Simulating Specific Language Impairment:
Effects of Sentence Length and Input Rate on Complex Sentence Comprehension

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This thesis titled
Simulating Specific Language Impairment:
Effects of Sentence Length and Input Rate on Complex Sentence Comprehension

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ABSTRACT

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Purpose: Relative to their age peers, children with specific language impairment (SLI) demonstrate significantly greater difficulty processing and comprehending verbal be passive and object relative sentences, but not subject-verb-object (SVO) sentences. Children with SLI also consistently evidence reduced phonological short-term memory (pSTM) and slower processing speed. This project examined the potential association between these SLI characteristics by attempting to simulate the complex sentence comprehension problems in a group of typically developing children by inducing difficulty comprehending sentences involving syntactic movement (van der Lely, 2005).

Method: Thirty six 7- to 11-year-old children completed a real-time sentence comprehension task in which they selected the agent of the sentence. Sentence comprehension was made harder by introducing two stress factors, sentence length and input rate (designed to stress pSTM and speed of language processing), to passive, object relative, and SVO sentences. Children received equal numbers of 9-, 12-, and 15-word sentences of each sentence type blocked by normal rate, 20% faster rate, and 33% faster rate. The primary dependent variables were sentence comprehension accuracy and speed. The separate effects of sentence length and input rate were of central interest.
Results: The effect of sentence length on comprehension accuracy was not significant for any sentence type. Sentence length did significantly affect speed of comprehension, with processing of 12- and 15-word sentences being comprehended significantly faster than 9-word sentences. Input rate had no significant effect on the comprehension accuracy of any sentence type. However, speed of comprehension was significantly affected by input rate, with 33% rate compressed passive and object relative sentences being comprehended significantly more slowly relative to at least one of the other input rate sentences.

Conclusions: In typically developing children, increasing sentence length (and by extension stressing pSTM) did not induce poorer complex sentence comprehension that is characteristic of children with SLI. Increasing input rate (and, by extension, taxing language processing speed) did lead to slower speed of comprehension of complex sentences, but it did not impair comprehension accuracy. The children demonstrated a clear speed-accuracy tradeoff, sacrificing speed for accuracy.

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CHAPTER 1: INTRODUCTION

Despite the lack of hearing loss, general intellectual impairment, or physical, social or emotional problems (Leonard, 1998), children categorized as having specific language impairment (SLI) demonstrate varying degrees of language comprehension and production problems. Difficulty with complex sentence comprehension is a major distinguishing characteristic of SLI (van der Lely, 1996, 1998, 2005; van der Lely & Stollwreck, 1997). One of the fundamental questions in the study of SLI is whether there is a primary representational deficit in the grammar module or whether more general purpose processing mechanisms can account for these linguistic deficits.

In addition to language-specific deficiencies, children with SLI exhibit a wide range of cognitive processing limitations. The three areas of cognition most intensively examined include phonological short-term memory (pSTM), working memory, and speed of processing. Relative to age-matched peers, children with SLI show significantly reduced pSTM capacity (Adams & Gathercole, 2000; Archibald & Gathercole, 2006, 2007; Ellis Weismer et al, 2000; Gathercole & Baddeley, 1990; Montgomery, 1995, 2004; Montgomery & Windsor, 2007), working memory (Archibald & Gathercole, 2006, 2007; Ellis Weismer, Evans, & Hesketh, 1999; Mainela-Arnold & Evans, 2005; Marton & Schwartz, 2003; Montgomery, 2000a, 2000b), and speed of processing (Leonard et al., 2007; Miller, Kail, Leonard, & Tomblin, 2001; Montgomery, 2000a, 2002; Windsor & Hwang, 1999a, 1999b; Windsor, Milbrath, Carney, & Rakowski, 2001).
While there is evidence for an association between SLI children’s cognitive processing deficits and global language problems (Leonard et al., 2007; Montgomery & Windsor, 2007) relatively little is known about how these same cognitive deficits relate to these children’s complex sentence comprehension problems. If it were possible to demonstrate that the specific profile of language difficulties seen in SLI does not depend on impaired linguistic representations, this would provide strong support for a processing explanation of SLI (Hayiou-Thomas, Bishop, & Plunkett, 2004).

This project attempted to simulate the complex sentence comprehension deficits characteristic of SLI in 7-11 year-old typically developing children. It is important to note that, regardless of language ability, a distinct sentence comprehension pattern is generally seen in all children with canonical sentences being correctly comprehended with the greatest consistency and object relative sentences with the least consistency: (simple) subject-verb-object = subject relatives > passives > object relatives. However, children with SLI are significantly slower and less accurate when processing passives and object relatives than same-age peers (Dick, Wulfeck, Krupa-Kwiatkowski & Bates, 2004).

To simulate an SLI-like comprehension profile, the current investigation stressed pSTM and processing speed. These stress factors were applied to a continuum of three sentence structures (simple, passive, and object relative clause). Three sentence lengths were created for each sentence type with the intent of simulating the reduced phonological storage capacity in SLI (Archibald & Gathercole, 2006, 2007; Montgomery, 1995, 2004; Montgomery & Windsor, 2007). Three input rates (normal rate, 20% rate
compression, 33% rate comprehension) were created with the intent of inducing slower processing as seen in SLI (Kail, 1994; Montgomery, 2006; Windsor & Hwang, 1999b). The successful simulation of an SLI-like pattern of comprehension in children with intact linguistic systems by increasing these cognitive processing demands would support the idea that the mechanisms of pSTM and processing speed play a part in causing the profile of language difficulty that characterizes SLI.
CHAPTER 2: REVIEW
SLI and Sentence Comprehension

Children categorized as having SLI demonstrate two chief deficits: difficulties learning and using grammatical morphology, and difficulties producing and comprehending complex syntax. Whereas typically developing children show evidence of increasingly mature, adult-like comprehension of a wide range of syntactic structures (Dick et al., 2004), children with SLI do not (Froud & van der Lely, 2008, Marinis & van der Lely 2007; van der Lely, 1996; 2006; van der Lely & Battell, 2003). Difficulty with complex sentence comprehension is a defining characteristic of SLI.

Explanations of these children’s complex sentence comprehension problems broadly fall within two overarching frameworks. First, linguistic (modular) accounts view their problems as a reflection of a deficit in the syntactic computational system (van der Lely, 1996, 1998, 2005; van der Lely & Battell, 2003; van der Lely & Stollwreck, 1997). Second, processing-based accounts view their deficit as related to limitations in cognitive processing (Bishop, Bright, James, Bishop, & van der Lely, 2000; Leonard, Ellis Weismer, Miller, Francis, Tomblin, & Kail, 2007; Montgomery & Windsor, 2007). In keeping with the second view, many children with SLI exhibit a variety of cognitive processing limitations, including phonological short-term memory (pSTM), working memory (WM, the ability to engage in simultaneous information processing and storage), and speed of processing. Multiple studies have demonstrated significant correlations between children’s cognitive processing deficits and global language problems (Leonard et al., 2007; Montgomery & Windsor, 2007). However, comparatively few studies have
examined how these same cognitive deficits relate to specific areas of linguistic difficulty, namely, the comprehension of complex syntax.

Not all sentence structures are problematic for children with SLI to understand. In English, the simplest and most often used sentence structure, the canonical word order, is subject-verb-object (SVO). Children with SLI have little difficulty comprehending semantically reversible sentences containing canonical word order (e.g., *The boy is hugging the girl*). They also have little trouble understanding canonical sentences containing various conjoined phrases (e.g., *The man was walking his puppy by the pond*). SVO sentence interpretation derives from the verb phrase (VP), directly assigning an appropriate thematic role to each argument position. The agent role is assigned to the pre-verb subject argument (NP1) and the theme/patient role is assigned to the post-verb object argument (NP2). Children with SLI, however, have difficulty understanding sentences involving noncanonical order and syntactic movement. The problem is that a word or phrase occupies a syntactic position that is different from the position that, in canonical sentences, determines its semantic role. A fundamental assumption underlying sentence comprehension is that listeners attempt to recover canonical order from noncanonical input (Chomsky, 1995; Kayne, 1994). This is accomplished through a process referred to as syntactic “movement.” There are a number of different linguistic formulations of movement (e.g., Chomsky, 1995; Hornstein & Nunes, 2002; Kayne, 1994), but these theoretical differences are not relevant to the proposed study. Rather, the interest is in syntactic movement in general.
Most of the research characterizing the syntactic nature of the sentence comprehension problems of children with SLI has been conducted by van der Lely and colleagues (van der Lely, 1996, 1998, 2005; van der Lely & Battel, 2003; van der Lely & Harris, 1990; van der Lely, Rosen, & Adlard, 2004; van der Lely & Stollwerck, 1997) and Friedman and Novogrodsky (2004). The aim of these researchers’ work has been to address whether these children’s comprehension problems stem from a deficit within the language system itself. Van der Lely and associates have studied verbal be reversible passives and sentences containing pronominals. Friedman and Novogrodsky have examined relative clause comprehension. In both verbal be passives (The boy i was kissed ti by the girl) and sentences containing an object relative clause (The boy i that the girl kissed ti on the nose ran away) children are not able to use the canonical SVO strategy to interpret NP1 as the agent and NP2 as the patient. Instead, they must come to realize that NP1 functions as the patient (object) and NP2 as the agent. In order to recover an SVO representation, children must perform a syntactic movement operation to establish what is called a “filler-gap dependency,” i.e., move NP1 (referred to as the “filler”) to the gap site (post-verb slot).

---

1 Syntactic markings of noncanonical sentences defined.

**Filler:** Noun phrase (NP) in a noncanonical sentence that moves to the post verbal position to “fill” the gap and establish an SVO representation.

**Gap:** Post verb location in a noncanonical sentence to which the “filler” NP moves.

**Trace (ti):** Position of “filler” NP as it assumes SVO structure.

**Co-indexing (i):** The marked original position of the “filler” NP (i) in relation to the trace position (ti) at the gap.
Both verbal *be* passives and object relatives pose special problems for children with SLI because these sentences involve syntactic movement. In order to regain canonical word order in the passive sentence *The boy *was kissed *by the girl on the head*, NP1 (*the boy*), which is the object NP, moves to an argument position. This movement leaves behind an argument chain established between the trace (t) at the gap and the moved NP (filler), with the relationship between the boy and its original position in the sentence specified through co-indexing (i). The agent role is transmitted to NP2 (*the girl*) appearing in a by-phrase from the passive morpheme (-ed; Guasti, 2002).

Object relatives also involve movement. They involve wh-movement of a NP from the object position to a nonargument position and movement across clausal boundaries. To understand the sentence *The boy *that the girl had kissed *on the nose ran away*, NP1 (*The boy*) moves from its fronted object position to its post-verb canonical position (*the girl had kissed the boy*). When NP1 moves it leaves a phonologically empty NP at the gap position (ti). The trace is linked to the antecedent through co-indexing (i). During comprehension the antecedent (NP1, again referred to as the “filler”) is reactivated at the gap to occupy the post-verb canonical object position (thus establishing a “filler-gap” dependency). At this point the proper thematic roles can be assigned by the verb. Thus, both sentence types require building a syntactic dependency between the moved element and the position from which it moved. However, because passives and object relatives involve different kinds of movement there are potential implications for timing differences in when NP1 is reactivated and processed as the agent of the sentence. NP1 reactivation in object relatives occurs at the gap (Lewis et al., 2006), but in passives the
most robust/reliable reactivation is about 1000 ms after the gap (Osterhout & Swinney, 1993). It may be that the presence of a relative pronoun in object relatives cues the upcoming gap while in passives there is no such cue (Osterhout & Swinney, 1993).

Across numerous studies using conventional picture pointing tasks, children with SLI, relative to CA peers, consistently show poorer comprehension of reversible *be* passives (van der Lely, 1996, 1998; van der Lely & Harris, 1990; van der Lely & Stollwerck, 1997). Nonreversible passives (e.g., *The milk was spilled by the boy*), however, pose no trouble because correct interpretation can be derived from pragmatic knowledge. Likewise, truncated passives (e.g., *The fish was eaten*) are not problematic (Bishop et al., 2000; van der Lely, 1996) because children can adopt an adjectival interpretation. In the sentence above, *eaten* is interpreted as a stative verb (i.e., an adjective) rather than a passive participle.

To account for the comprehension problems of children with SLI, van der Lely has proposed the Deficit in Computational Grammatical Complexity (CGC) hypothesis (Marshall & van der Lely, 2006; van der Lely, 2005), a modification of the earlier Representational Deficit for Dependent Relationships (RDDR) hypothesis (van der Lely, 1998; van der Lely & Battell, 2003). The main thrust of the hypothesis is the claim that the core deficit in SLI is in the representation and/or mechanism responsible for building hierarchical grammatical structures, i.e., difficulty computing syntactic dependencies. It is further proposed that children with SLI treat movement as optional; chronologically age matched children (CA) treat it as obligatory. Treating movement as optional does not ensure children with SLI will use the operation when it is needed. This leads to
inconsistent movement of NP1 and inconsistent assignment of proper thematic roles to
the NPs while processing sentence. A final assumption of the CGC/RDDR hypothesis is
that cognitive processing contributions are “secondary” factors in complex sentence
comprehension, subordinate to the overarching constraints of the syntax system (van der
Lely, 2005).

Friedman and Novogrodsky (2004) have extended the work of van der Lely by
studying the relative clause processing of Hebrew-speaking children with SLI. In their
2004 study, a group of children with SLI (7- to 11-year-olds) and two younger control
groups of children were studied. Children listened to object relative clause sentences
(e.g., *This is the girl, that the grandmother is kissing* ti) and SVO sentences (e.g., *The
girl is kissing the grandmother*). Immediately after hearing a sentence, children saw two
pictures and selected the one that matched the sentence. Results showed that the groups
performed comparably on the SVO sentences. For the object relative sentences, the SLI
group’s performance was worse than the 6-year-olds but comparable to the 4-year-olds.
The pattern of results was interpreted to be consistent with the CGC/RDDR account in
that children with SLI have a deficit in comprehending sentences that require syntactic
movement.

The claim that children with SLI have a syntactic movement deficit is based on
findings from conventional off-line picture pointing comprehension tasks. Off-line tasks,
however, assess comprehension after the fact, not during comprehension. To demonstrate
comprehension, children presumably must: (a) interpret the meaning of the input
sentence; (b) store the sentence representation in memory; (c) visually process each of the
pictures in the array and generate a linguistic representation of each picture; (d) reactivate the representation of the input sentence; (e) compare this representation to each representation corresponding to each picture; (f) rule out one or more possible picture choices and select the correct picture; and (f) plan and execute a pointing response. For many children, such coordination is not a problem. But for children with SLI it may be a problem, because their comprehension apparatus appears more vulnerable to breakdown given their cognitive processing limitations (Leonard et. al., 2007; Montgomery, 2002b; Montgomery & Windsor, 2007).

Sentence comprehension occurs in the moment or real time as listeners generate a linguistic representation from a transient acoustic signal. Understanding sentence comprehension and its underlying processes requires the use of techniques that are sensitive to comprehension as it occurs in real time. A variety of “on-line” methods exist, including word monitoring, agent selection, cross modal picture or lexical priming, eye tracking, and event-related potentials. The advantage of such measures over off-line tasks is that they provide investigators a window into when, during ongoing comprehension, various operations take place (e.g., building syntactic dependencies, structural attachments, and context effects), unconfounded by post-sentence processing demands.

The study of on-line sentence comprehension in SLI is limited. There is an emerging body of literature with typically developing children. Before reviewing the SLI literature, a brief overview of the developmental literature is provided as a backdrop to the issues driving the on-line comprehension research and the methods that have been used.
On-line Sentence Comprehension in Children

Background with Typically Developing Children

Bates and her colleagues (Dick et al., 2004; Leech et al., 2007; Von Berger, Wulfeck, Bates, & Fink, 1996) have conducted three studies examining typically developing children’s on-line grammar processing. The aim of their studies was to understand the developmental changes in children’s processing strategies (i.e., determining which of two NPs is functioning as agent) during the processing of different sentence structures. Children (5- to 17-year-olds) listened to such constructions as SVO sentences (e.g., The dog is biting the cat), subject relatives (e.g., It’s the bird that is biting the dog), passives (e.g., The cat is bitten by the dog), and object relatives (e.g., It’s the cat that the dog is biting). Children were tested using an “Agent Selection” method in which they saw pictures of two animals on a computer screen and then heard a sentence. Children were asked to choose as quickly as possible the animal that performed the action.

The Agent Selection task has important advantages over other real-time methods such as word monitoring (Von Berger et al., 1996). For example, word monitoring tasks ask children to monitor and respond to a specific word or parts of words during the processing of a sentence. Such responses reflect processing decisions made over relatively small stretches of input, i.e., 300-1000 ms range. Alternatively, the Agent Selection method requires children to maintain one or more noun phrases in memory before the verb can assign the proper thematic roles to each NP. Thus, the task reflects integrative processes spanning several words in the sentence and yields processing times
in the 2000 ms range. Noncanonical structured sentences, such as passives and object relatives, therefore require more time to process than simple SVO and subject relative structures. The method thus provides indicators for both processing accuracy and speed. The present study employed this same method.

The same response pattern was found in each study. Younger children (6- to 7-year-olds) were significantly less accurate (and slower) to process both the passives and object relatives than the older children (10- to 12-year-olds). Object relatives were found to be harder than the passives for both groups. However, both groups showed comparable comprehension of SVO and subject relative sentences, with both sentence types being easier than the passives and object relatives. The poor passive and object relative processing of the younger children was attributed to their continuing to interpret NP1 as the agent.

The Dick et. al. (2004) study also included a small group of children with SLI (7- to 15-year-olds). Two key findings emerged. First, the children with SLI showed the same comprehension pattern as the control children: SVO = subject relatives > passives > object relatives. Second, the children with SLI were significantly slower and less accurate processing passives and object relatives than same-age peers. The SLI and control groups showed comparable SVO and subject relative processing.

The comprehension of object relatives by young typically developing children was also recently studied by Love (2007) using a cross modal picture priming (CMPP) task to yield a finer-grained view of the time course underlying children’s complex sentence comprehension. In a CMPP task, a picture is displayed at some theoretically
relevant (or control) position while children are listening to a sentence. They are asked to make a simple classification decision as quickly as possible about the picture (e.g., the object is edible or a living thing). In some of the sentences the prime picture was either a picture of NP1 (“related” prime) or an “unrelated” prime picture (another animal or a non-animal object) that appeared at the gap site in the sentence (e.g., *The zebra, that the hippo had kissed, on the nose ran away*). In other sentences, the related prime picture was of NP2 (agent) or an unrelated prime picture appearing at the gap. In object relatives, once the critical verb is encountered, NP1 must move to its post-verb gap site (after the VP), at which point both NP1 and NP2 can then be integrated with the VP and the thematic roles assigned. The CMPP method is especially robust in allowing investigators to determine at what point during comprehension listeners build this syntactic dependency.

Children listened to sentences during which time they made a classification decision about a prime picture (whether the object was edible or not). If children correctly comprehend these sentences by moving NP1 to the gap they should show faster reaction time (RT) for NP1 pictures relative to (a) the “unrelated” prime pictures and (b) NP2 pictures. Clearly, NP2 should not move to the gap since it is not the object in the sentence. The data showed that 4- to 6-year-olds do move NP1 (not NP2) to the gap. The findings were interpreted to suggest that syntactic gaps represent part of children’s syntax processing mechanism such that the proper NP is automatically moved to the gap site upon encountering the critical verb.
The above review suggests that even young typically developing children have the ability to comprehend complex sentences involving syntactic movement. Moreover, it appears that children as young as 4 or 5 have the ability to automatically reactivate NP1 in object relative sentences in its rightful post-verb position during ongoing comprehension.

On-line Comprehension in Children with SLI

The on-line sentence processing of school-age children with SLI has been studied using word recognition RT tasks within the context of a sentence processing paradigm (Montgomery, 2000a, 2002, 2005, 2006; Montgomery & Leonard, 1998, 2006; Stark & Montgomery, 1995). On-line lexical processing studies allow investigators the unique opportunity to examine the unconscious mental representations and operations that are automatically deployed during the course of sentence comprehension (Tyler, 1992).

Results from several sentence processing studies consistently show that children with SLI are significantly slower when processing spoken language than their age peers (Montgomery, 2000, 2002, 2005, 2006; Montgomery & Leonard, 1998, 2006; Stark & Montgomery, 1995). This finding holds true regardless of how the sentence material is manipulated (e.g., input rate, phonetic content). Across all of these studies, children with SLI between the ages of 6 and 12 and age-matched children listened to simple sentences for the occurrence of a target word appearing in the beginning, middle or end of a sentence. As soon as the children recognized the target they pushed a response button, indexing word recognition RT. In each study, the children with SLI demonstrated significantly longer word recognition RT than the age-matched children. The slower
language processing of children with SLI has been interpreted to mean that they are less efficient when invoking/completing the various linguistic operations (e.g., lexical/morphological retrieval, lexical/morphological recognition and/or integration) during ongoing sentence comprehension as opposed to being less efficient at acoustically-phonetically processing the signal (Montgomery, 2002). Although complex sentence processing has not been investigated in children with SLI, it is logical to assume that these children would also be slower to process these sentences relative to age peers.

Cognitive Deficits in SLI

Children with SLI exhibit a range of cognitive limitations. The three broad areas of cognition most intensively examined include phonological short-term memory (pSTM), working memory, and speed of processing.

*Short-term Memory Storage*

According to Baddeley (1998, 2003), there are two domain-specific storage buffers, pSTM and visual short term memory. Each is capacity limited. PSTM is of interest in the proposed study. PSTM holds incoming speech momentarily. Incoming speech will decay quickly if it is not rehearsed or if the language system does not processes it. Evidence shows that pSTM capacity increases significantly over the first eight years (Gathercole, 1999).

Children with SLI show significantly reduced pSTM capacity relative to age peers (Archibald & Gathercole, 2006, 2007; Ellis Weismer et al., 2000; Gathercole & Baddeley, 1990; Montgomery, 1995, 2004; Montgomery & Windsor, 2007). PSTM is
assessed using a variety of span measures such as digit span or word span, as well as with non-word repetition tasks. For span tasks, participants are presented progressively longer lists of items and asked to recall each list in serial order. In nonword repetition, participants are asked to repeat nonsense words varying in length. No matter which tasks are used, comparative data show children with SLI encounter problems in retaining verbal material over brief periods (Adams & Gathercole, 2000; Archibald & Gathercole, 2006, 2007; Ellis Weismer et al., 2000; Gathercole & Baddeley, 1990; Montgomery, 1995, 2004; Montgomery & Windsor, 2007). Experimental results support the claim that children with SLI have limited pSTM capacity.

Working Memory

Working memory (WM) refers to “the set of mental processes holding limited information in a temporarily accessible state in service of cognition” (Cowan, Nugent, Elliott, Ponomarev, & Saults, 2005). It has also been argued that WM is a cognitive primitive. This means that, compared to pSTM, it is a much stronger predictor of children’s higher order cognitive abilities, including general intelligence (Adams & Hitch, 1997) and academic achievement (Gathercole, Tiffany, Briscoe, Thorn, & the ALSPAC team, 2005).

Children’s working memory capacity is typically assessed using a concurrent processing-storage task such as a listening span task. In one such task, Gaulin and Campbell (1994) presented 6- to 12-year-old children their Competing Language Processing Task (CLPT), a child-friendly version of the listening span task developed by Just and Carpenter (1992) for adults. Children are presented sets of 3-word sentences
(e.g., Pumpkins are purple, Fish can swim) and asked to comprehend each sentence (answer Yes/No question) followed by recalling as many sentence-final words as possible from each set. The task invites children to allocate their limited attentional resources (e.g., Baddeley, 1999) between language processing (i.e., comprehend each sentence) and verbal storage (i.e., retain sentence-final words). WM is typically defined as percent correct word recall. While the children showed high comprehension across the age span (i.e., ≥ 93%) their word recall steadily improved with age.

Children with SLI, irrespective of the type of span task (verbal or nonlinguistic), show reduced working memory relative to CA children (Archibald & Gathercole, 2006, 2007; Ellis Weismer et al., 1999; Mainela-Arnold & Evans, 2005; Marton & Schwartz, 2003; Montgomery, 2000a, 2000b). Using the CLPT, Ellis Weismer et al. (1999) were the first to compare the WM of school age children with SLI and their age peers. Whereas both groups showed similar comprehension (≥ 96% correct), the children with SLI yielded significantly poorer word recall (40% accuracy) than age peers (60% accuracy). Similar findings have been reported by Archibald and Gathercole (2006, 2007), Mainela-Arnold and Evans (2005), and Montgomery and Evans (2009). Using different concurrent processing-storage measures, Montgomery (2000a, 2000b) and Marton and Schwartz (2003) reported similar results (i.e., poorer word recall by children with SLI under loaded processing conditions) and also concluded that children with SLI have reduced working memory.
Processing Speed

Processing speed refers to processing efficiency or rate (Kail & Salthouse, 1994; Salthouse, 1996, 2000) and emphasizes the amount of cognitive work that can be completed in a given unit of time. An underlying assumption is that processing speed reflects “neural processing speed” (Cerella & Hale, 1994; Jensen, 1993), i.e., rate of synaptic transmission. The assumption is that if information is not processed with sufficient speed it is vulnerable to forgetting or interference. Children with faster processing are better able to remember and/or process greater amounts of information in the same unit of time than children with slower processor. Children’s processing speed is assessed using a variety of RT tasks that vary in cognitive load and decision making.

Relative to age peers, many children with SLI demonstrate significantly slower processing, regardless of the nature and modality of the task (Leonard et al., 2007; Miller et al., 2001; Montgomery, 2000a, 2002; Windsor & Hwang, 1999a, 1999b; Windsor et al., 2001).

To determine the degree of cognitive slowing in SLI, Kail (1994) applied a proportional mathematical equation to the mean RT of a group of children with SLI and a group of age-matched children. According to a proportional model, all cognitive processes occur at a similar rate and that for children with SLI all cognitive processes are slowed by a fixed proportion. The data came from a variety of past experiments representing a wide range of cognitive processing tasks. Results of proportional modeling indicated that the RT of the children with SLI were about one-third greater (or 33% slower) than those of the aged-matched children.
Winsor and Hwang (1999) also investigated SLI generalized slowing by comparing Kail’s proportional model of slowing with two other regression models, one linear and one nonlinear. They were interested in determining whether SLI cognitive slowing is best accounted for using a proportional model (Kail, 1994), a linear model (which assumes that cognitive processes are slowed by a fixed amount but sensorimotor processes are not), or a nonlinear model (which assumes that there is a progressive increase in slowing with each step in a complex mental task). They applied the three regression models to the RT data of a group of children with SLI and an age-matched group of children. Two primary findings emerged. First, each of regression models accounted for roughly the same amount of slowing in the SLI group (20% slowing). Second, the estimated cognitive slowing was markedly lower than Kail’s (1994) estimate of 33% slowing. Because the proportional model includes just one parameter and entails the fewest assumptions, Windsor and Hwang argue that the proportional model of slowing is the most parsimonious account of SLI cognitive slowing.

Although the link between processing speed and language performance has not yet been fully delineated in SLI, a few different viewpoints have been proposed. Kail (1994) and others (Miller et al., 2001; Windsor & Hwang, 1999a, 1999b) have suggested that all elementary cognitive operations (perception, encoding, decision making) may be slowed at the same rate in SLI, i.e., there is a general rate-limiting mechanism affecting linguistic and nonlinguistic performance. The critical variable in speed of task completion is the complexity of the task (i.e., number of neural processing “steps,” not the specific content of the task). This view is consistent with the developmental cascade perspective
that neural processing speed is the basic cognitive resource that directly affects higher-level cognition, including language. Others have suggested that the rate of slowing may vary depending on the nature of the task (Montgomery, 2000a, 2002; Windsor et al., 2001). In an analysis of 25 studies on children with SLI and age-matched peer groups’ linguistic and nonlinguistic RT, Windsor et al. (2001) found there was a significant difference in the extent of SLI slowing across the different studies that employed a wide range of tasks. Finally, it has been proposed that general and task-specific slowing mechanisms are not mutually exclusive but may co-exist, with task-specific constraints overlaying a general constraint (Windsor, 2002).

Relationship Between Cognitive Deficits and Comprehension Problems in SLI

Few SLI studies have investigated the relationship between cognitive processing limitations and sentence comprehension deficits in children with SLI. There is emerging evidence that the comprehension deficits of these children are associated with limited pSTM and WM. Montgomery (1995, 2000b) was one of the first to examine the potential role of pSTM and WM on sentence comprehension. The Montgomery (1995) study was developed to test Baddeley and Gathercole’s (1990) pSTM deficit hypothesis proposing that the language difficulties of children with SLI are related to a pSTM storage deficit. In this first study, children with SLI and a group of younger, receptive syntax-matched children completed a nonsense word repetition task and a sentence comprehension task that included simple sentences (e.g., *The dirty little boy climbed the big tall tree*) and sentences containing either one relative clause (e.g., *The girl who is laughing is touching the boy*) or
two relative clauses (e.g., *The little boy who is standing is hugging the girl who is sitting*). The sentences were crafted into a set of short sentences (containing both sentence types) and a set of long sentences. The aim of the study was to determine whether sentence length affected children’s comprehension. Relative to the controls, the SLI group performed less accurately on the nonword repetition task and comprehended fewer longer sentences. Correlation analysis showed a strong correlation between pSTM and comprehension, suggesting that the pSTM deficit in the children with SLI hindered their sentence comprehension. However, the analysis was computed on the groups and sentence lengths combined. In a subsequent study (Montgomery, 2004), using similar nonword repetition and comprehension tasks, children with SLI again showed poor pSTM and sentence comprehension relative to age peers. A correlation was computed between pSTM and comprehension for each group. However, no significant correlation was found for either group, perhaps due to low statistical power.

In a more recent study, Montgomery and Evans (2009) examined the role of both pSTM and WM in sentence comprehension in a group of children with SLI, a group of age peers, and a group of younger children matched to the SLI group on pSTM and WM. Children completed a nonword repetition task (pSTM) and the CLPT (WM). Children also completed a sentence comprehension task in which they heard simple sentences and “complex” passive sentences (van der Lely, 1998). Results showed that, relative to age peers, the SLI group performed worse on both memory tasks and comprehended fewer complex sentences than simple sentences. The SLI and younger children performed similarly. Correlation analyses revealed that for the age peer group no relation emerged
between the memory variables and either sentence type. However, for the children with SLI, a significant partial correlation (age removed) emerged between complex sentence comprehension and working memory (but not pSTM). A similar correlation occurred for the younger children. The results were interpreted to mean that even early-acquired complex sentences involve working memory resources by children with SLI. The lack of correlation between pSTM and complex sentence comprehension was interpreted to be a reflection of the sentences being too short (just 6 words) to invite pSTM involvement. It is reasonable to conjecture, though, that longer complex sentences would have instantiated pSTM.

Simulating SLI: A Novel Approach Borrowed From the Adult Literature

According to the RDDR/CGC account (Marshall & van der Lely, 2006; van der Lely, 2005), the complex sentence comprehension deficits of children with SLI are due to an impaired syntax module. However, as noted above, limited cognitive processing abilities also appear to play a part in these children’s comprehension difficulties. A novel approach was recently employed by Hayiou-Thomas, Bishop, and Plunkett (2004) to test another core language impairment characteristic of these children, namely, grammatical morphology. These investigators used an SLI simulation paradigm in which typically developing children were presented language material that was manipulated in terms of sentence length and presentation rate. These manipulations were intended to stress the children’s pSTM storage and rate of input processing. The logic of the manipulation was to determine whether the profile of grammatical morpheme deficits observed in children
with SLI could be simulated in a group of typically developing children when two
cognitive stressors (memory, speed of processing) were introduced. That was an
interesting experimental approach because if, in fact, limited pSTM and processing speed
are key cognitive factors associated with the comprehension problems in SLI, then
experimentally stressing these cognitive systems during sentence comprehension should
lead to comprehension profiles similar to those observed in SLI.

There is a rich adult language processing literature using the simulation paradigm to
“invoke” aphasic-like performance in non-impaired adults to better understand the nature
of the association between the cognitive and language deficits seen in aphasia (e.g.,
Blackwell & Bates, 1995; Dick et al., 2001; Kilborn, 1991; Miyake, Carpenter, & Just,
1994). Researchers have burdened processing by incorporating two distinct types of
stressors: (a) peripheral stress, which interferes with the speech signal, and (b) central
stress, which increases cognitive load (amount of stimuli), requires dual processing tasks,
or increases input rate. Studying the morphological processing of adults with normal
language, Dick et. al. (2001) compared the effects of peripheral and central stressors.
Peripheral processing was disturbed by introducing noise masks and filtered speech.
Central processing was disturbed by (a) introducing a working memory load and (b)
presenting materials at a faster (compressed) rate. Results indicated that each of the
cognitive stressors induced diminished language performance similar to what is observed in
Broca’s aphasia.

By stressing pSTM and processing speed, Hayiou-Thomas et al. (2004) explored
whether SLI could be simulated in 120 6-year-old children with typically developing
language. Their focus was on whether they could induce SLI inflectional morphology deficits (difficulty with past tense -ed; 3rd person-s; plural-s) in a grammaticality judgment task. Children listened to simple active sentences in which these morphemes were used obligatorily or were inappropriately missing. Three independent variables were applied to the simple active sentences: length, rate, and grammaticality (correct use of inflectional morphology).

Eight sets of sentence stimuli were created to test the effects of sentence speed and length on sensitivity to detect grammatical violations. A well-formed and an ill-formed version were created for each of the following four sentence conditions: normal-rate short sentences; normal-rate long sentences; fast-rate short sentences; and fast-rate long sentences. The standard sentence was a short canonical (subject-verb-object) sentence produced at a normal speaking rate. Long sentences were created by adding redundant verbiage (adjectives, adverbs) to the short version sentences. Fast sentences were created by compressing the original sentence to 50% its original duration. A between-group design was used in which 30 different children participated in each of the eight conditions. The investigators predicted that the greatest number of errors would occur for the past tense -ed sentences, followed closely by the third-person singular -s and finally by the plural -s. A control condition involving the prepositions in, on, and at was also included, for which all children were expected to perform at ceiling.

Hayiou-Thomas et al. (2004) study demonstrated that it is possible to simulate some of the linguistic characteristics of SLI. The results showed that both length (long normal sentences) and rate (short fast sentences) had an effect on grammaticality judgment.
However, based on the stimuli presented, increasing the speed of the sentences (through compression) appeared to diminish performance more than lengthening the sentences. The significantly stronger effect of rate led the authors to question whether doubling speed and doubling length stress language processing equally.

In the present study, a simulation paradigm was employed similar to Hayiou-Thomas et al. (2004). However, the present study differed in five ways. First, attempts were made to simulate the complex sentence comprehension deficits seen in children with SLI. The focus was on syntactic comprehension because complex grammar comprehension represents a chief receptive deficit for these children. To this end, a continuum of sentence structures were used that included simple sentences, verbal be passives, and object relative clause sentences. Inclusion of three sentence structures allowed the determination of whether different sentence types are differentially affected by the manipulation of sentence length and input rate. Second, the present study looked into whether it is possible to simulate the complex sentence comprehension deficits of SLI in real time rather than in an off-line (meta-linguistic) context. This study employed an on-line sentence processing task because comprehension occurs in the moment or real time. It is of theoretical interest to examine how the cognitive stressors of sentence length and input rate affect children’s ability to immediately generate a syntactic representation of input. Third, sentence length was manipulated along a continuum by including three sentence lengths, not just two. Hayiou-Thomas et al. (2004) found a significant effect for sentences length. Fourth, input rate was manipulated along a continuum as well. Whereas Hayiou-Thomas et al. (2004) used just two input rates (0% increase and 50% increase); input rates in the present study
included normal rate (0% increase in input rate), 20% increase and 33% increase. The input
rates of 20% and 33% were chosen because these rates represent two estimates of the
cognitive slowing in SLI (Kail, 1994; Windsor, 1999). Varying input rate according to
actual estimates of cognitive slowing in SLI was thought provide a more accurate test of
the cognitive slowing hypothesis of SLI. Fifth, a within-subjects design rather than a
between-subjects design was employed; all of the children were exposed to each of the
manipulations.

Aim and Research Questions for the Present Study

The present project employed an SLI simulation paradigm with the focus of
determining whether the profile of SLI complex sentence comprehension deficits can be
simulated by increasing the pSTM and speed of processing loads during children’s real-
time sentence comprehension. Memory load was manipulated by providing children with
sentences that varied according to three lengths. Processing speed was manipulated by
introducing three different input rates. Seven- to 11-year-old typically developing
children performed a real-time sentence comprehension task in which they were asked to
identify the agent NP in complex sentences (requiring syntactic movement) and simple
sentences (requiring no movement). Although working memory has been implicated in
the poorer complex sentence comprehension of children with SLI, the proposed project
began by investigating the role of pSTM, as there is evidence that pSTM plays a role in
SLI sentence comprehension (Montgomery, 1995; Montgomery & Evans, 2009). Because
this study examined real-time sentence processing, two dependent variables were examined, sentence comprehension accuracy and sentence comprehension speed.

Finally, the present study was interested in reporting the separate effects of pSTM and processing speed on sentence comprehension for purposes of theoretical model testing. Reporting separate effects will allow describing the role that each variable plays in complex sentence comprehension.

The following were the research questions, possible outcomes, and interpretations for the present study.

Research question 1a: Length effect. Will children demonstrate poorer complex sentence comprehension accuracy as sentence length increases, irrespective of input rate? If comprehension declines with increasing sentence length, results would suggest that longer sentences stress pSTM and impede comprehension. If comprehension is unaffected, results would suggest that increasing sentence length does not tax pSTM and compromise comprehension.

Research question 1b: Length effect. Will children demonstrate slower complex sentence comprehension speed as sentence length increases, irrespective of input rate? If comprehension speed increases with sentence length, results would suggest that comprehension is hindered with additional linguistic information. If comprehension speed remains stable, results would suggest that comprehension is facilitated by accumulating linguistic information.

Research question 2a: Input rate effect. Will children demonstrate poorer complex sentence comprehension accuracy as input rate increases, irrespective of
sentence length? If comprehension declines, results would suggest that increasing input rate taxes the language processing efforts of children and leads to poorer comprehension. If comprehension accuracy is unaffected, results would suggest that increasing input rate does not stress the language processing system.

*Research question 2b: Input rate effect.* Will children demonstrate slower complex sentence comprehension speed as input rate increases, irrespective of sentence length? If comprehension speed slows down, results would suggest that language processing efforts are increased in the face of faster input rate. If comprehension speed remains stable, results would suggest that language processing effort is unaffected by increases in input rate.

Collectively, if complex sentence understanding is affected by increasing both sentence length and input rate, such results would provide strong support for a cognitive processing deficit account of the poor sentence comprehension abilities of children with SLI and weak support for the CGC/RDDR account of the complex grammar comprehension deficits of SLI.
CHAPTER 3: METHOD

Participants

Thirty six typically developing children between the ages of 7 and 11 years (7; 0 - 11; 11) participated. All of the children were English-speaking. Sixteen boys and 20 girls participated.

All of the children demonstrated the following: (a) normal-range nonverbal IQ (≥ 85) on the Test of Nonverbal Intelligence-3 (TONI-3; Brown, Sherbenou & Johnsen, 1997); (b) normal-range hearing sensitivity as determined by screening for the frequencies 500Hz, 1 kHz, 2 kHz and 4 kHz at 25dB HL (ANSI, 1990); (c) normal or corrected vision; (d) no history of neurological impairment, psychological/emotional disturbance or attention deficit disorder (as determined by caregiver report, see Appendix A for caregiver questionnaire); (e) score at or above -1 SD from the mean on the Test for Reception of Grammar-2 (TROG-2; Bishop, 2003), a syntax-specific receptive measure, the Peabody Picture Vocabulary Test-3 (PPVT-3; Dunn & Dunn, 1997), and on subtests of the Clinical Evaluation of Language Fundamentals (CELF-4; Semel, Wiig, & Secord, 2003).

Recruitment Procedures

Children were recruited through a variety of means, including local newspaper and newsletter advertisements, OU list serve, and flyers posted at local churches and the Athens Community Center. Parents/caregivers who were interested in the study and passed a preliminary phone screening for eligibility were enrolled. Parental consent and
child assent were obtained and documented. Children received a toy after each visit and parents received a report of the child’s language test findings, as well as compensation of $10 per visit.

Sentence Comprehension Task

Children’s on-line sentence comprehension was assessed using the “Agent Selection” method developed by Bates and colleagues (Leech et al., 2007; Dick et al., 2004; Von Berger et al., 1996). In this task, children were presented a sentence (e.g., *It’s the big yellow cat that washed the black and white dog*) while looking at two pictures appearing on a computer screen (i.e., picture of agent, picture of patient). The child’s task was to touch the animal representing the agent of the sentence (the animal doing something to the other animal) as quickly as possible. The present study employed a within-subjects research design, all participants were presented with all of the sentence tasks. See Appendix B for instructions.

Sentence Stimuli

A set of 135 sentences were created. Forty five sentences were simple structures (i.e., requiring no syntactic movement), 45 were verbal *be* passives, and 45 were object-relative clause sentences. The simple and passive sentences were modeled after those used by Montgomery and Evans (2009), and the object relatives were adapted from the ones used by Dick et al. (2004). The rationale for employing these sentence types was twofold. First, passives and object relatives both entailed syntactic movement, a known difficulty for
children with SLI. The simple sentences involved no movement and thus served as control sentences. Second, Dick et al. (2004) have reported that typically developing children between the ages of 7 and 11 generally show a comprehension pattern of simple > passive > object relatives. Importantly, even 6- to 8-year-old children in the Dick et al. (2004) study showed good comprehension of passives and object relatives (75% or better accuracy). All of the sentences began with the *It’s* phrase followed by the rest of the sentence (e.g., *It’s the big grey mouse that licked the orange and white cat on the head; It’s the dog that the cat touched on the nose*). This manipulation provided a consistent sentence-initial structural and lexical cue across sentence types.

All of the sentences were controlled for lexical familiarity, using content words familiar to 6-year-old children’s spoken language (Fenson et al., 1993; Moe, Hopkins, & Rush, 1982). The picture stimuli were taken from Rossion and Pourtois (2004), who colorized the original black and white drawings of Snodgrass and Vanderwart (1980). The Rossion and Pourtois pictures, like those of Snodgrass and Vanderwart, have been standardized for name agreement, image agreement, familiarity, and visual complexity. All images were controlled by adjusting for size and visual intensity. In addition, within and across conditions, the location of the agent picture appeared equally often on the right and left side of the touchscreen. See Appendix B for sentence stimuli.

**Sentence Length Manipulation**

Three sentence lengths were created for each sentence type (simple, passive, and object relative clause) with the intent of stressing children’s phonological storage capacity. In 2004, Hayiou-Thomas et al. found a significant effect when increasing
sentences lengths from approximately 6-8 to approximately 12-15 words. Montgomery and Evans (2009) reported that 6-word sentences were too short to find a significant correlation between pSTM and complex sentence comprehension for either children with SLI or younger TD children. Studies by Montgomery (1995, 2000a, 2004) tested the sentence comprehension of children with SLI and TD children using sentences varying from 10 to 14 words and found that the children with SLI consistently had greater trouble with the longer sentences than the shorter sentences relative to TD children. For the present study, sentence length systematically varied between 9 words and 15 words. The sentence length sets corresponded to 9-word (e.g., *It’s the red fox that is smelling the horse*), 12-word (e.g., *It’s the fat pigs that are hiding the scared little baby sheep*) and 15-word (e.g., *It’s the black and white skunks that are running after the old fat brown duck*) sentences. The 12- and 15-word sentences were created by adding redundant verbiage (adjectives, adverbs) to the 9-word sentence structure (Hayiou-Thomas et al., 2004; Montgomery, 1995, 2000a). Due to concern about the potential oddity of 12- and 15-word sentences containing multiple adjectives and adverbs, a control set of sentences were added that included a sentence-final conjoined prepositional phrase instead of the extra verbiage (e.g., *The green slimy frogs are biting the little baby elephants on the toes*). The conjoined phrases were marked by the high frequency prepositions such as “on,” “by,” “around,” and “under.” These sentences were included simply as control sentences and were not analyzed for comprehension accuracy or comprehension speed.
Input Rate Manipulation

Three input rates were created with the intent of stressing children’s rate of linguistic processing. Forty five sentences remained at a normal rate (0% rate increase), 45 were rate compressed by 20% of their original duration, and 45 were compressed by 33% (Kail, 1994; Windsor & Hwang, 1999). Sentence compression was done using ProTools™ (Digidesign, 2000), a commercially available high-end digital audio workstation. Successful employment of this software was demonstrated in the Hayiou-Thomas et al. study (2004). The algorithms eliminated redundant information in the 5-20 ms time range. Thus, the temporal dimension of the original sentences was altered while the spectral and amplitude characteristics were preserved.

Blocks of Sentence Conditions

Because children listened to sentences varying in rate, the delivery of the sentences was blocked on this variable. That is, children received equal numbers of 9-, 12-, and 15-word simple, passive, and object relative sentences arranged in random order blocked by normal rate, 20% faster rate, and 33% faster rate. Blocking by input rate was necessary in order to prevent greater overall variability in children’s performance predicted if sentences of varying input rate had been delivered randomly (Montgomery, 2005; Montgomery & Leonard, 2006). Three counterbalanced orders of the sentence conditions were developed. Equal numbers of children (12) received each of the orders.

Sentence Recording and Editing

Sentence stimuli were recorded in an isolated acoustic booth using a high quality microphone connected to a Dell laptop. All of the sentences were read at a normal rate (~
4.4 syllables/sec; Ellis Weismer, & Hesketh, 1993) and with normal prosodic variation by an adult male speaker with a neutral Midwest dialect of the United States. All sentences were digitized (44 kHz), low pass filtered (22 kHz), and normalized for intensity. Each sentence file was interactively edited to eliminate any noise at the beginning or end of the file.

**Procedures**

*Task Procedures*

Children were told that they would be hearing a man saying some sentences and that some of the sentences would be short sentences, some would be long, and others might seem a little fast. They were asked to place their fingers in a response ready position on the cross appearing in the middle of the touch screen. They were told that two pictures would appear at the top of the screen and then shortly after they would hear a man saying a sentence (onset controlled by experimenter) that contained both animal names. They were told that one animal would be doing something to the other animal. They were asked to wait to respond until they are sure which animal was “doing something to the other animal.” As soon as they knew which animal performed the action, they were to touch that animal as quickly as possible (Dick et al., 2004; Leech et al., 2007). Both response accuracy and speed were stressed, not just speed. Children were presented two demonstrations and five practice items per rate block. The sentence stimuli were delivered from the computer (44 kHz) and controlled by E-Prime (Schneider,
All stimuli were binaurally delivered under high-quality headphones at a comfortable listening level as determined by the child. For all sentence types, the clock began at sentence onset and stopped as soon as the child touched a picture. Children were encouraged to make accurate yet fast responses. Due to the nature of the online task, children were told that they could respond at any point during or after the sentence. However, the earliest point for a valid response in active and passive sentences was after NP2, and after the main verb in object relatives. In noncanonical sentences, this marked the point at which the agent had been identified and included the movement gap. “Invalid” responses were accurate responses made before the movement gap. Only valid responses were considered in the final analysis of response time rates for speed of comprehension. Children had 5 seconds to make a response after the sentence ended (Dick et al., 2004). When a child failed to respond within 5 seconds, the response was counted as a miss. The computer automatically calculated and stored children’s processing time and response accuracy for each sentence. Both sentence comprehension accuracy and sentence processing speed were dependent variables.

**General Procedures**

All testing, including initial subject qualification testing, was individually administered to each child in the Developmental Psycholinguistics Lab. The initial screening was completed in the first session, lasting about 75 minutes with several 10 minute breaks. To minimize fatigue and potential learning effects, experimental testing was divided over three testing sessions, lasting about 20 minutes each.
Data Preparation Procedures

A mean processing time (PT_{mean}) was calculated for each child for each condition (e.g., normal rate 9-word SVO sentences) averaging across valid trials and removing all outliers (Bowers, Vigliocco, Stadthangen-Gonzalez, & Vinson, 1999). Outliers were defined as any trial where the PT was greater than ± 2 SD from a child’s own PT_{mean} relative to each condition. Less than 1% of the data were outlier responses.
CHAPTER 4: RESULTS

Prior to the analyses, the children’s sentence comprehension accuracy and sentence processing speed scores for each sentence type were evaluated to determine whether the scores were normally distributed. With respect to accuracy scores, each sentence type yielded a non-normal distribution, as determined by a Shapiro-Wilk test ($W < .825, p < .01$), as did the speed of comprehension for each sentence type ($W < .825, p < .01$). Therefore, the children’s scores were transformed into a log transform score. Transformed scores were used in all of the following analyses.

Effect of Sentence Length on each Sentence Type

Accuracy of Comprehension

Three separate one-way ANOVAs ($p < .05$) with Tukey HSD ($p < .05$) were computed to examine the effect of sentence length on the response accuracy of each sentence type (collapsing across input rate). Varying sentence length was found to have no significant effect on comprehension of either the passives $F(2, 105) = 1.26, p = .29$ or the object relatives $F(2, 105) = 1.86, p = .16$. Length also had no effect on the comprehension of SVO sentences $F(2, 105) = .314, p = .73$. Table 1 displays mean and standard deviations of accuracy (untransformed scores) for each sentence type by length.
Table 1

Comprehension of Each Sentence Type as a Function of Sentence Length

<table>
<thead>
<tr>
<th></th>
<th>9 words</th>
<th>12 words</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passive</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>M</strong></td>
<td>91.58</td>
<td>92.08</td>
<td>88.28</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>11.71</td>
<td>8.73</td>
<td>10.74</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>54.00 – 100.00</td>
<td>74.00 – 100.00</td>
<td>60.00 – 100.00</td>
</tr>
<tr>
<td><strong>Object Relative</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>M</strong></td>
<td>82.72</td>
<td>88.50</td>
<td>88.47</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>15.86</td>
<td>14.05</td>
<td>11.50</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>34.00 – 100.00</td>
<td>40.00 – 100.00</td>
<td>54.00 – 100.00</td>
</tr>
<tr>
<td><strong>SVO</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>M</strong></td>
<td>92.19</td>
<td>90.83</td>
<td>90.33</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>9.33</td>
<td>10.56</td>
<td>12.45</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>54.00 – 100.00</td>
<td>47.00 – 100.00</td>
<td>47.00 – 100.00</td>
</tr>
</tbody>
</table>

**Speed of Sentence Comprehension**

Criteria were developed to define valid response times to agent selection that would be used in the speed of comprehension analyses. A valid response was defined as (a) a correct agent selection and (b) a response occurring at or after noun phrase 2 (NP2). NP2 was the earliest point at which children could reliably identify both the agent and the patient of the sentence. Thus, a valid RT was a positive RT value. Invalid RTs were those
that entailed choosing the correct agent but prior to NP2. The invalid RT was not included in the general analyses. Table 2 displays mean, standard deviations and range of both valid and invalid (anticipatory) RT within each sentence type.

Table 2

Percent of Valid (Correct) and Invalid (Correct) Response Times per Sentence Type

<table>
<thead>
<tr>
<th></th>
<th>% Valid</th>
<th>% Invalid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>78.9</td>
<td>21.07</td>
</tr>
<tr>
<td>SD</td>
<td>16.80</td>
<td>16.80</td>
</tr>
<tr>
<td>Range</td>
<td>37.78 – 100.00</td>
<td>0.00 – 62.22</td>
</tr>
<tr>
<td>Object Relative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>92.73</td>
<td>7.27</td>
</tr>
<tr>
<td>SD</td>
<td>10.06</td>
<td>10.06</td>
</tr>
<tr>
<td>Range</td>
<td>60.56 – 100.00</td>
<td>0.00 – 39.44</td>
</tr>
<tr>
<td>SVO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>78.9</td>
<td>21.07</td>
</tr>
<tr>
<td>SD</td>
<td>16.19</td>
<td>16.19</td>
</tr>
<tr>
<td>Range</td>
<td>37.78 – 100.00</td>
<td>0.00 – 62.22</td>
</tr>
</tbody>
</table>

Three separate one-way ANOVAs (p < .05) with Tukey HSD (p < .05) were also computed to examine the effect of sentence length on the speed of comprehension of each
sentence type. For passive sentences, the effect of length was significant $F(2, 104) = 10.88, p = .001$, with the processing of 15-word sentences being significantly faster than 12-word sentences, and 12-word sentences being significantly faster than 9-word sentences. Similarly, for object relative sentences, the effect of length was significant $F(2, 105) = 16.13, p = .001$. The processing of 12- and 15-word sentences were significantly faster than 9-word sentences, while the 12- and 15-word sentences did not differ. For the control SVO sentences, the effect of length was also significant $F(2, 104) = 5.74, p = .004$. The processing of 15-word sentences was significantly faster than 9-word sentences, while the 12- and 15-word sentences did not differ. Table 3 displays mean and standard deviations of speed of comprehension (untransformed scores) for each sentence type by length.
Table 3

Response Time (msec) of Each Sentence Type as a Function of Sentence Length

<table>
<thead>
<tr>
<th>Sentence Type</th>
<th>9 words</th>
<th>12 words</th>
<th>15 words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M )</td>
<td>1631.16</td>
<td>1191.36</td>
<td>1015.84</td>
</tr>
<tr>
<td>( SD )</td>
<td>633.99</td>
<td>411.78</td>
<td>386.74</td>
</tr>
<tr>
<td>Range</td>
<td>803.00 – 3135.00</td>
<td>655.00 – 2035.00</td>
<td>451.00 – 2082.00</td>
</tr>
<tr>
<td>Object Relative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M )</td>
<td>1061.02</td>
<td>818.25</td>
<td>619.02</td>
</tr>
<tr>
<td>( SD )</td>
<td>530.91</td>
<td>419.88</td>
<td>238.06</td>
</tr>
<tr>
<td>Range</td>
<td>409.00 – 2706.00</td>
<td>205.00 – 2217.00</td>
<td>241.00 – 1060.00</td>
</tr>
<tr>
<td>SVO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M )</td>
<td>901.84</td>
<td>738.31</td>
<td>673.24</td>
</tr>
<tr>
<td>( SD )</td>
<td>317.66</td>
<td>297.15</td>
<td>316.81</td>
</tr>
<tr>
<td>Range</td>
<td>432.00 – 1705.00</td>
<td>134.00 – 1491.00</td>
<td>135.00 – 1299.00</td>
</tr>
</tbody>
</table>

Effect of Input Rate on Each Sentence Type

Next, the effect of sentence input rate (normal, 20% compressed, 33% compressed) on each sentence type was examined (collapsing across sentence length).

Accuracy of Comprehension

Three separate one-way ANOVAs \( p < .05 \) were computed to examine the effects of sentence input rate on the response accuracy in each sentence type. Varying sentence
input rate was found to have no significant effect on comprehension for either the
passives $F(2, 105) = .96, p = .39$, or the object relatives $F(2, 105) = .66, p = .52$. Input
rate also had no effect on the accuracy of comprehension in SVO sentences $F(2, 105) =
2.26, p = .11$. Table 4 displays mean and standard deviations of accuracy (untransformed
scores) for each sentence type by input rate.
Table 4

*Comprehension of Each Sentence Type as a Function of Input Rate*

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>20%</th>
<th>33%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passive</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M$</td>
<td>92.17</td>
<td>91.92</td>
<td>89.17</td>
</tr>
<tr>
<td>$SD$</td>
<td>8.56</td>
<td>10.54</td>
<td>10.51</td>
</tr>
<tr>
<td>Range</td>
<td>67.00 – 100.00</td>
<td>60.00 – 100.00</td>
<td>60.00 – 100.00</td>
</tr>
<tr>
<td><strong>Object Relative</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M$</td>
<td>88.81</td>
<td>85.11</td>
<td>84.92</td>
</tr>
<tr>
<td>$SD$</td>
<td>13.01</td>
<td>16.28</td>
<td>13.53</td>
</tr>
<tr>
<td>Range</td>
<td>34.00 – 100.00</td>
<td>34.00 – 100.00</td>
<td>40.00 – 100.00</td>
</tr>
<tr>
<td><strong>SVO</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M$</td>
<td>87.94</td>
<td>91.63</td>
<td>94.00</td>
</tr>
<tr>
<td>$SD$</td>
<td>13.78</td>
<td>12.66</td>
<td>7.49</td>
</tr>
<tr>
<td>Range</td>
<td>40.00 – 100.00</td>
<td>40.00 – 100.00</td>
<td>74.00 – 100.00</td>
</tr>
</tbody>
</table>

*Speed of Sentence Comprehension*

Three separate one-way ANOVAs ($p < .05$) with Tukey HSD ($p < .05$) were computed to examine the effects of sentence input rate on the speed of comprehension of each sentence type. For passive sentences, varying input rate affected speed of comprehension $F(2, 105) = 3.69, p = .03$, with the processing of 33% rate compressed sentences being significantly slower than the 0% compressed (normal rate) sentences.
The 20% compressed sentences did not significantly differ from either the 0% or 33% rate sentences. For object relatives, the effect of input rate was significant $F(2, 105) = 10.99, p = .001$, with the processing of 33% rate compressed sentences being significantly slower than the 20% rate compressed sentences. The 33% and 0% rate compressed sentences, however, did not differ from each other. Input rate had no statistical effect on the speed of comprehension of SVO sentences $F(2, 105) = 1.59, p = .21$. Table 5 displays mean and standard deviations of speed of comprehension (untransformed scores) for each sentence type by input rate.
Table 5

*Response Time (msec) of Each Sentence Type as a Function of Input Rate*

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>20%</th>
<th>33%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passive</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>M</em></td>
<td>728.36</td>
<td>800.31</td>
<td>973.97</td>
</tr>
<tr>
<td><em>SD</em></td>
<td>359.69</td>
<td>443.14</td>
<td>497.98</td>
</tr>
<tr>
<td><em>Range</em></td>
<td>199.00 – 1517.00</td>
<td>341.00 – 2076.00</td>
<td>345.00 – 2220.00</td>
</tr>
<tr>
<td><strong>Object Relative</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>M</em></td>
<td>1382.19</td>
<td>985.53</td>
<td>1473.19</td>
</tr>
<tr>
<td><em>SD</em></td>
<td>535.26</td>
<td>506.43</td>
<td>565.96</td>
</tr>
<tr>
<td><em>Range</em></td>
<td>426.00 – 12302.00</td>
<td>280.00 – 2331.00</td>
<td>517.00 – 3023.00</td>
</tr>
<tr>
<td><strong>SVO</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>M</em></td>
<td>727.47</td>
<td>725.58</td>
<td>839.22</td>
</tr>
<tr>
<td><em>SD</em></td>
<td>333.93</td>
<td>364.04</td>
<td>373.01</td>
</tr>
<tr>
<td><em>Range</em></td>
<td>218.00 – 1334.00</td>
<td>272.00 – 1491.00</td>
<td>293.00 – 1871.00</td>
</tr>
</tbody>
</table>

**Age Correlation**

Bivariate correlation analysis (*p < .01*) was computed to determine the correlation between age and comprehension accuracy for each sentence type. Age was significantly correlated with accuracy of passive sentences (*r = .279, p = .003*) and object relative sentences (*r = .390, p = .001*). For the control SVO sentences, age did not correlate with accuracy (*r = .006, p = .950*). Age also significantly correlated with speed of
comprehension of all three sentence types (passive: \( r = -.422, p = .001 \); object relative: \( r = -.457, p = .001 \); SVO: \( r = -.392, p = .001 \)).
CHAPTER 5: DISCUSSION

Relative to their age peers, children with SLI demonstrate significantly greater difficulty processing and comprehending verbal be passive and object relative sentences, but not SVO sentences. Children with SLI also consistently evidence reduced pSTM and slower processing speed. The present study attempted to simulate this profile of SLI complex sentence comprehension profile in a group of 7- to 11-year-old typically developing children by manipulating sentence length and input rate. Children listened to passive and object relative sentences corresponding to three different lengths (designed to stress pSTM) and three different input rates (designed to stress speed of language processing). The experimental paradigm was a real-time Agent Selection task in which children selected the agent of the sentence as soon as they knew its identity during the course of sentence processing. The primary dependent variables were sentence comprehension accuracy and speed. The separate effects of sentence length and input rate were of central interest.

Comprehension of Different Sentence Types

The typical developmental pattern of sentence comprehension of SVO, verbal be passives, and objective relatives is SVO > passive > objective relative. The present results partially replicated this pattern: SVO = passive > objective relative. The fact that SVO and passives showed comparable comprehension accuracy may be due to the fact that passives are early acquired structures and mastered by about age seven (Maratsos, 1974) and the children in the present study were between 7 and 11 years of age. It would
appear that the passives were well within the linguistic competence of the children in the present study. The fact that object relatives were comprehended with lower accuracy than SVO and passives is consistent with the developmental literature and suggests that the structures are developmentally more difficult for children between the ages of 7 and 11 years.

Effect of Sentence Length on Each Sentence Type

Accuracy of Comprehension

If the complex sentence comprehension problems in SLI can be simulated in typically developing children by stressing pSTM, we might expect that comprehension accuracy of passives and object relatives would suffer as sentence length increased. This hypothesis is based on the assumption that increasing sentence length should disrupt the memory for NP1 by the time NP2 or the critical VP is heard, the point at which the agent of the sentence can be reliably determined. Contrary to this expectation, sentence length had no detrimental effect on the children’s comprehension. Results showed that the children’s comprehension of short, medium, and long passive sentences was comparable. Similarly, the children’s comprehension of short, medium, and long object relatives was comparable. Sentence length also had no effect on the comprehension of SVO sentences. These results indicate that the complex sentence comprehension deficit of SLI was not simulated in typically developing children by manipulating sentence length, and, by extension, stressing pSTM storage.
These findings are at odds with those of Hayiou-Thomas et al. (2004) who attempted to simulate SLI grammatical morphology deficits in 6-year-old typically developing children. These authors presented children with sentences containing an appropriate use of a low-substance morpheme (past tense -ed; 3rd person-s; plural-s) or an inappropriate omission of the same morpheme. Sentences were manipulated for length (short, long) and input rate (normal, 50% rate comprehension). Children made a grammaticality judgment (correct, incorrect) after each sentence. These investigators showed that grammaticality judgment performance significantly declined for both longer sentences and faster sentences.

The vast methodological differences between the present study and the Hayiou-Thomas et al. (2004) study are probably responsible for the discrepant findings. First, the ages of the children in the Hayiou-Thomas et al. study were just 6 years old whereas in the present study children were 7 to 11 years of age. Second, Hayiou-Thomas et al. assessed children’s grammaticality judgments of low-phonetic grammatical morphemes. The present study assessed children’s real-time syntactic comprehension. Low-substance grammatical morphemes represent sublexical units which pose special problems for children with SLI to learn and use in their own speech. Even though complex sentence comprehension also represents a specific trouble spot for children with SLI, syntactic comprehension involves processing and comprehending acoustically more salient lexical units. It appears, then, that simulating SLI real time syntactic comprehension deficits in typically developing children is less sensitive to the manipulation of sentence length.
The present results, however, when viewed in the context of recent findings of Montgomery and Evans (2009), are not inconsistent with the SLI literature. These investigators examined the independent roles of pSTM and working memory (i.e., simultaneous processing and storage) on the comprehension of short verbal *be* passive sentences in children with SLI and control children. They found that whereas the comprehension of passives did not correlate with pSTM they did correlate with working memory in children with SLI. The findings from the present study coupled with those of Montgomery and Evans indicate that pSTM may not be the memory construct that plays a vital role in the complex sentence comprehension of children with SLI. That working memory appears to be critical to the comprehension of complex sentences entailing syntactic movement is consistent with the emerging developmental literature (Montgomery, Magimairaj, & O’Malley, 2008; Roberts, Marinis, Felser, & Clahsen, 2007).

*Speed of Sentence Comprehension*

If the complex sentence comprehension problems in SLI can be simulated in typically developing children by stressing pSTM, we might expect that speed of comprehension in passives and object relatives would suffer as sentence length increased. This expectation is based on the same assumption as noted above—that children may have more trouble maintaining NP1 in pSTM as greater amounts of language material occur between it and NP2 or the critical VP. Contrary to this expectation, increasing sentence length had no detrimental effect on the children’s speed of comprehension. Results showed that the children’s speed of comprehension during medium and long
passive sentences was comparable, and both were faster (not slower) than short sentences. Similarly, the children’s speed of comprehension during medium and long object relative sentences was comparable and both had faster accurate responses than for short sentences. This pattern was also seen in the control SVO sentences. These results indicate that the slowed processing of complex sentences seen in children with SLI was not simulated in typically developing children by stressing pSTM storage through the manipulation of sentence length.

It is possible that the amount of redundant verbiage added to the sentences simply was not enough to stress the pSTM of these typically developing children. Rather the pattern observed across all sentence types suggests that increasing sentence length facilitated sentence processing. That is the syntactic and lexical-semantic cues in the sentences provided children with contextual cues so their processing became faster as the sentence progressed.

In a study by Montgomery et al. (1990), real time language processing abilities of children with language impairment (7-12 years) and TD children (5-9 years) were investigated using a word recognition reaction time (RT) paradigm. One interesting finding was that word recognition RT was faster when the target word was later in the sentence relative to earlier. Both the SLI and TD groups showed the same pattern, i.e., decreased processing speed with increased sentence length, suggesting that contextual cues facilitated ongoing processing. It should be noted that the sentences in this study were simple SVO sentences. Similar results were found in a study by Montgomery (2000) who examined the influence of working memory on both the off-line and real-
time sentence comprehension/processing of children with SLI. In the real-time word recognition RT task, a post hoc analysis was computed to examine RT at each of three word positions (5, 7, 12) within the sentence. Both the children with SLI (ages 7-10 years) and the age-matched TD children demonstrated faster word recognition RT across word position. Their RT was significantly faster by the 7th word position relative to the 5th word position. Their RT to words appearing in the 10th position, however, was no faster than words appearing in the 7th position. The results from these studies provide evidence that even children with SLI benefit from context during sentence processing. Thus, faster sentence comprehension speed in response to increased sentence length is consistent with previous findings in the SLI literature and extends these findings to indicate that lexical-semantic context effects are also present in noncanonical sentences.

It can be noted from Table 2 that children produced a high rate of invalid RT in the passive and SVO sentences (21%), but not the object relative sentences (8%). An invalid RT was defined as correct agent selection made prior to hearing NP2. These responses likely reflected anticipatory responses, i.e., children knowing who the agent was before hearing both NPs. The early responses in the passive and SVO sentences can be explained on the basis that these structures are early acquired and mastered by about age 5 or 6 years. Because the children in the present study were 7-11 years of age, these structures were well within their linguistic competence and thus processed with relative ease and automaticity (e.g., Montgomery, 2008; Montgomery, Evans, & Gillam, 2009).
Effect of Input Rate on Each Sentence Type

Accuracy of Comprehension

In an attempt to simulate slower SLI sentence processing, the present study manipulated input rate by providing children with complex and SVO sentences at three different input rates. In addition to presenting sentences at a normal speaking rate, sentences were presented at two rates that are comparable to the estimates of cognitive slowing in SLI, 20% compression and 33% compression. If the complex sentence comprehension problems of SLI can be simulated in typically developing children by stressing processing speed, we might expect that comprehension accuracy of passives and object relatives would decline as sentence input rate increased. Counter to this expectation, input rate had no negative effect on the children’s comprehension. Results showed that the children’s comprehension of normal rate, 20% compressed, and 33% compressed passive sentences was comparable. Similarly, the children’s comprehension of normal rate, 20% compressed, and 33% compressed object relative sentences was comparable. Sentence input rate also had no effect on the comprehension of SVO sentences. These results indicate that increasing input rate, and by extension stressing processing speed, failed to induce a similar profile of complex sentence comprehension deficits observed in children with SLI. On this view, processing speed holds relatively little status in explaining the sentence comprehension deficits of children with SLI.

That the present study did not find any effect for input rate for accuracy is again at odds with the findings of Hayiou-Thomas et al. (2004), who demonstrated that grammaticality judgment performance significantly declined for faster sentences. Similar
to the earlier discussion on sentence length, the contradicting results may be due to differences in method. First, although children with SLI demonstrate significantly slower processing than age matched peers; processing speed continually decreases between the ages of 5 and 18 years (Kail & Ferrer, 2007). In the Hayiou-Thomas study, the children’s age was restricted to 6 years. In the present study, children ranged from 7 to 11 years of age, with marked developmental improvement in processing speed occurring during this period. Second, Hayiou-Thomas et al. assessed children’s grammaticality judgments of low-phonetic grammatical morphemes. The present study assessed children’s real-time syntactic comprehension. Further degrading already low-substance grammatical morphemes undoubtedly caused even greater difficulty perceiving the presence of these markers and making an appropriate grammatical judgment. It follows that the processing and comprehending of more acoustically salient lexical units would, by comparison, be less vulnerable to the manipulation of input rate. Third, and most notably, is a comparison of compression rates. Hayiou-Thomas et al. (2004) examined the effects of two input rates (normal, 50% compression) on accuracy. For the present study, three input rates were utilized (normal, 20% compression, 33% compression).

Hayiou-Thomas et al. (2004) found a significant effect of a 50% compression rate on grammaticality judgment accuracy. Fifty percent rate compression was chosen based on previous adult language literature, which had demonstrated that this compressed rate of input had a detrimental effect on the language systems of adults without language deficits. It would then be reasonable to expect that this high compression rate would negatively affect grammaticality judgments in children. Rather than duplicate this rate,
the present study chose two rates that mirrored estimates of cognitive slowing in SLI, 33% as reported by Kail (1994) and 20% as reported by Windsor and Hwang (1999). Clearly speeding up the sentences in the present study based on these estimates did not yield an SLI sentence comprehension profile. It may be that to induce an SLI profile it is necessary to select an input rate outside the bounds of SLI slowing.

The present results, however, when viewed in the context of recent findings of Leonard et al. (2007), are not out of line with the SLI literature. These investigators examined the separate effect of speed of processing and working memory on standardized language test performance in a large combined group of children with SLI and TD children. Results of factor analysis and structural equation modeling showed that speed of processing played a secondary role to working memory in explaining language performance. Although direct comparisons cannot be made, the much less central role of processing speed in children’s language performance reported by Leonard et al. is in keeping with the findings of the current study.

*Speed of Sentence Comprehension*

If the processing speed patterns for comprehending complex sentences in SLI can be simulated in typically developing children by stressing processing speed, we might expect that the speed of comprehension of passives and object relatives would increase as sentence input rate increased. Overall, the manipulation generally had its desired and predicted effect—slower comprehension speed of both the passive and object relative sentences as input rate increased. Regarding the passive sentences, the speed of comprehension of the 33% rate compressed sentences was significantly slower than the
0% compressed (normal rate) sentences. However, the 20% compressed rate sentences were not processed more slowly than the 0% rate compressed sentences. Children’s speed of comprehension of the object relatives varied slightly from this pattern. Comprehension speed of the 33% rate compressed sentences was significantly slower than that of the 20% rate compressed sentences. However, the 20% rate compressed sentences were not processed more slowly than the 0% compressed sentences. Finally, input rate had no effect on the speed of comprehension of SVO sentences. Taken together, these results indicate that stressing language processing speed by increasing the input rate of the sentences did simulate the profile of complex sentence comprehension deficits of SLI. For both the passives and objectives, only the 33% compression rate led to significantly slower comprehension speed.

The discussion will begin with the control SVO sentences. SVOs are the earliest acquired sentence structure in English. The findings for SVOs showed no slow down in comprehension speed with input rate. Typically developing children process these sentences easily and with little mental effort (Montgomery, 2008; Montgomery et al., 2009). It appears that the robust processing schemes supporting these well-learned structures are difficult to disrupt, regardless of how fast they are presented (Montgomery, 2005). For both the passives and object relatives, comprehension speed was negatively affected but only for the fastest sentences. Therefore, input rate did have a negative effect on comprehension speed. But recall that comprehension accuracy for both sentence types remained very high, irrespective of input rate. Taken together, these findings reveal a classic speed-accuracy tradeoff where the children sacrificed processing speed to
maintain high comprehension accuracy. There is relatively little evidence in the SLI literature indicating whether children with SLI also evidence speed-accuracy tradeoffs. In at least one lexical decision study by Edward and Lahey (1996), children with SLI did not show a speed-accuracy tradeoff relative to age mates; the children with SLI were both slower and less accurate in deciding the lexicality of nonwords.

This study borrowed from the established practice of using increased sentence length as a means of stressing pSTM. Varying length had no significant effect on accuracy. In addition, length had no detrimental effect on comprehension speed. Rate compression was used as a means of stressing processing by insisting that more information is processed in a shorter period of time. Increasing input rate had no detrimental effect on accuracy. However, increasing rate resulted in a general cognitive slowing for 33% compressed rate. These results are in opposition with the results of Hayiou-Thomas et al. (2004). However, the results are consistent with recent SLI literature. Together with other studies, the results raise the question as to the relative importance of pSTM in the comprehension of complex sentences.

Potential Alternative Explanations of Results

Increasing sentence length (and by extension stressing pSTM) did not induce poorer complex sentence comprehension characteristic of children with SLI. While increasing input rate (and by extension taxing language processing speed) did lead to slower speed of comprehension of complex sentences, it did not impair comprehension
accuracy. The children demonstrated a clear speed-accuracy tradeoff, sacrificing speed for accuracy.

Perhaps it is not possible to simulate the complex sentence comprehension characteristic of SLI by manipulating either length or speed. The lack of effect of either manipulation on comprehension accuracy may be due to the fact that the language systems of TD children are so robust that they are impervious to disruption when the manipulations designed to disrupt processing and comprehension are done so in a relatively small and incremental way. It may be that simulation of SLI comprehension deficits can only be achieved through more extreme manipulations (cf. Hayiou-Thomas et al., 2004). It may also be that pSTM and processing speed are not the most crucial cognitive mechanisms responsible for the complex sentence comprehension deficits of SLI. It may be that working memory and controlled attention are more important (e.g., Montgomery & Evans, 2009).

Potential Limitations of the Study

The present findings must be viewed within the context of at least four potential limitations. First, priming effects may have skewed the findings. The visual picture choices may have served as cues for agent selection, either by using a process of elimination or by using lexical cues provided by redundant verbiage (adjectives). That is, because the pictures were present during the entire sentence it is possible that the children were able to identify the agent visually without having to hear either NPs or the critical verb.
Second, the location of NP2 (passives, SVOs) and the critical VP (object relatives) were always in sentence final position. A number of sentences containing a prepositional phrase after NP2 or the critical VP were added to each to each sentence block to circumvent any possible predictable response pattern. However, there may have been too few of these “control” sentences to prevent the children from adopting a predictable response strategy.

Third, it is possible that the amount of redundant verbiage added to the sentences was not enough to stress the pSTM of the children and the input rates were insufficient to tax the speed of their language processing systems. Fourth, although the instructions stressed both accuracy and speed, asking children to be certain they knew the Agent before responding (implying accuracy was more important than speed) may have given rise to the speed-accuracy tradeoff. For example, some children who had a more impulsive response style naturally may have taken more time to respond to ensure accuracy.

Because the present study used a within-subject design, some of the limitations may have been minimized. That is, because each child received the same instructions and all the sentences he/she would likely respond in the same fashion across the different experimental conditions, thereby minimizing random performance differences across conditions.
Future Directions of Study

Results from this study open up several lines of important methodological approaches designed to simulate SLI. First, if pSTM is a candidate mechanism to explain SLI sentence comprehension deficits, future studies may wish to expand the range of sentence length. However, expanding the range of sentence length has important methodological implications. First, sentences would appear to be constrained by natural boundaries of length. One could conceivably create exceptionally long sentences that exceed “normal,” ecologically-valid lengths. Second, and relatedly, there are few good options available to increase sentence length without also fundamentally changing the syntactic complexity of the sentence and yielding sentences that are incomprehensible. The present study suggested that increasing sentence length by adding extra verbiage to NPs and VPs may have provided lexical priming to the children. Therefore, using even more NP-modifying adjectives and VP-modifying adverbs does not seem reasonable. One possible solution to increase sentence length without changing the primary syntactic processing demands (i.e., using syntactic movement) in comprehension is to use embedded prepositional phrases between NP1 and NP2.

With respect to further manipulating input rate, it does not seem theoretically relevant to extend this variable outside the bounds of SLI slowing. If we wish to build simulated models of SLI, our modeling building efforts should be guided by the available data.

Future studies, however, may wish to assess the potential role of working memory in complex sentence comprehension by manipulating external memory load. Working
memory has been assessed using concurrent processing-storage tasks. Dual load assessment might be created by using one established sentence length. A word might be presented before each sentence for the subject to remember after the processing task, with sentences presented in increasingly long blocks. Performance across sentence types could be analyzed. It may be that explicitly manipulating the dual demands of information processing and storage will disrupt TD children’s complex sentence comprehension.

Finally, it may be that the Agent Selection task is not the most sensitive method to index pSTM and processing speed effects and thus simulate SLI sentence comprehension deficits. It may be that other paradigms such as the cross modal picture priming task would yield a more fine-grained and sensitive index of real-time complex sentence processing. In this task, it would be possible to assess the relative time course of children’s ability to build syntactic filler-gap dependencies.

The simulation design may ultimately help to identify key cognitive mechanisms involved in complex sentence comprehension, thereby indicating the processing deficits in SLI syntactic comprehension. Understanding which processes have little effect on complex syntactic comprehension holds an equally important role. Once these are established, it will be important to determine the relative significance of various cognitive mechanisms during complex sentence processing.
REFERENCES


# APPENDIX A: CAREGIVER QUESTIONNAIRE

**Subject Code:** __________  **Age:** ________  **Gender:** ________  **Subject Match:** __________

1. Is English your child’s 1st (native) language?  
   Y / N

2. Is English the primary language spoken at home primary caregiver and child?  
   Y / N

**Speech-Language History**

3. Was your child "slow" to talk - saying his/her first words and/or putting words together?  
   Y / N

4. Was your child diagnosed with speech and/or language problems during preschool years?  
   Y / N

5. Has your child ever received speech or language therapy in the past?  
   Y / N
   If Yes:
   - What Age? __________________________________
   - For What? ________________________________
   - How Long? ________________________________

6. Do you have any concerns right now about your child's speech and language abilities?  
   Y / N
7. Is your child now receiving speech-language therapy right now?  
   Y / N

8. Does your child's teacher have any concerns about your child's language skills?  
   Y / N

**Hearing History**

1. Does your child have a history of brief episodes of ear infections as a youngster?  
   (i.e. infections lasting less than 3 weeks at a time)  
   Y / N

   Does your child have a history of chronic ear infections as a youngster?  
   (i.e. infections lasting 3 months or longer)  
   Y / N

   If so, how many ear infections has he/she had during the following ages (make a good guess):  
   1-2 years ________ 2-3 years ____________ 3-4 years ____________  
   4-5 years ________ 5 years and older ____________

**General Health History**

1. Has your child ever been diagnosed by a Psychologist or Developmental Pediatrician  
   as having an Attention Deficit Disorder (using formal behavioral questionnaires)?  
   Y / N

   Does he/she take any medication for attention problems? ________________  
   Y / N
2. Has your child ever been diagnosed having neurological problems like seizures, cerebral palsy or having a serve head injury?  
Y / N

3. Has your child ever been diagnosed having emotional, psychological, or behavioral disorder requiring medication or therapy?  
Y / N

4. Does your child take any kind of medication on a regular basis?  
Y / N
If yes, what is the reason and what is the medication: ____________________________
_____________________________
_____________________________

5. Does your child have normal vision or normal corrected vision (i.e. wears glasses)?  
Y / N

**Academic History of Child**

1. Is your child currently working at grade level in all subjects as determined by his/her grades and teacher report?  
Y / N

If NO, circle those academic skill areas in which your child's grades are below grade level:

- Reading
- Writing
- Math

2. Do you have concerns about your child's academic learning?  
Y / N
What Areas: ____________________________
3. Does your child's teacher have concerns about his/her learning? Y / N
   What Areas: ________________________________

4. Has your child ever repeated a grade in school? Y / N
   If so, which grade(s)? ________________________________

5. Has your child ever been identified as having a learning disability? Y / N

6. Is your child presently classified as a student with a Learning Disability? Y / N
   If so, is he/she receiving Special Educational Services? Y / N
   In what Area(s): ________________________________

Academic/Occupational History of Primary Caregiver/Mother

What is the highest grade that you (mother) have attained? (Circle one)

High School Degree  College Degree  Graduate Degree

What is your present occupation? ________________________________
APPENDIX B: EXPERIMENTAL SENTENCE STIMULI

Normal Rate Condition: Instructions and Task

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Gender</th>
</tr>
</thead>
</table>

**Instructions to Child:** To start, you will see some pictures on the screen and I will read you a couple of sentences. In these sentences, one animal will be doing something to another animal. Your job is to tell me which animal did something to the other animal. Ready?

(A static screen is activated which displays an image of a bird (on the upper-right) and a bear (on the upper-left). It’s the bear that is kissed by the little bird. (Pause) Which animal did something to the other animal? (If incorrect, repeat sentence and explain) Let’s try another.

It’s the bear that kissed the little yellow bird. (Pause) Do you know who did it? (If incorrect, repeat sentence and explain) Let’s try one more.

It’s the little bird that the bear is kissing. Which animal did something to the other animal? (If incorrect, repeat sentence and explain)

Some of the sentences you are going to hear may be silly, some might be a little long, and some may seem a little fast.

Now, I am going to explain the activity. The first thing that will happen is that you will put your fingers on a little black cross in the middle of the screen like this (examiner demonstrates). As soon as you do, the screen will change color. This means to get ready. Two pictures will appear on the screen, one animal picture is here (examiner points left) and another animal picture is here (examiner points right). As the pictures come on the screen, you will hear a sentence similar to the ones I read earlier, about an animal doing something to another animal. I want you to touch the animal that you think is doing something to the other animal as soon as you are sure who did it. I want you to be as fast as you can be. But even though I want you to be fast, I still want you be sure ‘who did it’ before touching the animal. Ok?

Let me show you how it’s done.

**Demo:**

1. (Pas) It’s the pretty cow that is kicked by the mean old goat  
2. (Act) It’s the little bird that touched the brown fuzzy bear

**Practice:** “Now, you try a few for practice.”

1. (Pas) It’s the furry black and white cat that is kissed by the fat baby horse  
2. (OSV) It’s the dog that the horse is biting  
3. (Act) It’s the big owl that is kissing the little brown fuzzy bear  
4. (OSV) It’s the little chicken that the dog is kicking on the leg  
5. (Pas) It’s the mouse that is licked by the bird
SENTENCE COMPREHENSION TASK: SIMULATING SLI
NORMAL RATE CONDITION

<table>
<thead>
<tr>
<th>Code</th>
<th>Sentence</th>
<th>Response</th>
<th>RT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>(Act-9) It’s the red fox that is smelling the horse</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>2.</td>
<td>(Pas-12) It’s the fox that is touched by the skunks on the nose</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>3.</td>
<td>(OSV-9) It’s the baby ducks that the cat is hiding</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>4.</td>
<td>(Pas-15) It’s the dirty smelly old goats that are washed by three big fat brown cows</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>5.</td>
<td>(Act-12) It’s the mama pigs that are busy waking the sleeping baby donkeys</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>6.</td>
<td>(OSV-15) It’s the wild baby horses that the big screeching eagles are biting on the head</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>7.</td>
<td>(Pas-9) It’s the spider that is helped by the mouse</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>8.</td>
<td>(Act-15) It’s the black and white skunks that are running after the old fat brown duck</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>9.</td>
<td>(OSV-12) It’s the baby tigers that the cows are touching on the ear</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>10.</td>
<td>(Act-9) It’s the cat that is scratching the little squirrels</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>11.</td>
<td>(Pas-15) It’s the smelly black cat that is pokèd by the scared duck in the eye</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>12.</td>
<td>(OSV-9) It’s the little deer that the fly is washing</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>13.</td>
<td>(Act-12) It’s the big zebra that is pushing the birds under the bush</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>14.</td>
<td>(Act-15) It’s the big mamma tiger that is kissing the grey donkey on her little ears</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>15.</td>
<td>(Pas-9) It’s the turtle that is kissed by the frogs</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>16.</td>
<td>(OSV-15) It’s the furry brown squirrel that the excited little rabbits are tickling on the tummy</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>17.</td>
<td>(Pas-12) It’s the little baby rabbits that are fed by the little chicken</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>18.</td>
<td>(Act-15) It’s the big hungry brown snakes that are feeding the little brown and black owls</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>19.</td>
<td>(OSV-9) It’s the donkey that the pretty butterflies are touching</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>20.</td>
<td>(OSV-15) It’s the cold baby white cats that the white and gray mother cows are feeding</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>21.</td>
<td>(Act-12) It’s the fat pigs that are hiding the scared little baby sheep</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>22.</td>
<td>(Pas-15) It’s the little grey mice that are bitten by the big yellow and black bird</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>23.</td>
<td>(OSV-9) It’s the baby skunk that the turtle is helping</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>24.</td>
<td>(Pas-12) It’s the baby flies that are chased by the big wild horses</td>
<td>A</td>
<td>B</td>
</tr>
</tbody>
</table>

Experimental (Act = Active; Pas = Passive; OSV = Object Relative // 9 = 9 word sentences; 12 = 12 word sentences; 15 = 15 word sentences)

Scoring: Circle child’s picture choice (answer is in **bold** and underlined: A = Left; B = Right). Record child’s RT for each trial (record NR for no responses).
25. (Act-9) It's the dog that is biting the dirty skunk

26. (OSV-12) It's the long spotted snake that the big hungry bears are eating

27. (Pas-9) It’s the goats that are pinched by the lions

28. (Act-12) It’s the monkey that is touching the dirty cow on the ear

29. (OSV-12) It’s the elephant that the happy owl is kissing on the foot

30. (Pas-15) It’s the big furry momma bear that is watched by the little baby brown owls

31. (Act-15) Its’ the fat slimy frogs that are biting the little baby elephants on their toes

32. (OSV-12) It’s the tiny pink pigs that the little furry mouse is feeding

33. (Pas-15) It’s the scared little lion that is pinched by the hairy elephants on the shoulders

34. (Act-12) It’s the nice cats that are holding the scared little smelly skunk

35. (Pas-9) It’s the fly that is kicked by the donkey

36. (Act-12) It’s the hot squirrels that are kicking the heavy green spotted turtle

37. (OSV-15) It’s the big black and white striped zebras that the hungry old lion is chasing

38. (Pas-15) It’s the furry orange cat that is rudely grabbed by the black and white dog

39. (Pas-12) It’s the cat that is splashed by the tiger on the face

40. (Act-12) It’s the brown mouse that is pushing the fat and slow turtle

41. (Pas-9) It’s the zebras that are scratched by the eagle

42. (Act-15) It’s the cute little chicken that is helping the big green and gray slimy fish

43. (OSV-12) It’s the big mean barking dogs that the huge lions are catching

44. (Act-15) It’s the sleepy old eagle that is gently scratching the tired and old gray goat

45. (OSV-12) It’s the big black flies that the careful green spider is watching

46. (Pas-12) It’s the little squirrel that is caught by the two striped tigers

47. (Act-9) It’s the baby rabbits that are licking the goats

48. (Pas-15) It’s the smelly fat pig that is carefully cleaned by the wrinkly old grey elephants

49. (Pas-12) It’s the dogs that are quickly caught by the surprised little eagles

50. (OSV-9) It’s the sheep that the little zebras are feeding

51. (OSV-15) It’s the little black and white furry cat that the big red fox is pinching

52. (Act-15) It’s the dirty wet sheep that are softly poking the dry and fuzzy baby lions

53. (Pas-12) It’s the gold tigers that are touched by the brave little sheep

54. (OSV-15) It’s the smelly little goat that the big red and blue bird is watching closely

55. (OSV-12) It’s the sweet little skunk that the dirty gray rabbits are smelling

56. (Act-9) It’s the lions that are chasing the scared eagle

57. (OSV-15) It’s the cold yellow and grey birds that the nice brown monkeys are badly cleaning A

B
Compressed Rate Condition (20%): Instructions and Task

Subject ___________________________ Age ______ Gender ______

Instructions to Child: To start, you will see some pictures on the screen and I will read you a couple of sentences. In these sentences, one animal will be doing something to another animal. Your job is to tell me which animal did something to the other animal. Ready?

(A static screen is activated which displays an image of a bird (on the upper-right) and a bear (on the upper-left). It’s the bear that is kissed by the little bird. (Pause) Which animal did something to the other animal? (If incorrect, repeat sentence and explain) Let’s try another.

It’s the bear that kissed the little yellow bird. (Pause) Do you know who did it? (If incorrect, repeat sentence and explain) Let’s try one more.

It’s the little bird that the bear is kissing. Which animal did something to the other animal? (If incorrect, repeat sentence and explain)

Some of the sentences you are going to hear may be silly, some might be a little long, and some may seem a little fast.

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Demo:
1. (Pas) 20% It’s the pretty cow that is kicked by the mean old goat B
2. (Act) 20% It’s the little bird that touched the brown fuzzy bear A

Practice: “Now, you try a few for practice.”

1. (Act) 20% It’s the little happy cat that is licking the big sad dog B
2. (Pas) 20% It’s the old black and yellow dog that is kicked by the fat baby chicken B
3. (OSV) 20% It’s the bird that the giraffe is kissing on the tummy A
4. (OSV) 20% It’s the little chicken that the dog is kicking on the leg A
5. (Pas) 20% It’s the mouse that is licked by the bird B
SENTENCE COMPREHENSION TASK: SIMULATING SLI
20% FASTER CONDITION

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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**Experimental**  (Act = Active; Pas = Passive; OSV = Object Relative // 9 = 9 word sentences; 12 = 12 word sentences; 15 = 15 word sentences)

**Scoring:** Circle child’s picture choice (answer is in **bold** and **underlined**: A = Left; B = Right). Record child’s RT for each trial (record NR for no responses).

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<tr>
<th>Code</th>
<th>Sentence</th>
<th>Response</th>
<th>RT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. (Act-9) 20%</td>
<td>It’s the tiny spider that is kissing the monkey</td>
<td><strong>A</strong></td>
<td>B</td>
</tr>
<tr>
<td>2. (Act-12) 20%</td>
<td>It’s the big fuzzy eagle that is pulling the lost red foxes</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>3. (Pas-9) 20%</td>
<td>It’s the cow that is pulled by the dogs</td>
<td><strong>A</strong></td>
<td>B</td>
</tr>
<tr>
<td>4. (OSV-9) 20%</td>
<td>It’s the tiger that the little bird is hugging</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>5. (Pas-12) 20%</td>
<td>It’s the rabbits that are chased by the donkey by the pond</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>6. (OSV-15) 20%</td>
<td>It’s the fast yellow birds that the scared mother eagles are biting on the neck</td>
<td><strong>A</strong></td>
<td>B</td>
</tr>
<tr>
<td>7. (OSV-12) 20%</td>
<td>It’s the little deer that the skunk is pulling under the bush</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>8. (Pas-15) 20%</td>
<td>It’s the young monkeys that are kicked by the sick and tired old mother deer</td>
<td><strong>A</strong></td>
<td>B</td>
</tr>
<tr>
<td>9. (Act-12) 20%</td>
<td>It’s the mean old ducks that are kicking the big fat sheep</td>
<td><strong>A</strong></td>
<td>B</td>
</tr>
<tr>
<td>10. (Act-9) 20%</td>
<td>It’s the monkey that is poking the old goat</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>11. (OSV-12) 20%</td>
<td>It’s the smiling green frogs that the tiny fuzzy ducks are poking</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>12. (Pas-15) 20%</td>
<td>It’s the black and orange fish that is bumped by the fast swimming scared turtles</td>
<td><strong>A</strong></td>
<td>B</td>
</tr>
<tr>
<td>13. (Act-15) 20%</td>
<td>It’s the tiny black snakes that are biting the mean old mice on the nose</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>14. (OSV-12) 20%</td>
<td>It’s the skinny goat that the chickens are pushing under the fence</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>15. (OSV-9) 20%</td>
<td>It’s the fish that the baby cows are splashing</td>
<td><strong>A</strong></td>
<td>B</td>
</tr>
<tr>
<td>16. (Pas-15) 20%</td>
<td>It’s the slimy green frog that is hugged by the old skunk around his neck</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>17. (Act-12) 20%</td>
<td>It’s the fat cows that are pushing the chickens in the back</td>
<td><strong>A</strong></td>
<td>B</td>
</tr>
<tr>
<td>18. (Pas-9) 20%</td>
<td>It’s the fox that is tickled by the goat</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>19. (OSV-15) 20%</td>
<td>It’s the little brown and red squirrel that the old spotted brown owl is tickling</td>
<td><strong>A</strong></td>
<td>B</td>
</tr>
<tr>
<td>20. (Pas-12) 20%</td>
<td>It’s the hairy lions that are teased by the crazy old ducks</td>
<td><strong>A</strong></td>
<td>B</td>
</tr>
<tr>
<td>21. (Pas-9) 20%</td>
<td>It’s the eagle that is dropped by the cat</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>22. (Act-15) 20%</td>
<td>It’s the orange striped tiger that is licking the smelly little black and white skunk</td>
<td><strong>A</strong></td>
<td>B</td>
</tr>
<tr>
<td>23. (OSV-12) 20%</td>
<td>It’s the lost little sheep that the nice hungry lions are helping</td>
<td>A</td>
<td>B</td>
</tr>
</tbody>
</table>
24. (Pas-12) 20% It’s the brown cow that is helped by the busy little squirrels
25. (OSV-15) 20% It’s the strong old father monkeys that the big black and white zebra is riding
26. (Pas-15) 20% It’s the foxes that are licked by the black and white zebra on the ears
27. (Act-12) 20% It’s the gray mouse that the rabbit is kissing
28. (Act-15) 20% It’s the pretty black and white dog that is watching all the yellow song birds
29. (OSV-15) 20% It’s the noisy brown bears that the tired old donkey is kicking on the back
30. (Act-15) 20% It’s the wet brown mice that are dropping the scared little squirrels on their backs
31. (Pas-12) 20% It’s the spider that is dragged by the butterflies under the rock
32. (Act-12) 20% It’s the pretty black and white dog that is watching all the yellow song birds
33. (Pas-15) 20% It’s the sleeping brown grizzly bears that are bitten by the scary big black flies
34. (Pas-9) 20% It’s the pigs that are bitten by the snake
35. (Act-12) 20% It’s the baby tigers that are smelling the tired and hungry zebras
36. (Act-15) 20% It’s the lucky red fox is noisily washing the old duck
37. (Act-15) 20% It’s the cold thirsty snakes that are quietly biting the hungry and sleepy baby lions
38. (Act-9) 20% It’s the cat that is cleaning the dirty turtle
39. (OSV-12) 20% It’s the tall sad white horse that the big orange eyed black cats are pinching
40. (Act-15) 20% It’s the little spotted owls that are carefully touching the old sick brown horse
41. (Pas-20) 20% It’s the monkeys that are kicked by the horses
42. (Pas-15) 20% It’s the blue and yellow butterfly that is bumped by the silly old white horse
43. (OSV-12) 20% It’s the cute baby tigers that are being hugging the green skinny snakes
44. (Act-15) 20% It’s the big brown mice that the fast flying eagles are catching
Compressed Rate Condition (33%): Instructions and Task

**Instructions to Child:** To start, you will see some pictures on the screen and I will read you a couple of sentences. In these sentences, one animal will be doing something to another animal. Your job is to tell me which animal did something to the other animal. Ready?

(A static screen is activated which displays an image of a bird (on the upper-right) and a bear (on the upper-left). It’s the bear that is kissed by the little bird. (Pause) Which animal did something to the other animal? (If incorrect, repeat sentence and explain) Let’s try another.

It’s the bear that kissed the little yellow bird. (Pause) Do you know who did it? (If incorrect, repeat sentence and explain) Let’s try one more.

It’s the little bird that the bear is kissing. Which animal did something to the other animal? (If incorrect, repeat sentence and explain)

Some of the sentences you are going to hear may be silly, some might be a little long, and some may seem a little fast.

Now, I am going to explain the activity. The first thing that will happen is that you will put your fingers on a little black cross in the middle of the screen like this (examiner demonstrates). As soon as you do, the screen will change color. This means to get ready. Two pictures will appear on the screen, one animal picture is here (examiner points left) and another animal picture is here (examiner points right). As the pictures come on the screen, you will hear a sentence similar to the ones I read earlier, about an animal doing something to another animal. I want you to touch the animal that you think is doing something to the other animal as soon as you are sure who did it. I want you to be as fast as you can be. But even though I want you to be fast, I still want you be sure ‘who did it’ before touching the animal. Ok? Let me show you how it’s done.

**Demo:**
1. (Pas) 33% It’s the pretty cow that is kicked by the mean old goat B
2. (Act) 33% It’s the little bird that touched the brown fuzzy bear A

**Practice:** “Now, you try a few for practice.”

1. (OSV) 33% It’s the big old squirrel that the brown bear is touching A
2. (Act) 33% It’s the mama horse that is holding the little bird by the leg B
3. (Pas) 33% It’s the fuzzy brown and white mouse that is pushed by the little baby goat B
4. (OSV) 33% It’s the little chicken that the dog is kicking on the leg A
5. (Pas) 33% It’s the mouse that is licked by the bird B

**Subject __________________________ Age _________ Gender _________**
**SENTENCE COMPREHENSION TASK: SIMULATING SLI**

**33% FASTER CONDITION**

<table>
<thead>
<tr>
<th>Code</th>
<th>Sentence</th>
<th>Response</th>
<th>RT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>(Act-9) 33% It’s the nice dog that is feeding the turtle</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>2.</td>
<td>(OSV-12) 33% It’s the old black spotted owl that the hungry tigers are cleaning</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>3.</td>
<td>(Pas-9) 33% It’s the spider that is chased by the ducks</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>4.</td>
<td>(Pas-15) 33% It’s the fat grey mouse that is tickled by the black cats under the chin</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>5.</td>
<td>(Act-15) 33% It’s the big black and white zebra that is biting the yellow and white cat</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>6.</td>
<td>(OSV-12) 33% It’s the dog that the little deer are chasing by the road</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>7.</td>
<td>(Pas-15) 33% It’s the slow old turtles that are bumped by the silly young thirsty brown bear</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>8.</td>
<td>(Act-12) 33% It’s the silly little brown bear that is hugging the fluffy dogs</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>9.</td>
<td>(OSV-15) 33% It’s the big mean white rabbit that the poor little quiet green turtle is teasing</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>10.</td>
<td>(Pas-12) 33% It’s the cows that are bitten by the pig on the ear</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>11.</td>
<td>(OSV-9) 33% It’s the baby bear that the fish are washing</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>12.</td>
<td>(Act-15) 33% It’s the smart old spotted owl that is touching the funny little green eyed goat</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>13.</td>
<td>(OSV-12) 33% It’s the slow and careful squirrels that the fast eagles are riding</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>14.</td>
<td>(Pas-12) 33% It’s the small duck that is fed by the nice hungry monkey</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>15.</td>
<td>(OSV-15) 33% It’s the old fat goats that the baby yellow duck is poking on the tummy</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>16.</td>
<td>(Act-9) 33% It’s the baby chickens that are hugging the ducks</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>17.</td>
<td>(Pas-15) 33% It’s the scared dog that is dragged by the grumpy old goats by his tail</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>18.</td>
<td>(OSV-9) 33% It’s the little goat that the skunk is touching</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>19.</td>
<td>(Act-12) 33% It’s the long legged spiders that are grabbing the green bumpy frogs</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>20.</td>
<td>(Act-15) 33% It’s the old white horses that are kicking the naughty sheep on the back legs</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>21.</td>
<td>(Pas-9) 33% It’s the sheep that are watched by the turtles</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>22.</td>
<td>(Act-12) 33% It’s the scared rabbits that are biting the eagle on the leg</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>23.</td>
<td>(Pas-15) 33% It’s the naughty pink pig that is pushed by the hungry group of noisy chickens</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>24.</td>
<td>(OSV-9) 33% It’s the pigs that the nice dogs are helping</td>
<td>A</td>
<td>B</td>
</tr>
</tbody>
</table>
25. (Pas-12) 33% It’s the deer that are hugged by the squirrels around the leg A B _____
26. (Pas-15) 33% It’s the happy bald eagles that are smelled by the family of hungry brown bears A B _____
27. (Act-12) 33% It’s the baby mice that are chasing the donkey past the tree A B _____
28. (OSV-15) 33% It’s the black and white striped zebras that the fat old grey elephants are pushing A B _____
29. (Pas-9) 33% It’s the black and white striped zebras that the fat old grey elephants are pushing A B _____
30. (Act-15) 33% It’s the brown mama cows that are licking the old sleepy lion on his cheek A B _____
31. (Pas-15) 33% It’s the warm fuzzy sheep that are carefully fed by the big brown eyed squirrel A B _____
32. (Act-12) 33% It’s the big hairy flies that the green bumpy frog is watching A B _____
33. (Act-9) 33% It’s the tiger that is chasing the slippery snake A B _____
34. (OSV-12) 33% It’s the fox that the angry sheep is dragging by the barn A B _____
35. (Act-9) 33% It’s the cat that is cleaning the smelly monkeys A B _____
36. (Pas-12) 33% It’s the bumpy fat frog that is kissed by the heavy elephants A B _____
37. (OSV-15) 33% It’s the hungry black cat that the silly white mice are biting on the ear A B _____
38. (Pas-15) 33% It’s the nice little baby elephant that is quietly ridden by the strong white horse A B _____
39. (OSV-9) 33% It’s the fuzzy donkey that the cow is bumping A B _____
40. (Act-12) 33% It’s the fat old chicken that is watching the little blue fish A B _____
41. (OSV-12) 33% It’s the large white chicken that the little scared sheep is kicking A B _____
42. (OSV-15) 33% It’s the long green and purple snakes that the scared old mother horse is biting A B _____
43. (Pas-9) 33% It’s the rabbits that are teased by the owls A B _____
44. (Act-12) 33% It’s the mice that are happily dragging the soft and furry squirrel A B _____
45. (Pas-12) 33% It’s the black flies that are eaten by the tiny yellow birds A B _____
46. (Act-12) 33% It’s the red and orange fish that are splashing the cute little thirsty grey elephants A B _____
47. (OSV-12) 33% It’s the silly red squirrels that the old black dogs are pinching A B _____
48. (Act-15) 33% It’s the lost spotted grey owls that are happily riding the little white headed eagles A B _____
49. (Pas-12) 33% It’s the skunks that are ridden by the smelly old grey owls A B _____
50. (OSV-15) 33% It’s the wet noisy pink pig that the dirty yellow and brown ducks are splashing A B _____
51. (Act-9) 33% It’s the baby birds that are teasing the fox A B _____
52. (Pas-9) 33% It’s the chickens that are pushed by the donkey A B _____
53. (Act-15) 33% It’s the dirty mice that are helping to wash the little slimy green bumpy frogs A B _____
54. (OSV-9) 33% It’s the screaming monkeys that the lions are hiding A B _____
55. (Pas-12) 33% It’s the zebras that are splashed by the tall and brown donkeys A B _____
56. (Act-12) 33% It’s the strong brown bear that is quickly swinging the yellow lion A B _____
57. (OSV-15) 33% It’s the red and orange fish that the quiet little green spotted turtles are watching A B _____