Selective Attention in Children with Specific Language Impairment:

Auditory and Visual Stroop Effects

by

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Abstract

SELECTIVE ATTENTION IN CHILDREN WITH SPECIFIC LANGUAGE IMPAIRMENT:

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The aim of this study was to determine whether children with Specific Language Impairment (SLI) have deficits in selective attention (inhibition and interference) as measured by Stroop interference tests. Stroop interference tests can be used to quantify interference and inhibition control. Sixteen children with SLI (ages 8-10) and 16 age-matched typically developing children (TLD) (ages 8-10) completed auditory and visual Stroop tasks. The auditory task involved identifying via button press either the voice (perceptual target) (male, female, girl or boy) or word (linguistic target) (man, women, boy, girl, car, ball, fish, dog) they heard through headphones. The relationship between the voice and the word defined the type of condition (congruent, incongruent, or neutral). The visual task consisted of eight words (linguistic target) (red, blue, green, yellow, ball, fish, dog, and car) and four ink colors (perceptual target) (red, blue, green, and yellow). The relationship between the color of the ink and the word defined the condition (congruent, incongruent, and neutral). Reaction time and accuracy was analyzed for each subject group (SLI, TLD) across each Stroop condition (congruent, incongruent, and neutral), target (linguistic and perceptual) and modality (auditory and visual). Results revealed Stroop effects for both groups across each target and modality. However, children with SLI demonstrated longer reaction times and an increased number of errors compared to age-matched controls during incongruent trials regardless of modality or target. Longer reaction times and an increased number of errors in the presence of distracters suggest deficits in selective attention.

Results are discussed in terms of inhibitory related functions. Clinical implications of the study are reviewed.

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CHAPTER 1: INTRODUCTION

Executive functions are a set of cognitive abilities that control and regulate other abilities and behaviors (Gilbert & Burgess, 2008). They are essential to adapting, responding, and learning in a changing environment and contribute to success in work and school (Im-Bolter, Johnson, & Pascual-Leone, 2006). They are believed to consist of related, but distinct, abilities that direct, organize, and mediate problem-solving action (Gilbert & Burgess, 2008). The terms *initiate*, *sustain*, *inhibit*, and *shift* have been used to characterize executive function (Baddeley, 1996; Barkley, 1996). These terms have also been used to define the various levels of attention (orienting, sustaining, selecting, and dividing) (Parasuraman, 2000).

Attention is a limited capacity system (Broadbent, 1958). It is not a single entity but a set of cognitive processes that interact with other cognitive processes to accomplish perceptual, cognitive and motor tasks (i.e., learning and language development) (Campbell & McNeil, 1985; Lewis & Baldini, 1979; Robin & Rizzo, 1992; Torro, Sinnett, & Soto-Foraco, 2005). Selective attention is the ability to focus on a specific feature, stimulus, or stimulus stream while ignoring the other, potentially distracting or irrelevant, stimuli. Many situations, such as speech processing, require that we attend to a specific stimulus (i.e., speech) in an environment that contains competing signals (talker variability, multiple talkers, environmental noises, etc.). Selective attention is a likely candidate for deficits in children with Specific Language Impairment. Thus, the aim of this study was to determine if children with SLI demonstrate deficits in selective attention; more specifically, to ask if children with SLI exhibit deficits in inhibition and interference.

Specific Language Impairment

Children with SLI have difficulty with word retrieval, morphology, syntax, and vocabulary (German, 1987; Leonard, 1998). They also have difficulty perceiving brief and rapidly changing speech and nonspeech stimuli (Tallal & Piercy, 1973, 1974, 1975; Tallal & Stark, 1981; Ziegler, Pech-Georgrel, George, Alario, & Lorenzi, 2005). Finally, despite having normal intelligence, children with Specific Language Impairment (SLI) have deficits in cognitive processes such as auditory perception, verbal working memory, and processing speed (Dollaghan & Campbell, 1998; Gathercole & Baddeley 1990; Miller, Kail, Leonard, & Tomblin, 2001; Montgomery, 2002a; Montgomery 2005; Tallal, 1990; Tallal & Piercy, 1973, 1974; Tallal & Stark, 1981). Children with SLI do perceive features of language and perform accurately on speeded presentation or temporal order tasks (Leonard, 1998), but their performance is statistically poorer than their typically language developing peers.

There is some evidence that suggests a relation between SLI and attention (Campbell & McNeil, 1985; Finneran, Francis, & Leonard, 2009; Johnston & Smith, 1997; Hanson & Montgomery, 2002; Robin, Tomblin, Kearney, & Hug, 1989; Shafer, Ponton, Datta, Morr, & Schwartz 2006; Stevens, Sanders, Neville 2006; Niemi, Gunderson, Leppasaari, & Hugdahl 2003; Noterdaeme, Amorosa, Mildenberger, Sitter, & Minow 2001). Spaulding, Plante, and Vance (2008) found that preschool children with SLI performed poorer on sustained auditory attention tasks while Finneran, Francis, & Leonard (2009) found that children with SLI perform less accurately on tasks of sustained visual attention compared to typically developing peers. Campbell and McNeil (1985) examined auditory comprehension skills in language-disordered children. They hypothesized that by slowing presentation rate of a primary sentence, comprehension of a secondary sentence would improve. Pairs of sentences were presented simultaneously. Results showed that slowing the presentation rate of the primary sentences significantly improved comprehension of the secondary sentences, even though secondary sentences were presented at a normal rate of speech. Researchers postulated that impaired attention was contributing to, or possibly causing, the deficits in comprehension. The study, however, has serious methodological flaws. The language impairments in all seven participants resulted from a seizure disorder. It is unclear whether the brain dysfunction or the language impairments influenced the results. Also, by today's standards, these participants would not meet the criterion of SLI.

Noterdaeme, Amorosa, Mildenberger, Sitter, & Minow (2001) found that children with SLI display deficits in sustained and selective attention. They compared children with autism, SLI, and children with typical language development on various attention and executive function tasks: simple reaction time, selective visual attention, selective auditory attention, sustained visual attention, sustained auditory attention, incompatibility, go/no go, attentional shift, and visual scanning. The children with SLI performed significantly poorer on tasks of sustained auditory attention and auditory selective attention compared to children with autism and age-matched controls. However, findings should be interpreted with caution. Subjects varied across a wide age range (between 7 and 21 years of age) as well as IQ (85-123), thus limiting the validity of the findings. Selective attention skills vary with age and correlate with cognitive abilities (Johnson, Im-Bolter, & Pascual-Leone, 2003). Children enrolled in gifted programs that have higher than average intelligence performed better on attention tasks.

Similarly, Niemi, Gunderson, Leppasaari, & Hugdahl (2003) concluded that children with SLI evidence deficits in attention. Using a dichotic listening task, they investigated hemisphere lateralization for speech perception in a Finnish family with SLI. Two different speech stimuli were presented simultaneously, one in each ear under three different instructions: *attend to the right ear stimulus*, *attend to the left ear stimulus*, or with *no instruction* about attention. There were no differences between the groups during the *no instruction* condition, indicating normal speech lateralization in the SLI group. However, the SLI group had difficulty modifying the ear advantage through focused attention to the left ear. They concluded that individuals with SLI have an attention deficit as well as a language-processing deficit related to left hemisphere function.

Several studies have used ERPs to examine aspects of attention to speech and language in children with SLI. For example, in a task that involved passive listening or directed attention to speech sounds, event-related potentials were recorded from children with and without SLI (Shafer, Ponton, Datta, Morr, and Schwartz, 2007). In the *attend* condition children with and without SLI performed in a similar fashion compared to adults. A negative shift was found which is consistent with the Nd found in adults. Children with and without SLI were able to direct their attention to the auditory modality to process speech sounds. However, the groups differed in the passive condition. Typically developing children showed greater negativity compared to the children with SLI. Results suggest that children with SLI are less efficient at allocating attentional resources to speech during a passive task. Stevens, Sanders, & Neville (2006) recorded evoked-related potentials to attended and unattended linguistic and nonlinguistic stimuli in 12 children with SLI and 12 age-matched controls. The children were instructed to attend to one of two simultaneously presented stories. The location (left/right speaker), gender of the voice (male/female), and content varied. Typically developing children as early as 100ms showed amplification to the attended stimuli compared to the unattended stimuli. Children with SLI did not demonstrate this amplification despite performing appropriately on behavioral tasks.

Although these studies suggest the existence of an attention deficit in children with SLI, the disparity between the findings related to modality and level of demand of task make them difficult to interpret.

Finally, a review of the current theories of SLI fails to explain the varied and complex difficulties children with SLI exhibit. There are many instances in which children with SLI preform in a fashion similar to age-matched peers. For example, children with SLI preform as well as age-matched peers on conceptual rule learning (Bishop, 1992). Additionally, poor performance by children with SLI across a variety of production, comprehension, perception, and motor tasks suggests that these children are not lacking in any single domain but rather perform poorly across multiple domains (Campbell & McNeil, 1985; Helzer, Chapman, & Gillam, 1996; Im-Bolter, Johnson, & Pascual-Leone, 2006; Johnston, 1994; Stark & Montgomery, 1995). It is suggested, therefore, that children with SLI do not have reduced processing capacity per se, but instead have difficulty allocating their resources due to deficits in executive function, more specifically selective attention.

Specific Language Impairment and Modality

It has been suggested that the deficits (speech perception, word learning, etc.) in children with SLI result from deficiencies specific to the auditory modality (Campbell & McNeil, 1985; Helzer, Chapman, & Gillam, 1996; Montgomery, 2004; Noterdaeme, Amorosa, Mildenberger, Sitter, & Minow 2001; Ziegler, Pech-Georgrel, George, Alario, & Lorenzi, 2005). More specifically children with SLI suffer from auditory processing deficits, which in turn impact their ability to learn language efficiently. The research that drives this theory is based on results from studies investigating the processing of rapid and brief stimuli (verbal and nonverbal). It is theorized that since many of the aspects of speech consist of brief and rapid stimuli, a deficit in perceiving them accurately would make the task of learning them difficult. An alternate theory is that there are separate attentional capacities for different stimulus modalities. In other words, information that is processed auditorally draws from attentional resources specific to the auditory system and information processed visually draws from attentional resources specific to the visual modality. Children with SLI therefore have deficits in attention but this deficit exists only in the auditory modality. There is some support for this theory in the literature. Spaulding, Plante, and Vance (2005) found that children with SLI exhibited poorer performance on sustained selective attention tasks (linguistic and non-linguistic) presented in the auditory modality under high attentional load conditions. However performance on visual attention tasks did not differ from peers regardless of load. The problems with these theories is that children with SLI have been noted to have deficits in areas of processing that do not involve audition (i.e., visuo-spatial short-term memory as well as tasks of mental imagery; Hick, Botting, & Conti-Ramsden, 2005; Johnston and Ramstad, 1983). Additionally, Shafer et al (2007) found that children with SLI exhibit differences in ERP recordings compared to TLD controls during cross-modal tasks (attend visual, ignore auditory). Finally, Finneran, Francis, & Leonard (2009) found that children with SLI perform less accurately on tasks of visual-sustained attention compared to typically developing peers.

Domain-Specific versus Domain-General Deficits

Researchers have long debated the nature of SLI. Are deficits language-specific or do they result from a deficit in a more general mechanism such as attention that interferes with learning across domains. When the term *SLI* was first used to characterize children with language deficits, the disorder was thought only to impact language. However, more recently researchers have noted that children with SLI present with deficits in nonlinguistic domains (mental imagery, visuo-spatial short-term memory, etc.) (Dollaghan & Campbell, 1998; Edwards & Lahey, 1998; Ellis Weismer, Evans, & Hesketh, 1999; Johnston & Ellis Weismer, 1983; Miller, Kail, Leonard, & Tomblin, 2001; Stark & Montgomery, 1995; Tallal, 1980; Windsor & Hwang, 1999). Despite these findings, it remains unclear whether SLI results from domain-general or domain specific deficits. It is possible that children with SLI have deficits in both linguistic and nonlinguistic areas that co-occur and are not caused by the same *faulty system*. A deficit specific to language might suggest separate systems that process linguistic and perceptual information differently.

Research by Jerger and colleagues has shown that this is not the case. The processing of the perceptual dimensions of speech occurs to some degree with semantic involvement (Jerger & Stout, 1993). Using auditory Stroop tasks, they investigated the influence of the semantic dimension on the processing of the perceptual dimension on children with and without hearing impairments. Difficulties on Stroop tasks are thought to occur because the perceptual and semantic dimensions of the stimulus are not processed independently (MacLeod, 1991). Jerger and colleagues found that children with hearing impairments demonstrated minimal Stroop interference whereas children with normal hearing demonstrated significant Stroop interference. Their findings suggest that speech processing by children with hearing impairment was carried out in less stimulus bound manner. If children with SLI have deficits specific to the linguistic domain, perceptual stimuli should, therefore, not cause interference during selective attention tasks.

Attention and Speech-Language Development

Selective attention is an integral part of speech and language development. An infant’s ability to orient to a voice and to a spatial location is a precursor to language development

(Fischler, 2000; Locke, 1997). Infants and young children must selectively attend to speech and to native-language-relevant dimensions of speech and language (Kuhl, 1979; Jusczyk, 1997; Jusczyk, Bertonicini, Bijeljac-Babi, Kennedy, & Mehler, 1990). Learning the phonetic categories specific to one's native language is necessary for word learning and speech segmentation. According to Jusczyk's (1997) model of development, an infant's ability to attend to relevant information in the speech signal becomes automatic over time thus allowing for efficient and rapid speech-language development. However, until speech perception becomes automatic, it results from attentional shifts to differentially weighted acoustic cues (Nittrouer & Crowther, 1998).

Speech processing requires listeners to attend simultaneously to the speakers' voice (perceptual), to the content of the message (linguistic), and the spatial location (Hugdahl, Thomsen, Ersland, Rimol, & Niemi 2003; Jerger, Pearson, & Spence, 1999). The speech signal varies in the relative salience of its units. The relative salience affects the level of processing the signal receives. For example, infants attend more to stressed syllables than to unstressed syllables (Jusczyk, 1997). This could account for unstressed syllable deletion in young children's productions (Gleitman & Wanner, 1982) or for the deletion of initial unstressed syllables in English (Gerken, 1994). Infants and children must also be able to attend selectively to speech in the presence of distracting information (talker variability, noise, etc.). The acoustic structure of a language provides important cues to elements of syntactic organization as well as phonetic information. Many of the grammatical morphemes specific to English are of short duration (third person singular *–s*, past tense *–ed* inflections, possessive's, articles, copula, and auxiliary *be* forms). Their brevity and sentence location demand a high level of selective attention (Leonard. 1998). The acoustic properties of grammatical morphemes can complicate the task of learning them (Jusczyk, 1997; Slobin, 1973). Regardless of language characteristics, infants and children are differentially attentive to certain elements, patterns, and frequency distributions in the speech signal.

Evidence for the role of attention in speech and language development also comes from the cross-linguistic literature. Learning a second language especially the acoustic-phonetic structure of that language requires a significant degree of attention. Francis, Baldwin, and Nusbaum (2000) demonstrated how training subjects to shift their attention from one acoustic cue to another generalized to novel phonetic contexts. English-speaking participants completed a training study in which they were taught to direct their attention to various acoustic cues in order to identify a syllable. Using visual and auditory feedback to train participants, the subjects learned to attend to those cues that facilitated identification and ignore those cues that were less useful.

Attention and Language Processing

Attention appears to play a critical role in language processing as evidenced in typical and atypical language processing studies (Deutsch & Bentin, 1994; Deutsch & Bentin, 1996; Peelle, McMillan, Moore, Grossman, & Wingfield, 2004). Altering speech rate as well as increasing syntactic complexity negatively affects sentence comprehension. This is likely due to the increase in attentional resources needed to process the information**.** Selective attention is also important for syntactic processing. Sentences that are lengthy or complex require the listener to focus attention on the most relevant aspects of the sentence for correct interpretation. For example in the passive sentence *the woman was kissed by the tall man who is talking* the listener must attend to the cue *–ed* and the functor *by* rather than just the main verb and the nouns for correct interpretation. Failure to attend to these cues would lead to incorrect comprehension and representation of these sentences (Jusczyk, 1997; Fischler, 2000).

The syntactic context in which words are embedded also affects the level of processing. Words embedded in syntactic congruent sentences are processed faster and more accurately than incongruent syntactic contexts (Deutsch & Bentin, 1996). Deutsch & Bentin (1996) examined **s**yntactic context effects on the identification of spoken words in seventh-grade children with and without reading disabilities. They hypothesized that inefficient attentional control underlies the syntactic-processing deficiencies observed in reading-disabled children. Participants identified target words masked by white noise embedded in three sentence types (*syntactic congruent*, *syntactic incongruent*, and *neutral*). In their study agreement rules were manipulated in Hebrew sentences. Since the role of agreement rules in Hebrew is to specify the syntactic relation between the constituents of a sentence, there is no effect on semantic processing. Congruent sentences consisted of a target word that fit with the syntactic structure of the sentence whereas in incongruent sentences the target did not fit with the syntactic structure. Syntactic violations consisted of gender agreement between subject and predicate, number agreement between subject and predicate, both gender and number agreement between subject and predicate, and finally decomposition between the conjunctive form of preposition and pronoun. Results revealed that for both groups of children, inhibition and facilitation were involved in the identification of auditory masked words in varying sentence types based on syntactic congruence and incongruence. Relative to a syntactically neutral context, congruent targets facilitated identification and syntactically incongruent targets inhibited identification in both groups.

Further evidence for the role of attention in language processing comes from the findings of a common attentional system for language and attention. Brain imaging measures such as

PET and fMRI implicate the anterior cingulate gyrus during tasks that involve a high degree of attention (Pardo, Pardo, Janer, & Raichle, 1990; Shaywitz, Shaywitz, Pugh, Fulbright, Skudlarski, Menci, Constable, Marchione, Fletcher, Klorman, Lacadie, & Gore, 2001). This area is also activated in a number of language tasks such as sentence comprehension and word generation tasks (Fischler, 2000; Peelle, McMillan, Moore, Grossman, & Wingfield, 2004). Activity in the anterior cingulate gyrus was noted when participants generated verbs for visually presented nouns (Peterson, Fox, Snyder, & Raichle, 1990) as well as when participants had to shadow auditory messages (Peterson, Fox, Posner, Mintun, & Raichle, 1989). Selective attention, specifically inhibitory control, is also important to the development of nonliteral language skills (Champagne, Desautels, & Joanette, 2004). For example, understanding idioms requires the suppression of the literal meaning in order to understand the nonliteral meaning.

Models of Selective Attention

Models of selective attention have emerged primarily from two schools of thought, bottleneck theories (Broadbent, 1958; Deutsch & Deutsch, 1963; Treisman 1960) and resource theories (Kahneman, 1973; Norman & Bobrow, 1975). Bottleneck theories attempt to define the point at which selection occurs in information processing. Resource models of attention were developed because it was noted that when subjects were asked to perform two tasks simultaneously there was a decline in performance (Kahneman, 1973; Norman & Bobrow, 1975). Results from studies examining dual task performance led researchers to suggest that cognitive resources are limited and subjects can, when instructed, prefer one task over another. Resource theories suggest that reduced processing of unattended messages is caused by allocation of fewer resources whereas *bottleneck* theories claim that declines in dual task performance results when both tasks require processing that can only be used for one task at a time (Cohen, 2003).

The debate continues today, however another possibility exists. There may be more than one source of limitation in the stream of processing. Models described thus far assume a single selective attention mechanism. There may be at least two distinct levels in which selection may take place; a high level selection used for strategic choices and a lower level selection mechanism that may be modality specific. Strategic selection has been suggested to be performed by a set of processes called *executive functions* (Cohen, 2003).

Executive functions (EFs) have received increased attention in the literature over the past decade (Gilbert & Burgess, 2008; Friedman & Miyake, 2004; Norman & Shallice, 1986: Posner, 1990). EFs are believed to regulate perception, thought, and behavior through activation and inhibition of other brain areas. They are believed to improve with age and are strongly associated with the development of the prefrontal cortex (Dempster, 1993). Therefore, it is impossible to discuss selective attention without reviewing the literature on executive functions. At the core of executive functions are the concepts of inhibition and interference. Inhibition and interference are believed to be essential to the development of cognitive abilities (Ridderinkhof, van der Molen, Band, & Bashore, 1997). They have also been suggested to be deficient in certain disorders, such as Attention Deficit Hyperactivity Disorder (ADHD), autism and schizophrenia (Barkley, 1997, Nestor & O'Donnell; 1998). In fact differences in individual inhibition related functions in typical adults have been proposed as underlying various failures in memory and reading comprehension tasks (DeBeni, Palladino, Pazzaglia & Cornoldi, 1998; Gernsbacher, 1990).

Executive function has been referred to as *the supervisory system* (Norman & Shallice, 1986), and *the executor* (Posner, 1990), not a unitary system but one made up of separable inhibition-related functions. EFs are involved in planning and decision making; error correction or trouble shooting; situations where responses are not well rehearsed or contain novel sequences; dangerous or difficult situations; and situations that require overcoming a strong habitual response (Norman & Shallice, 1986). EFs are believed to control attention and other cognitive processes. Executive functions improve with age (Cherry 1981; Doyle, 1973; Berman & Friedman, 1995; Brocki, & Bohlin, 2004; Clifton & Bogartz, 1968; Wright & Wanley, 2003). As children grow older, they are less susceptible to interference of irrelevant information (Band, van der Molen, Overtoom, & Verbaten, 2000; Ridderinkhof, van der Molen, Band, & Bashore 1997). The concepts of inhibition and interference control are central in research exploring cognitive control.

Several models have been proposed regarding inhibition and interference. The *inefficient inhibition* model (Bjorklund & Harnishfeger, 1995) suggests that inhibitory processes become more efficient with development. The result is a reduction in irrelevant information entering working memory and an increase in functional capacity (Ridderinkhof, van der Molen, Band, & Bashore, 1997). Responding appropriately to a situation requires not only the ability to select the relevant target for processing, but also the ability to inhibit inappropriate responses (Booth, Burman, Myer, Lei, Trommer, Davenport, Li, Parrish, Gitelman, Mesulam, 2003). The *susceptibility to interference* model (Dempster, 1993) suggests a developmental change in the ability to resist interference. Interference refers to a competitive interaction whereas inhibition refers to active suppression. Interference disrupts processing because it produces a bottleneck (Broadbent, 1958; Bjorklund & Harnishfeger, 1995). It may result from a perceptual filter deficiency (Broadbent, 1958). If attention is not focused exclusively on the relevant target, several targets may be processed simultaneously and selection occurs post perceptual analysis. The terms of inhibition and interference are often broad and at times have been used interchangeably.

Recently it has been proposed that the executive functions of inhibition-related processes are a family of functions rather than a single unitary construct (Friedman & Miyake, 2004). Friedman and Miyake (2004) explored this idea by examining three inhibition-related functions in adults. The three functions were Preponent Response Inhibition (PRI), Resistance to Distractor Interference (RDI) and Resistance to Proactive Interference (RPI). Preponent Response Inhibition is defined at the ability to suppress automatic responses. Resistance to Distractor Interference is the ability to resist interference from irrelevant information in the environment for the task at hand. Resistance to Proactive Interference is the ability to resist memory intrusions that were once relevant to the task but are not longer relevant. Results indicated that PRI and RDI were closely related but neither of them was related to RPI. Friedman and Miyake concluded that EFs are not a unitary system but rather separable and related functions that share some underlying commonality. Therefore, the current research specifically examined inhibition-related functions, which includes resistance to interference.

Selective Attention Tasks

There are several different types of tasks designed to investigate selective attention and to reveal interference and inhibition effects. The best known is the Stroop task (Stroop, 1935). Stroop tasks typically involve three conditions (*congruent, incongruent,* and *neutral*) that describe the relationship between the relevant and irrelevant dimension and two target dimensions (nonlinguistic/perceptual and linguistic/semantic). During a Stroop task, the subject is asked to attend to a target dimension while ignoring a nontarget dimension. For example, a subject is asked to read a color word (red, green, blue, or yellow) while ignoring the color of the ink (printed in red, green, blue, or yellow). The relationship between the word and the ink color defines the condition (red word printed in red ink is congruent; red word printed in blue ink is incongruent). The interference that occurs when the condition is incongruent is known as the *Stroop effect*.

Typically developing adults and children (Wright & Wanley 2003) as well as disordered populations (reading impairments, ADHD, brain damage) (Kingma, La Heij, Fasotti, Eling, 1996; Savitz & Jansen, 2003; Stuss, Floden, Alexander, Levine, Katz, 2001) exhibit Stroop Interference. Stroop interference is thought to occur because of the conflict between controlled and automatic processing. Word reading is thought to be automatic and thus requires the participant to actively ignore the meaning of the word while trying to name the color. However, there have been some studies that indicate word reading is not automatic for some populations (i.e., young children and disordered populations). Savitz and Jansen (2003) compared performance of 36 boys with and without ADHD on a Stroop Task. They divided the groups into two age groups (between 8 and 10 years of age and 10 and 12 years). The participants were asked to read colors words (control condition) and name the color of the word (interference condition). They predicted that the Stroop Test would be sensitive to age-related changes as well as discriminate between high and low readers. The control group outperformed the ADHD group on word reading and color naming. The older controls performed better on the interference condition than the younger controls. They were better able to inhibit responses. In contrast, the younger children with ADHD performed better on the interference condition than the older ADHD children. Results suggest word reading was not automatic for the younger controls and, therefore, did not cause interference during color naming.

The original Stroop task used visual stimuli (specifically the color words), however since its early inception in attention research the task has been modified to include different stimuli (pictures and letters) and to examine the auditory modality (Cohen & Martin, 1975; Green & Barber, 1981, 1983; Jerger, Martin, & Pirozzolo, 1988). Typical auditory Stroop tasks have required subjects to respond to voice or pitch of speech targets while ignoring semantic content. Jerger, Martin and Pirozzolo (1988) found that in typically developing children the meaning of a word (semantic) was processed automatically and, therefore, interfered with the identification of the perceptual component (gender). Auditory Stroop tasks also involve three conditions (*congruent*, *incongruent*, and *neutral*).

Stroop tasks are effective for studying selective attention. The to-be-ignored dimension captures attention and influences performance, despite the subject's intentions, because the dimensions of the stimulus are not processed independently. The result is an increase in reaction time to incongruent conditions, reflecting selective attention interference. These tasks can be used to examine selective attention in children with SLI. Specifically, they can help determine if the deficits result from a lack of inhibition. Additionally it has been demonstrated that Stroop effects are not modality-specific and, in fact, performance on visual and auditory Stroop tasks are processed similarly in the brain (Lew, Chimel, Jerger, Pomerantz, & Jerger, 1997). Following this line of thinking, auditory and visual Stroop tasks would help delineate auditory-specific deficits versus a more general deficit in children with SLI. Additionally, comparing the performance of children with SLI across visual and auditory Stroop tasks as well as comparing their performance to typically developing children will help shed light on the role of selective attention in SLI.

Summary

Despite the apparent role of attention in speech and language development, there are few studies that have specifically investigated selective attention in children with SLI, and none have used Stroop tasks. Deficits in selective attention, specifically inhibition and interference, may be the initial source of difficulties in language acquisition and contribute to the maintenance of these deficits. An understanding of the nature of SLI and possible underlying and contributing factors will enable researchers and clinicians to develop more effective intervention and treatment strategies.

Thus, the overall aim of this study is to determine whether children with SLI have deficits in attention as measured by Stroop tasks. The specific goals are to investigate the following research questions: (1) Do children with SLI demonstrate more errors during conflict conditions compared to age-matched controls? (2) Do children with SLI demonstrate increased reaction times during conflict conditions compared to age-matched controls? (3) Do children with SLI demonstrate differences in performance across visual and auditory modalities compared to age-matched controls? (4) Do children with SLI demonstrate differences in reaction time during different attend targets (perceptual, linguistic) compared to age-matched controls?

CHAPTER 2. METHODS

Participants

Thirty-four native English-speaking, school age children participated in the study. Children were recruited from local schools and speech-language clinics. Seventeen children (10 male and 7 female) had SLI and ranged in age from 8 to 10 years (mean age of 8.5 years). The children in the typical language development (TLD) group (3 male and 14 female) were age-matched to the children with SLI (+ or – 3 months). They had a mean age of 8.9 years and an age range of 8 to 10 years. All children were evaluated using a number of formal and informal assessments, which included the Clinical Evaluation of Language Fundamentals-4 (CELF-4, Semel, Wiig, & Secord 2003) and the Test of Nonverbal Intelligence (TONI, Brown, Scherbenou, & Johnsen, 1990).

The children with SLI scored at least one standard deviation or more below the mean (< 85) on the overall receptive and expressive language score. Children were considered TLD if they scored within one standard deviation of the mean on all language assessments. All children passed a hearing screening at 20db for frequencies of 500, 1000, 2000, and 4000 Hz (ANSI, 1989). The children who participated in the study had no evidence or diagnosis of neurological or behavioral problems. All children came from middle- and upper-middle-class homes. All children who participated in the study gave their assent and were compensated $15 at the completion of the study. All parents signed a consent form giving their child permission to participate (Appendix D). All children signed an assent (Appendix E). One typically developing child did not complete all experimental trials and, therefore, was eliminated and one child with SLI was eliminated from analysis because he was later identified by the parent as having Attention Deficit Disorder. Table 1 represents a description of the participants' gender (M

= male, F = female); age; language skills; and IQ. Means and standard deviations are reported (Following Directions (FD), Recalling Sentences (RS), Word Class Receptive (WCR), and Word Class Expressive (WCE) mean (M) = 10, standard deviation (SD) = 3; TONI-3: M = 100, SD = 15) for the children with typical language development (TLD) and children with Specific Language Impairment (SLI).

Table 1.

Gender; Age; Language; and IQ for SLI and TLD participants.

		Gender	Age	TONI-3	FD	RS	FS	WCR	WCE
SLI									
	M	9 M	8.05	*104.68	*7.62	*6.25	*8.37	*7.93	*6.25
	SD	7 F	.73	4.77	1.62	1.06	2.68	2.43	1.12
TLD									
	M	13 M	8.09	110.56	10.75	12	11.75	11.94	10.56
	SD	3 F	.67	5.65	1.91	2.03	1.77	2.69	1.09

Note. TONI-3 – Test of nonverbal intelligence; Language subtests taken form the Clinical Evaluation of Language Fundamentals-4 (FD = following directions; RS = recalling sentences; FS = formulated sentences; WCR = word classes receptive; WCE = word classes expressive).
*Significant difference from TLD group.

An analysis of variance performed on IQ (TONI) revealed significant differences between the two groups. $F(1,30) = 10.085$, $p = .003$. $\eta_p^2 = .252$, ^$p = .867$. Children with SLI had lower TONI scores overall. Significant differences were also found for language scores. Following Directions (FD), $F(1, 30) = 24.736$, $p = .0001$, $\eta_p^2 = .452$, ^$p = .998$. Recalling Sentences (RS), $F(1,30) = 100.443$, $p = .0001$, $\eta_p^2 = .770$, ^$p = 1.0$ Formulated Sentences (FS), $F(1,30) = 17.666$, $p = .000$, $\eta_p^2 = .371$, ^$p = .982$. Word Classes Receptive, $F(1, 30) = 19.406$, $p = .000$, $\eta_p^2 = .393$, ^$p = .989$. Word Classes Expressive, $F(1, 30) = 120.838$, $p = .000$, $\eta_p^2 = .801$, ^$p = 1.0$. Children with SLI performed worse on all language tests compared to age-matched controls.

Stimuli

The visual stimuli consisted of four color words (*red, blue, green*, and *yellow*) printed in the color consistent with the word (congruent) and in a color that conflicted (incongruent) with the word (e.g., the word *red* printed in red ink or the word *red* printed in blue ink). Four CVC words were also included for the neutral conditions (*dog, ball, car* and *fish*). Stimuli were created using Microsoft Image Composer. Words had a font size of 48 and viewing distance was approximately 18 inches.

The auditory stimuli consisted of four words produced by four different speakers to create congruent and incongruent conditions. The words were *boy, girl, man*, and *women* spoken by a man, a woman, a boy, and a girl. Four CVC words were recorded for the neutral condition (*dog, ball, car*, and *fish*). Stimuli were recorded in a quiet room by an adult male (42 years of age), female (43 years of age), nine-year-old boy, and an eight-year-old girl on a digitized tape recorder (DAT recorder). Ten judges (five adult and five children) listened to each stimulus and reported if the speaker was a girl, boy, man, or woman. Only those words judged unanimously as being produced by a boy, a girl, a man, or a woman were used in the experimental task. The stimuli were digitized at a sampling rate of 22050 Hz with a 16-bit amplitude resolution and normalized using Sound Forge software for presentation through E-Prime 1.1 (2003).

Design and Procedure

The research design included three Stroop conditions: congruent, incongruent, or neutral and included four tasks based on modality (visual versus auditory) and attended target type (perceptual versus linguistic) (see Figure 1). Participants completed 8 sets of trials consisting of four visual and four auditory tasks. The visual and auditory tasks varied in attend type (four perceptual and four linguistic). Each set contained 16 trials (see Appendix B). Each set was administered four times to each participant for a total of 64 trials within that set. All conditions and tasks were administered to every participant for a total of 512 trials. The order of conditions and tasks was counterbalanced across subjects. A Latin Square design was used to determine the order of set presentation (see Appendix A). Additionally, to avoid subjects perseverating on a previous item, conditions (modality and attend target) did not vary within a set.

Each subject participated in two sessions conducted on two separate days within two weeks. Prior to the experimental task, all subjects received up to three training sessions to ensure comprehension of the task. The training session consisted of 10 trials of each Stroop condition, modality (auditory, visual), and target (linguistic, perceptual). No subject required more than one training session. A reading pre-test was also completed prior to the experimental task. Participants sat at a table with a four-button response box and computer monitor placed in front of them. The response box contained four colored buttons (*red, blue, yellow, green*) or four pictures (*dog, fish, car, and ball*). The words *red, blue, green, yellow, dog, fish, car* and *ball* were presented on the computer screen in black ink (Appendix C). Subjects were instructed to read each word and press the corresponding button. Accuracy and reaction times (RT) were recorded.

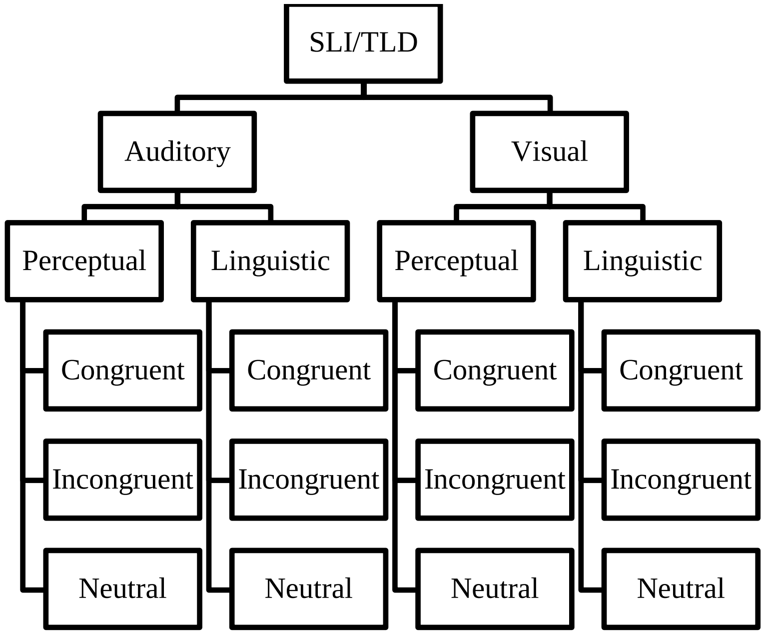

Figure 1. Flow chart representing experimental design.

Baseline Reaction Time Tasks

Prior to the experimental task, visual and auditory baseline reaction times were recorded. Participants were instructed to press a button as soon as they saw an object on the computer screen. The object was a .5 x .5 inch square. The interstimulus interval (ISI) was 250 ms, 500 ms, or 750 ms. The ISI was randomized so that participants could not anticipate the next stimulus. Each participant completed two sets of 20 trials following four practice trials. Participants were instructed verbally and in written form to press a button when the object appeared. Reaction times were recorded for the time between the onset of the target and the execution of a motor response. The auditory baseline RT task consisted of participants pressing a button as soon as they heard a sound presented binaurally through the headphones. The sound was a 100 ms 1000 Hz tone created on Sound Forge software. As in the visual task, ISI varied (250 ms, 500 ms, or 750 ms). The subjects completed four practice trials followed by two sets of 20 trials.

Selective Attention Tasks

Selective attention tasks varied by modality (auditory and visual) and attend target (perceptual and linguistic). The attend target is defined as the target that the subject is instructed to respond to. For the perceptual attend task, subjects are instructed to identify the color of the word (for the visual task) or the speaker (for the auditory task). They are to ignore the semantic aspect of the target (i.e. the actual word). In contrast for the linguistic attend task, subjects are instructed to identify the meaning of the word by pressing a matching button. They are instructed to ignore the perceptual dimension of the stimulus (color or speaker). For example for a linguistic visual task, the subject might see the word blue printed in red ink. The subject is instructed to read the word and press the button corresponding to the meaning of the word, in this case the blue button. On the other hand if the task is a perceptual auditory task, the subject might hear a man saying the word *girl*. The subject is instructed to identify the speaker and ignore what is said, in this case the picture of the man.

Visual Task

Participants sat at a table with the same four-button response box and computer monitor used in the baseline and reading reaction time pre-test. Instructions were read to each participant as well as presented in written form on the computer screen. Participants were instructed to attend to the color or to the word depending on the attend target and to press the button that corresponded to the target stimulus (color or word). Each participant completed four experimental runs containing 64 trials in each run for a total of 256 trials. Response times along with accuracy were recorded by E-prime (Psychology Software Tools, 2002). The time window for children to respond was four seconds, therefore, responses greater than four seconds were recorded as *no response*.

Auditory Task

Participants were seated at the same table with the same four-button response box and computer monitor in front of them. In the auditory task, the response buttons had pictures of a *man, woman, boy*, and *girl,* or *dog, car, fish,* and *ball* depending on the condition. Instructions were read to each participant as well as presented in written form on the computer screen. The auditory stimuli were presented binaurally through headphones at 75 dB SPL. The experimental task was the same as in the visual task and composed of three Stroop conditions and two attend targets for each stimulus. Participants were instructed to attend to the speaker (*man, woman, boy, girl*) or the word (*man, woman, boy, girl, dog, fish, ball, car*) depending on the task and to press the button that corresponded to the target stimulus (speaker or word). E-Prime recorded reaction time and accuracy. The ISI was 500 ms. The same number of trials was completed as in the visual task. The same window of time (four seconds) used in in the visual task was used in the auditory task.

CHAPTER 3: RESULTS

General Analysis

The data were analyzed for accuracy and reaction time (RT). Observations where the participant failed to make a response or the response was incorrect were excluded from the RT analysis. Additionally responses that fell below 300 ms were eliminated from analysis as they were determined to be false hits. Errors accounted for 5% of trimmed data. Initially, stimuli that fell 1.5 standard deviations above or below the mean RT were eliminated, however too many responses ended up being eliminated and it was determined that further trimming would eliminate significant effects. A 3(congruence) x 2(attend target) x 2(modality) x (classification) repeated measures analysis of variance (ANOVA) was conducted on the participants responses with classification serving as the between-subject variable and congruence, attend target, and modality serving as within subject variables. SPSS 18 software (2009) was used to analyze the data. For all analyses an alpha level of .05 was used.

Means and standard deviations for baseline reaction time and reading pre-test for children with SLI and TLD are presented in Table 2.

Table 2.

Reading and Baseline Reaction Times for SLI and TLD Groups.

	Classification	Mean	SD
Reading RT	SLI	*925.62	142.69
	TLD	827.14	103.46
Auditory RT	SLI	*476.10	60.72
	TLD	434.99	52.92
Visual RT	SLI	*519.03	78.89
	TLD	457.74	67.56

Note. *Significant difference from the TLD group

Three separate ANOVA's were completed on reading, auditory, and visual reaction times Results revealed that the SLI group was slower than the TLD group in the Auditory Modality F *(1,30)* = 4.170, *p* = .050, η_p^2 = .122, ^*p* = .507 and the Visual Modality *F(1,30)* = 5.571, *p* = .025, η_p^2 = .157, ^*p* = .627. Results also indicate significant differences on the reading task, with the SLI group performing slower than the TLD group. *F(1, 30)* = 4.994, *p* = .033, η_p^2 = .143, ^*p* = .580.

Accuracy Analysis

Accuracy data was analyzed in terms of the number of errors calculated as proportions under each condition (modality, attend target and congruence). Error proportions were calculated by dividing the number of errors by the number of trials under each condition (Table 3). An arcsine transformation was initially performed on the proportions but after viewing the distributions of both the transformed data and the error proportions the transformations did not appear to make the distributions more normal. Additionally, arcsine transformations is not particularly good if a substantial number of proportions are equal to 0 or 1 or for values at the extreme ends of the possible range. This is the case with the current data set. Means only ranged from .02 to .22 reflecting ceiling effects. Therefore, a repeated-measures general linear model was used to analyze the error proportions. Finally, IQ was considered as a covariate since initial analysis revealed significant differences between the two groups. However, the actual overall differences between the two groups were quite small. Additionally, according to Dennis, Francis, Cirino, Schachar, Barnes, and Fletcher (2009), IQ does not meet the requirements for a covariate. They also suggest when the covariate is an attribute of the disorder; it becomes meaningless to alter the treatment effects for differences in the covariate. It is not uncommon for children with SLI to have lower IQs compared to typically developing peers. Therefore, IQ was not included in the final analysis.

Table 3

Error Proportions for SLI and TLD Participants Across All Conditions

	ANL	ACL	AIL	ANP	ACP	AIP	VNL	VCL	VIL	VNP	VCP	VIP
SLI												
M	.067	.11	.17	.11	.15	.22	.14	.08	.26	.08	.08	.17
SD	.057	.10	.17	.10	.09	.14	.10	.07	.19	.10	.10	.15
TLD												
M	.024	.05	.07	.07	.08	.11	.10	.05	.15	.02	.02	.07
SD	.041	.08	.09	.07	.08	.05	.09	.07	.14	.03	.04	.10

Note. Auditory Stroop tasks (ANL=Auditory linguistic neutral, ACL=Auditory linguistic congruent, AIL=Auditory linguistic incongruent, ANP=Auditory perceptual neutral, ACP=Auditory perceptual congruent, AIP=Auditory perceptual incongruent). Visual Stroop Tasks (VNL=Visual linguistic neutral, VCL=Visual linguistic congruent, VIL=Visual linguistic incongruent, VNP=Visual perceptual neutral, VCP=Visual perceptual congruent, VIP=Visual perceptual incongruent).

The degrees of freedom for congruence were corrected using Greenhouse-Geisser estimates of sphericity. Within subject effects were found for congruence $F(1.69, 50.784)$ = 46.49., p = .000, η_p^2 = .608, ^p = 1.0. Both groups demonstrated Stroop effects (increased number of errors for incongruent conditions compared to congruent and neutral tasks). An interaction for congruence by classification was also found $F(1.69, 50.78)$ = 6.13, p = .006, η_p^2 = .170, ^p = .829. Children with SLI demonstrated an increased number of errors compared to age matched controls (TLD) during incongruent tasks (Figure 2).

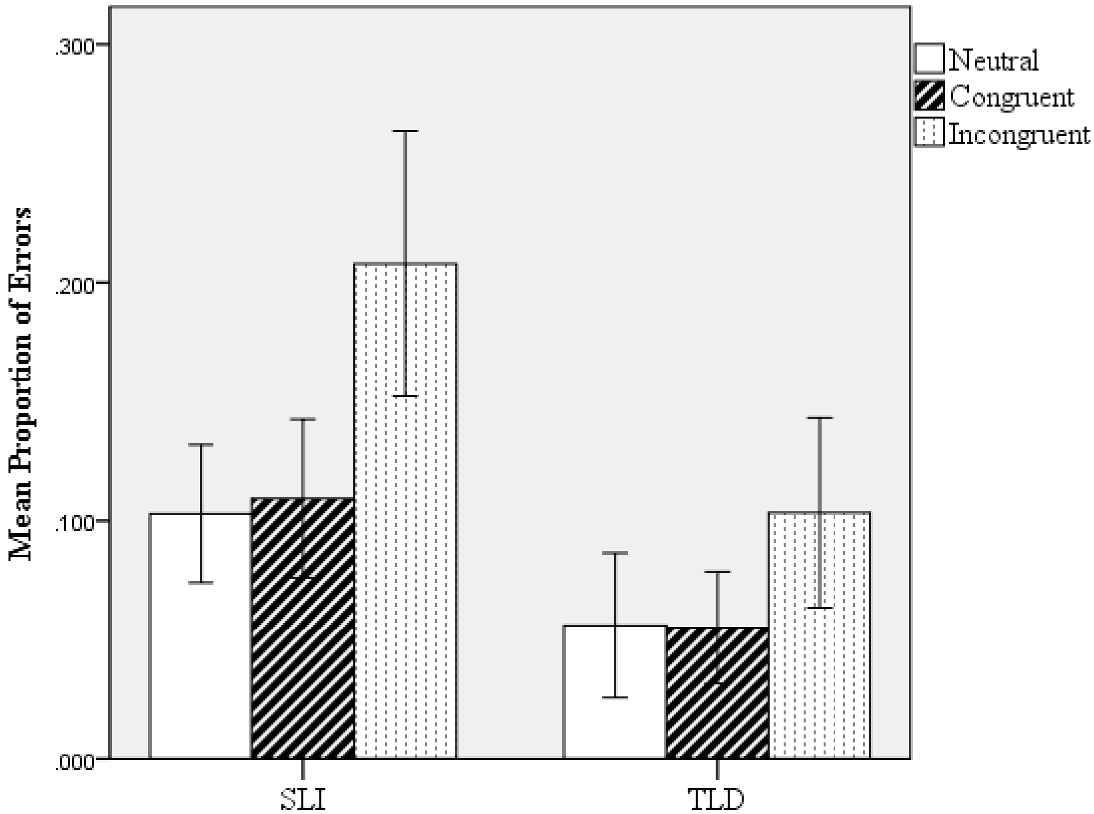

Figure 2. Mean proportion of errors for the TLD and SLI group by congruence.

There was no main effect for modality $F(1, 30)$ = .003, p = .958, η_p^2 = .000, ^p =. 050. Children with and without SLI did not perform differently on auditory tasks compared to visual tasks (Figure 3). Additionally, there was no interaction between classification (SLI, TLD) and modality $F(1, 30)$ = .055, p = .816, η_p^2 = .002, ^p = .056. Children with SLI did not perform any differently compared to age-matched, typically developing peers across modality. There was no interaction by modality, classification, and attend target $F(1, 30)$ = .010, p = .922, η_p^2 = .000, ^p = .051.

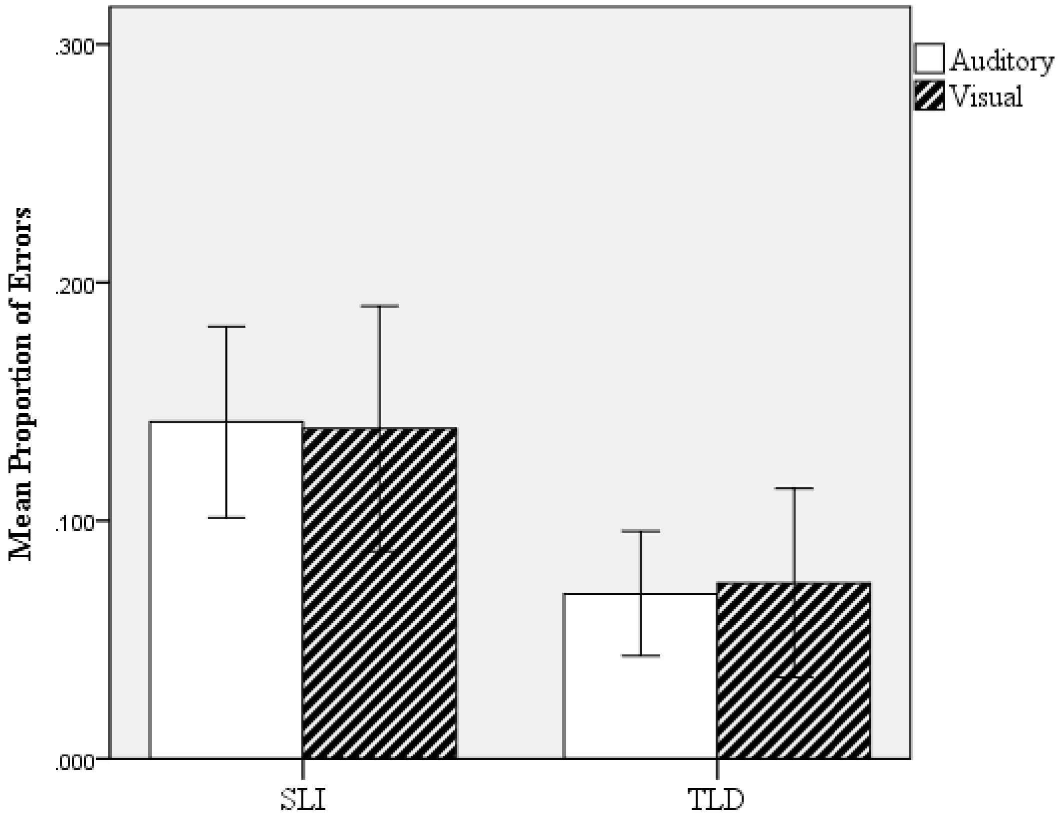

Figure 3. Mean proportion of errors for the TLD and SLI group by modality.

There was an interaction for modality by congruence *F(2, 29)* = 6.01, *p* = .007, η_p^2 = .293, ^*p* = .846 (Figure 4).

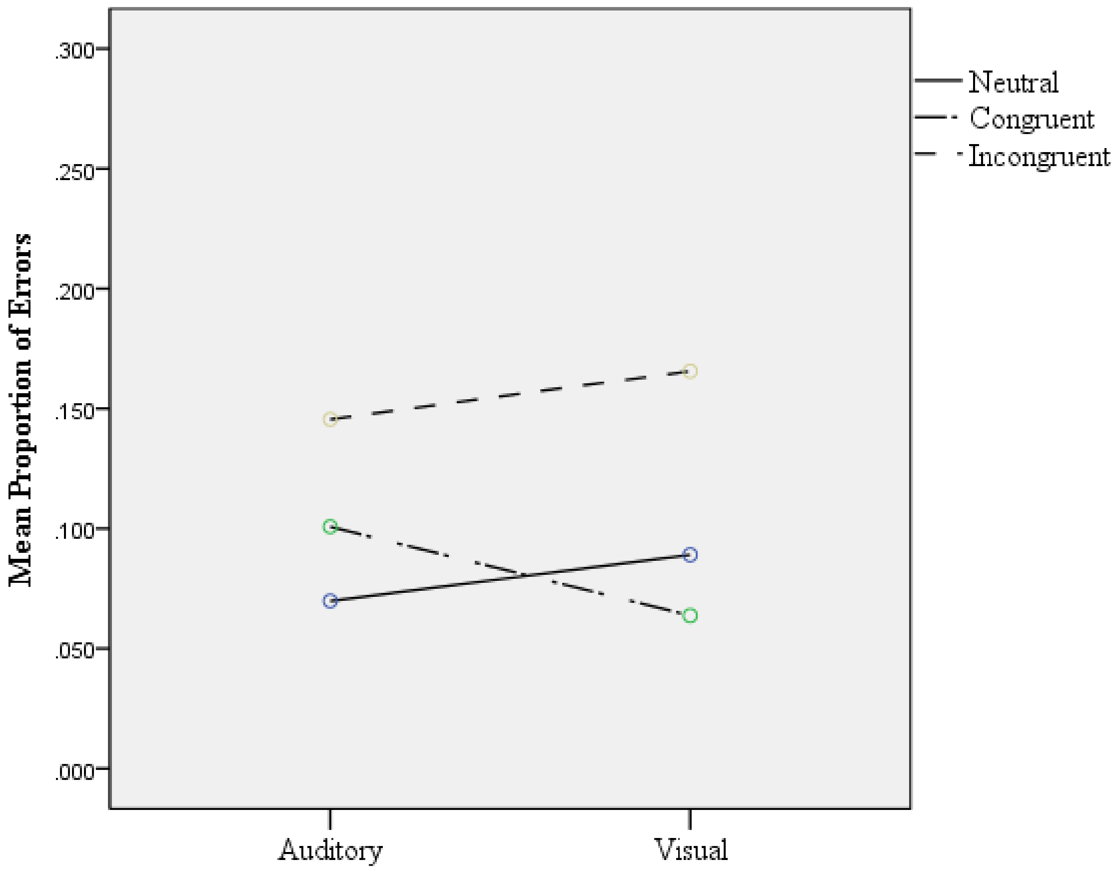

Figure 4. Mean proportion of errors collapsed across groups (TLD, SLI) for modality and congruence.

Accuracy was higher in the visual condition involving congruent stimuli while accuracy was higher in the auditory condition involving neutral stimuli. Despite this, accuracy was poorest overall during the incongruent condition regardless of modality.

There was no main effect for attend target *F(1, 30)* = .551, *p* = .464, η_p^2 = .018, ^p =. 111. Children with and without SLI did not perform differently on attend linguistic compared to attend perceptual (Figure 5). Additionally, there was no interaction between classification (SLI, TLD) and attend target *F(1, 30)* = .346, *p* = .561, η_p^2 = .011, ^*p* = .088. Children with SLI did not perform any differently compared to age-matched typically developing peers across attend targets.

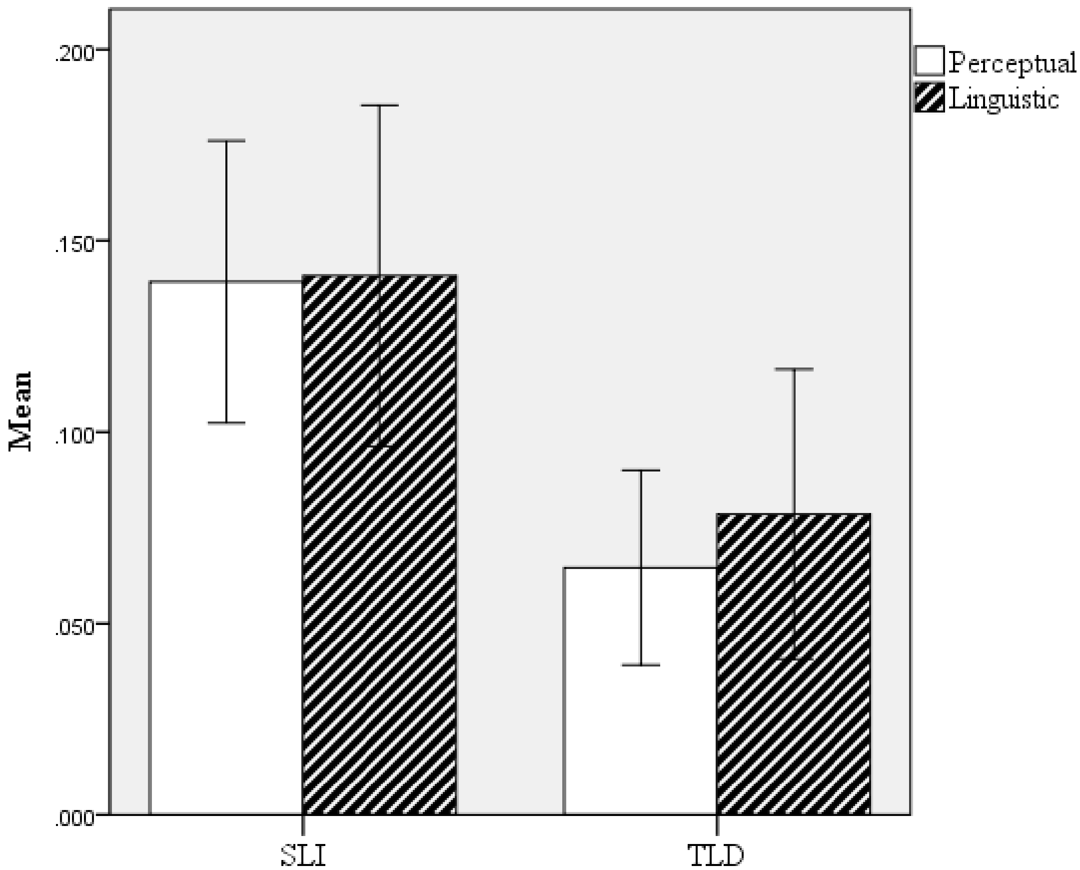

Figure 5. Mean proportion of errors for the TLD and SLI group by attend target

There was no interaction by modality, classification and attend target $F(1, 30) = .010$, $p = .922$, $\eta_p^2 = .000$, ^p = .051. Finally there was an interaction for modality by attend target $F(1, 30) = 22.609$, $p = .000$, $\eta_p^2 = .430$, ^p = .996 (Figure 6)

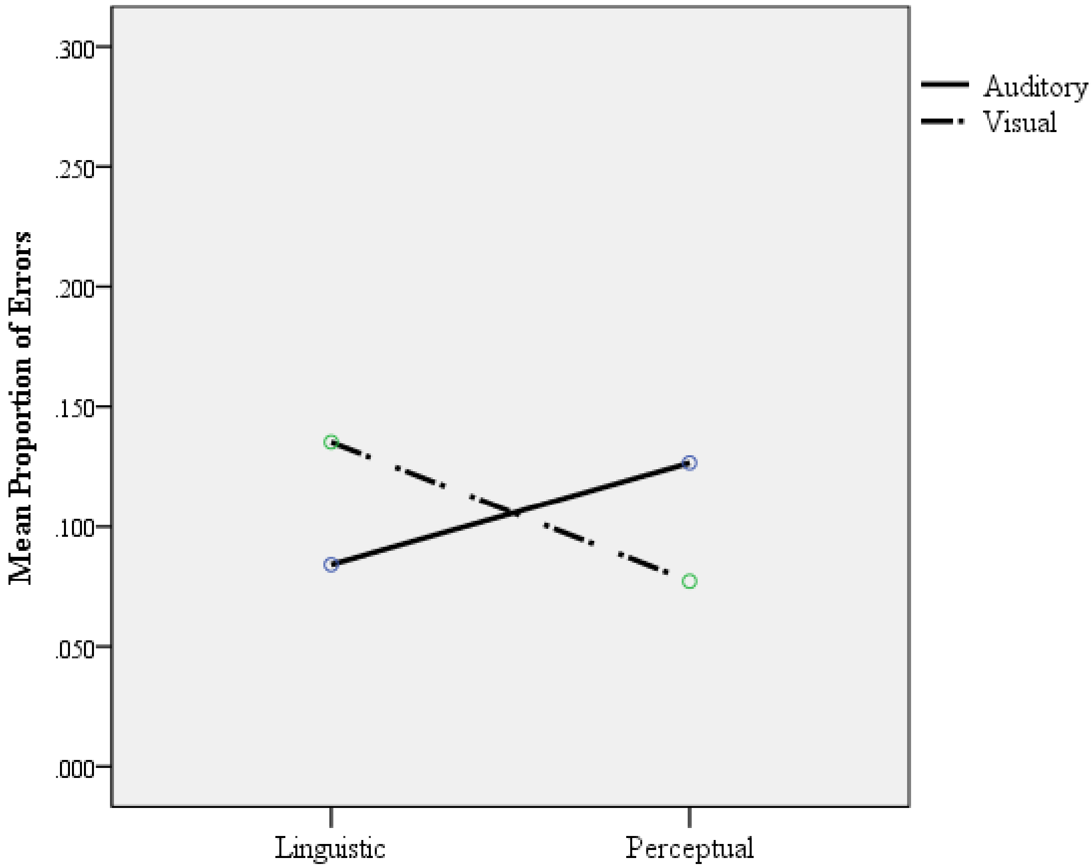

Figure 6. Mean proportion of errors collapsed across groups (TLD, SLI) for attend targets and modality.

Accuracy is higher in the auditory modality during the linguistic condition, while accuracy is higher in the visual modality during the perceptual condition.

There were no main effects for congruence, modality, or attend target. There was a significant interaction for congruence by classification $F(2, 28) = 4.129$, $p = .027$, $\eta_p^2 = .228$, ^p = .682. Children with SLI produced more errors during incongruent conditions than their typically developing peers.

There was also between subject effects $F(1, 29) = 9.00$, $p = .005$, $\eta_p^2 = .237$, ^p = .827. Children with SLI produced more errors overall.

Reaction Time Analysis

An analysis of variance was completed on RTs with classification (SLI and TLD) serving as the between-subject variable and congruence (neutral, congruent, incongruent), attend target (perceptual and linguistic) and modality (auditory and visual) serving as within subject variables. As with accuracy, IQ was not included as a covariate. Reaction time means and standard deviations for group by modality, attend target, and congruence are presented in Table 4.

Table 4.

Reaction Time Means for the SLI and TLD Groups Across All Conditions

		ANL	ACL	AIL	ANP	ACP	AIP
TLD	Mean	1192.61	1072.94	1287.17	908.59	976.17	1073.15
	SD	223.86	221.43	312.93	143.35	154.32	221.25
SLI	Mean	1307.54	1199.52	1489.88	1146.09	1160.87	1348.38
	SD	209.40	235.81	360.83	250.66	221.39	318.56

		VNL	VCL	VIL	VNP	VCP	VIP
TLD	Mean	967.48	1036.97	1107.55	1061.38	1136.51	1218.59
	SD	141.16	194.59	191.08	184.95	164.11	139.96
SLI	Mean	1144.02	1277.30	1367.26	1219.21	1381.80	1545.22
	SD	122.21	214.05	236.15	252.08	269.84	299.85

Note. Auditory Stroop tasks (ANL=Auditory linguistic neutral, ACL=Auditory linguistic congruent, AIL=Auditory linguistic incongruent, ANP=Auditory perceptual neutral, ACP=Auditory perceptual congruent, AIP=Auditory perceptual incongruent). Visual Stroop Tasks (VNL=Visual linguistic neutral, VCL=Visual linguistic congruent, VIL=Visual linguistic incongruent, VNP=Visual perceptual neutral, VCP=Visual perceptual congruent, VIP=Visual perceptual incongruent).

The degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. A main effect was found for congruence *F(1.618, 48.553)*, = 57.700, p = .000, η_p^2 = .658, ^*p* = 1.0. Both groups demonstrated increased reaction times for incongruent trials compared to congruent and neutral trials. There was an interaction of congruence by classification *F(1.618, 48.553)* = 3.492., p = .048, η_p^2 = .104, ^p = .566. The SLI group performed slower during incongruent trials compared to the TLD group, demonstrating greater interference (Figure 7) and supporting the first prediction. Children with SLI demonstrated greater Stroop interference than their typically developing peers.

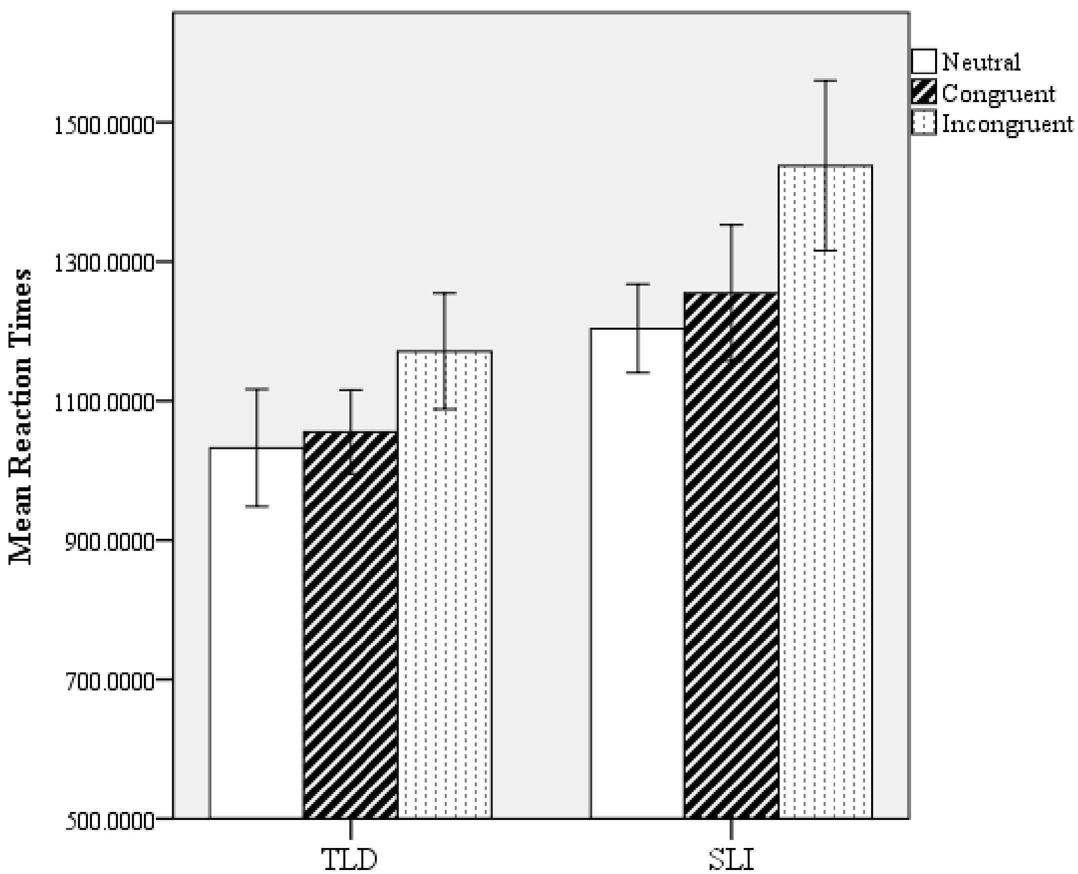

Figure 7. Mean reaction times for the TLD and SLI group by congruence.

There was an interaction of modality by congruence *F(1.723, 51.685)* = 8.255., *p* = .001, η_p^2 = .216, ^*p* = .928 (Figure 8). Subjects were faster during the auditory congruent trials compared to the visual congruent trials; however the opposite was true for the neutral trials. Subjects were faster on visual neutral trials compared to visual auditory trials. There was no difference between incongruent trials for auditory or visual stimuli. It could be that congruence provided greater facilitation, hence faster reaction times, for auditory stimuli than for visual stimuli. Results of the neutral trials could be a product of task difficulty. In other words visual trials under the neutral condition were easier than auditory trials.

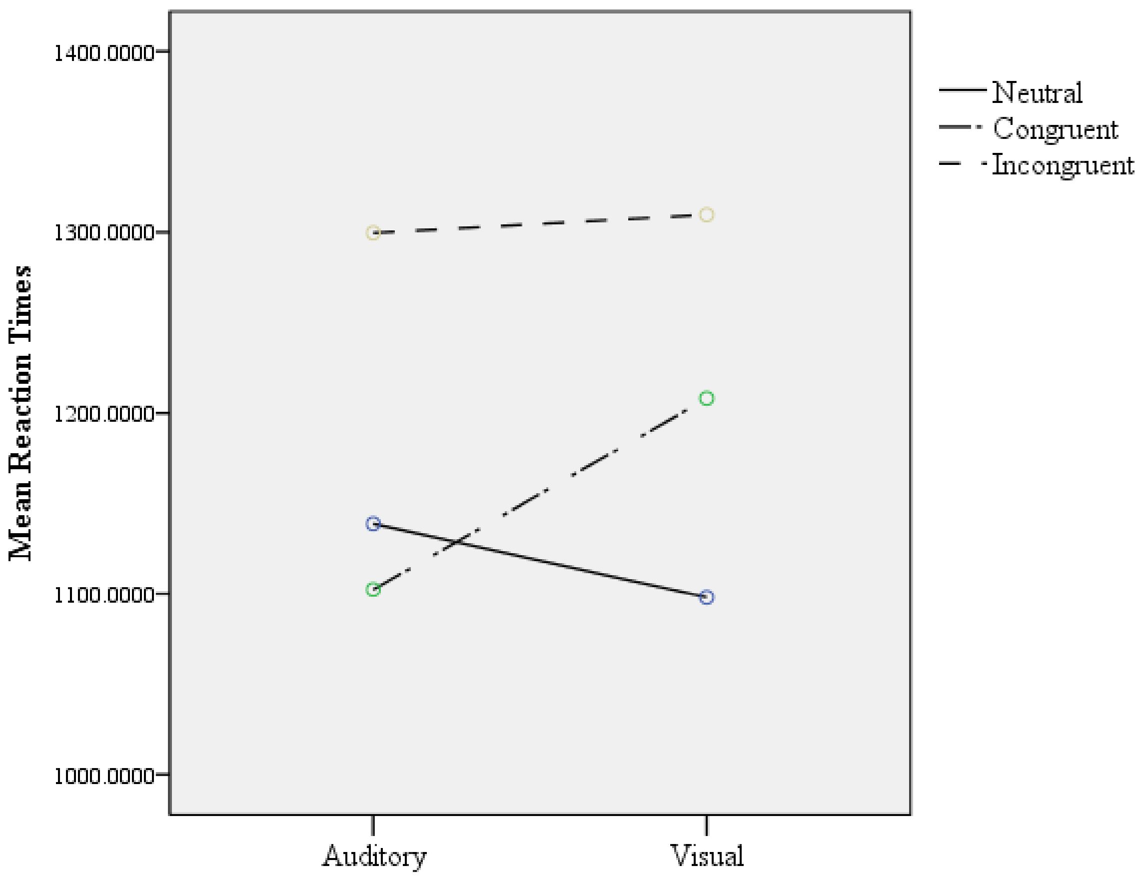

Figure 8. Mean reaction times collapsed across groups (TLD, SLI) for modality by congruence.

There was an interaction of attend target by congruence $F(2, 60) = 3.542$, $p = .05$, $\eta_p^2 = .106$, $\hat{p} = .519$ (Figure 9). Subjects were faster on perceptual neutral trials compared to linguistic neutral and congruent linguistic trials. Subjects performed similarly on congruent and neutral linguistic trials. There was no difference between incongruent trials for linguistic and perceptual trials. There is no evidence of facilitation effects for attend targets. Results may indicate that perceptual neutral trials were significantly easier than the perceptual congruent as well as the linguistic trials.

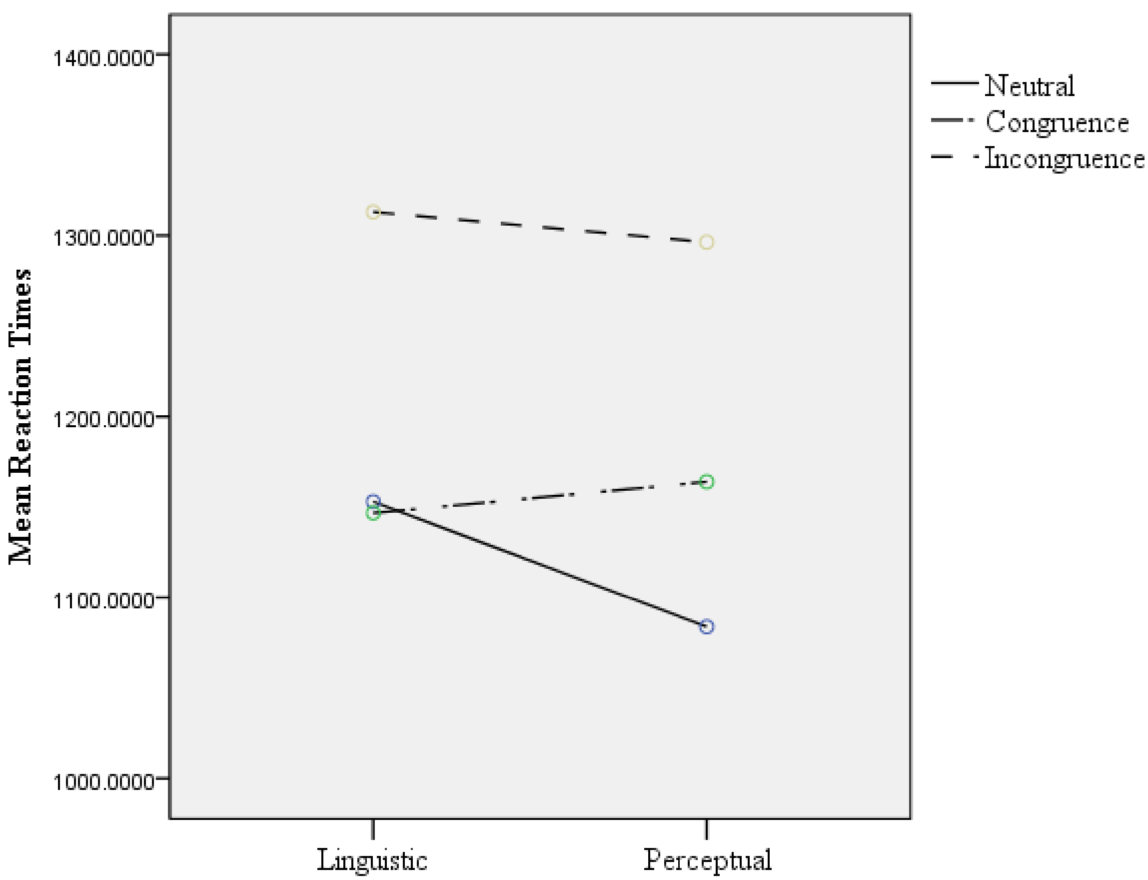

Figure 9. Mean reaction times collapsed across groups (TLD, SLI) for attend target by congruence.

There was an interaction of modality by attend target $F(1, 30)$ = 42.237., p = .000, η_p^2 = .585, ^p = 1 (Figure 10). Subjects were faster during the auditory perceptual trials compared to the auditory linguistic trials; however the opposite was true for the visual trials. Subjects were faster on visual linguistic trials compared to visual perceptual trials. This is likely due to task difficulty and differences between auditory and visual stimuli.

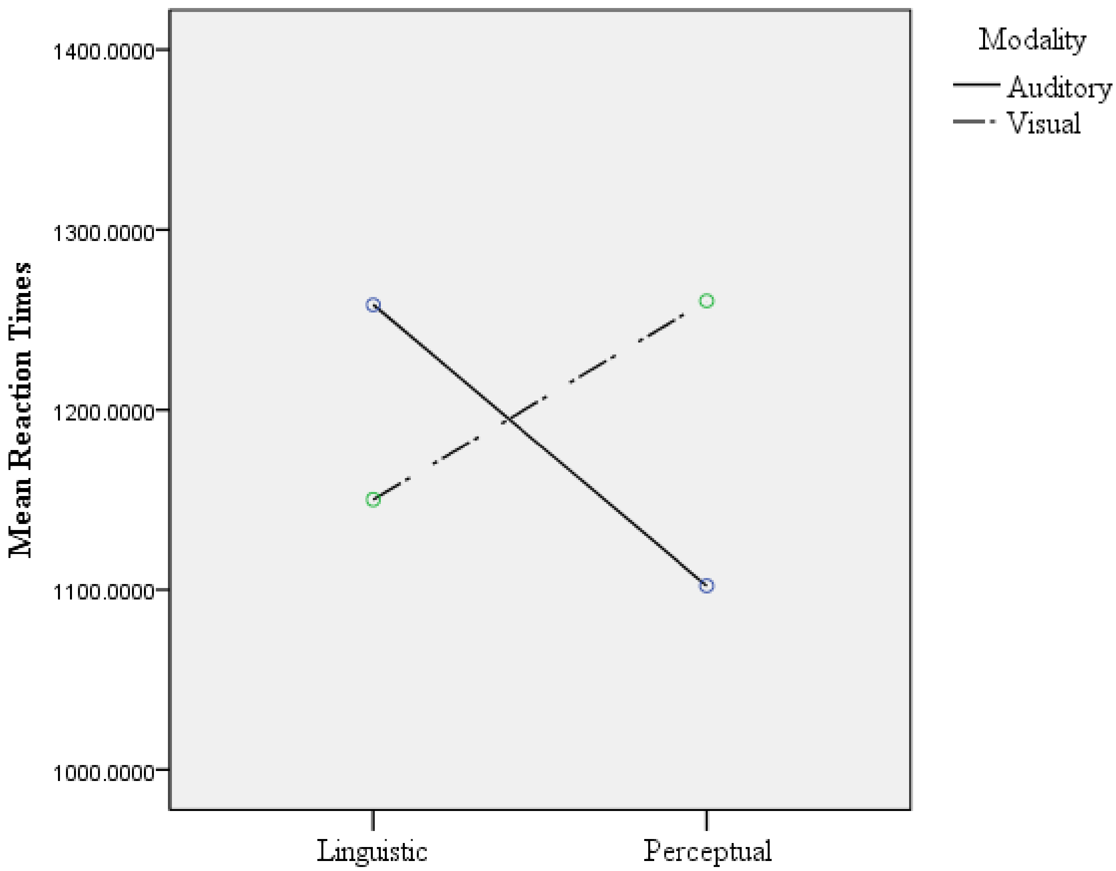

Figure 10. Mean reaction times collapsed across groups (TLD, SLI) for modality by target.

Finally between subject effects were found for the SLI and TLD groups $F(1, 30)$ = 15.534, p = .000, η_p^2 = .339, ^p =. 966. The SLI group was slower across all Stroop tasks.

There were no main effects for modality $F(1, 30) = .636$, $p = .431$, $\eta_p^2 = .021$, ^$p = .121$ and attend target $F(1, 30) = .961$, $p = .335$, $\eta_p^2 = .031$, ^$p = .158$. Subjects did not perform differently across modality or attend target. Additionally, there was no interaction between classification (SLI, TLD) and modality $F(1, 30) = .494$, $p = .488$, $\eta_p^2 = .016$, ^$p = .104$. Children with SLI did not perform differently compared to age-matched, typically developing peers on modality or visual tasks. Finally, there was no interaction for attend target by classification $F(1, 30) = 1.20$, $p = .282$, $\eta_p^2 = .038$, ^$p = .185$. Children with SLI did not perform significantly different compared to age-matched, typically developing peers on perceptual tasks compared to linguistic tasks suggesting that the slower responses in SLI are not domain specific.

A final set of analyses was completed on interference and facilitation scores. Interference was calculated by subtracting the mean reaction time of the neutral condition from the incongruent condition (Table 5). Facilitation was calculated by subtracting the congruent condition from the neutral condition (Table 6).

Table 5

Interference Scores

Group	Mean	Std. Deviation
SLI	213.64	189.13
TLD	94.50	74.62
Total	154.07	153.84

*Mean interference scores collapsed by group

Table 6

Facilitation Scores

Group	Mean	Std. Deviation
SLI	-31.25	142.83
TLD	21.61	93.61
Total	-4.81	121.79

*Mean facilitation scores collapsed by group

Interference scores were analyzed using a general linear model univariate analysis. There was a significant difference between the SLI and TLD group for interference *F(1, 30)* = 5.49, *p*=.026, η_p^2 = 155, ^*p* = .621. Children with SLI exhibited greater interference compared to their typically developing peers. Facilitation scores were analyzed using a general linear model univariate analysis. There was no significant difference between the SLI and TLD group for facilitation *F(1, 30)* = 1.533, *p*=.225, η_p^2 = .049, ^*p* = .224. Neither group exhibited significant facilitation. Figure 11 displays interference and facilitation scores by group.

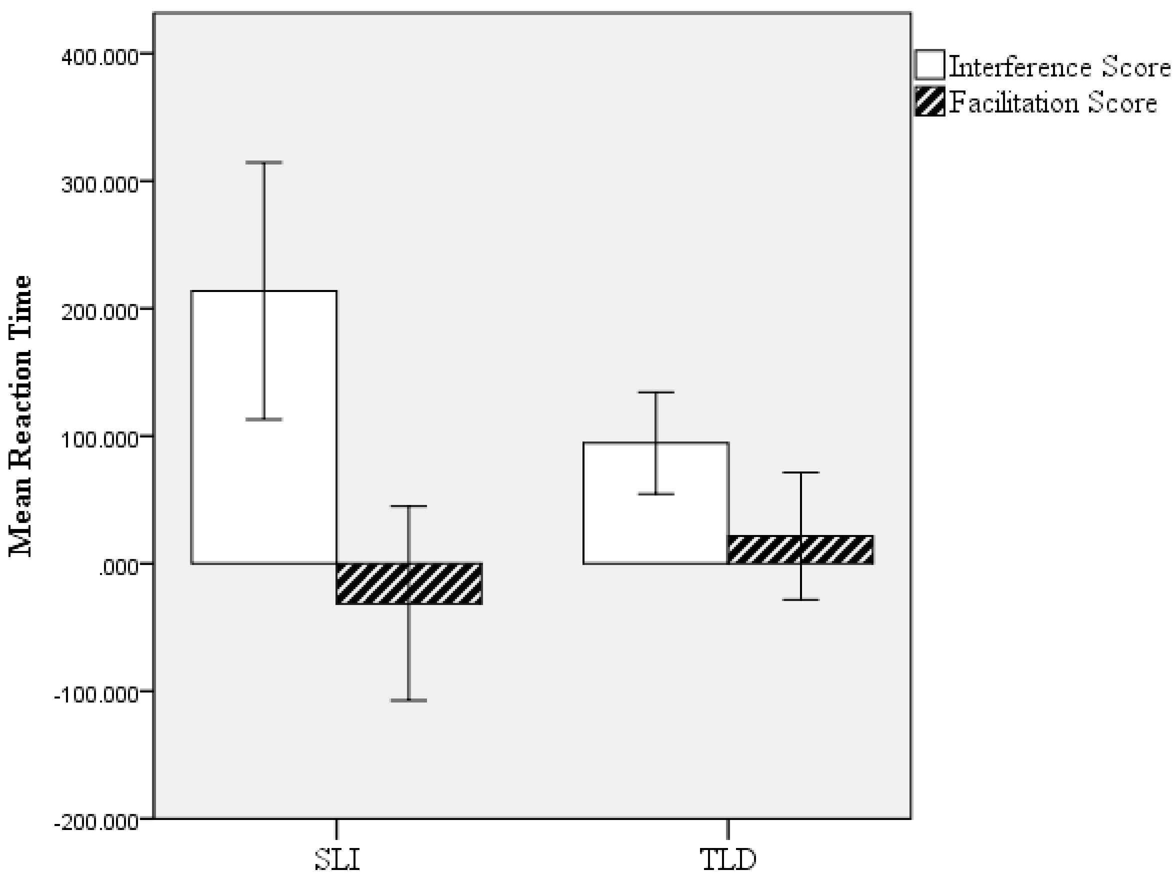

Figure 11. Mean reaction times for the SLI and TLD group for facilitation and interference scores

CHAPTER 4: DISCUSSION

Children with SLI exhibit deficits in language without associated physical, neurological, emotional, or intellectual deficits. Research has revealed that in addition to the obvious language deficits, children with SLI also display weaknesses in nonlinguistic as well as cognitive tasks (temporal processing, visuo-spatial, short-term memory, and mental imagery; Hick, Botting, & Conti-Ramsden, 2005; Johnston and Ramstad, 1983, Tallal & Piercy, 1973, 1974, 1975). There has been much debate over the last decade as to the underlying cause of SLI. Several theories suggest that the deficits are language-specific and/or result from deficits in auditory processing while others maintain a more general processing limitation (for a review, see Leonard, 1998). This study provides preliminary evidence that children with SLI exhibit deficits in selective attention that is neither modality nor domain-specific. These deficits may be the initial cause or at least contribute to the multitude of deficits seen in children with SLI.

Selective attention is essential to learning and language development. It is especially important in tasks that involve conflict (Miller, 2000). In experimental and everyday tasks, conflict exists and a degree of inhibitory control is required. Infants learning language must selectively attend to relevant cues while ignoring irrelevant cues, such as linguistic cues, inter- and intra-speaker variability. In the current Stroop study, participants were required to suppress the dominant response in order to select the nondominant response. Stroop interference is thought to occur because of the conflict between controlled and automatic processing. The results of this investigation will be discussed in terms of inhibition-related functions.

Inhibition and Interference

This study supports the hypothesis that children with SLI exhibit deficits in selective attention, specifically inhibition-related functions. Children with SLI and typically developing children exhibited an increased number of errors and increased reaction times during times of conflict (word *blue* in red ink or male voice saying *women*); however, children with SLI exhibited significantly more errors and longer reaction times than their TLD peers. Poor inhibitory control in children with SLI has been noted in previous studies (Bishop & Norbury, 2005; Im-Bolter, Johnson, & Pascual-Leone, 2006).

It has been suggested that inhibition and interference is not a unitary construct but rather consist of a family of functions (Friedman & Miyake, 2004; Nigg, 2000). Nigg (2000) classified inhibitory functions into four types of effortful inhibition—interference control, cognitive inhibition, behavioral inhibition, and ocular inhibition. In this study, interference control and behavioral inhibition were investigated. The ability to resist interference from automatic processes such as word reading during the visual Stroop task was reduced in children with SLI. But children with SLI not only had difficulty during Stroop tasks that involved the automatic process of word reading, they had difficulty on all tasks that involved conflict. This was demonstrated by their longer reaction times during tasks of conflict. Children with SLI also had difficulty suppressing a preponent response. This was evidenced by their increased number of errors during tasks of conflict. Results of this study also fit with Miyake and Friedman's fractionated model of inhibition-related functions. In their 2004 research on inhibition-related functions they found that Preponent Response Inhibition (PRI) and Resistance to Distractor Interference (RDI) are closely related and involve to some extent common inhibition ability. Children with SLI demonstrated an increased number of errors (PRI) and slower RTs (RDI), results that support Miyake and Friedman's model. The third function that was investigated by Miyake and Friedman, Resistance to Proactive Interference (RPI) was not investigated in this study. RPI, as mentioned in the introduction, is the ability to resist memory intrusions from information that was previously relevant to the task but has since become irrelevant. According to Friedman and Miyake (2004), it is not highly correlated to PRI and RDI, suggesting to some degree that not all inhibition functions. Resistance to PI reflects perseverations, as participants get stuck on a previous relevant stimulus. This study did not explore perseverations. Tasks were counterbalanced and subjects did not switch modality or attend target within each task.

Children with SLI performed more poorly than age-matched controls during times of conflict because they directed too much attention to the irrelevant information. Their poor performance was evident in both modalities (auditory and visual) as well as for both attend targets (perceptual and linguistic). This could result from weak inhibitory functions such as preponent response inhibition and/or resistance to distractor interference. These functions normally limit the processing of irrelevant information. Deficits in these functions allow task-irrelevant information to access working memory systems. The result is a response to nontarget stimuli. Faulty inhibitory functions thus interfere with effective learning, language achievement, speech discrimination, and perceptual learning (Bishop & Norbury, 2005; Bjorklund & Harnishfeger, 1995; Francis, Baldwin & Nusbaum, 2000; Wolfe & Bell, 2003). Language development and processing involves suppressing competing information while attending to important linguistic or perceptual cues (such as speaker variability, unstressed syllables, and morphological markers) and, thus, can be negativity impacted by inefficient inhibition.

Deficits in inhibition-related functions can be used to explain the word retrieval deficits children with SLI exhibit (German, 1987; McGregor & Leonard, 1995; Rapin & Wilson, 1978; Weiner, 1974). Theories of lexical access suggest that upon hearing a sequence of speech sounds, reading a sequence of letters, or preparing to produce a word, all words that are related phonologically and semantically are activated. The task is to find the match and suppress all related words. Word finding deficits are characterized by circumlocutions, long pauses, and use of nonspecific words. Additionally, children with word finding deficits often produce naming errors (*spork* for *fork*, *tiger* for *lion*) (German & Simon, 1991). These word-finding problems may reflect inadequate activation of the target word and an inability to suppress related, nontarget words. Additionally, delays in naming may occur because of the conflict among semantically, grammatically, or phonologically related words that are stored in memory. This conflict may occur because of difficulties with early word learning. If attention is not fully focused on a stimulus during processing, storage of that stimulus may be compromised. Thus, what is stored in memory depends on the amount of attention given to a particular stimulus at any given moment. An intact memory system is necessary for storage and retrieval of information and, as previously reported, children with SLI have deficits in verbal working memory as well as word retrieval (Ellis Weismer et al., 1999). This interpretation is supported by fMRI findings from adolescents with SLI (Ellis Weismer, Plante, Jones, & Tomblin, 2005). While performing a verbal memory task, participants with SLI exhibited significant activation differences, not only in areas associated with encoding and recall of the verbal material, but also in regions associated with attention. Deficits in selective attention interfere with the accurate storage of words in one's lexicon, which in turn leads to difficulty with retrieval.

Inefficient inhibition-related functions may also help to explain deficits in figurative language (Nippold & Fey, 1983). Comprehension of ambiguous, syntactically complex or nonspecific information requires the listener to attend to the relevant aspects and inhibit responses to irrelevant information. For example in the sentence *She stole my heart*, the listener must suppress the literal meaning in order to interpret the figurative meaning. Similar to Stroop tasks, accurate interpretations of idioms, multiple meaning words, similes, and metaphors require the listener to actively inhibit a response to a nontarget dimension. This is also true for comprehension of sentences that contain ambiguous words. Language comprehension requires understanding of words in isolation as well as the ability to integrate these words in order to build mental representations of objects and events. Mental representations are formed by interpreting linguistic and nonlinguistic information from the beginning of an utterance (Norbury, 2005). For correct comprehension, one must direct attention to the linguistic structure as well as attend to the supra-segmental features (tone, prosody, intonation etc.). Prosody can change the meaning of a sentence without changing the order of words. For example, *That's a dog* could either be a statement or a question, depending on the intonation. These nuances of language require the listener to attend to all aspects of the message.

In a study by Norbury (2005), lexical ambiguity resolution was examined as a means of investigating differences in contextual processing. Children with language impairments and autism spectrum disorder were compared to typically developing peers on comprehension tasks that involved multiple meaning words. Their ability to understand the dominant and subordinate meanings of the words as well as their ability to use context to determine correct meaning was evaluated. Results indicated that children with language impairments had difficulty integrating ideas to resolve ambiguous conflict. This difficulty may have resulted from the inability to suppress or inhibit irrelevant information. If the listener does not have adequate representations of word meanings or fails to attend grammatical and extra linguistic cues, comprehension will fail.

Domain-Specific versus Domain-General Deficits

Children with SLI had difficulty regardless of whether the distractor was perceptual (voice or color) or linguistic (word), discounting the notion that SLI is language-specific and pointing to a more domain-general deficit. These findings are important because language development and processing involve linguistic and perceptual cues. One of the hallmarks of SLI is deficits in morphosyntax affecting the production of inflectional morphology (Gillam & Johnston, 1992; Leonard, 1998; Oetting & Horohov, 1997; Rice, Wexler & Cleave, 1995). Inflectional morphemes in English are particularly limited in their perceptual salience (Leonard, 1998). In typical development, infants and children depend on selective attention to learn these and other language specific features (Jusczyk, 1997; Slobin 1973). Children with and without SLI were taught a nonsense affix that was to be used with nonsense nouns (Swisher, Restrepo, Plante, & Lowell 1995; Swisher & Snow, 1994). The children with SLI had more difficulty applying the morpheme than age-matched controls. Difficulty in applying this newly learned affix may have resulted from limitations in selective attention rather than a linguistic deficit. If SLI were a language-specific disorder, nonlinguistic stimuli should not cause interference. This was not the case. Both linguistic and perceptual stimuli caused interference and led to an increased number of errors and longer reaction times. Stroop interference is believed to occur because the physical dimension, in this case the color or voice, and the semantic dimension, the meaning of the word, are not processed independently. In this study the perceptual dimension (voice/color) is considered to be nonlinguistic because it is processed based on physical cues rather than linguistic ones.

Modality

Modality effects have been observed in children with SLI on tasks of attention (Finneran, Francis & Leonard, 2009; Gomes et al, 2004; Noterdaeme et al, 2000; Spaulding et al, 2008). The current study, however, found no modality effects. Children with and without SLI performed no differently on auditory compared to visual tasks. Additionally there was no difference between the SLI and TLD groups in auditory and visual tasks. The difference in results from previous research might be because different inhibitory functions are recruited for different types of tasks as well as for different domains of attention. The previous studies (Finneran, Francis & Leonard, 2009; Gomes et al, 2004; Noterdaeme et al, 2000; Spaulding et al, 2008) examined sustained and divided attention whereas the current research investigated selective attention. These results suggest that inhibitory functions may employ common processes across modalities in selective attention tasks during times of conflict.

Finally, these study results further support that SLI does not result from deficits in auditory processing. If this were the case then an increase in the number of errors as well as longer reaction times would only be noted during auditory trials.

Current Theories

The current study is consistent with previous studies that discount theories suggesting SLI is modality-specific (i.e., auditory processing disorder) and language-specific. Children with SLI performed no differently on the auditory and visual Stroop tasks. Additionally, performance was not impacted by distractor type (perceptual versus linguistic). Children with SLI did, however, consistently perform more poorly on conditions that were incongruent when compared to neutral conditions as well as compared to age-matched typical controls. This performance difference is consistent with deficits in selective attention.

The current findings (slower reaction times) might initially fit with the Generalized Slowing Hypothesis (Miller, Kail, Leonard, & Tomblin, 2001). Slower reaction times have often been reported in SLI literature. Kail (1994) found that children with SLI present with reaction times that are about 33% slower than age-matched peers on a variety of tasks. But this theory can only account for the overall differences in reaction time. Interference scores were calculated and analyzed to eliminate the overall delays in reaction time. Interference scores were calculated by subtracting the reaction time from the neutral condition from the reaction time of the incongruent condition. The resulting score is known as the interference score. It reflects the reaction time that is related specifically to the conflict of the condition (the word *red* printed in blue ink). Children with SLI exhibited greater interference compared to TLD peers reflecting deficits in selective attention (Resistance to Distractor Interference).

Deficits in selective attention can account for the overall reaction time differences as well as the significant differences on tasks of conflict. Since selective attention can be viewed as a capacity limited system, tasks that require greater selection would use a greater number of resources. This would result in a decrease in available resources for further processing of other stimuli. It is feasible that children with SLI do not initially differentiate between relevant and irrelevant stimuli and, therefore, attend to both. This results in overall decrease in efficiency of their attentional system, which then results in unsuccessful completion of a task.

Children with SLI appear to have more limited processing capacity than their typically developing peers, perhaps due to poor resource allocation or the need to devote greater resources to certain aspects of language processing than their typically developing peers (Adams & Gathercole, 2000; Dollaghan & Campbell, 1998; Ellis Weismer & Evans, 2002; Lahey, Edwards, & Munson, 2001; Leonard, 1998; Miller et al., 2001). However, there are alternate explanations. Many of the studies that suggest a limited processing capacity have employed complex tasks that are actually measuring Executive Functions (EFs). Children with SLI do not perform poorly on all tasks, in fact often times they perform similarly to age-matched peers (Bishop, 1992). Recent research has indicated that EFs are a set of separate but related functions. This would explain why children with SLI do not always demonstrate differences on experimental tasks. The task may in fact be measuring an EF that is not impaired. The impurity of tasks across a wide variety of research makes interpreting the results difficult.

In fact, within the last decade it has been suggested that attention is not a limited capacity system (Melera & Algom, 2001). This contradicts much early research on attention (Broadbent, 1958; Kahneman, 1973). According to Melera's tectonic theory of selective attention, selection is driven by dimensional imbalance and dimensional uncertainty. Thus, humans are drawn to different forms of nonattended information, which includes surprising, salient, and correlated information. This theory also distinguishes between failure of selection and failure of performance. In different situations, imperfect focus is as likely to improve performance as it is to impair performance. When selection is compromised, it is not by a limitation in the system, but rather a normal, persistent, unconscious drive to process irrelevant information. So if failure in selective attention is necessary in certain situations for successful performance in learning, then it is possible that children with SLI are not necessarily unable to select, or alternatively they may be *too good* at selecting. In the latter case, their focus may be too narrow, resulting in decreased processing of new information necessary for learning. Although the current study does not specifically address this hypothesis, it should be considered in future research.

Conclusion

The present study provided evidence that children with SLI display selective attention deficits. Specifically, children with SLI exhibit deficits in inhibition-related functions as evidenced by an increased number of errors and reaction times on Stroop tasks. Selective attention plays an important role in language and learning. Every day, children are barraged with multiple stimuli, and they must successfully choose the most relevant targets while ignoring irrelevant stimuli. These deficits in selective attention may underlie many of the linguistic and nonlinguistic deficits children with SLI exhibit. A better understanding of the cause of SLI will help professionals develop better, more targeted treatment programs for children. Remediation strategies directed at a range of inhibition-related functions as well as language should be included in intervention programs. They could include listening in the presence of background noise or presenting information that involves conflict, such as multiple meaning words or idioms. As Francis and colleagues (2000) have demonstrated non-native speakers can be trained to direct their attention to various acoustic cues contained in the speech signal. More fascinating is that the newly learned acoustic cues generalized to novel contexts. Stevens, Fanning, Coch, Sanders, and Neville (2008) investigated the effects of computerized training on selective auditory attention. They measured changes in selective attention using ERPs as well as behavioral measures. Results indicated that computerized tasks designed to improve language skills ended up improving auditory selective attention skills at the neural level as well as behaviorally. These results provide strong evidence for targeting attention during language therapy.

In conclusion, this study provides further support that selective attention is deficient in children with SLI. More research is needed to investigate more specifically the role of inhibition-related functions and language development as well as language disorders. No task is a pure measure of inhibition (Miyake & Friedman, 2004). A large proportion of the variance associated with inhibition tasks may reflect individual variations rather than inhibitory control processes. Future research should employ multiple experimental tasks that have been found to reliably evaluate inhibition functions as well as tasks that are correlated to each other.

Appendix A

Sample Latin Square for presentation of conditions to six subjects

	Sub 1	Sub 2	Sub 3	Sub 4	Sub 5	Sub 6
1	ACL	AIL	ANL	VCL	VIL	VNL
2	AIL	ANL	VCL	VIL	VNL	ACP
3	ANL	VCL	VIL	VNL	ACP	AIP
4	VCL	VIL	VNL	ACP	AIP	ANP
5	VIL	VNL	ACP	AIP	ANP	VCP
6	VNL	ACP	AIP	ANP	VCP	VIP
7	ACP	AIP	ANP	VCP	VIP	VNP
8	AIP	ANP	VCP	VIP	VNP	ACL
9	ANP	VCP	VIP	VNP	ACL	AIL
10	VCP	VIP	VNP	ACL	AIL	ANL
11	VIP	VNP	ACL	AIL	ANL	VCL
12	VNP	ACL	AIL	ANL	VCL	VIL

Note. AL-auditory-linguistic, AP-auditory perceptual, VL-visual linguistic, VP-visual perceptual

Appendix B

Perceptual visual task

Trial	Modality	Target	Distractor	Stimulus Color/Word	Stroop
1	Visual	Perceptual	Linguistic	Red/Red	Congruent
2	Visual	Perceptual	Linguistic	Yellow/Yellow	Congruent
3	Visual	Perceptual	Linguistic	Green/Red	Incongruent
4	Visual	Perceptual	Linguistic	Red/Yellow	Incongruent
5	Visual	Perceptual	Linguistic	Blue/Red	Incongruent
6	Visual	Perceptual	Linguistic	Red/Blue	Incongruent
7	Visual	Perceptual	Linguistic	Blue/Green	Incongruent
8	Visual	Perceptual	Linguistic	Blue/Yellow	Incongruent
9	Visual	Perceptual	Linguistic	Green/Green	Congruent
10	Visual	Perceptual	Linguistic	Red/Green	Incongruent
11	Visual	Perceptual	Linguistic	Yellow/Blue	Incongruent
12	Visual	Perceptual	Linguistic	Green/Yellow	Incongruent
13	Visual	Perceptual	Linguistic	Yellow/Red	Incongruent
14	Visual	Perceptual	Linguistic	Blue/Blue	Congruent
15	Visual	Perceptual	Linguistic	Green/Blue	Incongruent
16	Visual	Perceptual	Linguistic	Yellow/Green	Incongruent

Appendix C

Computer Stations for Experimental Trials

Note. Visual task represents congruent trial for attend to *color* of word and select button that matches color of the word. Auditory task represents congruent trial for attend to *voice* of speaker and select button that matches the speaker.

Appendix D

Parental Permission Form

My name is Bernadette P. Kuntz and I am a doctoral student in the Speech and Hearing Sciences Program at the Graduate School and University Center, the City University of New York (CUNY). I am also a certified Speech-Language Pathologist. I am conducting a study entitled Selective Attention in Children with Specific Language Impairment: Auditory and Visual Stroop Effects.

The purpose of this project is to investigate how children (8-10 years old) direct their attention while looking at pictures and/or listening to sounds. The experiment will involve up to three sessions, each lasting approximately 45 minutes. Your child is free to take breaks as needed. I will conduct speech/language evaluations of your child. The sessions will be conducted at the City University of New York, Graduate Center, at your home, or a place convenient to you. Sessions will take place after school hours. Your child's participation will contribute greatly to the understanding of attention and language processing.

Your child will be asked to agree to participate. He/she will sit in front of a computer screen with a keypad and will listen to a series of words presented at a comfortable level over headphones and look at words/drawings presented on the computer screen. Your child will be asked to make a decision about the sounds and word/drawings by pressing a button. After making the decision he/she will see feedback presented on the screen.

There are no known or expected risks in this research. The benefit of your child's participation is that he/she will receive a complete speech, language and hearing evaluation. There will be approximately 40 children taking part in this study. Information collected during this project will be presented at professional meetings and will be published. However, your child's name and any other identifying information will not be used in any of the publications or presentations of this study. Data collected from this study will be stored in a locked file cabinet in my office that only my advisor or I will have access.

You and your child are free to withdraw at any time. At the end of each session, your child will be compensated for his/her participation ($5 per session). Upon your request the Speech/Language and Hearing assessment results will be made available to you. Please provide me with your address if you would like a copy of the completed study or assessment results. When necessary, referrals for further language evaluations will be provided. If you have any questions about this research you can contact me at (914)-582-9187, bkuntz@gc.cuny.edu or contact my advisor, Dr. Richard G. Schwartz at (212) 817-8804, rschwartz@gc.cuny.edu. If you have questions about your child's rights as a participant, you can contact Kay Powell, IRB Administrator, The Graduate Center, CUNY, at (212) 817-7525 or kpowell@gc.cuny.edu.

The study described has been explained and I voluntarily consent to my child's participation. I have been informed of the details of the experiment. I understand that I can stop at any time without penalty. I have had the chance to ask questions and they been answered.

Child's Name: ________________Parent/Guardian's Signature_________________Date_________

Investigator's Signature________________________Date_______________

Appendix E

Developmental Language Lab
Child Assent Script

Session 1 (Standardized Testing) –"Today we are going to do lots of different things. We will look at some pictures and I might ask you some questions about the pictures. Some of the questions might be really easy for you and seem silly and others might be a little bit harder. I want you to try to do your best, and if a question is too difficult you can say that you don't know and we'll move to the next question. That's fine. If you need to take a break at any point, let me know and we'll stop. If you don't want to finish, please tell me and we will stop."

Session 2 & 3 (Testing Paradigm) – "Do you remember what we did the last time we met? Well today we will do something a little different. You are going to sit in front of this computer and wear these earphones that are attached to the computer. You will listen to sounds and look at words. Then you will be asked to make decisions about the sounds or the words by pressing keys on the computer. If you need to take a break at any point let me know and we will stop.

The tests are safe and do not hurt. You do not have to do the tests if you don't want to. If you change your mind after the test has started you can tell us and we will stop.

Let's start OK?

Session 1 Child's Name: ____________________ Date: ___________________

Session 2 Child's Name: ____________________ Date: ___________________

Session 3 Child's Name: ____________________ Date: ___________________

Copies to:
Investigator's File

References

American National Standards Institute (1989). *Specifications of audiometers*. (ANSI S3.6-1989). New York: ANSI.

Baddeley, A. D. (1996). Exploring the central executive. *Quarterly Journal of Experimental Psychology, 49A*, 5-28.

Band, G. P. H., van Der Molen, M. W., Overtoom, C. C. E., & Verbaten, M. N. (2000). The ability to activate and inhibit speeded responses: Separate developmental trends. *Journal of Experimental Child Psychology, 75*, 263-290.

Barkley, R. A. (1996). Linkages between attention and executive functions. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, memory, and executive function* (pp. 307-325). Baltimore: Paul H. Brookes.

Berman, S., & Friedman, D. (1995). The development of selective attention as reflected by event-related brain potentials. *Journal of Experimental Child Psychology, 59,* 1-31.

Bishop, D.V.M. (1992). The underlying nature of specific language impairment. *Journal of Child Psychology and Psychiatry, 33,* 3-66.

Bishop, D.V.M., & Norbury, C. F. (2005). Executive functions in children with communication impairments, in relation to autistic symptomatology. *Autism, 9*(1), 29-43.

Bjorklund, D., & Harnishfeger, K. (1995). The evolution of inhibition mechanisms and their role in human cognition and behavior. In F. Dempster & C. Brainerd (Ed.s), *Interference and inhibition in cognition* (pp. 141-173).

Booth, J. R., Burman, D. D., Meyer, J. R., Lei, Z., Trommer, B. L., Davenport, N. D., Li, W., Parrish, T. B., Gitelman, D. R., & Mesulam, M. M. (2003). Neural development of selective attention and response inhibition. *NeuroImage, 20,* 737–751.

Broadbent, D. E. (1958). *Perceptions and communication*. London, Oxford: Pergamon Press.

Brocki, K. C., & Bohlin, G. (2004). Executive function in children age 6-13: a dimensional and developmental study. *Developmental Neuropsychology, 26*(2), 571-593.

Campbell, T., & McNeil, M. (1985). Effects of presentation rate and divided attention on auditory comprehension in children with an acquired language disorder. *Journal of Speech and Hearing Research, 28*(4), 513-520.

Champagne, M., Desautels, M.C., & Joanette, Y. (2004). Lack of inhibition could contribute to non-literal language impairments in right-hemisphere-damaged individuals. *Brain and Language, 91*, 172-174.

Cherry, R. (1981). Development of selective auditory attention skills in children. *Perceptual and Motor Skills*, *52,* 379-385.

Clifton, C., & Bogartz, R. (1968). Selective attention during dichotic listening by preschool children. *Journal of Experimental Child Psychology, 6,* 483-491.

Cohen, A. (2003). *Selective attention: Encyclopedia of cognitive science*. Nature Publishing Group (Macmillan).

Cohen, G., & Martin, M. **(**1975). Hemisphere differences in an auditory Stroop test. *Perception & Psychophysics, 17*, 79-83.

DeBeni, R., Palladino, P., Pazzaglia, F., & Cornoldi, C. (1998). Increases in intrusion errors and working memory deficit of poor comprehenders. *Quarterly Journal of Experimental Psychology*, *51*(A), 305-320.

Dempster, F. (1993). Resistance to interference: Developmental changes in a basic processing mechanism. In M. Howe & R. Pasnak (Eds.), *Emerging themes in cognitive development: vol. 1 Foundations* (pp. 3-27). New York: Springer-Verlag.

Dennis, M., Francis, D. J., Cirino, P. T., Schachar, R., Barnes, M. A. & Fletcher, J. M. (2009). Why IQ is not a covariate in cognitive studies of neurodevelopmental disorders. *Journal of International Neuropsychological Society, 15*(3), 331-343.

Deutsch, A., & Bentin, S. (1994). Attention mechanisms mediate the syntactic priming effect in auditory word identification. *Journal of Experimental Psychology, 20*(3), 595-607.

Deutsch, A., & Bentin, S. (1996). Attention factors mediating syntactic deficiency in reading-disabled children. *Journal of Experimental Child Psychology, 63*, 386-415.

Deutsch, J. A., & Deutsch, D. (1963). Attention: some theoretical considerations. *Psychological Review, 70,* 80-90.

Dollaghan, C., & Cambell T. (1998). Nonword repetition and child language impairment. *Journal of Speech, Language and Hearing Research*, *41*(5), 1136-1146.

Doyle, A. (1973). Listening to distraction: a developmental study of selective auditory attention. *Journal of Experimental Child Psychology, 15*, 100-125.

Edwards, J. & Lahey, M. (1998). Nonword repetitions of children with specific language impairment: Exploration of some explanations for their inaccuracies. *Applied Psycholinguistics*, *19*, 279-309.

Ellis Weismer, S., Evans, J., & Hesketh, L. J. (1999). An examination of verbal working memory capacity in children with specific language impairment. *Journal of Speech, Language, & Hearing Research, 42*, 1249-1260.

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

Finneran, D., Francis, A. L. & Leonard, L, B. (2009). Sustained attention in children with specific language impairment (SLI). *Journal of Speech, Language, and Hearing Research, 52,* 915-929.

Fischler, I. (2000). Attention and language. In R. Parsuraman (Ed). *The Attentive Brain* (pp. 381-399). Cambridge, MA: The MIT Press.

Francis, A. L., Baldwin, K, & Nusbaum, H. C. (2000). Effects of training on attention to acoustic cues. *Perception and Psychophysics, 62*(8), 1668-1680.

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology: General, 133*(1), 101-135.

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

Gerken, L. (1994). Young children's representations of prosodic phonology: Evidence from English-speaker's weak syllable productions. *Journal of Memory and Language, 33,* 19-38.

German, D. (1987). Spontaneous language profiles of children with word-finding problems. *Language, Speech, and Hearing Services in Schools, 18*, 217-230.

German, J. D., & Simon, E. (1991). Analysis of children's word-finding skills in discourse. *Journal of Speech and Hearing Research, 34*, 309-316.

Gernsbacher, M. A. (1990). *Language comprehension as structure building*. Hillsdale, NJ: Erlbaum.

Gilbert, S., & Burgess, P. (2008). Executive function. *Current Biology (18)*3, 110-114.

Gillam, R.B., & Johnston, M.A. (1992). Spoken and written language relationships in language/learning impaired and normally achieving school-age children. *Journal of Speech and Hearing Research, 35,* 1303-1315.

Gleitman, L., & Wanner, E. (1982). The state of the art. In E. Wanner and L. Gleitman (Eds), Language acquisition: The state of the art. Cambridge: Cambridge University Press.

Green, E., & Barber, P. (1981). An auditory Stroop effect with judgments of speaker gender. *Perception and Psychophysics, 30*, 459-466.

Hanson, R. A., & Montgomery, J. W. (2002). Effects of general processing capacity and sustained selective on temporal processing performance of children with specific language impairment. *Applied Psycholinguistics 23,* 75-93.

Helzer, J., Chapman, C. & Gillam, R. (1996). Auditory temporal resolution in specifically language-impaired and age-matched children. *Perceptual and Motor Skills, 83,* 1171-1181.

Hick, R., Botting, N., & Conti-Ramsden, G. (2005). Cognitive abilities in children with specific language impairment: consideration of visuo-spatial skills. *International Journal of Language and Communication Disorders, 40*(2), 137-149.

Hollingshead, A. (1975). *Four factor index of social status*, Unpublished manuscript, Department of Sociology, Yale University, New Haven, CT.

Hugdahl, K., Thomsen, T., Ersland, L., Rimol, L. M. & Niemi, J. (2003). The effects of attention on speech perception: An fMRI study. *Brain and Language. 85,* 37-48.

Im-Bolter, N., Johnson, J., & Pascual-Leone, J. (2006). Processing limitations in children with specific language impairment: the role of executive function. *Child Development. 77*(6), 1822-1841.

Jerger, S., Martin, R.C., & Pirozzolo, F. (1988). A developmental study of the auditory Stroop effect. *Brain Language*, *35*(1), 86-104.

Jerger, S., Stout, g., Albritton, E. Loiselle, L., Blondaru, R., Jorgenson, S. (1993). Auditory Stroop effects in children with hearing impairment. *Journal of Speech and Hearing Research, 36*(5), 1083-96.

Jerger, S., Pearson, D. & Spence, M. (1999). Developmental course of auditory processing interactions: Garner Interference and Simon Interference. *Journal of Experimental Child Psychology*, *74,* 44-67.

Johnston, J., & Ellis Weismer, S. (1983). Mental rotation abilities in language disordered children. *Journal of Speech and Hearing Research, 26,* 397-403.

Johnston, J. (1994). Cognitive abilities of children with language impairment. In R. Watkins & M. Rice (Eds), *Specific language impairments in children* (pp.107-121). Baltimore: Paul H. Brookes.

Johnston, J., & Ramstad, V. (1983). Cognitive development in preadolescent language impaired children. *British Journal of Disorders of Communication, 18,* 49-55.

Johnston, J. R., & Smith, L. B. (1997). Cognition and communication: Referential strategies used by preschoolers with specific language impairment. *Journal of Speech, Language, and Hearing Research, 40*(5), 964-974.

Johnson, J., Im-Bolter, N., & Pascual-Leone, J. (2003). Development of mental attention in gifted and mainstream children: The role of mental capacity, inhibition, and speed of processing. *Child Development, 74*(6), 1594-1614.

Jusczyk, P. (1997). *The discovery of spoken language*. Cambridge, MA: MIT.

Jusczyk, P. Bertonicini, J., Bijeljac-Babi, R., Kennedy, L. & Mehler, J. (1990). The role of attention in speech perception by infants. *Cognitive Development*, *5*, 265-286.

Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice Hall.

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

Kingma, A., La Heij, W., Fasotti, L., & Eling, P. (1996). Stroop interference and disorders of selective attention. *Neuropsycholgia*, *34*(4), 273-81.

Kuhl, P. (1979). Speech perception in early infancy: Perceptual constancy for spectrally dissimilar vowel categories. *Journal of the Acoustical Society of America*, *66*, 1668-1679.

Lahey, M., Edwards, J., & Munson, B. (2001). Is processing speed related to severity of language impairment? *Journal of Speech, Language, and Hearing Research, 44*, 1354-61.

Leonard, L. (1998). *Children with specific language impairment*. Cambridge, MA: The MIT Press.

Lew, Chimel, Jerger, Pomerantz, & Jerger, 1997. Electrophysiologic indices of Stroop and Garner interference reveal linguistic influences on auditory and visual processing. *Journal of American Academy of Audiology*, *8*(2), 104-118

Lewis, M., & Baldini, N. (1979). Attentional processes and individual differences. In A.H. Gordon & M. Lewis (Eds.), Attention and cognitive development, New York: Plenum Press, 135-172.

Locke, J. L. (1997). A theory of neurolinguistic development. *Brain and Language*. *58*(2), 265-326.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109,* 163-203.

McGregor, K., & Leonard, L. (1995). Intervention for word-finding deficits in children. In M. Fey, J. Windsor, & S. Warren (Eds.), *Language intervention: Preschool through the elementary years* (pp. 85-105). Baltimore: Paul H. Brookes.

Melera, R.D., & Algom, D. (2003). Driven by information: A tectonic theory of Stroop Effects. *Psychological Review, 110*(3), 422-471.

Miller, E. K. (2000). The prefrontal cortex and cognitive control. *Nature Reviews Neuroscience, 1*, 59-65

Miller, C. A., Kail, R., Leonard, L. B., & Tomblin, J. B. (2001). Speed of processing in children with specific language impairment. *Journal of Speech, Language and Hearing Research. 44*(2), 416-33.

Montgomery, J. W. (2002a). Examining the nature of lexical processing in children with specific language impairment: a temporal processing or processing capacity deficit? *Applied Psycholinguistics, 23*, 447-470.

Montgomery, J.W. (2004). Sentence comprehension in children with specific language impairment: effects of input rate and phonological working memory. *International Journal of Language and Communication Disorders, 39*(1), 115-133.

Montgomery, J. W. (2005). Effects of input rate and age on the real-time language processing of children with specific language impairment. *International Journal of Language and Communication Disorders, 40*(2), 171-88.

Nestor, P. G., & O’Donnell, B. F. (1998). The mind adrift: Attentional dysregulation in schizophrenia. In R. Parasuramen (Ed.), *The Attentive Brain*, 527-546. Cambirdge, MA: MIT Press.

Niemi, J., Gunderson, H., Leppasaari, T., & Hugdahl, K. (2003). Speech lateralization and attention/executive functions in a Finnish family with specific language impairment (SLI). *Journal of Clinical and Experimental Neuropsychology, 25*(4), 457-464.

Nippold, M., & Fey, S. (1983). Metaphoric understanding in preadolescents having a history of language acquisition difficulties. *Language, Speech, and Hearing Sciences in Schools, 14,* 171-180.

Nittrouer, S., & Crowther, C. S. (1998). Examining the role of auditory sensitivity in the developmental weighting shift. *Journal of Speech, Language & Hearing Research, 41,* 809-818.

Norman, D. A., & Bobrow, D. G. (1975). On date-limited and resource limited processes. *Cognitive Psychology, 7,* 44-64.

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and self regulation: Advances in Research and Theory, 4,* 1-18. New York: Plenum Press.

Noterdaeme, M., Amorosa, H., Mildenberger, K., Sitter, S., Minow, F. (2000). Evaluation of attention in children with autism and children with a specific language disorder. *European Journal of Child Psychology, 10*, 58-66.

Norbury, C.F. (2005). Barking up the wrong tree? Lexical ambiguity resolution in children with language impairments and autistic spectrum disorders. *Journal of Experimental Child Psychology. 90*, 142-171.

Oetting, J.B., & Horohov, J.E. (1997). Past-tense marking by children with and without specific language impairment. *Journal of Speech, Language, and Hearing Research, 40*, 62-74.

Parasuraman, R. (2000). The attentive brain: Issues and prospects. In R. Parasuraman (Ed). *The Attentive brain* (pp. 3-15). Cambridge, MA: The MIT Press.

Pardo, J. V., Pardo, P.J., Janer, K. W., & Raichle, M. E. (1990). The anterior cingulate cortex mediates processing selection in the Stroop attentional conflict paradigm. *Proceedings of the National Academy of Sciences, 87*, 256-259.

Peelle, J. E., McMillan, C., Moore, P., Grossman, M., & Wingfield, A. (2004). Dissociable patterns of brain activity during comprehension of rapid and syntactically complex speech: Evidence from fMRI. *Brain and Language, 91*, 315-325.

Peterson, S. E., Fox, P. T., Posner, M., Mintun, M., & Raichle, M .E. (1989). Positron emission tomographic studies of the processing of single words. *Journal of Cognitive Neuroscience, 1*, 153-170.

Peterson, S. E., Fox, P. T., Snyder, A., & Raichle, M. E. (1990). Activation of extrastriate and frontal cortical activity by words and word-like stimuli. *Science, 249*, 1041-1044.

Posner, M. (1990). Hierarchical distributed networks in the neuropsychology of selective attention. In Carramaza (Ed.), *Cognitive neuropsychology and neurolinguistics: Advances in models of cognitive function and impairment.* New York: Plenum (pp. 187-210)

Rapin, I., & Wilson, B. (1978). Children with developmental learning disability: Neurological aspects and assessment. In M. Wyke (Ed.), *Developmental dysphasia* (pp. 13-41). London: Academic Press.

Ridderinkhof, K., van der Molen, M., Band, G. & Bashore, T. (1997). Sources of interference from irrelevant information: A developmental study. *Journal of Experimental child psychology, 65*, 315-341.

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

Robin, D. A., Tomblin, J. B., Kearney, A., & Hug, L. H. (1989). Auditory temporal pattern learning in children with speech and language impairments. *Brain and Language*, *36,* 604-613.

Robin, D., & Rizzo, M. (1992). Orienting in audition and between audition and vision in: young and elderly subjects. *Journal of Speech and Hearing Research, 35,*701-707.

Savitz, P., Jansen, J.B. (2003). The Stroop color—Word Interference Test as an indicator of ADHD in poor readers. *Journal of Genetic Psychology, 164*, 319-334.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime Reference Guide*. Pittsburgh: Psychology Software Tools Inc.

Semal, E., Wiig, E., & Secord, W. A., (2003). *Clinical Evaluation of Language Fundamentals-4*. San Antonio, TX: The Psychological Corporation, a Harcourt Assessment Company.

Shafer, V. L., Ponton, C., Datta, H., Morr, M. L., & Schwartz, R. G. (2007). Neurophysiological indices of attention to speech in children with SLI. *Clinical Neurophysiology, 118* (6), 1230-1243.

Shaywitz, B. A., Shaywitz, S. E., Pugh, K. R., Fulbright, R. K., Skudlarski, P., Menci, W. E., Constable, R. T., Marchione, K. E., Fletcher, J. M., Klorman, R., Lacadie, C., & Gore, J. C. (2001). The functional neural architecture of components of attention in language-processing tasks. *Neuroimage, 13*, 601-612.

Slobin, D. (1973). Cognitive prerequisites for the development of grammar. In C. Ferguson & D. Slobin (Eds.), *Studies of child language development* (pp. 1157-1249). Hillsdale, NJ: Lawrence Erlbaum.

Spaulding, T.J., Plante, E. & Vance, R. (2008). Sustained selective attention skills of preschool children with specific language impairment: Evidence for separate attentional capacities, *Journal of Speech, Language, and Hearing Research, 51*, 16-34.

SPSS Inc. (2009). *SPSS Base 18.0 for Windows User's Guide*. SPSS Inc., Chicago IL.

Stark, R., & Montgomery, J. (1995). Sentence processing in language-impaired children under conditions of filtering and time compression. *Applied Psycholinguistics, 16*, 137-154.

Stevens, C., Sanders, L. and Neville, H. (2006). Neurophysiological evidence for selective auditory attention deficits in children with specific language impairment. *Brain Research, 111*, 143-152.

Stevens, C., Fanning, J., Coch, D., Sanders, L., & Neville, H. (2008). Neural mechanisms of selective auditory attention are enhanced by computerized training: Electrophysiological evidence from language-impaired and typically developing children. *Brain Research, 1205*, 55-69.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643-662.

Stuss, D. T., Floden, D., Alexander, M. P., Levine, B., & Katz, D. (2001). Stroop performance in focal lesion patients: dissociation of processes and frontal lobe lesion location. *Neuropsycholgia, 39*(8), 771-786.

Swisher, L., Restrepo, M. A., Plante, E., & Lowell, S. (1995). Effect of implicit and explicit “rule” presentation on bound-morpheme generalization in specific language impairment. *Journal of Speech and Hearing Research, 38,* 168-173

Swisher, L., & Snow, D. (1994). Learning and generalization components of morphological acquisition by children with specific language impairment: Is there a functional relation? *Journal of Speech and Hearing Research, 37*, 1406-1413

Tallal, P. (1990). Fine-grained discrimination deficits in language-learning impaired children are specific neither to the auditory modality nor to speech perception. *Journal of Speech and Hearing Research. 33*(3), 616-619.

Tallal, P. (1980). Auditory temporal perception, phonics, and reading abilities in children. *Brain and Language, 9,* 182-198

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

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

Tallal, P., & Piercy, M. (1975). Developmental aphasia: The perception of brief vowels and extended stop consonants. *Neuropsychologia. 13*, 69-74.

Tallal, P., & Stark, R. (1981). Speech and acoustic-cue discrimination abilities of normal developing and language impaired children. *Journal of the Acoustical Society of America. 66*, 1364-1380.

Torro, J.M., Sinnett, S., & Soto-Faraco, S. (2005). Speech segmentation by statistical learning depends on attention. *Cognition. 97*, 25-34.

Treisman, A. (1960). Contextual cues in selective listening. *Quarterly Journal of Experimental Psychology, 12,* 242-238.

Windsor, J., & Hwang, M. (1999). Testing the generalized slowing hypothesis in specific language impairment. *Journal of Speech, Language, and Hearing Research. 42*, 1205–1218.

Wolfe, C. D, & Bell, M. A. (2003). Working memory and inhibitory control in early childhood: Contributions from physiology, temperament and language. *Developmental Psychobiology 44*, 68–83.

Wright, B. C., & Wanley, A. (2003). Adults' versus children's performance on the Stroop task: interference and facilitation. *British Journal of Psychology, 94*(4), 475-485.

Ziegler, J. C., Pech-Georgrel, C., George, F., Alario, F. X., & Lorenzi, C. (2005). Deficits in speech perception predict language learning impairment. *Proceedings of the National Academy of Science*, *102*(39), 14110-14115.

Weiner, P. (1974). A language-delayed child at adolescence. *Journal of Speech and Hearing Disorders, 39*, 202-212.