inflection *–lli*, C/C (morpho-syntax), and words/t-unit measure. ISL correlated negatively with average morpho-syntax revision and words/clauses measure. In summary, in SLI group at least one (language) measure in derivational, inflectional, morpho-syntax and sentence complexity correlated with sequence learning. Studies in the past did not explore specific correlation between aspects of grammar and sequence learning ability. However, overall correlation between language measure and sequence learning was reported (Evans, Saffran, & Robe-Torres., 2009, Gabriel et al., 2011 Gabriel et al., 2012, Gabriel et al., 2013; Hedenius et al., 2011, Lum et al., 2011, Tomblin et al., 2007).

In view of the objective of the present study being to investigate the relationship between language and sequence learning, it is essential to discuss the pattern observed in correlation result from grammar as sequence learning perspective. Among the TD participants, the non-adjacent operations correlated well (negatively) with sequence learning, suggesting a strong relation between them. Therefore, strengthening our prediction earlier, which stated that non-adjacent operations would be more related to sequence learning. Furthermore, as predicted in the present study none of the derivational morphemes correlated with sequence learning suggesting lack of necessity from sequence learning operations for derivational morphemic performance. One striking performance among SLI children was that the grammar performance (at least a measure from each language measure) correlated with sequence learning quantity (ISL value) only and not with sequence learning progress (SLavg scores). Therefore, the correlation results on SLI indicate a hazy relation between sequence learning and language measure. It is justifiable, as a group of SLI (SLI1) did not show any sequence learning progress at all. Moreover, unlike TD group, SLI children did not show high correlation between language measure and sequence learning suggesting a moderate nature of relation between the variables. The hazy nature of correlation between language and sequence learning in children with SLI could be explained by involvement of systems other than procedural memory system for language operations in them. There could be a possible declarative memory system contributing to scores of language in children with SLI. However, the present study did not employ any direct measure of declarative memory system to consolidate the role of declarative memory system. Therefore, such claims could be confounded. Even though, PDH claims such compensation in children with SLI, the extent and nature of compensation of associative memory system is arguable without studies examining the clear contribution and compensation between memory systems (for review Thomas, 2005). Hence, in the present study the poor correlation between language and sequence learning suspects possibility of other learning mechanisms (apart from procedural mechanism) for language compensation and demands further investigation.

Hedenius et al. (2011) and Tomblin et al. (2007), reported positive correlation between procedural memory and grammar performance. Hedenius et al. (2011) reported that procedural memory correlated with grammar, but not with vocabulary or broader language measure, which could be broadly in support of the present results. Tomblin et al. (2007) reported that when language impairment was defined in terms of grammar the sequence learning was slower. However, when language impairment was defined as poor lexical knowledge the sequence learning was similar to TD children, suggesting the strong relation between sequence learning and grammar. Therefore, study by Tomblin et al, is also in favor of the results of present study. In another implicit statistical learning study by Evans, Saffran, and Robe-Torres (2009) verbal sequence learning patterns in SLI correlated with receptive language score in SLI.

Study by Kuppuraj and Prema (2013d) showed an inconsistent relation between sequence learning and language measures. Therefore, literature also gives evidence that grammar learning could be related to sequence learning that is procedural memory system. There has been evidence from correlation results that is suggestive of alternative compensatory mechanism with in PDH that could be fostering grammar performance. That is the declarative system (Lum et al., 2011; Kuppuraj & Prema, 2013d). For instance, Lum et al. (2011) found correlation between grammatical abilities and declarative memory in SLI group. Lum et al correlation analysis showed that neither visuo-spatial nor verbal memory correlated with either lexical or grammatical knowledge in either the SLI or the TD children. However, declarative memory correlated with lexical abilities in both the groups. Finally, grammatical abilities correlated with declarative memory in SLI children but with procedural memory in TD children. Study by Lum et al is evidence to one of the claims of PDH that certain grammatical abilities could be taken over by declarative memory system, which is relatively intact in children with SLI (seesaw effect by Ullman, 2004). Applying Lum et al. results in view of the present result an interesting finding could be driven.

In the present study, very few grammar parameters have shown perfect correlation with ISL value in SLI children compared to TD children. A closer observation also states that none of the sequence learning averages correlated with grammar performance in SLI. Therefore, the findings could be in support of Lum et al. (2011) where it could be explained, as the grammar knowledge in SLI children is least depended on procedural memory and could be driven by declarative memory system in them. Studies that resisted the relation between grammar and sequence learning have shown no correlation between grammar and sequence learning in both TD and SLI groups. They have reported that neither TD nor SLI groups correlated with grammar or lexical knowledge (Gabriel et al., 2011; Gabriel et al., 2012; Gabriel et al., 2013). Sequence learning did not correlate with language scores in either children with SLI or TD children even when examined across auditory and visual modalities. The present study that showed correlation between sequence learning and language is therefore, is in support of PDH but not with the findings of Gabriel and her colleagues.

4.4. General Discussion

The present study was designed to examine the relationship between procedural memory deficit and language impairment. Procedural deficit hypothesis (Ullman & Pierpont, 2005) states that children with SLI show deficits beyond language domain in cognitive systems that govern implicit learning. Procedural memory system, which is the core of PDH, was phylogenetically involved in operating implicit unconscious learning. In the course of human evolution for tool usage and cultural needs, the procedural memory system has exapted itself for modern language by naturally selecting some of procedural elements such as sequence learning and statistical learning (Christiansen, 1994; Kuppuraj & Prema, 2013b). The DP model (the seminal model of PDH) is one of the dual mechanism models, which claims that lexicons are stored in declarative memory system and grammar operations are governed by procedural system. According to PDH, most of language deficits in children with SLI could be explained using procedural mechanism dysfunction in them. Furthermore, it was claimed to account for any cross-linguistic, heterogeneous nature of SLI data. Some studies showed evidence in favor of PDH (Lum et al., 2010; Kuppuraj & Prema, 2013d). However, none of the studies attempted to describe language deficits in SLI using principles of PDH. That is, no attempt has been made earlier to particularly relate the language deficits to procedural memory mechanism deficits. The present study makes predictions based on the PDH for language deficits in SLI. Research questions were formed in the realm of PDH and the predictions were examined using motor sequence learning and grammar learning data from children with typical language and SLI. The predictions were that children with SLI would show sequence learning deficit if the claims of PDH stating that language deficits in SLI children involve system beyond language. Further, grammatical operations such as derivations would require lesser demand from sequence learning compared to non-adjacent operations such as inflections and morpho-syntax. The assumption was that because derivations do not need relation between words in a sentence (operates more like a lexicon), they would be least affected by sequencing deficits followed by procedural system dysfunction. On the other hand, non-adjacent operations would need greater sequencing skills for operation therefore; non-adjacent operations would be more vulnerable to sequencing deficits followed by procedural memory dysfunction (i.e., in children with SLI). The prediction added that since the merge operation required for making sentences were procedural, children with procedural deficit would also show deficits in sentence complexity measures. To discuss all the assumptions it was essential to examine the procedural mechanism (deficits) in SLI and relation between procedural memory and language in SLI. In this section, all the addressed research questions and predictions are discussed to answer the main objective. That is, how the sequence learning is related to various language aspects in TD and language impaired population.

The first research question posed in the present study was ‘do children with SLI perform sequence learning tasks slower than TD children?’ Discussing this question would answer the first objective of the study. The present results showed that children with SLI do perform sequence learning tasks significantly slower than typically developing children. Further, the differential learning patterns for TD and SLI children observed in the present study could have implications related to language acquisition. The learning pattern examined in most SRT tasks (including the present AD-SRT task) were deterministic in nature since a set pattern was established and repeated for measuring sequence learning. On the corollary, for learning syllable transition patterns for word segmentation, the pair wise associations established through procedural learning could have served as the mechanism as evidenced from artificial grammar learning studies (Aslin et al., 1998). Studies gathered evidences suggesting that the sequence learning pattern acquired in SRT task could be applicable to predict abilities beyond adjacent relations, more closely to probabilistic relations required to acquire language (Gomez, 2002). Similarly, the significant slow learning and early asymptote observed in children with SLI (SLI2, in particular) in the present study could be implied to their grammar learning (SLI1 did not show any sequence learning). One such transformation between grammar and sequence learning pattern could be that because they have inappropriate sequence learning, acquisition of grammar could be slow/inadequate. The poor sequence learning shown by early asymptote of SLI children’s learning curve reveals that the procedural mechanism, which helps learning grammar unconsciously in TD children, is not readily available for SLI children (Kuppuraj & Prema, 2012a). One direction of research has consistently reported of poor general motor speed caused by general slowness in SLI (Kail, 1994; Leonard et al., 2007; Miller et al., 2001). Therefore, there could be an issue in accepting the poor performance in sequence learning task by SLI in the present study. That is, how could one rule out the general motor speed in children with SLI from their poor RT scores in sequence learning task. Conventional SRT tasks use a random average measure of SLI children to match them with TD children to account for general motor speed variables. The present study also (or any SRT task) uses such paradigm to rule out the variability caused by motor slowness in their sequence learning performance. In the present study, it was random learning average (RLavg). The data showed that children with SLI did not show significant difference compared to TD on this scores. Moreover, children with SLI were matched with TD children for their attention and vigilance performance using two choice reaction time tasks (TCRT task). Children with SLI showed significant poor performance in sequence learning portion of the AD-SRT task even after controlling for external motor and attention related variables. Therefore, the results could be solely attributable to sequence learning deficits. Thus, the answer for the first research question is positive since children with SLI showed poor sequence learning compared to TD children. However, a particular finding in the present study which showed that SLI2 group had sequence learning pattern similar to TD2 (but not quantity) could be in support of general motor delay hypothesis (Kail, 1994). The need for more studies to moderate the effects of general motor delay in sequence learning tasks is warranted.

The second and third objectives are not clearly distinctive. Therefore, in this section the questions framed under objective two and three are discussed together. The raised questions were do children with SLI perform lower compared to TD children on grammar task. If so, can PDH explain all the grammatical deficits in SLI. The questions were further extended such as how is grammar deficit in SLI related to sequence learning deficits and are all the aspects of grammar equally affected by sequence learning deficits? Answering these questions would serve the objective of exploring relation between sequence learning and grammar in SLI (which was the main aim of the study). Though there is enough evidence stating that children with SLI perform lower than TD children on majority of the functional grammar (Rice et al., 1995), in the present study the need was to examine the predictions that were made according to PDH. In other words, it was intended to report the extent to which grammatical deficits in SLI could be explained by the principles of PDH, such as sequence learning and statistical learning. Findings showed that children with SLI performed poorly even on derivational morphemes compared to TD children, which was in contrast to the prediction. Though the results showed significant poor performance of SLI children on derivational tasks, a straightforward interpretation is confounded. The support could be results from discriminant function analysis that did not discriminate well between TD and SLI on derivational morphemic performance. Moreover, children with SLI performed 66.6% (4 out of 6) of derivational revisions on par with TD children. Discussions showed that the PDH could explain the results of derivational morphemic performance using the intricacy between declarative memory system and procedural memory system in operation. That is, declarative memory system is expected to be affected in procedural memory deficit conditions, due to its anatomical and functional proximity to procedural systems (review). Therefore, it is possible that the lexical dependent (operated by declarative memory system) derivational morphemes were affected in children with SLI as well. Specific findings on judgment and revision were explained using statistical knowledge and sequence knowledge deficits in SLI children.

On the other hand, as predicted children with SLI showed deficits on non-adjacent operations. The results on non-adjacent operations were discussed using sequence-learning deficits in SLI. Non-adjacent operations such as inflections and morpho-syntax are likely to demand greater sequence learning. Difficulties in judgment of non-adjacent operations (in SLI children) were also explained using lack of statistical knowledge to identify the word boundaries and poor sequence learning for predicting the upcoming elements in speech. Revision difficulties in non-adjacent were explained using involvement of declarative memory system deficit in procedural memory deficits.

One question that might arise is why derivational deficits were discussed as an effect of deficits in declarative system and non-adjacent deficits were discussed as a direct effect of sequence deficits when children with SLI produced deficits in both derivational as well as non-adjacent operations. Firstly, is it not possible to relate derivational deficit from sequence learning perspective, because derivations do not rely on relation between words (sequence) in a sentence. On the other hand, the sequencing principles apply well for non-adjacent operations, which depend on relation between words in a sentence for operation (sequence). Second justification for discussing derivational as declarative deficit comes from the result itself. That is, when the judgment of inflection and derivation compared with in TD and SLI groups it was observed that children with SLI performed inflections significantly lower compared to derivations. The difference was not present in TD group. The findings suggest that children with SLI when compared within TD group showed greater deficits in non-adjacent operation compared to derivational operations. Therefore, it is logical to believe that poor sequence learning has affected non-adjacent operations more adversely compared to derivational operations (remember SLI children in the present study showed sequence learning deficit). Finally, there could be another reason for affiliating poor sequence learning performance with non-adjacent operations more than derivations, which was evident from correlation results of TD group. Children with TD showed better sequence learning and they showed that the sequence learning performance correlated well with some of non-adjacent operations and not derivational performance. One could assume that the TD children would have probably showed correlation between declarative memory and derivational morphemes, if they were examined (the present study did not examine such correlation). Children with SLI performed all the sentence complexity measures lower compared to TD children. The present study explained it from procedural deficit point of view by considering merge as a procedural skill.

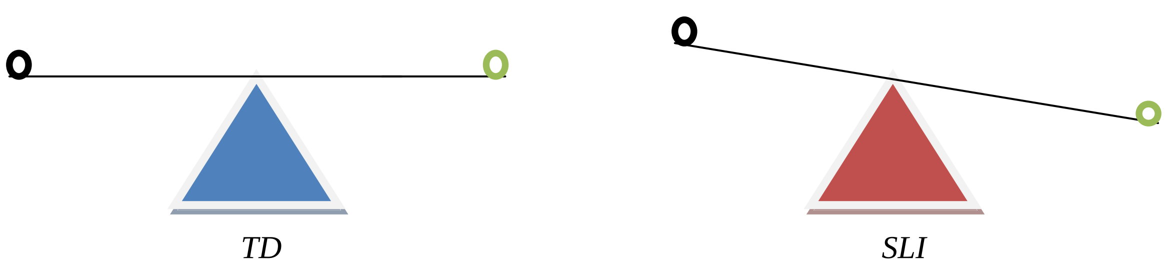
Results of factor analysis could serve as added evidence that states that derivational morphemes could be lesser related to sequence learning compared to non-adjacent operations. The variable reduction procedure showed that 91.6 % (11 out of 12) clinical markers were non-adjacent operations. Moreover, among the grammar performance discriminant function analysis showed that derivational morphemes did not differentiate between TD and SLI groups well. Whereas, non-adjacent operations and sentence complexity measures differentiated TD and SLI clearly. This could be an additional reason or evidence/supporting findings to state that children with SLI as easily discriminable on non-adjacent and merge operations from TD but not on derivational operations. Therefore, the answer for the questions under objective two is that not all grammatical operations could be analogously affected by procedural deficit. The operations, that are non-adjacent and operations involved in sentence making, are expected to be more affected compared to derivational morphemic operations. Further, PDH can account for explanation of all the grammatical deficits in SLI (at least all those were studied in the present study). However, there could be a chance factor in judgment task in the present study, where the participant had to decide the sentence as correct or incorrect. The present study could not rule out such chance factor in the present design. Nevertheless, stimuli needed revision was free from chance factor in the present study.

The third research question was what is the relation between grammar and procedural learning in TD and SLI (if any). Results on correlation analysis are used to answer this question. In TD children, none of the derivational language measures correlated with sequence learning. On the other hand, derivations and morpho-syntax correlated negatively with some of the sequence learning averages in TD group. That is, the performance of non-adjacent grammar increased with faster sequence learning (remember the measure is RT, therefore lesser RT for faster learning). Similar correlation was observed between sequence learning and sentence complexity measures. The correlation results between language measures of SLI with sequence learning showed that none of the sequence learning averages correlated with any of the language measures in SLI. However, ISL values always correlated with any one of the measures from derivational, non-adjacent, and sentence complexity measure. It was difficult to extract a consistency in correlation between language measures and ISL in SLI group as some showed negative and some showed positive correlation. Nevertheless, one finding was striking. That is, all the grammatical operations that supposed to be driven by sequence learning (as evidenced from TD correlation data) has been taken over by system that is not specific for it in children with SLI. Therefore, the correlation results of present study are an additional evidence to say that compensatory mechanism (possibly declarative memory system) has taken over the function of sequence learning. Nevertheless, the compensatory interpretation results based on present correlation data to relate language and sequence learning in TD and SLI involving declarative memory system could be confounded, as declarative memory in the present study was not examined. Finally, there was issue addressed regarding the applicability of PDH in explaining language deficits in agglutinating language such as Kannada. It was assumed that considering the highly inflectional nature of agglutinating language they would be demanding greater sequencing abilities. Present result shows a greater relation between sequence learning and inflectional operations, it could be stated that highly inflectional languages would require greater sequencing knowledge. However, research addressing such statements is warranted.

Based on the findings and discussions of the present study the insights derived on the relation between sequential learning and language in TD and SLI children are projected in the Figure 4.4.1. The schematic illustration considers the procedural and declarative systems at either ends of lever that is placed on a fulcrum. The cognitive control exercised by the pre-frontal cortex is denoted by the fulcrum that balances two memory systems at the two ends. The results of the study indicated a strong correlation between sequence learning and non-adjacency in TD children whereas impaired sequence learning / uncompensated non-adjacency operations in children with SLI. The fulcrum takes control of distributing division of labour appropriately between the two memory systems. It is quite likely that the hypothesized fulcrum is a structure that is subjected to capacity limitations and hence, memory systems although interactive, some functions are exclusively assigned to specific memory system. Forcing the non-dedicated system to learn with inappropriate function would exhaust the fulcrum's capacity leading to inaccuracies in the non-assigned function. Alternatively, in TD children, owing to the intact procedural memory system that supports sequence learning, any slight imbalance, for reasons unknown, would still allow the declarative system to compensate by exercising pre-frontal cognitive control mechanisms thus holding the see-saw balanced on the fulcrum with resultant normal language

The imbalance in the fulcrum sketched for children with SLI in the see-saw raises interesting speculations. The reasons for the declarative system not supporting for compensation to learn all the inflections generated due to non-adjacent operations are likely to be questioned, if the premise in the previous paragraph is accepted. Further, it can also be argued that since declarative system is a store of million other words, there is no reason for not supporting compensation for a few word combinations in order to balance the see-saw as seen in TD children. From the findings of the present study, it could be stated with brevity that the imbalance could be caused by specific procedural memory function deficit that supports sequence learning. Tomblin and colleagues have shown that the sequential function is a dedicated function of procedural memory system. And, any variations in FOXP2 SNPs causes variations in sequence-learning performance in typical individuals. In other words, the non-adjacency, which is sequential, would not be compensated either by intact or by enhanced declarative system thus showing these non-adjacent units of language as strong clinical markers for SLI children.

To summarize the role of hypothesized fulcrum (cognitive control) in SLI children, the fulcrum is least helpful in balancing the edges because the vital force (sequential/non-adjacency functions) on one edge is compromised. Because the cognitive control and declarative memory could be subjected to division of labour or capacity limitation, it could never allow a compensation for non-adjacency or sequence learning, which is implicit. In order to hold non-adjacent sequence in declarative system, the capacity of executive control (fulcrum) could be completely exhausted. Even if such non-adjacencies are taught / attempted to learn explicitly loading the declarative system, the labour cost dedicated for such learning could be demanding. As a consequence, this may have impact on other secondary linguistic skills such as early literacy. In sum, the phenomenon in SLI calls for assessment and intervention techniques designed on the principle of implicit memory and implicit learning that would in turn, facilitate language units that can be drawn from the other capacity-limited systems with dedicated functions. The above insights could have a bearing on planning and designing intervention techniques for children with SLI.



Procedural Memory	Shared function	Declarative Memory	Procedural memory	Shared function	Declarative memory
Good Sequencing	Good Word retrieval	Good derivational morphemes	Poor sequencing	Compromised Word retrieval & derivational morphemes	Unable to compensate
Good non-adjacency computation			Poor non-adjacency computation		Unable to compensate
Good Merging			Poor merging		Compensated to an extent

Normal Language

As a result non-adjacent operations & sequence learning as clinical markers in SLI

Figure 4.4.1 Schematic illustrations of memory and language interactions
P.S.: Black circle on the lever= procedural function; Green circle on the fulcrum =Declarative function

Chapter 5
Summary and Conclusion

5.1. Summary

Declarative procedural (DP) model (Ullman, 2001) states that lexical storage and retrieval is mediated by declarative memory system which substrates on temporal-hippocampal formations. Meanwhile, human grammar is mediated by procedural memory system which substrates on fronto-basalganglia-cerebellar circuits. Declarative and procedural memory is contrasted by their retrieval nature. While information stored in procedural memory is retrieved in implicit manner (unconscious retrieval) that in declarative memory is explicitly retrieved (conscious retrieval). Procedural memory mediates implicit learning and observable while learning sequences and extracting statistical information (Hsu & Bishop, 2011). Learning sequences or sequence learning operates in accumulating knowledge of sequences such as what follows next if the element of interest is "x" and therefore, also accumulating the knowledge of prediction. Learning implicitly the statistical probabilistic knowledge is also mediated by procedural memory. The statistical probabilistic knowledge is the ability to calculate the chances of two sounds occurring together in a language. For instance, in a running speech *"/u:/ /Ta/ /ma:/ /di/ /de/"* (u*:Ta ma:dide – I ate food*) there are lower chances of /Ta/ being followed by /ma:/ in Kannada as the child considers that junction as a word boundary by virtue of scaffolding principle. This statistical knowledge is a procedural skill and has been reported to help in word learning (Lany & Saffran, 2010) and also auditory sentence comprehension in early stages of language development (Conway, Karpicke & Pisoni, 2007). Procedural deficit Hypothesis (Ullman & Pierpont, 2005) which evolved from DP model to account for language behavior in SLI states that children with SLI have problem in mechanism beyond language, which enables in mediation of sequencing knowledge and other operations mediated by procedural memory system. PDH has been examined in children with SLI and other individuals with basal ganglia lesions (Parkinson's disease) and shown that they do indeed show sequence learning problems. PDH claims to account for cross linguistic and intra-group heterogeneity in children with SLI. Sequence learning is conventionally measured using serial reaction time task (SRT) in which the reaction time (RT) for sequentially appearing trials are subtracted from RTs of earlier randomly appeared trials. The present study aims to relate sequence learning and its relation to various aspects of grammar operations. Studies in the past though assumed relation between grammar and sequence learning, none of them made specific predictions based on PDH for language behavior of SLI. Based on PDH some of grammatical operations such as inflectional grammar is assumed to be more difficult compared to derivational grammar. This is because inflectional grammar operations are non-adjacent and require relation between words that are not closer to each other and therefore would demand greater sequencing knowledge compared to derivational operations. The study further assumes that sentence complexity also would pose difficulty because of merging operations, a procedural skill. In the present study a sequence learning task and various grammar tasks such as derivational, inflectional, morpho-syntax and sentence complexity measures were extracted from children with SLI and TD children and were compared.

33 TD children and 31 SLI children in the age range of >8 - ≤13 years were selected for the study. All the participants were given a visuo-motor sequence-learning task and a grammar task. Prior to the initiation of the study all the SLI participants were screened for any attention and vigilance deficits that could contribute to the sequence learning (visuo-motor) task. Participants were given an adapted-serial reaction time (AD-SRT) task for sequence learning measurements. Grammar task given to participant had sections for derivational morphemes, inflectional morphemes, morpho-syntax, and sentence complexity. The sequence learning task was designed to give random trials followed by sequence trials. Average sequence learning over three phases of trials, such as in the beginning, middle and towards and of the task was calculated to derive an index of sequence learning (ISL). The measures were used to report on quantity and pattern in sequence learning between TD and SLI children. The stimuli for grammar focusing on adjacent and non-adjacent operations were presented orally and participants were asked to judge and/or revise the stimuli wherever necessary. Participants were given clue if they found it difficult to revise on their own. The grammar task had a section for sentence complexity which was measured using various measures such as number of t-units, number of words, clauses, words per t-unit, clauses per t-unit, and words per clause. This section summarizes the findings addressing the research questions posed for the study.

Objective one: Comparison of performance of a group of Kannada speaking children with Specific Language Impairment (SLI) and typically developing (TD) children on procedural learning skill.

Findings: Mann-Whitney U test showed that ISL values (sequence learning quantity) of SLI were significantly poorer than TD children. Furthermore, two way MANOVA showed that on AD-SRT task children with SLI performed significantly poorer compared to TD children. Mixed ANOVA showed that atleast SLI1 children had a different pattern of learning compared to TD children.

Research question: Do children with SLI show poor sequence learning? Do they vary in sequence learning pattern compared to TD children?

The children with SLI showed poor sequence learning quantity compared to TD children. SLI1 participants did not show any sequence learning. Instead, they showed a consistent decline in the pattern of learning whereas the SLI2 showed pattern but not the quantity compared to TD2.

Objective two: Comparison of performance of Kannada speaking SLI and TD groups on grammar tasks

Findings: Analysis such as two way MANOVA was done to compare between individual morpheme judgments across groups. Two way ANOVA was done to compare average judgment and average revision performance across groups. Cross tabs were done to report on frequency of distribution of participants across scores on individual revision performance. Discriminant function analysis was done to report how well the SLI group is discriminated from TD group on each grammar task such as derivational, non-adjacent and sentence complexity. In order to decide on the clinical markers of SLI, a principal component analysis was done. On derivational task, children with SLI performed significantly lower compared to TD children on judging majority of derivational morphemes, but not on adverb derivations. Children with SLI performed significantly lower compared to TD children on average derivational judgment and average derivational revisions. While revising individual morphemes SLI children performed like TD children on revision of*–ga:ra, -iga,* and *–pu* (both the groups revised with same difficulty, scores were around 75% to 100%). However, the performance of SLI was towards 25% or 50% (i.e., not revised until clue was given) for revision of *–vanta, -ige,* and *–ka:ra.* Discriminant analysis did not differentiate between the performance of TD and SLI groups on derivational morphemes. On the inflectional task, children with SLI performed significantly lower compared to TD children on case marker and agreement judgments but not on plural judgment. On average inflectional judgment performance, SLI children performed significantly lower compared to TD children. The same significant poor performance applied to comparison on average case marker revision (inflection) and average agreement revision (inflection). The same results apply to morpho-syntax judgment and revision, where SLI performed significantly lower compared to TD on all morpho-syntax judgment and revision tasks. On the individual revisions of morpho-syntax elements children with SLI always performed under 50%, with most participants scoring 25%. Overall, on revising individual inflectional/morpho-syntax items children with SLI always performed lower than 50% (i.e., peaking around 25%). While compared within group between derivational versus non-adjacent performance (inflection & morpho-syntax) results showed that children with SLI performed non-adjacent judgment significantly lower than derivational judgment. However, TD children did not show such difference. Results on sentence complexity measures revealed that all the parameters measured were significantly lower for SLI group compared to TD group. Neither TD nor SLI groups showed chronological age difference in sentence complexity measure. Discriminant function analysis discriminated well between TD and SLI groups when non-adjacent and sentence complexity measures used as variables. On Principal Component Analysis, non-adjacent operations were extracted as significant clinical markers for children with SLI but not derivational morphemes. Even though, the present study did not aim at extracting general clinical markers, the extracted non-adjacent markers shows that children with sequence learning problems are likely to show deficits in non-adjacent functions (inflection/morpho-syntax) than adjacent functions (derivational morphemes). This is in consonance with the earlier prediction that procedural memory deficits affects non-adjacent operations more compared to adjacent operations.

Research questions

1. Does procedural learning deficit affect all grammatical aspects equally?

Procedural learning deficit affect non-adjacent operations and merge operations more compared to derivational operations. Deficits in derivational morphemes were attributed to poor declarative memory system associated to procedural system deficit in present study. However, deficits in non-adjacent operation and merge operations for sentence complexity were attributed to sequence learning deficits in turn supporting PDH.

2. Does PDH explain grammar behavior in children with SLI in an agglutinating language?

PDH is a relatively new neuro-linguistic approach and therefore studies have not attempted to report the relation between components of language and sequence learning operations. In fact, there are less than ten published studies that examined sequence learning in SLI, even though some looked for correlation between language and sequence learning. Kuppuraj & Prema (2013d) reported the relation between various components and sequence learning. Results of the present study combined with the results from Kuppuraj & Prema (2013d) it could be suggested that PDH (sequence learning deficit) along with secondary principles such as statistical learning deficit and compensatory deficits (see-saw effect) could explain the grammatical behavior in SLI examined in the present study especially in an agglutinating language.

3. What are the grammatical markers of SLI?

In children with SLI procedural memory deficit can be manifested predominantly through inflectional or morpho-syntax deficits (non-adjacent operations) rather than derivational deficits. Therefore, non-adjacent operations deficits could be clinical markers of children with SLI who have procedural memory deficits.

Objective three: *To examine the relation between sequence learning and language in Kannada speaking TD and SLI children.*

Findings: TD and SLI groups were run correlation analysis separately between sequence learning and grammar scores to report on the relation between sequence learning and grammar operation in each group. TD group did not show any correlation between derivational morphemes and sequence learning scores. Among inflectional morphemes, revision of *–ige* correlated highly negatively with SLavg1 & SLavg2. SLavg1 & SLavg2 correlated negatively with C/C & average morpho-syntax revision. Positive correlation between ISL and average morpho-syntax revision was observed. Words/t-unit measure in sentence complexity measure correlated negatively with SLavg1, SLavg2, & SLavg3 and positively with ISL in TD group. If there was any correlation grammar scores of SLI group showed with sequence learning, it was with ISL value. In the SLI group, ISL correlated positively with average derivation judgment, revision of inflection *–lli*, C/C (morpho-syntax), and words/t-unit measure. ISL correlated negatively with average morpho-syntax revision and words/clauses measure. Interpretation of correlation results could be that at least one measure in derivational, inflectional, morpho-syntax and sentence complexity correlated with sequence learning in SLI.

Research questions: How is language related to sequence learning/ what are the aspects of grammar sensitive to procedural memory deficits?

The nature of negative correlation between sequence learning measure, non-adjacent grammar and merge operations it could be stated that TD children use procedural sequence knowledge for non-adjacent and merge operations but not for derivational operations (which might depend on declarative system). On the other hand, children with SLI did not show any consistent correlation between sequence learning and grammar suggesting that in children with SLI the typical sequence learning language operations were taken over by system which is not specialized for it (probably a declarative system) in children with SLI. From earlier objectives in this study we could say that procedural memory system affects non-adjacent operations and merge operations for learning syntax more compared to adjacent operations.

The study was limited in the following respects

1. The language measure used to measure language ability of children with SLI (and also TD) was a receptive language tasks. However, the major dependent variable in the present study was expressive grammar. It is plausible that a group of children with SLI could have specific expressive language deficits therefore, affecting their grammar and sentence complexity measure (the major dependent variables in this study).

2. The AD-SRT task used in this study had provision to measure sequence learning at three intervals (average RT in beginning, middle & towards end of trials) however, the design failed to pick RTs of individual trials. Picking up individual RTs for each trial would enable examiners to remove RTs (or button presses) that are too lesser to be considered as genuine responses (probably RTs <100ms). Presence of these responses could have affected the interpretation to an extent. Moreover, the AD-SRT task did not measure the accuracy of response as separate entity. Accuracy is accounted by delay in RTs in the AD-SRT design.
3. Several findings such as unclear correlation pattern in children with SLI between sequence learning and grammar performance in the present study were attributed to possible declarative memory compensation on the basis of PDH. However, the present study did not use direct measures to quantify the declarative memory of children with SLI.
4. The present study explains the poor grammar performance in children with SLI using sequence learning deficit and statistical learning deficit. Though sequence learning measure was done (using AD-SRT task), the study did not employ method to measure statistical learning in children with SLI. Nevertheless, the statistical mechanism deficits have been assumed in children with SLI (because there was procedural memory deficit) on the basis of the results that showed poor performance in judgment of morphemes by children with SLI.

5.2. Conclusion.

The present study examines a neuro-linguistic account (PDH) and its explicability in some of linguistic and non-linguistic behavior in children with SLI in an agglutinating language Kannada, spoken in Karnataka, Southern State in India. The present study is first of its kind that relates various aspects of grammar operation to procedural memory function which could be a significant contribution in the field of cognitive linguistics despite its caveats such as using simplified SRT task which is prone to RT perturbations and absence of initial measure of expressive syntax.

5.2.1. Implications and Future directions.

1. The present study shows that language which is implicit (automatic/effortless) is operated somewhat explicitly (voluntary/effortful) in children with SLI. The present study could bear scientific perspectives to the current language intervention methods and individual variation in response to intervention. The findings of present study could favor conventional explicit language teaching methods. Considering the relatively intact declarative memory system reported (and related compensatory mechanisms) explicit language teaching methods could be an appropriate intervention procedure for children with sequencing deficits. Explicit language techniques such as shape coding (Ebbels, 2007) has been employed to teach grammar over other conventional language techniques because it uses the intact declarative system for language teaching. Implications of the findings from the present study for individual's response to language intervention, it could be stated that children with varying degrees of compromised declarative system would respond differently to conventional language techniques (Lum et al., 2011, for compromised declarative and working memory system in SLI). That is, involvement of various memory systems and their differential degree of deficits could be a major reason why children with language impairment respond differently to different language intervention techniques. Language behavior of a child who is intervened could vary depending on the procedural function that could be taken over by declarative system. For instance, if a child has strong declarative system he/she would learn almost all procedural grammar explicitly, yet performing in normal world without language deficits (using compensatory seesaw effect). Future studies could be designed to document such interaction between memory systems and language prognosis. Another perspective that could be implied from the findings of present study to language teaching could be contrary to present language teaching methods. That is, training in implicit sequence learning and in turn expecting improvement in language scores. This might appear ambitious considering the modality and domain mismatch. However, group of studies conducted by Conway, Pisoni, Anaya, Karpicke, & Henning (2011) showed that children who had hearing deficits congenitally showed suppressed nonverbal sequence learning

scores. Their non verbal sequence learning performance began to get unblocked once they started to hear the real world sequences of verbal sounds. Hence, predicting a cross modality transformation of sequencing skills could be justifiable.

2. Having identified relation between language and sequence learning it could be possible to use sequence learning measures to predict children's future language learning ability before the age of one. Literature exists for statistical learning being affected in children as young as 8 months; similarly such a research can be conducted for sequence learning. If learning motor sequences can be used to identify language impairments in children, it would be useful to teachers and speech language pathologists to determine whether the child is typical second language learner or has special difficulties learning the structure of language in children who come from different language diversities. If non-verbal abilities, like the ability to learn a motor sequence discriminate between individuals who differ in the neural-biological ability of language learning, it is possible that in the future, they can be used as diagnostic or screening tools that are cost and time effective but with higher potential benefits.
3. Research shows relation between FOXP2 and procedural memory (Kuppuraj & Prema, 2013b), it would be interesting to procedural memory variation as SNP (single neucliotide polymorphism) variations in FOXP2 among TD and SLI individuals.
4. Future studies shall also focus on the role of sequence learning and grammar in word order dependent (English) versus high agglutinating language (Kannada). Comparison such as this will gather evidence for one of the discussions in present study that states that the cognitive systems essential for different type of language would vary depend on language structure. This in turn could be used for answering cross linguistic variations in SLI such as why in certain languages SLI symptoms are not as aggravated as other languages. The assumption is, if certain language structure is more procedural dependent the procedural memory deficit in SLI could easily be manifested in that particular language.
5. Though compensatory systems have been used to explain some of behaviours in SLI in present study, future research shall focus on extent and nature of compensatory system offered by intact declarative memory system in SLI. By word "extent", we mean that some of phrases can be stored as chunks in declarative memory system like words. By

the term “nature”, we mean the type of compensation that is possible by declarative memory system. The need for studying the extent and nature of could be to address issues like why not all grammatical operations are compensated by declarative memory system.

6. Currently the implications of research in procedural memory and language have been to use intact declarative memory system to teach grammar explicitly. Rather, therapy techniques to teach grammar implicitly through procedural system with its residual power can be proposed and evidence can be gathered in future.

References

Adi-Japha, E., Strulovich-Schwartz, O., & Julius, M. (2011). Delayed motor skill acquisition in kindergarten children with language impairment. *Research in Developmental Disabilities, 32*, 2963-2971.

Aldridge, J. W., & Berridge, K. C. (1998). Coding of serial order by neostriatal neurons: A 'natural action' approach to movement sequence. *Journal of Neuroscience, 18*, 2777-2787.

Alexander, G. E., DeLong, M. R., & Strick, P. L. (1986). Parallel organization of functionally segregated circuits linking basal ganglia and cortex. *Annual Review of Neuroscience, 9,* 357–381.

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental Disorders,* (4th ed., text revision). Washington, DC: American Psychiatric Association.

Amunts, K., Schleicher, A., Beurgel, U., Mohlberg, H., Uylings, H. B. M., & Zilles K. (1999). Broca's region revisited: Cytoarchitecture and inter subject variability. *Journal of Comparative Neurology, 412,* 319-341.

Aram, D., & Eisele, J, A. (1994). Intellectual stability in children with unilateral brainlesions. *Neuropsychologia,* 32, 85–95.

Aram, D. M., & Nation, J. E. (1975). Patterns of language behavior in children with developmental language disorders. *Journal of Speech and Hearing Research*, *18*, 229-241.

Archibald, L. M. D., & Gathercole, S. E. (2006a). Nonword repetition: A comparison of tests. *Journal of Speech Language and Hearing Research*, *49*, 970-983.

Archibald, L.M., Joanisse, M.F., (2013). Domain-specific and domain-general constraints on word and sequence learning. *Memory and Cognition*, 41(2):268-80. doi: 10.3758/s13421-012-0259-4.

Arndt, B, K., & Schuele, C. M. (2012). Production of infinitival complements by children with specific language impairment. *Clinical Linguistics and Phonetics*, *26*, 1-17.

Ashby, F. G., & Valentin, V. V. (2005). Multiple systems of perceptual category learning: Theory and cognitive tests. In H. Cohen & C. Lefebvre (Eds.), *Handbook of categorization in cognitive science* (pp. 547–572). New York: Elsevier.

Aslin, R. N., Saffran, J. R., & Newport, E. L. (1998).Computation of conditional probability statistics by 8month-old infants. *Psychological Science, 9*, 321–324.

Baddeley, A. D. (2003). Working memory: Looking back and looking forward. *Nature Reviews Neuroscience, 4*, 829-839. doi:10.1038/nrn1201.

Bartlett, G.J., Porter, C.T., Borkakoti, N., &Thornton, J.M. (2002). Analysis of catalytic residues in enzyme active sites. *Journal of Molecular Biology*, *15*: 324(1), 105-21.

Bartak, L., Rutter, M., & Cox, A. (1977). A comparative study of infantile autism and specific developmental receptive language disorder. III. Discriminant function analysis. *Journal of Autism and Childhood Schizophrenia, 7,* 383-396.

Bedore, L., & Leonard, L. (1998). Specific language impairment and grammatical morphology: A discriminant function analysis. *Journal of Speech Language and Hearing Research, 41*, 1185–1192.

Bellugi, U., Bihrle, A., Jernigan, T., Trauner, D., & Doherty. S. (1990). Neuropsychological, neurological, and neuroanatomical profile of Williams Syndrome. *American Journal of Medical Genetics Supplement, 6,* 115-125.

Benasich, A. A., & Spitz, R. (1999). Insights from infants: Temporal processing abilities and genetics' contribution to language impairment. In: Whitmore K, Hary H, Willems G, editors. *A neurodevelopmental approach to specific learning disorders*. London: Mac Keith Press, pp. 191–209.

Bishop, D. V. M. (1989). Autism, Asperger's syndrome, and semantic-pragmatic disorder: where are the boundaries?. *British Journal of Disorders of Communication*, 24, 107–21.

Bishop, D. V. M. (1997). *Uncommon Understanding: Comprehension in Specific Language Impairment*. Psychology Press, Hove, UK.

Bishop, D. V. M. (2002). The role of genes in the etiology of specific language impairment. *Journal of Communication Disorders,* 35(4):311–328.

Bishop, D. V. M. (2006). What Causes Specific Language Impairment in Children? *Current Directions in Psychological Science*, 15(5): 217–221. doi: 10.1111/j.1467-8721.2006.00439.x

Bishop, D. V. M., Bishop, S. J., Bright, P., James, C., Delaney, T. & Tallal, P. (1999). Different origin of auditory and phonological processing problems in children with language impairment: evidence from a twin study. *Journal of Speech Language and Hearing Research*, 42, 155 – 68.

Bishop, D. V. M., Bright, P., James, C., Bishop, S. J., & van der Lely, H. K. J. (2000). Grammatical SLI: a distinct subtype of developmental language impairment?. *Applied Psycholinguistics, 21*, 159– 81.

Bishop, D. V. M., Holt, G., Line, E., McDonald, D., McDonald, S., & Watt, H. (2012). Parental phonological memory contributes to prediction of outcome of late talkers from 20 months to 4 years: a longitudinal study of precursors of specific language impairment. *Journal of Neurodevelopmental Disorders,* 4 (3), doi: 10.1186/1866-1955-4-3.

Bishop, D. V. M., & Rosenbloom, L. (1987). Childhood language disorders: Classification and overview. In: Yule, W. and Rutter, M. editors, *Language development and disorders*. London: MacKeith Press.

Bishop, D. V. M., & Snowling, M. J. (2004). Developmental dyslexia and Specific Language Impairment: Same or different? *Psychological Bulletin*, *130*, 858–886.

Boecker, H., Ceballow-Baumann, A. O., Bartenstein, P., Dagher, A., Forster, K., Haslinger, B., Brooks, D. J., Schwaiger, M., & Conrad, B. (2002). A H215O positron emission tomography study on mental imagery of movement sequences-the effect of modulating sequence length and direction. *NeuroImage*, *17*, 999-1009.

Bol, G. W., & Kuiken, F. (1988). Grammaticale analyse van taalontwikkelingsstoornissen. (PhD thesis), University of Amsterdam.

Bolender, J., Erdeniz, B., & Kerimoglu, C. (2008). Human Uniqueness, Cognition by Description, and Procedural memory. *Biolinguistics, 2*, 129-151.

Borer, H., & Wexler, K. (1987). *The maturation of syntax*. In: T. Roeper and E. Williams (eds) Parameter Setting. 123-172. Dordrecht: Reidel.

Bortolini, U., Caselli, M. C., Deevy, P., & Leonard, L. B. (2002). Specific language impairment in Italian: the first steps in the search for a clinical marker. *International Journal of Language and Communication disorders, 37* (2), 77-93.

Botting, N., & Conti-Ramsden, G. (2003). Autism, primary pragmatic difficulties and specific language impairment: Can we distinguish them using psycholinguistic markers? *Developmental Medicine and Child Neurology*, *45*, 515-524.

Boudreau, D., & Hedberg, N. (1999). A comparison of early literacy skills in children with specific language impairment and their typically developing peers. *American Journal of Speech-Language Pathology, 8*, 249–260.

Bradshaw, J. L. (2001). *Developmental Disorders of the Frontostriatal System*. Hove, East Sussex, Great Britain: Psychology Press.

Brinton, B., & Fujiki, M. (1991). Responses to requests for conversational repair by adults with mental retardation. *Journal of Speech and Hearing Research*, *34* (5), 1087-95.

Cantwell, D. P., Baker, L., Rutter, M., & Mawhood, L. (1989). Infantile autism and developmental receptive dysphasia: A comparative follow-up into middle childhood. *Journal of Autism and Developmental Disorders*, *19*, 19–31.

Carey, D. P., Perrett, D. I., & Oram M. W. (1997). Recognizing, understanding and reproducing action. In F Boller and J Grafman (Eds), *Handbook of Neuropsychology*. Amsterdam: Elsevier Science BV, pp. 111-129.

Carlsson, P., & Mahlapuu, M. (2002). Forkhead transcription factors: key players in development and metabolism, *Developmental Biology*, *250* (1), 1-23.

Census of India, (2011). Retrieved from *http://censusindia.gov.in/2011-Documents/Houselisting%20English.pdf.*

Chafee, M.V., & Ashe, J. (2007). Intelligence in action. *Nature Neuroscience*, 10, 142–143.

Chomsky, N. (1995). *The minimalist program*. Cambridge, MA: MIT Press.

Christiansen, M. H. (1994). Infinite languages, finite minds: Connectionism, learning and linguistic structure. *Unpublished doctoral dissertation*, Centre for Cognitive Science, University of Edinburgh, U.K.

Christiansen, M. H., & Devlin, J. T. (1997). Recursive inconsistencies are hard to learn: A connectionist perspective on universal word order correlations. *In Proceedings of the 19th Annual Cognitive Science Society Conference* (pp. 113118). Mahwah, NJ: Lawrence Erlbaum Associates.

Clahsen, H. (1989). The grammatical characterization of developmental dysphasia. *Linguistics*, *27*, 897-920.

Clahsen, H. (1991). Child language and developmental dysphasia. *Linguistic studies of the acquisition of German*. Amsterdam: Benjamins.

Clahsen, H. (2008). Chomskyan syntactic theory and language disorders. In M. J. Ball, M. Perkins, N. Mueller & S. Howard (eds.), *The handbook of clinical linguistics,* pp. 165-183. Blackwell: Oxford.

Clahsen, H., Bartke, S., & Göllner, S. (1997). Formal features in impaired grammars: a comparison of English and German SLI children. *Journal of Neurolinguistics*, 10, 151-171.

Clahsen , H., & Almazan, M. (1998). Syntax and morphology in Williams Syndrome. *Cognition*, *68,* 167-198.

Clahsen, H., & Dalalakis, J. (1999). Tense and agreement in Greek SLI: A case study. *Essex Research Reports in Linguistics, 24*, 1-25.

Coltheart, M. (2005). Conscious Experience and Delusional Belief. *Philosophy, Psychiatry, and Psychology, 12* (2), 153-157.

Conti-Ramsden, G., & Botting, N. (2008). Emotional health in adolescents with and without a history of specific language impairment (SLI). *Journal of Child Psychology and Psychiatry, 49,* 516-525.

Conti-Ramsden, G., & Jones, M. (*1997*). Verb use in specific language impairment. *Journal of Speech and Hearing Research*, *40,* 1298-1313.

DeThorne, L.S., & Watkins, R. V. (2001). Listeners' perceptions of language skills in children. *Language, Speech and Hearing Services in Schools, 32*(3), 142-148.

Di Sciullo, A. M., & E. Williams, 1987. *On the Definition of Word*. Cambridge, MA. MIT Press.

Dockrell, J. E., & Messer, D. (2007). Language profiles and naming in children with word finding difficulties. *Folia Phoniatrica et Logopaedica, 59,* 318-23.

Dunn, L., & Dunn, L. (1981). *Peabody picture vocabulary test-revised*. American Guidance Service, Circle Pines, MN.

Edelman, S., & Waterfall, H. R. (2007). Behavioral and computational aspects of language and its acquisition. *Physics of Life Reviews*, 4, 253–277.

Eichenbaum, H., & Cohen, N. J. (2001). *From conditioning to conscious recollection: memory systems of the brain.* New York: Oxford University Press.

Eisenbeiss, S., Bartke, S., & Clahsen, H. (2006). Structural and lexical case in child German: Evidence from language-impaired and typically-developing children. *Language Acquisition, 13*, 3-32.

Eisenson, J. (1968). Developmental aphasia: A speculative view with therapeutic implications. *Journal of Speech and Hearing Disorders, 33,* 3-13.

Elliott, L. L., Hammer, M. A., & Scholl, N. E. (1990). Fine-grained auditory discrimination and performance on tests of receptive vocabulary and receptive language. *Annals of Dyslexia, 40*, 170-179.

Ellis Weismer, S., Plante, E., Jones, M., & Tomblin, J.B. (2005). A functional magnetic resonance imaging investigation of verbal working memory in adolescents with specific language impairment. *Journal of Speech Language and Hearing Research*. 48(2):405–425.

Ellis Weismer, S., Tomblin, J. B., Zhang, X., Buckwalter, P., Chynoweth, G. J., & Jones, M. (2000). 'Non-word repetition performance in school-age children with and without language impairment.' *Journal of Speech, Language, and Hearing Research, 43,* 865 –78.

Evans, J. L., Saffran, J. R., & Robe-Torres, K. (2009). Statistical learning in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 52*, 321–355.

Fey, M. E., Leonard, L. B., & Wilcox, K. A. (*1981*). *Speech-style modifications of language-impaired children*. *Journal of Speech and Hearing Disorders, 46*, 91-97.

Fischel, J.E., Whitehurst, G.J., Caulfield, M.B., & DeBaryshe, B. (1989).Language growth in children with expressive language delay. *Pediatrics, 83*(2):218-27.

Fisher, S. E. (2005). Dissection of molecular mechanisms underlying speech and language disorders. *Applied Psycholinguistics, 26*, 111-128.

Fodor, J. A. (1983). *The Modularity of Mind*. Bradford Books. MIT Press, Cambridge, MA.

Friedmann, N., & Novogrodsky, R. (2004). The acquisition of relative clause comprehension in Hebrew: A study of SLI and normal development. *Journal of Child Language*, *31*, 661–681.

Friedmann, N., & Novogrodsky, R. (2006). SLI has many faces: Dissociations between syntactic, lexical, and phonological deficits. *Presented at the Israeli Association for Literacy SCRIPT conference*, Bar Ilan, Israel.

Gabriel, A., Maillart, C., Guillaume, M., Stefaniak, N., Meulemans, T. (2011). Exploration of Serial Structure Procedural Learning in Children with Language Impairment. *Journal of the International Neuropsychological Society, 17*, 336–343.

Gabriel, A., Maillart, C., Stefaniak, N., Lejeune, C., Desmottes, L., & Meulemans, T. (2013). Procedural learning in specific language impairment: effects of sequence complexity. *Journal of the International Neuropsychological Society, 19* (3), 264-271.

Gabriel, A., Maillart, C., Stefaniak, N., Lejeune, C., Desmottes, L., & Meulemans, T. (2014). Procedural learning across modalities in French speaking children with specific language impairment. *Applied Psycholinguistics*, doi: 10.1017/S0142716413000490.

Gabriel, A., Stefaniak, N., Maillart ,C., Schmitz, X., & Meulemans, T. (2012). Procedural visual learning in children with specific language impairment. *American Journal of Speech Language Pathology, 21*(4):329-41.

Gardner, H., Froud, K., McClelland, A., & van der Lely, H. (2006). Development of the Grammar and Phonology Screening (GAPS) test to assess key markers of specific language and literacy difficulties in young children. *International Journal of and Communication Disorders, 41* (5), 513-540.

Gathercole, S., & Baddeley, A. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language*, *29*, 336-360.

Gathercole, S. E., Tiffany, C., Briscoe, J., Thorn, A. S. C., & ALSPAC Team (2005). Developmental consequences of poor phonological short-term memory function in childhood: A longitudinal study. *Journal of Child Psychology and Psychiatry, 46*, 598-611.

Gillon, B., & Gopnik, M. (1994). Grammatical number in subjects with genetic language impairment. *The McGill working papers in linguistics: Linguistic aspects of familial language impairment* (Vol. 10, pp. 41–49). Montreal: McGill University Press.

Gleitman, L. (1990). The structural sources of verb meanings.*Language Acquisition*, 1, 135-176.

Gomez, R. (2002). Variability and detection of invariant structure. *Psychological Science,* 431–436.

Gomez, R., & Gerken, L. (1999). Artificial grammar learning by 1-year-olds leads to specific and abstract knowledge. *Cognition, 70,* 109–135.

Gonzalez, D. O., Cáceres, A. M., Bento-Gaz, A. C., & Befi-Lopes, D. M. (2012). the complexity of narrative interferes in the use of conjunctions in children with specific language impairment. *Jornal Da Sociedade Brasileira De Fonoaudiologia*, *24,*152-6.

Gopnik, M. (1994d). Impairments of tense in a familial language disorder. *Journal of Neurolinguistics*, 8 (2), 109–133.

Gopnik, M. (1999). Familial language impairment: more English evidence. *Folia Phoniatrica et Logopaedica, 51*, 5–19.

Gopnik, M., & Crago M. B. (1991). Familial aggregation of a developmental language disorder. *Cognition*, 39, 1-50.

Grela, B., Rashiti, L., & Soares, M. (2004). Dative prepositions in children with specific language impairment. *Applied Psycholinguistics, 25*, 467-480.

Hadley, P. A., & Rice, M. L. (*1996*). Emergent uses of BE and DO: Evidence from children with specific language impairment. *Language Acquisition*, 5, 209-243.

Hagoort, P. (2005). "On Broca, brain, and binding: a new framework". *Trends in Cognitive Science, 9 (9):* 416–23. doi:10.1016/j.tics.2005.07.004

Hamaguchi, P. A. (2001). *Childhood speech, language, and listening problems: What every parent should know*. New York: John Wiley & Sons, Inc.

Hansson, K., Nettelbladt, U., & Nilholm, C. (2000). Contextual influence on the language production of children with speech/language impairment. *International Journal of Language and Communication Disorders*, 35 (1): 31–47, *http://dx.doi.org/10.1080/136828200247232*.

Hauser, M., Chomsky, N., & Fitch, W. T. (2002). The language faculty: What is it, who has it, and how did it evolve? *Science, 298*, 1569-1579.

Haynes, C., & Naidoo, S. (1991). *Children with specific speech and language impairment*. London: MacKeith Press.

Hedenius, M., Persson, J., Tremblay, A., Adi-Japha, E., Verissimo, J., Dye, C. D., Alm, P., Jennische, M., Tomblin, J. B., & Ullman, M. T. (2011*). Research in Developmental Disabilities, 3*2, 2362–2375.

Hegde, M. N., & Maul, C. A. (2006). *Language disorders in children: An evidence-based approach to assessment and treatment.* Boston: Allyn and Bacon.

Hill, P. R., Hogben, J. H., & Bishop, D. M. V. (2005). Auditory frequency discrimination in children with specific language impairment: A longitudinal study. *Journal of Speech, Language and Hearing Research*, *48*, 1136-1146.

Howard, J, H., Howard, D., Japikse, K, A., & Eden, G, F. (2006). Dyslexics are impaired on implicit higher-order sequence learning, but not on implicit spatial context learning. *Neuropsychologia*, 44 (7), 1131-44.

Hurst, J. A., Baraister, M., Auger, E., Graham, F., & Norell, S. (1990). An extended family with dominantly inherited speech disorder. *Developmental Medicine and Child Neurology, 32*, 352-355.

Hsu, H. J., & Bishop, D. V. M. (2011). Grammatical Difficulties in Children with Specific Language Impairment: Is Learning Deficient? *Human Development, 53*, 264–277.

Hynd, G. W., Marshall, R. M., & Gonzalez, J. (1991). Learning disabilities and presumed central nervous system dysfunction. *Learning Disabilities Quarterly*, 14, 283-296.

International Classification of Diseases (ICD). World Health Organization. Retrieved on 15th Nov, 2012, *http://www.who.int/classifications/icd/ICD10Volume2_en_2010.pdf.*

Jellama, T., & Perretti, D. I. (2001). Coding of visible and hidden actions. In W Prinz and B Hommel (Eds), Attention and Performance XIX: *Common mechanisms in perception and action.* Oxford: Oxford University Press, pp. 334-355.

Jiménez-Fernández, G., Vaquero, J. M., Jiménez, L., & Defior, S. (2011). Dyslexic children show a deficit in implicit sequence learning, but not in contextual cueing or in explicit sequence learning. *Annals of Dyslexia, 61*, 85-110.

Joanisse, M. F., & Seidenberg, M. S. (1998). Specific Language Impairment: A deficit in grammar or processing? *Trends in Cognitive Sciences*, 2, 240-247.

Kail, R. (1994). A method for studying the generalized slowing hypothesis in children with specific language impairment. *Journal of Speech and Hearing Research*, 37, 418-421.

Karanth, P. (1980). Linguistic Profile Test in Kannada. *Journal of AIISH.*

Keele, S. W., Ivry, R., Mayr, U., Hazeltine, E., & Heuer, H. (2003). The cognitive and neural architecture of sequence representation. *Psychological Review,* 110, 316–339.

Kempen, G, E., & Hoenkamp, (1987). An incremental procedural grammar for sentence formulation, Cognitive *Science, 11*, 201-258.

Knowlton, B. J., Mangels, J. A., & Squire, L. R (1996). A neostriatal habit learning system in humans. *Science, 273,* 1399-402.

Kraus, N., McGee, T. J., Carrell, T. D., Zecker, S. G., Nicol, T. G., & Koch, D. B. (1996). Auditory neurophysiologic responses and discrimination deficits in children with learning problems. *Science*, *273*, 971-973.

Kuppuraj. S., & Prema K. S. R. (2012a). Grammar as motor sequence learning. *Indian Linguistics. 73* (1-4), 147-164.

Kuppuraj. S., & Prema K. S. R. (2012b). Is Non-word repetition a True Clinical Marker of SLI?, *Journal of All India Institute of Speech and Hearing*, 31, 120-129.

Kuppuraj. S., & Prema K. S. R (2013a). Sequence learning pattern in children with specific language impairment, *International Journal of Disability and Human Development, DOI:10.1515/ijdhd-2012-0003.*

Kuppuraj. S., & Prema K. S. R (2013b). Grammar Specific Language Impairment: An Evolutionary Default? *Netherlands Journal of Psychology, 68* (2), 43-60.

Kuppuraj, S., & Prema, K. S. R. (2013c). An adapted serial reaction time task for procedural learning measurements. *Psychological Studies, 58, (3),* 276-284.

Kuppuraj, S., & Prema, K. S. R. (2013d). Aspects of grammar sensitive to procedural memory deficits in children with specific language impairment. *Research in Developmental Disabilities, 34*, 3317–3331.

Kuppuraj, S., & Prema, K. S. R. Inflectional versus derivational abilities of children with specific language impairment-A panorama from sequential cognition. Manuscript submitted for publication.

Lahey, M., & Edwards, J. (1996). Why do children with specific language impairment name pictures more slowly than their peers?. *Journal of Speech and Hearing Research*, *39*(5):1081-98.

Lahey, M., & Edwards, J. (1999). Naming errors of children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, *42*, 195-205.

Leonard, L. (1989). Language learnability and specific language impairment in children. *Applied Psycholinguistics, 10,* 179-202.

Leonard, B. L. (1998). The language characteristics of SLI: A detailed look at English. In B. L. Leonard (ed.), *Children with Specific Language Impairment* (pp. 43-88). Cambridge, MA: MIT Press.

Leonard, L., & Leonard, J. (1985). The contribution of phonetic context to an unusual phonological pattern: A case study. *Language, Speech and Hearing Services in Schools*, *16,* 110-118.

Leyfer, O. T., Tager-Flusberg, H., Dowd, M., Tomblin, J.B., & Folstein, S. E. (2008). Overlap between autism and specific language impairment: Comparison of Autism Diagnostic Interview and Autism Diagnostic Observation Schedule Scores. *Autism Research, 1*, 284-296.

Ling, D., & Ling, A. (1978). *Aural Habilitation*. Washington, DC: Alexander Graham Bell Association for the Deaf.

Lum, J. A., Gelgic. C., & Conti-Ramsden, G. (2010). Procedural and declarative memory in children with and without specific language impairment. *International Journal of Language and Communication Disorders*, *45*(1):96-107.

Lum, J. A. G., Conti-Ramsden, G., Page, D., & Ullman, M. T. (2011).Working, declarative and procedural memory in Specific Language Impairment. *Cortex*, *48, 1138-1154.*

Marinellie, S. A. (2004). Complex syntax used by school-age children with specific language impairment (SLI) in child-adult conversation. *Journal of Communication Disorders, 37,* 517-533.

Marshall, C. R., & van der Lely. (2007). The impact of phonological complexity on past tense inflection in children with Grammatical SLI. *Advances in Speech and Language Pathology, 9,* 191-203.

Martin, A., Ungerleider, L. G., & Haxby, J. V. (2000). Category specificity and the brain: the sensory/motor model of semantic representations of objects. In MS Gazzaniga (Ed), *The Cognitive Neurosciences*. Cambridge, MA: MIT Press, 2000, pp. 1023-1036.

Mawhood, L., Howlin, P., & Rutter, M. (2000). Autism and developmental receptive language disorder - a comparative follow-up in early adult life. I: Cognitive and language outcomes. *Journal of Child Psychology and Psychiatry and Allied Disciplines,* 41, 547–559.

Mayes, A., Montaldi, D., & Migo, E. (2007). Associative memory and the medial temporal lobes. *Trends in Cognitive Sciences, 11*, 126-135.

McArthur, G. M., & Bishop, D. V. M. (2004a). Frequency discrimination deficits in people with specific language impairment: reliability, validity and linguistic correlates. *Journal of Speech, Language and Hearing Research, 47*, 527-541.

McArthur, G. M., & Bishop D. V. M. (2004b). Which people with specific Language impairment have auditory processing deficits? *Cognitive Neuropsychology, 21*, 79-94.

McArthur, G. M., & Bishop, D. V. M. (2005). Speech and non-speech processing in people with specific language impairment: A behavioural and electrophysiological study. *Brain and Language, 94*, 260-273.

Merzenich, M. M., Jenkins, W. M., Johnston, P., Schreiner, C., Miller, S. L., & Tallal P. (1996). Temporal processing deficits of language-learning impaired children ameliorated by training, *Science, 271*, 77-81.

Merzenich, M. M., Recanzone, G., Jenkins,W. M., Allard, T. T., & Nudo, R. J. (1998). Cortical representational plasticity. In P Rakic and W Singer (Eds), *Neurobiology of Neocortex*. Chichester: John Wiley and Sons, pp. 41-67.

Middleton, F. A., & Strick, P. L. (2000a). Basal ganglia and cerebellar loops: motor and cognitive circuits. *Brain Research Reviews, 31*, 236-250.

Middleton, F. A., & Strick, P. L. (2000b). Basal ganglia output and cognition: evidence from anatomical, behavioral, and clinical studies. *Brain and Cognition, 42*(2), 183–200.

Miller, C. A., Kail, R., Leonard, L. B., & Tomblin, J. B. (2001). Speed of processing in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 44*, 416-433.

Miller, C., Leonard, L, B., Kail, R., Zhang, X., Tomblin, J, B., & Francis, D. (2006). Response time in14-year-olds with language impairment. *Journal of Speech, Language, and Hearing Research*, 49(4):712-728.

Miller, C. A., Leonard, L. B., & Finneran, D. (2008). Grammaticality judgments in adolescents with and without language impairment. *International Journal of Language and Communication Disorders*, 43(3), 346-360.

Miller. C., Kail. R., Leonard. L., & Tomblin. J, B. (2001). Speed of processing in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, *44*(2), 416-433.

Montgomery, J. W. (1995). Sentence comprehension in children with specific language impairment: The role of phonological working memory. *Journal of Speech and Hearing Research, 38*, 187-199.

Montgomery, J. W. (2000). Relation of working memory to offline and real-time sentence processing in children with specific language impairment. *Applied Psycholinguistics, 21*, 117-148.

Nam, C., & Benasich, A. A. (2003). A Family Aggregation Study: The Influence of Family History and Other Risk Factors on Language Development. Journal of Speech Language and Hearing Research, 46(2): 261–272. doi: 10.1044/1092-4388(2003/021).

Neligan ,G. A., & Prudham, D. (1969). Norms for four standard developmental milestones by sex, social class and place in family. *Developmental Medicine* & *Child Neurology*, 11:413-422.

Nelson, N. (1993). *Childhood language disorders in context: Infancy through adolescence*. New York: macMillan Publishing Co.

Newbury D. F., Winchester, L., Monaco, A. P. (2009). CMIP and ATP2C2 Modulate Phonological Short-Term Memory in Language Impairment. *The American Journal of Human Genetics,* doi:10.1016/j.ajhg.2009.07.004.

Newbury, D. F., Bishop, D. V. M., & Monaco, A. P. (2005). Genetic influences on language impairment and phonological short-term memory. *Trends in cognitive Sciences,* 9(11):528-34.

Nissen, M. J., & Bullemer, P. (1987). Attentional requirements of learning: evidence from performance measures. *Cognitive Psychology*, *19,* 1-32.

Novogrodsky, R., & Friedmann, N. (2006). "The production of relative clauses in SLI: A window to the nature of the impairment," *Advances in Speech-Language pathology*, *84,* 364-375.

Ors, M., Ryding, E., Lindgren, M., Gustafsson, P., Blennow, G., & Rosén, I. (2005). *SPECT* findings in children with specific language impairment. *Cortex,* 41(3):316–326.

Packard, M., & Knowlton, B. (2002). Learning and memory functions of the Basal Ganglia. *Annual Review of Neuroscience, 25,* 563-593.

Paradis, M., & Gopnik, M. (1997). Compensatory strategies in genetic dysphasia: Declarative memory. *Journal of Neurolinguistics, 10,* 173-185.

Paul, R. (1991). Profiles of toddlers with slow expressive language development. *Topics in Language Disorders*, *11*, 1–13.

Paul, R. (1996). Clinical implications of the natural history of slow expressive language development. *American Journal of Speech-Language Pathology*, *5,* 5-21.

Perrett, D. I., Harries, M. H., Bevan, R., Thomas, S., Benson, P. J., Mistlin, A. J., Chitty, A. J., Hietanen, J. K., & Ortega, J. E. (1989). Framework of analysis for the neural representation of animate objects and actions. *Journal of Experimental Biology, 146,* 87-113.

Perrett, D. I., Mistlin A. J., Harries, M. H., & Chitty, A. J. (1990). Understanding the visual appearance and the consequence of hand actions. In: Goodale MA (ed) *Vision and action: the control of grasping*. Ablex, Norwood, pp 163-180.

Pickering S. J., & Gathercole S. E (2001). *Working memory battery for children.* University of Bristol.

Pinker, S. (1994). *The language instinct: How the mind creates language*. New York: William Morrow.

Plante, E., Gómez, R. L., & Gerken, L. (2002). Sensitivity to word order cues by normal and language/learning disabled adults. *Journal of Communication Disorders*, *35*, 453–462.

Poldrack, R, A., Wagner, A.D., Prull, M. W., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. E. (1999). Functional specialization for semantic and phonological *Presented at the Israeli Association for Literacy SCRIPT conference*, Bar Ilan, Israel.

Prema, K. S., Prasitha, P., Savitha, S., Purushothaman, P., Chitra, R., & Balaji, R. (2010). Clinical Markers for Identification of Children with Specific Language Impairment (SLI). *Indian Journal of Applied Linguistics*, *36*, 1-2.

Puglisi, M. L., Befi-lopes, D. M., & Takiuchi, N. (2005). Use and comprehension of prepositions by children with specific language impairment, *Pró-Fono Revista de Atualização Científica*, *17*, (3), 331-344.

Rapin, I., & Allen, D. A. (1983). “Developmental language disorders: Nosological considerations.” In: Kirk, U. (Ed.), *Neuropsychology of Language, Reading and Spelling*. Academic Press, New York, 155-184.

Ravid, D., Levie, R., & Ben-Zvi, G. A. (2003). The role of language typology in linguistic development: Implications for the study of language disorders. In Y. Levy, & J. Schaeffer (Eds.), Language competence across populations: Towards a definition of specific language impairment. Mahwah, NJ: Lawrence Erlbaum.

Reber, A. S. (1967). "Implicit learning of artificial grammars.” *Verbal Learning and Verbal Behavior, 5* (6): 855–863.

Records, N., & Tomblin, J. B. (1994) ‘Clinical decision-making: describing the decision rules of practicing speech-language pathologists.’ *Journal of Speech and Hearing Research*, *37*, 144 –56.

Reed, V. (2005). *An introduction to Children with Language Disorders*. 3rd Ed. Boston: Pearson/Allyn & Bacon, San Diego, USA.

Redington, M., Chater, N., & Finch, S. (1998). Distributional information: A powerful cue for acquiring syntactic categories. *Cognitive Science*, *22*, 425-469.

Rescorla, L. (1989). The Language Development Survey: A screening tool for delayed language in toddlers. *Journal of Speech and Hearing Disorders, 54*, 587–99.

Rescorla, L., & Lee, E. (2001). Language impairment in young children. In T. Layton, E. Crais, & L. Watson (Eds.), Handbook of early language impairment in children: *Nature* (pp. 1–55). Albany, NY: Delmar.

Rescorla, L., Roberts, J., & Dahlsgaard, K. (1997). Late talkers at 2: Outcome at age 3. *Journal of Speech & Hearing Research*, *40*, 556-566.

Rescorla, L., & Schwartz, E. (1990). Outcome of toddlers with specific expressive language delay. *Applied Psycholinguistics*, *11*, 393–407.

Rice, M. L., Kenneth., & Hershberger, S. (1998). Tense over time: The longitudinal course of tense acquisition in children with specific language impairment. *Journal of Speech, Language and Hearing Research*, *41*, 1412-1431.

Rice, M. L., Sell, M. A., & Hadley, P. A. (1991). Social Interactions of Speech, and Language Impaired Children. *Journal of Speech and Hearing Research*, *34*, 1299-1307.

Rice, M. L., Tomblin, J. B., Hoffman, L., Richman, W. A., & Marquis, J. (2004).Grammatical tense deficits in children with SLI and non-specific language impairment: Relationships with nonverbal IQ over time. *Journal of Speech, Language, and Hearing Research*, *47*, 816–834.

Rice, M. L., & Wexler, K. (1996a).Toward tense as a clinical marker of Specific Language Impairment in English-speaking children. *Journal of Speech and Hearing Research, 39*, 1239-1257.

Rice, M. L., & Wexler, K. (1996b). A phenotype of specific language impairment: Extended optional infinitives. In M. L. Rice (Ed.), *Toward a genetics of a language* (pp. 215-237). Mahwah, NJ: Lawrence Erlbaum.

Rice, M. L., Wexler, K., & Cleave, P. L. (1995). Specific language impairment as a period of extended optional infinitive. *Journal of Speech and Hearing Research, 38,* 850-863.

Rice, M. L., Wexler, K., & Hershberger, S. (1998). Tense over time: The longitudinal course of tense acquisition in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 41*, 1412–1431.

Rice, M. L., Wexler, K., Marquis, J., & Hershberger, S. (2000). Acquisition of irregular past tense by children with SLI. *Journal of Speech, Language, and Hearing Research, 43*, 1126–1145.

Rice, M, L., Wexler, K., & Redmond, S, M. (1999). Grammaticality judgments of an extended optional infinitive grammar: Evidence from English-speaking children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 42* (4), 943-961.

Rizzolatti, G., Fogassi, L., & Gallese, V. (2000). Cortical mechanisms subserving object grasping and action recognition: A new view on the cortical motor functions. In MS Gazzaniga (Ed) *The New Cognitive Neurosciences.* Cambridge, MA: MIT Press, pp. 539-552.

Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Reviews Neuroscience, 2*, 661-670.

Robertson, E. M., Tormos, J. M., Maeda, F., & Pascual-Leone, A. (2001). The role of the dorsolateral prefrontal cortex during sequence learning is specific for spatial information. *Cerebral Cortex, 11*, 628–635.

Saffran, J. R. (2001). The Use of Predictive Dependencies in Language Learning, *Journal of Memory and Language,* 44,493–515

Saffran, J. R. (2002). Constraints on statistical language learning. *Journal of Memory and Language, 47*, 172–196.

Saffran, J. S. (2003). Statistical language learning: Mechanisms and constraints. *Current Directions in Psychological Science, 12*, 110-114.

Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996).Statistical learning by 8-month-old infants. *Science, 274*, 1926–1928.

Schacter, D. L., & Tulving, E. (1994). What are the memory systems of 1994? In D. L. Schacter and E. Tulving, Eds., *Memory Systems.* Cambridge, MA: MIT Press, pp. 1-38.

Schluter, N. D., Krams, M., Rushworth, M. F., & Passingham, R. E. (2001). Cerebral dominance for action in the human brain: the selection of actions. *Neuropsychologia*, 39(2):105-13.

Schu¨tze, C. T., & Wexler, K. (1996). Subject case licensing and English root infinitives. In A. String fellow, D. Cahma-Amitay, E. Hughes & A. Zukowski (eds), *Proceedings of the 20th Annual Boston University Conference on Language Development*, 670–81.Somerville, MA: Cascadilla Press.

Schuele, C. M., & Tolbert, L. (2001).Omissions of obligatory relative markers in children with specific language impairment. *Clinical Linguistics and Phonetics*, *15*, 257-274.

Scott, C. M., & Windsor, J. (2000). General language performance measures in spoken and written narrative and expository discourse of school-age children with language learning disabilities. *Journal of Speech, Language, and Hearing Research*, *43*, 324–339.

Seidler, R. D., Alberts, J. L., & Stelmach, G. E. (2002). Changes in multi-joint performance with age. *Motor Control*, 6, 19–31.

Shaalan, K. (2010). Rule-based Approach in Arabic Natural Language Processing. *International Journal on Information and Communication Technologies,3,*(3),11-19.

Squire, L. R., & Knowlton, B. J. (2000). The medial temporal lobe, the hippocampus, and the memory systems of the brain. *In The New Cognitive Neurosciences, 2nd Edition*. (M. Gazzaniga, ed.) Cambridge, MA; MIT Press pp. 765-779.

Sheng, L., & McGregor, K. K. (2010). Lexical-semantic organization in children with Specific Language Impairment. *Journal of Speech*, *Language and Hearing Research*, 53, 146-159. doi:10.1044/1092-4388(2009/08-0160).

Shu, W., Yang, H., Zhang, L., Lu, M. M., & Morrisey, E. E. (2001). Characterization of a new subfamily of winged-helix/forkhead (Fox) genes that are expressed in the lung and act as transcriptional repressors. *The Journal of Biological Chemistry*, 276, 27488–27497.

Singhi. P., Kumar, M., Malhi, P., & Kumar, R. (2007).Utility of the WHO ten questions screen for disability detection in rural community-The North Indian experience. *Journal of Tropical Paediatrics, 53(6*), 383-387.

Song, S., Howard, H, Jr., & Howard, D.V. (2007). Implicit probabilistic sequence learning is independent of explicit awareness. *Learning and Memory*, 14:167–176.

Squire, L. R., Knowlton, B., & Muse, G. (1993). The structure and organization of memory. *Annual Review* of *Psychology*, *44*, 453-95.

Squire, L. R., Stark, C. E., & Clark, R. E. (2004). The medial temporal lobe. *Annual Review of Neuroscience*, *27*, 279-306.

Stokes, S. F., Wong, A. M.Y., Fletcher, P., & Leonard, L. B. (2006). Nonword repetition and sentence repetition as clinical markers of SLI: The case of Cantonese. *Journal of Speech, Language, and Hearing Research, 49*, 219-236.

Squire, L. R., & Zola, S. M. (1996). Structure and function of declarative and nondeclarative memory systems. *Proceedings of the National Academy of Science, USA, 93,* 13515-13522.

Tager-Flusberg, H., & Cooper J (1999). Present and future possibilities for defining a phenotype for specific language impairment. *Journal of Speech, Language, and Hearing Research, 42*, 1275-1278.

Tallal, P. (1990). Fine-grained discrimination deficits in language- learning impaired children are specific neither to the auditory modality nor to speech perception. *Journal of Speech and Hearing Research*, *33*, 616-617.

Tallal, P., Miller, S. L., Bedi, G., Byma, G., Wang, W., Nagarajan, S. S., Christoph, S., Jenkins, W. M., & Merzenich, M. M. (1996). Language comprehension in language-learning impaired children improved with acoustically modified speech. *Science, 271,* 81-84.

Tallal, P., Miller, S., & Fitch, R. H. (1993). *Neurobiological basis of speech: A case for the preeminence of temporal processing.* In: P. Tallal, A. M. Galaburda, R. R. Llinas & C. von Euler (eds.), Temporal information processing in the nervous system. Annals of the New York Academy of Sciences, Vol. 82 (pp. 27–47). New York: New York Academy of Sciences. Paper reprinted in *Irish Journal of Psychology*, (1995), *16*, 194-219.

Tallal, P., & Piercy, M. (1973b). Developmental aphasia: Impaired rate of nonverbal processing as a function of sensory modality. *Neuropsychologia, 11,* 389-398.

Tallal, P, & Piercy, M. (1974). Developmental aphasia: Rate of auditory processing and selective impairment of consonant perception, *Neuropsychologia, 12,* 83-93.

Tallal, P., Stark, R. E., & Mellits, D. (1985). The relationship between auditory temporal analysis and receptive language development: Evidence from studies of developmental language disorder. *Neuropsychologia. 23,* 527-534.

Tallal, P., Townsend, J., Curtiss, S., & Wulfeck, B (1991). Phenotypic profiles of language-impaired children based on genetic/family history. *Brain and Language*, 41:81–95.

Thal, D., Tobias, S., & Morrison, D. (1991). Language and gesture in late talkers: A 1-year follow-up. *Journal of Speech and Hearing Research*, 34, 604–612.

The SLI Consortium. (2002). A genome wide scan identifies two novel loci involved in specific language impairment. *American Journal of Human Genetics, 70*, 384-398.

The SLI Consortium. (2004). Highly significant linkage to the SLI1locus in an expanded sample of individuals affected by specific language impairment. *American Journal of Human Genetics, 74*, 1225-1238.

Thomas, M. S.C. T. (2005). Characterizing Compensation (Commentary on Ullman and Pierpont, "Specific Language Impairment is not Specific to Language: The Procedural Deficit Hypothesis"), *Cortex*, 41, 434-442.

Tomasello, (2000). Do young children have adult syntactic competence? *Cognition, 74*, 209-253.

Tomblin, B. (1991). Examining the cause of specific language impairment. *Language, Speech and Hearing Services in Schools,* 22, 69-74.

Tomblin, J. B., & Zhang, X. (1999) 'Language patterns and etiology in children with specific language impairment.' In H. Tager-Flusberg (ed.), *Neurodevelopmental Disorders: Developmental Cognitive Neuroscience*, pp. 361– 82. Cambridge, MA: MIT Press.

Tomblin, J. B., Abbas, P. J., Records, N. L., & Brenneman, L. M. (1995). Auditory evoked responses to frequency- modulated tones in children with specific language impairment. *Journal of Speech and Hearing Research, 38*, 387-392.

Tomblin, J.B., Christiansen, M.H., Bjork, J.B., Iyengar, S.K., & Murray, J.C. Association of FOXP2 genetic markers with Procedural Learning and Language. Retrieved from *http://www.ashg.org/genetics/ashg07s/f20690.htm* on 1st January, 2013.

Tomblin, J. B., Mainela-Arnold, E., & Zhang, X. (2007). Procedural learning in adolescents with and without specific language impairment. *Language Learning and Development, 3*, 269-293.Tomblin, J. B., Records, N., & Zhang, X. (1996). A system for the diagnosis of specific language impairment in kindergarten children. *Journal of Speech and Hearing Research,* 39(6):1284-94.

Trauner, D., Wulfeck, B., Tallal, P., & Hesselink, J. (1995). '*Neurologic and MRI profiles of language impaired children.*' Technical Report CND-9513, Center for Research in Language, University of California at San Diago.

Uddén, J., Ingvar, M., Hagoort, P., & Petersson, K. M. (2012). Implicit acquisition of grammars with crossed and nested non-adjacent dependencies: Investigating the push-down stack model. *Cognitive Science, 36,* 1078–1101. *http://dx.doi.org/10.1111/j.1551-6709.2012.01235.x.*

Ullman, M. T. (2001). The Declarative/Procedural Model of Lexicon and Grammar. *Journal of Psycholinguistic Research, 30,* 1, 37-69.

Ullman, M. T. (2004). Contributions of memory circuits to language: The declarative/procedural model. *Cognition, 92* 231-270.

Ullman, M. T (2005). A cognitive neuroscience perspective on second language acquisition: The declarative/procedural model. In: Sanz C., editor. *Mind and Context in Adult Second Language Acquisition: Methods, Theory and Practice*. Georgetown University Press; Washington, DC: pp. 141–178.

Ullman, M. T. (2006a). The declarative/procedural model and the shallow-structure hypothesis. *Journal of Applied Psycholinguistics*, 27(1):97–105.

Ullman, M. T. (2006b). Is broca's area part of a basal ganglia thalamocortical circuit?. *Cortex*, 42(4):480–485.

Ullman, M. T., Corkin, S., Coppola, M., Hickok, G., Growdon, J. H., Koroshetz, W. J., & Pinker, S. (1997). A neural dissociation within language: Evidence that the mental dictionary is part of declarative memory, and that grammatical rules are processed by the procedural system. *Journal of Cognitive Neuroscience*, *9*, 266–276.

Ullman, M. T., & Gopnik, M. (1994). The production of inflectional morphology in hereDidary specific language impairment. In J Matthews (Ed), *The McGill working papers in linguistics: Linguistic aspects of familial language impairment*. Montreal: McGill, pp. 81-118.

Ullman, M. T., & Gopnik, M. (1999). The production of inflectional morphology in hereDidary specific language impairment. *Applied Psycholinguistics, 20*, 51-117.

Ullman, M. T., & Pierpont. E. (2005). Specific Language Impairment is not specific to Language: The Procedural Deficit Hypothesis. *Cortex, 41*, 399-433.

Van der Lely, H. K. J. (1998). G-SLI in children: Movement, economy and deficits in the computational syntactic system. *Language Acquisition, 7*, 161-193.

van der Lely, H. K. J. (1999). Learning from Grammatical SLI: a response to J. Tomblin and J.B. Pandich. *Trends in Cognitive Sciences,* 3, 8, 286-288.

Van der Lely, H. K. J. (2005). Domain-specific cognitive systems: Insight from grammatical specific language impairment. *Trends in Cognitive Sciences*, *9*, 53-59.

Van der Lely, H. K. J., & Howard, D. (1993). Children with specific language impairment: Linguistic impairment or short-term memory deficit? *Journal of Speech and Hearing Research, 36*, 1193-1207.

Van der Lely, H. K. J, Rosen S., & McClelland, A. (1998). Evidence for a grammar-specific deficit in children. *Current Biology, 8,* 1253-1258.

van der Lely, H. K. J., & Stollwerck, L. (1997). Binding theory and grammatical specific language impairment in children. *Cognition, 62,* 245-290.

van der Lely, H. K. J., & Ullman, M. (1996). The computation and representation of past-tense morphology in normally developing and specifically language impaired children. In A. Stringfellow, D.Cahana-Amitay, E. Hughes, & A. Zukowski, *Proceedings of the 20th Annual Boston University Conference on Language Development*, (pp. 816±827). Somerville, MA: Cascadilla Press.

Van der Lely, H. K. J., & Ullman, M. T. (2001). Past tense morphology in specifically language impaired and normally developing children. *Language and Cognitive Processes, 16*, 177-217.

Vargha-Khadem, F., Watkins, K., Alcock, K., Fletcher, P., & Passingham, R. (1995). Praxic and nonverbal cognitive deficits in a large family with a genetically transmitted speech and language disorder. *Proceedings of National Academy of Science*, USA, 92:930–933.

VarghaKhadem, F., Watkins, K. E., Price, C. J., Ashburner, J., Alcock, K. J., Connelly, A., et al. (1998). Neural basis of an inherited speech and language disorder. *Proceedings of National Academy of Science*, USA, 95, 12695-12700.

Vernes S. C., Newbury D. F., Abrahams B.S., Winchester L., Nicod, J., Groszer, M., Alarcón, M., Oliver P. L., Davies K. E., & Geschwind, D. H. A. (2008). Functional genetic link between distinct developmental language disorders. The *New England Journal of Medicine,* 359:2337–2345.

Watkins, R. V., & Rice, M. L. (1991).Verb particle and preposition acquisition in language-impaired preschoolers. *Journal of Speech and Hearing Research, 34,* 1130–1141.

Watkins, R., Rice, M., & Molz, C. (1993). 'Verb use by language-impaired and normally developing children.' *First Language*, 37, 133 – 43.

Wetherell, D., Botting, N., & Conti-Ramsden, G. (2007). Narrative in adolescent specific language impairment (SLI): A comparison with peers across two different narrative genres. *International Journal of Language & Communication Disorders*, 42(5), 583–605.

Wexler, K. (1994). Optional infinitives, head movement and the economy of derivations. In D. Lightfoot and N. Hornstein (eds.), *Verb Movement*. Cambridge University Press: Cambridge, U.K., 305-35.

Wexler, K. (1998). Very early parameter setting and the unique checking constraint: A new explanation of the optional infinitive stage, *Lingua, 106*, 23-79.

Wexler, K., Gavarro, A., & Torrens, V. (2004a). Feature checking and object clitic omission in child Catalan and Spanish. In: Bok-Bennema, R.,Hollebrandse, B., Kampers-Manhe, B., Sleeman, P. (Eds.), *Romance Languages and Linguistic Theory 2002: Selected Papers From 'Going Romance',* Groningen, 28--30 November 2002. John Benjamins, Amsterdam, pp. 253-268.

Windsor, J., & Hwang, M. (1999). Derivational suffix productivity for students with or without language-learning disabilities. *Journal of Speech, Language and Hearing Research, 42*, 220–230.

Windsor, J., Milbrath, R. L., Carney, E. J., & Rakowski, S. E. (2001). General slowing in language impairment: Methodological considerations in testing the hypothesis. *Journal of Speech, Language, and Hearing Research, 44,* 446–461.

World Health Organization. (1993). *The ICD-I0 Classification of Mental and behavioral disorders: Diagnostic criteria for research*. Geneva: WHO.

Young, A. B., & Penney, J. B (1993). Biochemical and functional organization of the basal ganglia. In J Jankovic and E Tolosa (Eds), *Parkinson's Disease and Movement Disorders.* Baltimore: Williams and Wilkins, pp. 1-11.

Appendix A- Ling's 6 Sound for Hearing Screening

<u>Test administration</u>

The examiner utters sounds m, s, Sh, aa, ee, & oo. The task for the participant is to repeat the sound after the examiner

<u>Logic behind administration</u>

The Ling 6 sound test was developed as a quick and easy test that parents and professionals can use to check their child's hearing. The test checks that the child can hear (detection) and recognize each sound (identification) across the different speech frequencies. Asking the typical children to repeat after the examiner is also an accepted way of administration.

<u>Why these 6 sounds</u>

The Ling 6 sounds are the particular sounds that occur at particular speech frequencies.

<u>Ling sound Frequency</u>

/m/ Is a low frequency sound and if your child cannot hear this sound it is likely they will not have sufficient low frequency information to develop speech with normal prosody and without vowel errors.

/u/ Has low frequency information.

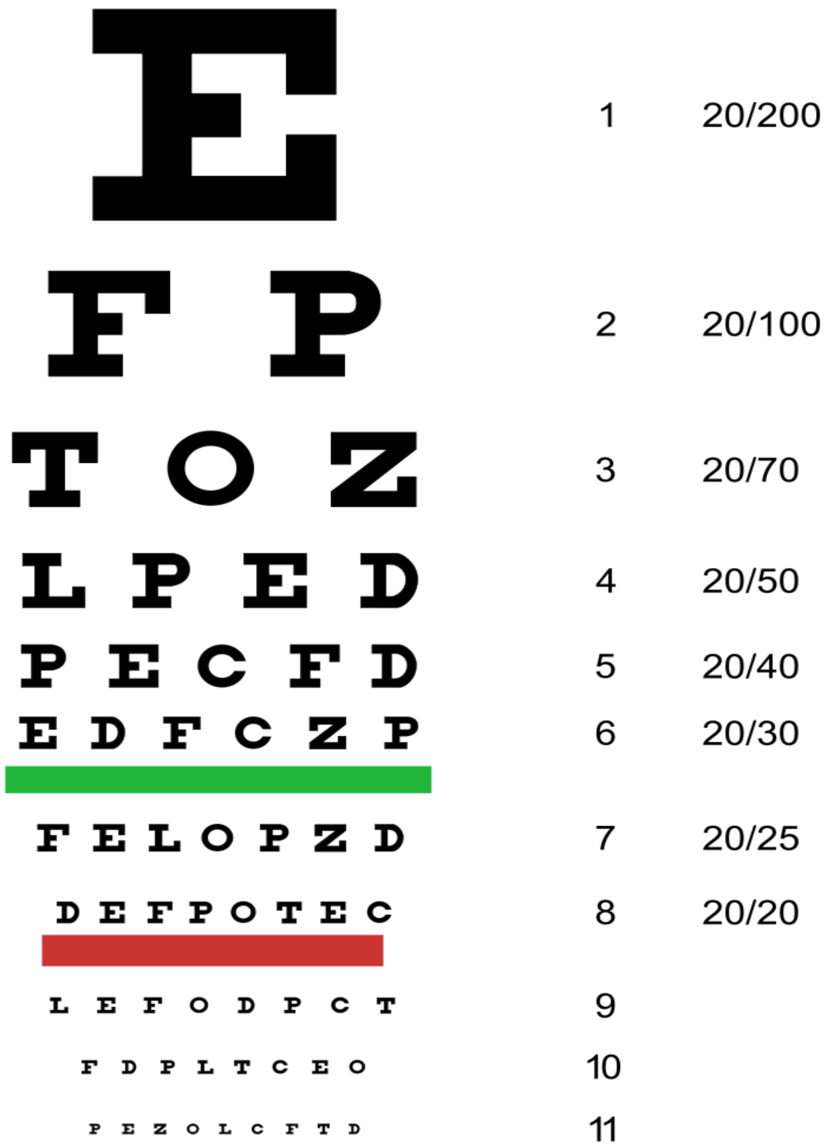
/i/ Has some low and some high frequency information.

/a/ Is at the center of the speech frequency range.

/sh/ Is in the moderately high frequency speech range.

/s/ Is in the very high frequency speech range.

Appendix B- Snellen's Chart for Vision Screening



<u>Administration</u>

1. Place the chart at 20 feet from the participant and ask to read the letters over the red line (20/20 vision)
2. If he/she reads correctly which means that the vision is adequate for daily life and activities.

<u>Note: The chart has been shrunk.</u>

Appendix C- NonWord Repetition Task Stimuli and Norms (In Kannada) (Source: Kuppuraj & Prema, 2012b)

Length -stimulus	% of syllables correct (SC)	Mean and SD for 7-10 years TD children (% of SC)	Mean and SD for 11- 13 years TD children (% of SC)
6-ra/la/tha/man/da/ni *6-Kam/ba/ru/li/ha/si* *6-she/ra/la/ma/sa/tha* *6-at/cha/da/ga/ni/lu* *6-a/gi/gu/na/va/nu* Total:	No. of syllables uttered correctly by total	Mean:83.5 SD: 10.1	Mean: 91.0 SD: 9.2
7-Ma/pa/lu/sa/ra/Li/ra *7-ra/sa/la/ga/khe/ra/lu* *7-Ka/ra/thi/hi/dve/be/thi* *7-a/ya/kru/ma/vi/nath/ya* *7-ra/sa/la/je:/ga/vi/lu* Total:	no. of syllables multiplied by 100	Mean:68.6 SD:14.2	Mean: 78.2 SD: 14.2
8-a:/ga/ra/na/dha/am/ba/di *8-Pu/ga/na/tha/shi/ka/ra/lu* *8-Swa/gan/thra/yo/tha/ru/la/ga* *8-dha/kru/thi/pra/tha/dham/sour/ya* *8-Pra/the/ga/shio/dha/yi/la/the* Total:	e.g., 4/6x100=66.6 5/7x100=71.4 5/8x100=62.5	Mean:56.7 SD: 17.4	Mean: 69.7 SD: 15.3

Appendix D- Leonard Exclusionary Criteria for Diagnosis of Children with SLI (1998)

Factor	Criterion
Language ability	Language test scores of -1.25 Standard deviations (SD) or lower
Nonverbal IQ	Performance IQ of higher than 85
Hearing	Pass screening at conventional levels
Otitis media with effusion	No recent episodes
Neurological dysfunction	No signs or treatment of seizure disorders, cerebral palsy, brain lesion
Oral structure	No structural anomalies
Oral motor function	Pass screening using developmentally appropriate items
Physical and social interaction	No autism or autism spectrum disorders, which surfaces in social interaction or activities

Appendix E-Ten Point Disability Checklist

1) Compared with other children did the child have any serious delay in sitting, standing and walking?
2) Does the child speak at all?
3) Can the child make himself understand words, can he say recognizable words?
4) Does the child have difficulty seeing?
5) Does the child have difficulty hearing?
6) When you ask the child to do something, does he seem to understand what you are saying?
7) Does the child have any weakness or stiffness in the limbs/ difficulty in walking or moving his limbs?
8) Has the child often had fits, become rigid or lost consciousness in the last 6 months?
9) Has the child had any other serious accidents / illness?
10) Compared with other children of his age, does the child appear in any way backward, slow or dull?

Appendix F- Grammatical Stimuli

1. Stimuli for morphemes for judgment and stimuli for morphemes for judgment and revision.

Practice items

1. koti maradalli irutade (Correct sentence- only judgment is required, Max. score 1)

2. maguv*annu* o:TTa tinnisu (***ige***) (Incorrect sentence-judgment & revision required, Max. score 4)

3. na:nu na:Le o:rinda *bande* (***bartini***) (Incorrect sentence-judgment & revision required, Max. score 4)

a. Derivational morphemes

Sl. No	*Stimuli (target morpheme is italicized)*	*Choice stimuli in two choice judgment frame*	*Scoring*
1	avanu mo:sa*ga:ra* he cheat 'He is cheat'		1 0
2	idu ha:sya*maya* kate this comic story 'This is wonderful story'		1 0
3	avanu tumba shakti*ga:ra* ***(vanta)*** he very strong 'He is very strong'	avanu thumba shakti*vanta*	1 2 3 4
4	maguvige u:tta tinn*isu* baby food feed 'Feed the baby'		1 0
5	mu:rka*tana* kelasa ha:Lu ma:Datte foolishness job spoil will 'Foolishness job will spoil'		1 0
6	kunTebille ondu *o:*DaTTa kuntibelle a game 'Kuntibille is a physical game'		1 0
7	dzo:pa:nav*a:gi* duDDannu upayo:gisabe:ku cautiously money used 'Money to be handled cautiously'		1 0
8	avana naDava*ne* sari illa ***(ige)*** his conduct good not 'His conduct is bad'	avana naDava*lige* sari illa	1 2 3 4
9	avan*u* yuddadalli ga:ya:Lu a:gidda he battle injured 'He was injured in battle'		1 0
10	avanu buddi*vanta* he brilliant 'He is brilliant'		1 0

11	na:vu chakkli tinn*o:Na* we chakli shall eat ‘shall we eat chakli’		1 0
12	namage halaya nena*pana* iruttade ***(pu)*** we old memories have ‘We have old memories’	namage halaya nena*pu* iruttade	1 2 3 4
13	na:vu padagala jo:D*ane* ma:Dutte:ve we words join ‘We join words’		1 0
14	avanu ra:dzana a:stanadalli he raja’s empire lekk*iga*na:giddane clerk ‘He is a clerk in raja’s empire’		1 0
15	krishna ra:dzana sere:yaL*u* krishna rajan’s prisoner ‘Krishna is Raja’s prisoner’		1 0
16	ha:va:di*ga:ra h*a:vannu a:Disuta:ne ***(iga)*** snake charmer snake charming ‘Snake charmer charms the snake’	ha:vadi*iga h*a:vannu a:Disuta:ne	1 2 3 4
17	simha ondu ha:ni*ka:ra* pra:ni lion a harmful animal ‘Lion is a harmful animal’		1 0
18	ramesha tumba tunT*a* ramesha very naughty Ramesha is very naughty		1 0
19	ni:nu a: kelasavannu prayathn*isu* you that job practice ‘You practice that job’		1 0
20	ni:nu ho:r*a:Du* you fight ‘You fight’		1 0
21	mare:v*u* ondu sahadza kriye forgetting a ordinary act ‘Forgetting is an ordinary act’		1 0
22	avanu bharat*i:ya* he indian He is an Indian		1 0
23	ganesha suLL*a* ganesha liar Ganesha is a liar		1 0
24	hechu thinnuvutu ha:ni*maya* ***(ka:ra)*** too much easting harmful ‘Eating too much is harmful’	hechu thinnuvuthu ha:ni*ka:ra*	1 2 3 4
25	anta*ra:striya* praya:Na kashTa overseas journey difficult ‘Travelling overseas is difficult’		1 0

26	nidhanav*a:gi* kelasavannu madabekku slowly work do 'Do the work slowly'		1 0
27	va:ni ha:dannu *ha:Dutaho:dalu* va:ni-song-sing-going 'Vani is singing the song and going'		1 0
28	go:liyannu chella*:Du* goli spill play 'Spill the goli and play'		1 0
29	doDDa*tana* namalli irabe:ku greatness in us required 'Greatness is required in us'		1 0
30	avanu kate*vanta* ***(ga:ra)*** he writer He is a writer	avanu kate*ga:ra*	1 2 3 4

Derivational morphemes contd…

Category	*Morphemes*	*Stimuli numbers for judgment*	*Stimuli numbers for judgment and revision*
Nouns derived from nouns	-ga:ra, -a, -u, -iga, & -vanta	1, 9, 10, 14, 15, 18, & 23	3, 16, & 30
Nouns derived from verbs	o:, -u, -pu, -ane, & -ike	6, 11, 13, & 21	8 & 12
Verb derived from noun	-isu	4 & 19	-
Verb derived from verb	–a:Du	20 & 28	-
Adjective derived from nouns	-maya, -iya, & -ka:ra	2, 22, & 17	24

- *Scoring for stimuli for judgment*
  "1" for correct, "0" for incorrect
- *Scoring for stimuli for judgment and revision (presented in forced binary choice)*
  "4" for judging and revising, "3" for judging correct and revising after clue, "2" for judging and not revising after clue, "1" for not judging but revising after clue, "0" for neither judging nor revising even with clue

b. Inflectional morphemes

Sl. No	*Stimuli (target morpheme is italicized)*	*Choice stimuli in two choice judgment frame*	*Scoring*
1	idu mara (pic a) this tree 'This is tree'		1 0
2	ivu mara*gaLu* (pic b) these trees 'These are trees'		1 0
3	ive na:yi*gaLu* (pic c) **(yi)** these dogs 'These are dogs'	idu na:*yi*	1 2 3 4
4	baratad*alli* iruvavaru ellaru annattamandiaru in india everyone brothers 'everyone in India are brothers'		1 0
5	avaLu kere:*ge* ne:ru taralu hoguvaLu she lake to get water will go 'She will go to lake to get water'		1 0
6	idu avan*ige* mane ***(a)*** this his house 'This is his house'	idu avan*a* mane	1 2 3 4
7	namma manej*alli* TV ide our home tv is there 'TV is there in our home'		1 0
8	maguv*lli* sh:le:ge karedukonDu ho:gu ***(annu)*** child school take with you 'Take the child to school with you'	maguv*(annu)* sh:lege karedukonDu ho:gu	1 2 3 4
9	na:vu de:var*annu* po:jisute:ve we god worship 'We worship god'		1 0
10	na:vellaru bussina samayak*ke* tumba ka:yute:ve we for bus time very much wait 'We wait so much for bus to come'		1 0
11	avanu mane*jannu* hogutida:ne ***(ige)*** he house going 'He is going to house'	avanu mane*ge* hogutida:ne	1 2 3 4
12	adu ra:man*a* ka:ru that raman's car 'That is Raman's car'		1 0
13	namma sha:l*ege* kampu:tar ide ***(lli)*** our school has computer 'Our school has computer'	namma sha:lea*lli* computer ide	1 2 3 4
14	appa: kelasa*nnu* ho:guta:re ***(kke)*** father for work go 'Father goes to work'	appa: kelasak*ke* hoguta:re	1 2 3 4

15	indu maLe baruth*__ade__* today rain will come 'It will rain today'		1 0
16	huduga ni:ru *__kudiako:gutha:ida:ne__* (pic d) ***(kudiuta:ida:ne)*** boy water going to drink 'The boy is going to drink water'	huduga ni:ru *__kudiutaida:ne__*	1 2 3 4
17	indu maLe bara*__bohudu__* today rain may come 'It may rain today'		1 0
18	na:Le na:vu cinema:*__ge__* ho:guvevu tomorrow we for cinema will go 'We will go for cinema tomorrow'		1 0
19	avanu o:TTa maD*__ida__* he food had 'He ate food'		1 0
20	avanu ninne o:ruge *__o:daru__* ***(hoda)*** he yesterday to his place went 'He went to his place yesterday'	avanu ninne o:ruge *__hoda__*	1 2 3 4
21	huduga keLage *__biddida:ne__* (pic e) ***(bi:Luta:ida:ne)*** boy down fell 'Boy fell down'	huduga keLage *__bi:Luta:ida:ne__*	1 2 3 4

Inflectional morphemes contd…

Category	*Morphemes*	*Stimuli for judgment*	*Stimuli for judgment and revision*
Plurals	-gaLu	1, 2, & 4	3
Case markers	-annu, -lli, -a, ige, -ike	9,7,12,5,& 10	8,13, 6,11, & 14
Tense/Agreement	-Dita-, -hoda, -Lutha-	15,17,18, & 19	16, 20, & 21

- *Scoring for stimuli for judgment*
  "1" for correct, "0" for incorrect.
- *Scoring for stimuli for judgment and revision*
  "4" for judging and revising, "3" for judging correct and revising after clue, "2" for judging and not revising after clue, "1" for not judging but revising after clue, "0" for neither judging nor revising even with clue.

c. Morpho-syntax

Sl. No	*Stimuli (target morpheme is italicized)*	*Choice stimuli in two choice judgment frame*	*Scoring*
1	me:dzaina <u>*keLage*</u> tzenDu ide (pic f) ***(me:lide)*** table under ball is there 'Ball is under the table'	me:dzaina <u>*me:le*</u> tzenDu ide	1 2 3 4
2	me:dzaina <u>*pakka*</u> tzenDu ide (pic g) table adjacent ball is there 'Ball is adjacent to the table'		1 0
3	tzenDu dabbada <u>*oragide*</u> (pic h) ***(holage ide)*** ball box outside 'Ball is outside the box'	tzenDu dabbada <u>*ola:g ide*</u>	1 2 3 4
4	ka:gada <u>*dzotte*</u> pennide (pic i) paper with pen 'Pen is with the paper'		1 0
5	bisilu maLe <u>*a:dame:le*</u> ka:manabillu barutade sun rain after rainbow 'Rainbow comes after sun and rain'		1 0
6	kudire:<u>*ginta*</u> a:ne doDDadu hoarse -than elephant bigger 'Elephant is bigger than hoarse'		1 0
7	avanu ga:Dialli hoda <u>*athva*</u> nida:nava:gi hoda ***(a:dare)*** he vehicle went but slowly went 'He went in vehicle yet slowly'	avanu ga:Dialli ho:da <u>*a:dare*</u> nida:nava:gi hoda	1 2 3 4
8	ga:dialli nida:nava:gi ho:gu <u>*illadiddare*</u> biddo:gtia vehicle go slow or you skid 'Go slowly in vehicle or you will skid'		1 0
9	avanu buddivanta <u>*a:dare*</u> baDava he brilliant but poor 'He is brilliant but poor'		1 0
10	manealli ti:vi <u>*iddare*</u> be:dzara:gala home TV there boredom no 'If there is TV in home, you do not get boredom'		1 0
11	nanage ti: <u>*a:dare*</u> ka:fi koDi ***(athva)*** me tea but coffee give 'Give me tea but coffee'	nanage ti: <u>*athva*</u> ka:fi koDi	1 2 3 4
12	avanu gadde kelasa:n<u>*o:*</u> ga:re kelasa:no: ma:Duta:ne he agri or daily labor does 'He does agri or daily labor'		1 0
13	na:nu tinDige iDli <u>*mattu*</u> chatni tinde i breakfast idli and chatni ate 'I ate idli and chatni for breakfast'		1 0

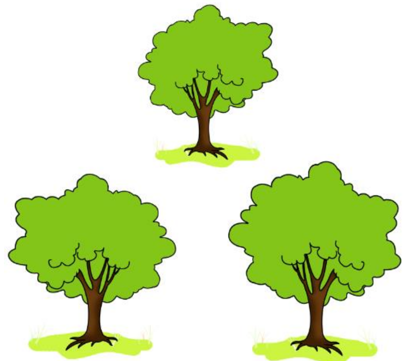
Morpho-syntax contd…

Category	*Morphemes*	*Stimuli for judgment*	*Stimuli for judgment and revision*
Preposition	keLage, pakka, horage, dzote, a:dame:le	2,4, &5	1 & 3
Cond/Conj/Compa	-iddre, -mattu, -a:dare, -atva, -o:, :iladiddare, -ginda	6,8,9,10, 12, & 13	7 &11

- *Scoring for stimuli for judgment*
  "1" for correct, "0" for incorrect
- *Scoring for stimuli for judgment and revision*
  "4" for judging and revising, "3" for judging correct and revising after clue, "2" for judging and not revising after clue, "1" for not judging but revising after clue, "0" for neither judging nor revising even with clue

Pictures


a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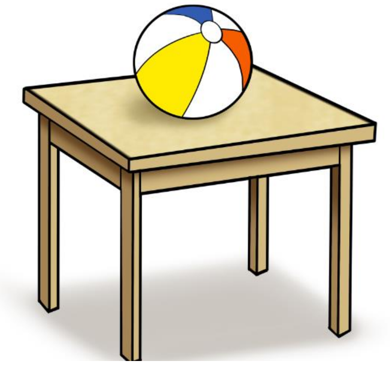
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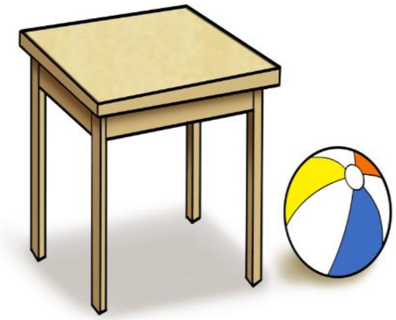
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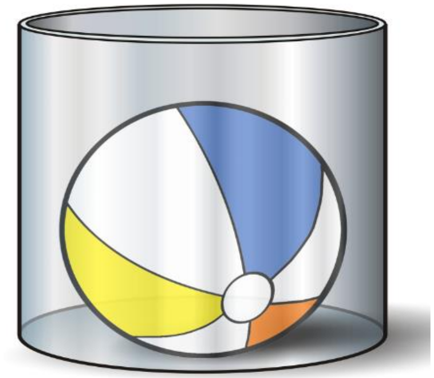
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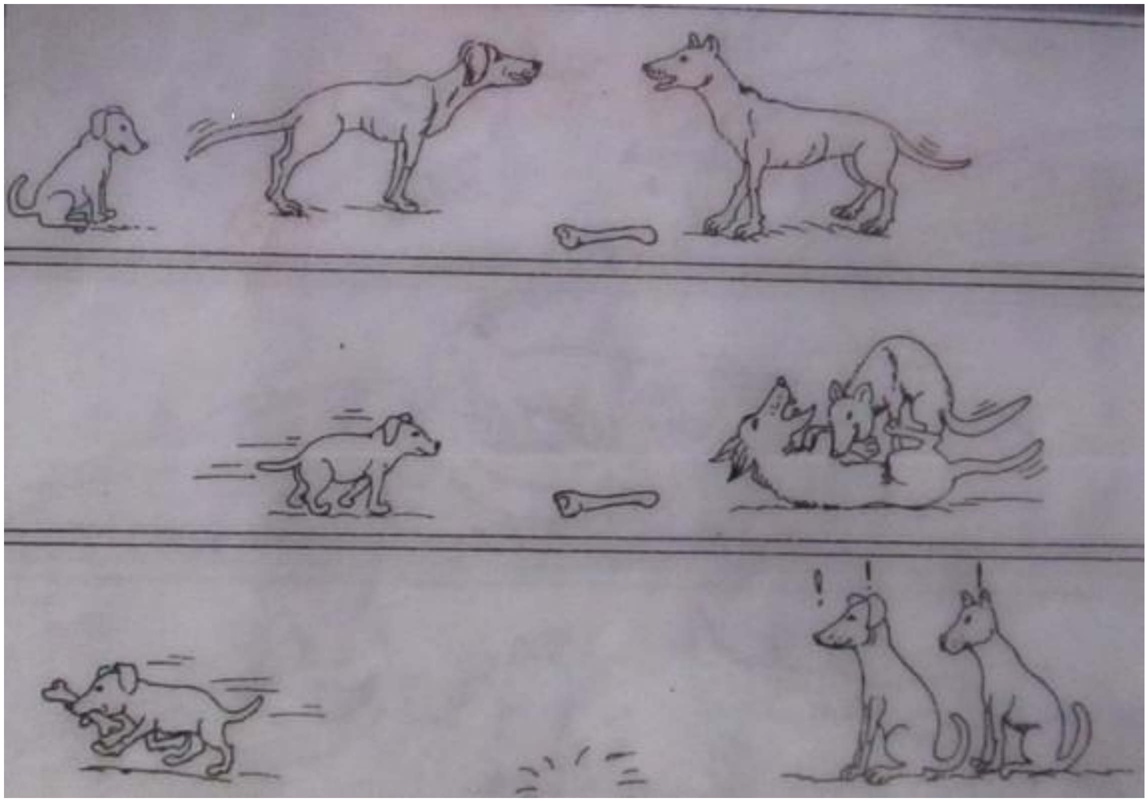
i

2. Stimuli for Grammatical complexity task

Following is the sequential picture used



List of Publications Related to Thesis

Completed

1. Kuppuraj. S., & Prema K. S. R. (2012a). Grammar as motor sequence learning. *Indian Linguistics. 73* (1-4), 147-164. **(First page attached)**
2. Kuppuraj. S., & Prema K. S. R. (2012b). Is Non-word repetition a True Clinical Marker of SLI?, *Journal of All India Institute of Speech and Hearing*, 31, 120-129 **(First page attached)**
3. Kuppuraj. S., & Prema K. S. R (2013a). Sequence learning pattern in children with specific language impairment, *International Journal of Disability and Human Development*, *DOI: 10.1515/ijdhd-2012-0003*. ***(Complete paper attached)***
4. Kuppuraj. S., & Prema K. S. R (2013b). Grammar Specific Language Impairment: An Evolutionary Default? *Netherlands Journal of Psychology, 68* (2), 43-60. http://www.psynip.nl/index.php?p=977689 **(First page attached)**
5. Kuppuraj, S., & Prema, K. S. R. (2013c). An adapted serial reaction time task for procedural learning measurements. *Psychological Studies, 58, (3),* 276-284, http://link.springer.com/article/10.1007%2Fs12646-013-0204-z ***(Complete paper attached)***
6. Kuppuraj, S., & Prema, K. S. R. (2013d). Aspects of grammar sensitive to procedural memory deficits in children with specific language impairment. *Research in Developmental Disabilities, 34*, 3317–3331. *http://www.ncbi.nlm.nih.gov/pubmed/23911642* ***(Complete paper attached)***

Under Review

1. **“**Implicit Sequence Learning and Recursion Deficit in Children with Specific Language Impairment: A Neurocognitive Triad” *Journal of Child Language Acquisition and Development*

Ready for Submission

1. Kuppuraj, S., & Prema, K. S. R. Inflectional versus derivational abilities of children with specific language impairment-A panorama from sequential cognition.