# Sustained Attention in Children With Specific Language Impairment (SLI)

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**Purpose:** Information-processing limitations have been associated with language problems in children with specific language impairment (SLI). These processing limitations may be associated with limitations in attentional capacity, even in the absence of clinically significant attention deficits. In this study, the authors examined the performance of 4- to 6-year-old children with SLI and their typically developing (TD) peers on a visual sustained attention task. It was predicted that the children with SLI would demonstrate lower levels of performance in the absence of clinically significant attention deficits.
**Method:** A visual continuous performance task (CPT) was used to assess sustained attention in 13 children with SLI ($M = 62.07$ months) and 13 TD age-matched controls ($M = 62.92$ months). All children were screened for normal vision, hearing, and attention. Accuracy ($d'$) and response time were analyzed to see if this sustained attention task could differentiate between the 2 groups.
**Results:** The children with SLI were significantly less accurate but not significantly slower than the TD children on this test of visual sustained attention.
**Conclusion:** Children with SLI may have reduced capacity for sustained attention in the absence of clinically significant attention deficits that, over time, could contribute to language learning difficulties.

**KEY WORDS: specific language impairment (SLI), attention, information processing**

Children with specific language impairment (SLI) demonstrate marked language difficulties in the absence of typically associated factors such as hearing loss, neurological damage, or mental retardation (Leonard, 1998). Although these children have normal nonverbal IQ scores, researchers have found robust evidence of information processing deficits that may be attributed to limited working memory capacity (Bavin, Wilson, Maruff, & Sleeman, 2005; Ellis Weismer et al., 2000; Gillam, Cowan, & Marler, 1998; Hoffman & Gillam, 2004; Montgomery, 1995, 2000, 2003). In fact, Leonard et al. (2007) reported that the verbal working memory deficits exhibited by children with SLI accounted for a significant amount of the variance in composite language test scores.

In the investigation of working memory in the larger population, a number of models (e.g., Baddeley, 2001, 2003; Cowan, 1999, 2001, 2005) have identified attention as playing an important role in information processing. Attention is generally viewed as a limited-capacity system (e.g., Kahneman, 1973; Lavie, 2005; Lavie, Hirst, De Fockert, & Viding, 2004) composed of a number of different mechanisms including (but not exclusive to) sustained, selective, and divided attention (Leclercq, 2002). As attention is considered to be a limited-capacity system, so are the mechanisms that are associated with attentional control in these models (e.g., the central executive [Baddeley, 2003], the focus of attention

[Cowan, 2005]). It has been proposed that individual variations in working memory are associated with variations in attentional abilities (Engle, Tuholski, Laughlin, & Conway, 1999; Kane, Bleckley, Conway, & Engle, 2001; see Cowan et al., 2005, and Engle, 2002, for reviews) and that factors that limit attentional capacity would impair performance on working memory tasks (see Baddeley, 2001, for a discussion).

Given that attention is considered to be a system that is deeply involved in information processing, and working memory is critical to language learning (Baddeley, 2003), it is not surprising, then, that attention is considered to play an important role in language processing (e.g., Conner, Albert, Helm-Estabrooks, & Obler, 2000; Posner, 1995). In the adult literature, for example, this relationship between attention and language learning has been demonstrated for natural languages (e.g., Guion & Pederson, 2007) as well as artificial languages (e.g., Toro, Sinnett, & Soto-Faraco, 2005).

In the literature on child development, the relationship between attention and language is usually addressed by examining the comorbidity of language impairments and attention deficits. There is robust evidence to suggest that children with language impairments have a higher incidence of attention deficits (e.g., Willinger et al., 2003), and children with clinical attention deficits have a higher incidence of language impairments (see Tannock & Schachar, 1996, for a review) than their peers. Some have proposed that clinical attention deficits and developmental language impairments are both a result of an underlying neurodevelopmental deficit, whereas others have proposed that deficits in one area may contribute to deficits in the other (see Redmond, 2005, for a review).

In light of the evidence for comorbidity of attention deficits and developmental language impairments, it is not surprising that researchers have begun to specifically relate attentional limitations to the language difficulties seen in SLI. For example, Helzer, Champlin, and Gillam (1996) suggested that the extra number of trials required by children with SLI to reach criterion on a test measuring auditory thresholds may have been due to difficulty sustaining attention to the stimuli. Similarly, Stark and Montgomery (1995) reported that children with language impairment (LI) demonstrated more behaviors associated with poor attention (e.g., playing with the headphones) than did typically developing (TD) children. The authors suggested that the reduced attention demonstrated by the LI group may have contributed to these children's difficulty in monitoring for words in sentences. Subsequently, Montgomery (2005, 2006) associated real-time language processing in children with SLI with their ability to allocate required attentional resources. This association was also made by Campbell and McNeil (1985) in a study of language processing in children with acquired language impairment.

More explicit support for a possible relationship between SLI and deficits in basic attentional capacities may be found in a study by Im-Bolter, Johnson, and Pascual-Leone (2006). This study examined information processing and the role of executive function (i.e., the control of focused attention) in children with SLI as compared with age-matched TD peers. The authors reported significant group differences in attentional capacity, response inhibition, and working memory updating (an attentionally demanding process) as well as on visual and verbal processing tasks. The authors concluded that executive control of attention during information processing is an important factor in the relationship between information processing and language ability in SLI.

Finally, the proposed relationship between basic attentional processes and SLI is supported by the findings of Ellis Weismer, Plante, Jones, and Tomblin (2005). In this functional imaging study comparing children with SLI and TD peers performing linguistic tasks, children with SLI exhibited hypoactivation of parietal cortex, a brain region implicated in a variety of attentional processes, including sustained (Pardo, Fox, & Raichle, 1991), selective (Posner, 1990; Posner & Dehaene, 1994; Shaywitz et al., 2001), and divided attention (Shaywitz et al., 2001). This neuroanatomical evidence provides additional support for the hypothesis that a variety of attentional mechanisms may play a role in SLI, but this evidence does not clearly identify the contributions of specific types of attentional processes.

The current study specifically investigates sustained attention in children with SLI. *Sustained attention* has been described as the ability to continuously attend to input so that information in the input can be processed (Leclercq, 2002). It may be argued that sustained attention plays an important role in language acquisition, as children must sustain attention to the speech input, attending to relevant information and ignoring irrelevant information, in order to accurately perceive and correctly interpret the incoming linguistic information (see Montgomery, 2005, for a discussion of attentional mechanisms in sentence processing).

Given the role of sustained attention in information processing, it follows that there has been some recent attention given to sustained attention in children with SLI. In one study, Spaulding, Plante, and Vance (2008) investigated sustained selective attention in children with SLI and no diagnosis of attention-deficit disorder as compared with TD age-matched peers. In this study, the children were required to monitor (sustain attention to) a series of auditory or visual stimuli and press a response button when they saw a predetermined target (i.e., select the target from among the distractors, or nontargets). The auditory stimuli were either linguistic (words) or nonlinguistic (familiar sounds; e.g., keys rattling). The visual stimuli involved an airplane executing a series of flying maneuvers. The stimuli were presented in a standard condition and in a degraded condition (with added white noise, either visual or auditory). Both accuracy and response time (RT) for correct responses were measured. The authors reported significant group differences in accuracy in the degraded condition for the auditory stimuli such that the children with SLI performed less accurately than the age-matched control group. This finding was taken to suggest that children with SLI may have difficulties with sustained selective attention for auditory information. Spaulding et al. (2008) reported that there were no significant group differences in RT for either the auditory or visual stimuli.

The current study examines visual sustained attention. The study was designed based on another recent study of visual sustained attention in children with normal language development. In this study, Rose, Murphy, Schickedantz, and Tucci (2001) investigated visual sustained attention in 7- and 8-year old children with normal language and no evidence of clinical attentional deficits. The children completed a 14-min continuous performance task (CPT) in which they were instructed to push a button on a response box as soon as a small square appeared on a computer screen but not to push the button when a large square appeared. Rose et al. reported that the children demonstrated the quickest RTs and highest accuracy when the stimuli were presented at a fast rate (90 events per 2-min epoch) rather than at a slow rate (20 events per 2-min epoch). The children also demonstrated a decrement in sustained attention in terms of speed and accuracy over time.

In the present study, children between 4 and 6 years of age with SLI and TD age-matched peers completed a visual CPT similar to that used by Rose et al. (2001). In this task, the children monitored for targets among a series of distractors over a 5-min period in both fast and slow presentation rate conditions.

As in the Rose et al. (2001) study, the stimuli for the current study were visual and nonlinguistic. Although Spaulding et al. (2008) did not find a group difference on the visual sustained selective attention task in their study, their findings need not necessarily predict the results of the current study. This is because the two studies used very different tasks. The task employed by Spaulding et al. involved watching an airplane executing a series of flying maneuvers; the children were instructed to press the response button when the plane executed a particular maneuver (e.g., flipping). In the current study, as in the Rose et al. (2001) study, the stimuli were static red circles and squares; the children were instructed to press the response button when a circle appeared. Given that different tasks may impose different demands on information processing, and given that maintaining attention to dull tasks is more difficult than to more interesting ones, we expected the present task, using static balls and boxes, to impose greater demands on sustained attention than did monitoring the movements of an airplane in the Spaulding et al. study. Thus, it was predicted that the use of a simpler visual (and, therefore, more demanding) sustained attention task in the present study would more clearly distinguish children with SLI from their TD peers (see Corkum & Siegel, 1993, for a discussion on factors that impact performance on CPT tasks).

Visual rather than auditory stimuli were used so that performance on the sustained attention task would not be confounded with differences in auditory processing capabilities that are known to distinguish children with SLI from TD peers (Tallal & Piercy, 1973; Tallal, Stark, Kallman, & Mellits, 1981; Wible, Nicol, & Kraus, 2005). Nonlinguistic stimuli were used in this study under the assumption that the predicted attentional limitations are domain general rather than specific to linguistic input. This assumption was made based on the findings that information processing limitations in SLI are not exclusive to language processing tasks (e.g., word monitoring; Montgomery, 2000) but are also seen on tasks that involve information with minimal linguistic content (e.g., mental rotation [Johnston & Ellis Weismer, 1983]; arithmetic, pattern matching, and form completion [Windsor, Kohnert, Loxtercamp, & Kan, 2008]).

Three predictions were made at the start of the current study based on the findings of Rose et al. (2001) and current knowledge about SLI. The first two predictions pertain to language status: (a) The children with SLI would demonstrate poorer sustained attention when compared with the control group in terms of both accuracy and RT and (b) both groups would demonstrate a drop in performance over time, but the children with SLI would exhibit a greater decrement. These predicted group differences would lend further support to the growing body of evidence of attentional limitations in children with SLI who do not exhibit behaviors associated with clinically significant attention deficits. More specifically, the predicted group differences would indicate that children with SLI may have particular difficulty sustaining attention to the input, even for input with minimal nonlinguistic information. This finding, in combination with the findings of Spaulding et al. (2008), would suggest that children with SLI have limitations in sustained (and possibly selective) attention that may hinder their ability to process incoming information in different modalities. This, in turn, would be consistent with the notion of general processing limitations in SLI.

The final prediction pertains to the effect of event rate on performance. It was not clear whether the younger children in the current study would perform similarly to the older children in the Rose et al. study, so event rate was manipulated to determine which event rate would best facilitate performance. It was predicted that sustained attention would be best with the faster rate of stimulus presentation for all children.

# Method

## *Participants*

Twenty-six children participated in the current study, 13 with SLI (7 girls, 6 boys) and 13 with TD language skills (6 girls, 7 boys). Ten other children were recruited but did not complete the study. The 10 children who did not complete the study included 4 with SLI who were discontinued because they did not complete one of the testing sessions and 4 with SLI who were discontinued because they did not pass the attention screener (see the *Assessment* section). One TD child was discontinued because he did not appear to comprehend the task, and 1 TD child was discontinued due to low scores on a later language test. (A brief description of the children who did not complete the task is presented in the *Administration* section.) All children were of European descent and were living in monolingual English-speaking homes in Lafayette, Indiana, or in the surrounding area.

The 26 children included in this study were participating in a variety of other research experiments in the Child Language Development Laboratory at Purdue University at the time of this study. The 13 children with SLI were enrolled in a summer research program that provided speech therapy and a language-based classroom. The 13 children in the TD group were recruited separately, and their parents were reimbursed monetarily upon completion of the study. All children were given a "prize" of a small toy or book at the completion of each session.

*Subject matching.* The children who qualified as TD were selected to be an age match for a child with SLI if their chronological age fell within 2 months of the chronological age of a child in the SLI group. As a result, for each of the 13 children with SLI, there was an age-matched child in the TD group, and the two groups had comparable age distributions (SLI: $M$ = 62.07 months, range = 53–82 months; TD: $M$ = 62.92 months, range = 54–83 months).

*Assessment.* All children selected for this study participated in a speech and language assessment. To participate in the study, all children had to meet a series of requirements. All children had to pass a hearing screening at 25 dB (HL) for each ear at 500, 1000, 2000, and 4000 Hz and had to demonstrate adequate oral structure and function for speech (Robbins & Klee, 1987). Furthermore, all children had to demonstrate age-appropriate performance (age deviation scores [ADS] of 85 or above) on a test of nonverbal intelligence (Columbia Mental Maturity Scale [CMMS]; Burgemeister, Blum, & Lorge, 1972). It should be noted that although all standard scores fell at or above the cutoff (85), the mean ADS score for the children in the SLI group ($M$ = 108, $SD$ = 13, range = 85–135) was significantly lower than that for the children in the TD group ($M$ = 120, $SD$ = 11, range = 106–140), $t(24) = 2.46$, $p = .02$. The children who participated in the study all had a negative history of neurological impairment based on parent report and examiner observations.

In order to qualify as a participant in the SLI group, children had to score below the 10th percentile on the Structured Photographic Expressive Language Test–II (SPELT-II; Werner & Kresheck, 1983), a test of expressive morphology and syntax. To qualify as a participant in the TD group, the children had to score above the 10th percentile on this same test (all children in the TD group scored between the 21st and 100th percentile).

A measure of finite verb morphology known as *finite verb morphology composite* (FVMC; Leonard, Miller, & Gerber, 1999) was administered to assess expressive morphology in conversation. To qualify as a participant in the TD group, the children had to demonstrate age-appropriate expressive morphology skills on this measure (the children in the TD group achieved a mean score of 97%). Although this measure was not used to determine inclusion for the SLI group, the children with SLI demonstrated reduced performance on this measure ($M$ = 68%) as compared with the children in the TD group.

*Connors' ADHD/DSM-IV Scales–Parent (CADS-P).* The CADS-P (Conners, 1997) was completed by participants' parents in order to screen for problems with attention and/or hyperactivity. Participants for both the SLI and TD groups were included only if their standardized scores (called $T$-scores) for the Attention-Deficit/Hyperactivity Disorder (ADHD) Index and *Diagnostic and Statistical Manual of Mental Disorders–IV* (*DSM-IV*) Total measures fell within the typical range ($T$-score at or below 65, as recommended by the author). As noted earlier, 4 of the 10 children who did not complete the study had met all other qualifications for inclusion in the SLI group but were disqualified from further participation as a result of these criteria (and were therefore not included in the group of 26 children participating in the study). The $T$-scores for the 26 children in the SLI and TD groups did not differ significantly on the ADHD Index, $t(23) = 0.10$, $p = .92$, nor did they differ significantly on the DSM-IV Total measure, $t(23) = 0.89$, $p = .38$ (see Table 1 for a summary of assessment scores).

**Table 1.** Group means (and range) on diagnostic assessment tools.

| Group | Age (in months) | Gender | MLU (words) | SPELT-II | FVMC | CMMS | CADS-P | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | ADHD Index | DSM-IV Total |
| SLI | 62.07 (53–82) | 6M/7F | 4.25 (3.52–4.91) | 2 (1–9) | 68 (14–93) | 108 (85–135) | 48 (40–59) | 48 (41–60) |
| TD | 62.92 (54–83) | 7M/6F | 4.94 (4.07–7.06) | 64 (21–100) | 97 (95–100) | 120 (106–140) | 48 (40–59) | 50 (42–58) |

*Note.* MLU = mean length of utterance in number of words; SPELT-II = score on the Structured Photographic Expressive Language Test–II test of expressive morphology and syntax (see text) in terms of percentile rank; FVMC = score on the Finite Verb Morphology Composite test in terms of percentage of use in obligatory contexts; CMMS = score on the Columbia Mental Maturity Scale, a test of nonverbal intelligence (see text), in terms of age deviation score; CADS-P = Connors' ADHD/DSM-IV Scales–Parent; ADHD Index = ADHD Index subscale of the CADS-P test of attention (see text) in terms of *T*-score; DSM-IV Total = DSM-IV subscale of the CADS-P test of attention (see text) in terms of *T*-score; SLI = children with specific language impairment; TD = children with typical language development; M = male; F = female. Values are given in means; numbers in parentheses are group ranges.

## Procedure

The 26 participants (13 SLI, 13 TD) were tested on a CPT based on that of Rose et al. (2001). Where Rose and colleagues used a 14-min CPT with 7- and 8-year-old TD children, the current study used a CPT of abbreviated length (5 min), as the population tested was younger than that of Rose et al. (2001). A duration of 5 min was adopted, as there is evidence that TD children are able to complete a visual CPT of approximately 5 min in length by the age of 4;6 (years;months; Levy, 1980), which is comparable to the age range for the present study.

The CPT was run using the program E-Prime Version 1.1 (Schneider, Eschman, & Zuccolotto, 2002), which provides accurate millisecond timing by means of a separate response box. In the CPT, participants monitored for target stimuli (in this case, the appearance of a red circle, or "ball") while ignoring distractor stimuli (the appearance of a red square, or "box"). The visual stimuli (circle, square) were created in Microsoft PowerPoint with the dimensions 1.25″ × 1.25″. These stimuli were presented in the center of a white background covering the entire screen of a Dell computer monitor (9″ × 12″). The children sat approximately 15″ from the screen and were seated at a level such that the screen was at eye level or slightly below. However, the distance and relationship of the child to the screen varied, as some of the children moved around in their chairs while completing the task.

*Event rate.* The task consisted of two conditions based on rate of stimulus presentation: a fast event rate and a slow event rate condition. These two rate conditions were used in order to determine whether the fast or slow event rate would better facilitate performance. Rose et al. (2001) had tested both a fast and slow event rate with 7- and 8-year-old TD children and reported that performance was best in the fast rate condition. It was, however, unclear whether the fast event rate would best facilitate performance for the younger, language-impaired children participating in the present study.

In both event rate conditions, targets (balls) and distractors (boxes) were presented sequentially and appeared on the screen for 400 ms. The fast condition was conducted in a single 5-min session. Stimuli appeared at a rate of 40 tokens per minute with an interstimulus interval (ISI) of 1,100 ms. There were 16 targets and 24 distractors presented in random order each minute, so that 40% of all stimulus presentations were targets. A total of 200 stimuli were presented in the 5-min period (40 stimuli per minute × 5 min) with a total of 80 targets (16 targets × 5 min) and 120 distractors (24 distractors × 5 min).

Stimuli in the slow condition appeared at a rate of 10 tokens per minute; as a result, the ISI in the slow condition (5,600 ms) was greater than that in the fast condition (1,100 ms). As in the fast condition, 40% of the presentations were targets (4 targets, 6 distractors) in each minute. Therefore, in 5 min of the slow condition, there were a total of 20 targets (4 targets × 5 min) and 30 distractors (6 distractors × 5 min).

In order to facilitate analysis of performance across the rates of presentation, the slow condition was repeated over four 5-min sessions on separate days; as a result, in the slow condition there was the same total number of targets (4 sessions × 20 targets per session = 80) and distractors (4 sessions × 30 distractors per session = 120) as in the fast condition. This also allowed comparison of performance over the course of a 5-min session because there were as many target presentations in the first 1-min epoch of the fast condition session as there were cumulatively in the first 1-min epoch of each of the four slow sessions.

Each 5-min testing session (one fast, four slow) was conducted on a different day in order to lessen the impact of repeated presentations on performance. All participants completed the fast event rate condition on the first day of testing and the four slow sessions on the four subsequent sessions for a total of five testing sessions. The testing sessions were ordered in this way to allow for a more stringent test of the prediction regarding the effect of rate. Based on the findings of Rose et al. (2001), it was originally predicted that all children would perform better in the fast event rate condition than in the slow event rate condition. By presenting the fast event rate condition on Day 1 and the slow event rate condition on Days 2–5, any improvement that resulted from repeated administrations would impact performance on the slow rate condition. Given that the slow event rate is the condition in which all children were predicted to perform the worst, this ordering ensures a more stringent test of the rate prediction.

*Administration.* For each session, the child was seated in a chair in front of a computer monitor, with the examiner sitting on the right side of the child and no other people in the room. The child was presented with a color photograph of a puppy on the monitor. They were told that the puppy liked only balls because they were fun to play with but did not like boxes. The children were instructed to push a button on a response box (Cedrus, Model RB-620; Cedrus Corp., San Pedro, CA) as soon as they saw the target (ball) but not to push the button when they saw the distractor (box). Both speed and accuracy were emphasized in the instructions. The children were told to continue with the task until the puppy returned to the screen.

On the first day of testing, the children were shown a drawing of a red circle (ball) and a red square (box) on pieces of paper prior to starting the task. They were asked to point to each as they were named. All children were able to identify the ball and the box correctly. Following this, two series of familiarization trials were completed in order to introduce the task to the child. No data were collected during familiarization, as the purpose was simply to allow the children to become familiar with the experimental task. The first set of familiarization trials were completed on the first day only. In these trials, the children were presented with a randomized sequence of four balls and four boxes, each of which were presented for up to 400 ms. A button push within this time resulted in immediate visual feedback (happy face for a target, sad face for a distractor). If no button was pushed during the stimulus presentation, visual feedback was presented at the end of the 400 ms (happy face for a distractor, sad face for a target). The clinician clicked the mouse to present the next stimulus and provided verbal feedback (e.g., "Good. You caught a ball for the puppy," "That's a box. The puppy does not want boxes.").

The children then completed a second series of familiarization trials in order to practice the task without visual feedback. This 1-min session was presented after the first familiarization trials and then also at the beginning of each subsequent testing day in order to help the child recall the task. In this second set of familiarization trials, children were presented with 8 balls and 12 boxes (67% targets) sequentially in randomized order (presentation time = 400 ms; ISI = 2,600 ms). This task employed a higher target probability than the experimental task in order to ensure optimal performance, as higher probabilities are associated with better signal detection and RT. A rate of 20 events per minute was selected for the 1-min familiarization task, as it fell between the high and low rates during testing and it was not clear which rate would facilitate the best performance with this population. The children were encouraged to complete the task independently and did not receive any visual feedback. Verbal feedback was provided as needed in order to encourage participation (e.g., "You are doing a good job"), to redirect (e.g., "Watch"), or to train (e.g., "Push the button only when you see a ball").

The children completed testing immediately following the 1-min familiarization task for each experimental session. At the start of testing, the children were reminded of the instructions and were told to continue until the puppy reappeared on the screen. All children were praised for their participation and, as mentioned earlier, received a small prize (e.g., ball, Play-Doh, book) at the end of each testing session.

Following the terminology used in signal detection theory, the term *hits* is used to refer to the correct responses to stimulus-present trials (targets), and the term *false alarms* is used to refer to incorrect responses to stimulus-absent trials (distractors). For each experimental task, the numbers of hits and false alarms were recorded, as was the RT for hits. Accuracy, calculated using the signal detection theoretic statistic $d'$, was determined from the hit and false alarm rates (Macmillan & Creelman, 2005).

During the testing trials, the examiner provided verbal or visual feedback when needed to encourage participation and task completion. Prior to administration of the task, it was specified that the following feedback could be used if needed: instructions (provided when the child appeared not to understand the task; e.g., "Push the button only when you see the ball"), redirection (provided when the child appeared to be engaged in another activity and was thus distracted away from the task; e.g., playing with hands), and encouragement to continue the task (provided when the child appeared restless or increasingly distracted from the task; e.g., "You are finding lots of balls for the puppy," "Almost done"). The testing sessions were video recorded (with the exception of one session due to an equipment malfunction) for later analysis of the examiner feedback.

Of the 10 children who did not complete the study (see *Participants* section), 5 had demonstrated difficulty on the first day (the fast event rate condition) despite redirection and encouragement. These children were therefore discontinued from the study and are not included in the total sample size of 26 participants. These 5 children had met the criteria for either the SLI group (4) or TD group (1) and had passed the CADS-P. One of the 5 children (SLI) exhibited noncompliant behaviors (i.e., he pushed the button repeatedly and announced that he was going to "catch" the boxes instead of the balls). The other 4 children (3 SLI and the 1 TD) demonstrated confusion and/or frustration with the task: One child (SLI) stopped participating (i.e., he stopped attending to the screen and pushing the response button) and stated that he did not want to participate any longer; three children (2 SLI, 1 TD) appeared to be confused by the task and sporadically engaged in other activities, although they never expressed a desire to stop the task. The data for these 5 children were judged to be missing or unusable for the fast event rate condition, and the children were therefore dropped from the study. All children received a "prize" and positive feedback regardless of their ability to complete the task. All 5 children continued to participate in other research projects.

## Results

Because the two language groups (SLI, TD) differed in terms of nonverbal IQ scores, the accuracy data set and RT data set were first analyzed with IQ as a covariate in two separate analyses of covariance (ANCOVAs) in order to determine whether IQ, rather than language status, might better predict performance on the sustained attention task for each data set. The data sets were then analyzed in analyses of variance (ANOVAs) without IQ as a covariate. An alpha level of .05 was used in all analyses.

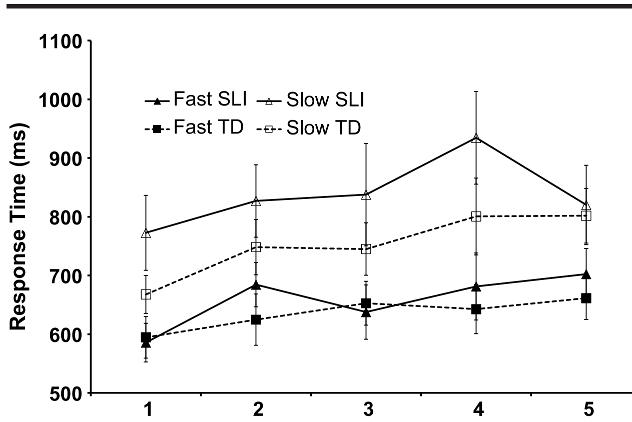
### *RT*

RT data were skewed to the right (Shapiro-Wilk, $W$ = 0.99, $p$ = .009), although all values were within three *SD*s of the mean. The statistical analyses were carried out on log-transformed values, but reported means, ranges, *SD*s, and standard errors (*SE*s) are untransformed. A mixed factorial ANCOVA was performed, with group (SLI, TD) as the between-subjects variable, event rate (fast, slow) and epoch (1st through 5th minute of testing) as within-subject variables, and nonverbal IQ scores as the covariate. The ANCOVA revealed no effect for group, $F(1, 23) = 0.07$, $p = .80$, and no effect for IQ, $F(1, 23) = 1.83$, $p = .19$. Based on these findings, it was determined that IQ did not predict performance as measured by RT on this sustained attention task.

Given that IQ was found not to be a significant factor in performance, the log-transformed RT data were then analyzed without IQ as a covariate in an ANOVA, with group (SLI, TD) as the between-subjects variable and event rate (fast, slow) and epoch (1st through 5th minute of testing) as within-subject variables. This analysis also revealed no effect for group, $F(1, 24) = 0.88$, $p = .36$. The analysis did reveal a significant main effect for rate, $F(1, 24) = 246.19$, $p < .0001$, $\eta^2 = .91$ (large effect size), where RT values were higher (i.e., responses slower) in the slow rate condition ($M$ = 796 ms, $SD$ = 181, range = 410–1,384 ms) than in the fast rate condition ($M$ = 646 ms, $SD$ = 107, range = 364–1,062 ms). There was a main effect for epoch, $F(4, 96) = 15.71$, $p < .001$, $\eta^2 = .40$ (large effect size); a Tukey's honestly significant difference (HSD) post hoc analysis revealed that responses in Epoch 1 ($M$ = 655 ms, $SD$ = 141, range = 396–1,062 ms) were significantly faster than those in Epoch 2 ($M$ = 721 ms, $SD$ = 153, range = 464–1,098 ms, $p < .001$), Epoch 3 ($M$ = 718 ms, $SD$ = 177, range = 364–1,384 ms, $p < .001$), Epoch 4 ($M$ = 765 ms, $SD$ = 206, range = 401–1,285 ms, $p < .001$), and Epoch 5 ($M$ = 746 ms, $SD$ = 152, range = 443–1,249 ms, $p < .001$), and RT for Epoch 3 ($M$ = 718 ms) was significantly faster than RT for Epoch 4 ($M$ = 765 ms, $p = .048$). The Group × Rate interaction was significant, $F(1, 24) = 6.44$, $p = .018$, $\eta^2 = .21$ (large effect size), although a Tukey's HSD post hoc analysis revealed no significant findings of interest (SLI fast vs. TD fast, $p = .97$; SLI slow vs. TD slow, $p = .51$). The Rate × Epoch interactions, $F(4, 96) = 1.75$, $p = .15$; Group × Epoch interactions, $F(4, 96) = 1.30$, $p = .28$; and Group × Rate interactions, $F(4, 96) = 2.13$, $p = .08$, were not significant (see Figure 1).

In examining these findings, it is notable that although the two language groups differed in terms of mean nonverbal IQ scores, IQ was not a significant

**Figure 1.** Mean response time (in ms) by epoch for children with specific language impairment (SLI) and age-matched typically developing (TD) controls at both fast and slow event rates (scale does not start at zero). Error bars indicate standard error of the mean.



factor when included in the analysis. Furthermore, results suggest that the model that excluded IQ from the analysis was, in fact, the preferred model for this data set. A comparison of the Akaike Information Criterion (AIC)[1] for the model with IQ (ANCOVA) and the model without IQ (ANOVA) was worse (i.e., larger; –101.0) when IQ was included as a variable and better (i.e., smaller; –102.7) when IQ was not included as a variable in the statistical model. Therefore, the addition of IQ as a variable in the model resulted in a small but quantifiable reduction in the goodness-of-fit of the model.

## Accuracy

Accuracy data were also non-normally distributed (Shapiro-Wilk, $W = 0.99$, $p = .011$), but again, all values were within three *SD*s of the mean. Following the procedures outlined by Kirk (1995, p. 105), it was determined that a square-root transformation was most appropriate for these data. As with RT, all reported means, *SD*s, and *SE*s are untransformed, and an alpha level of .05 was used in all analyses.

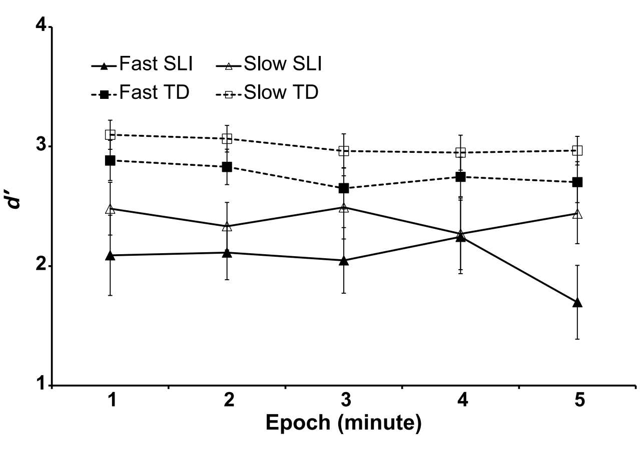
Given that the two language groups (SLI, TD) differed in terms of nonverbal IQ scores, the accuracy data were first analyzed to determine whether IQ, rather than language status, might better predict performance on the sustained attention task. The square-root-transformed accuracy data were analyzed in a mixed factorial ANCOVA, with group (SLI, TD) as the between-subjects variable, event rate (fast, slow) and epoch (1st through 5th minute of testing) as within-subject variables, and nonverbal IQ scores as the covariate. Results showed a significant main effect for group, $F(1, 23) = 11.31$, $p = .003$, $\eta^2 = .33$ (large effect size), where accuracy ($d'$) was higher for the TD group ($M = 2.89$, $SD = 0.78$, range = 1.31–3.27) than for the SLI group ($M = 2.22$, $SD = 0.43$, range = 0.11–3.27). There was no effect for IQ, $F(1, 23) = 0.30$, $p = .59$. Based on these findings, it was determined that IQ did not predict performance as measured by accuracy ($d'$) on this sustained attention task.

Given that IQ was found not to be a significant factor in performance, the square-root-transformed accuracy data were analyzed without IQ as a covariate in a mixed factorial ANOVA, with group (SLI, TD) as the between-subjects variable and event rate (fast, slow) and epoch (1st through 5th minute of testing) as within-subject variables. Results again showed a significant main effect for group, $F(1, 24) = 16.17$, $p < .001$, $\eta^2 = .40$ (large effect size), where accuracy ($d'$) was higher for the TD group ($M = 2.89$, $SD = 0.78$, range = 1.31–3.27) than for the SLI group ($M = 2.22$, $SD = 0.43$, range = 0.11–3.27). There was also a main effect for rate, $F(1, 24) = 28.21$, $p < .001$, $\eta^2 = .54$ (large effect size), in which accuracy for the set of all children was higher in the slow rate condition ($M = 2.71$, $SD = 0.63$, range = 0.71–3.27) than the fast rate condition ($M = 2.40$, $SD = 0.76$, range = 0.11–3.27). There was no effect for epoch, $F(4, 96) = 1.30$, $p = .28$, and no significant Rate × Group interactions, $F(1, 24) = 2.61$, $p = .12$; Rate × Epoch, $F(4, 96) = 1.55$, $p = .19$; Epoch × Group, $F(4, 96) = 0.59$, $p = .67$; or Rate × Epoch × Group, $F(4, 96) = 1.17$, $p = .33$ (see Figure 2).

As for the RT data, goodness-of-fit was better (i.e., AIC was smaller) for the statistical model (ANOVA) that did not include IQ as a variable than for the ANCOVA that did include IQ (ANOVA: –102.7; ANCOVA: –101.0). Therefore, as for the RT data, the addition of IQ as a variable actually resulted in a reduction in the goodness-of-fit of the model.

*Hits and false alarms.* Performance on an attentional task can be influenced both by the ability to correctly respond to target stimuli and by the ability to inhibit incorrect responses to distractors. In terms of signal detection theory (Macmillan & Creelman, 2005), these are measured as hit rate (proportion of correct responses to targets) and false alarm rate (proportion of incorrect responses to distractors). Note that because the number of responses that are made to targets is independent of the number of responses that may be made to distractors, hit rate and false alarm rate are mathematically independent. The number of false alarms has traditionally been considered a rough measure of impulsivity, such that more impulsive individuals are more likely to exhibit a heighted rate of false alarms (see

**Figure 2.** Mean accuracy ($d'$) by epoch for children with SLI and age-matched TD controls at both fast and slow event rates (scale does not start at zero). Error bars indicate standard error of the mean.



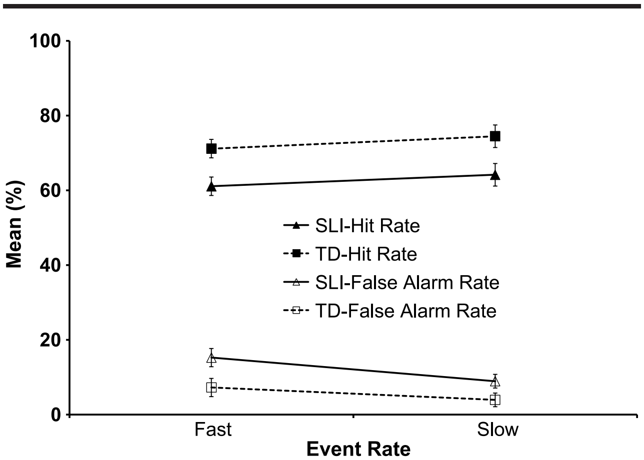

[1]The AIC is a number, based on residual sums of squares, that is used as a criterion for choosing between competing statistical models for the one that has the best goodness-of-fit. Given a particular set of data, the model having the lowest AIC is the preferred model for that data. AIC is generally expected to improve (decrease) with the addition of variables in a model (Davis, 2003).

Corkum & Siegel, 1993, and National Institute of Child Health and Human Development [NICHD] Early Child Care Research Network, 2003, for a review).

Thus, the false alarm data were analyzed in an attempt to determine whether the group differences in performance may be associated with poorer impulse control in the children with SLI. False alarms were totaled for each rate condition for each child and were analyzed in a mixed factorial ANOVA, with subject (SLI, TD) as the between-subjects variable and rate (fast, slow) as a within-subjects variable. There was a main effect for group, $F(1, 24) = 6.30, p = .019, \eta^2 = .21$, in which the children in the SLI group had significantly more false alarms ($M$ = 12.08, $SD$ = 10.49, range = 4–58) than the children in the TD group ($M$ = 5.58, $SD$ = 4.35, range = 4–32). There was a main effect for rate, $F(1, 24) = 9.02$, $p = .006, \eta^2 = .27$, in which there were significantly more false alarms in the fast rate condition ($M$ = 11.23, $SD$ = 9.52, range = 2–38) than in the slow rate condition ($M$ = 6.42, $SD$ = 6.94, range = 1–26). The Rate × Group interaction was not significant, $F(1, 24) = 0.88$, $p = .36$. These findings suggest that the children with SLI were, overall, more impulsive than the children in the TD group and that both groups of children demonstrated increased impulsivity when the event rate was higher (see Figure 3).

Hits were also analyzed as a rough measure of inattention (see Corkum & Siegel, 1993, for a discussion). The total number of hits were calculated for each event rate for each child, and the data were analyzed in a mixed factorial ANOVA, with subject (SLI, TD) as the between-subjects variable and rate (fast, slow) as a within-subjects variable (see Figure 3). Analysis of the data for hits revealed a main effect for group, $F(1, 24) = 8.52$, $p = .008$, $\eta^2 = .26$, in which the children in the SLI group had significantly fewer hits ($M$ = 62.62, $SD$ = 12.92, range = 36–79) than the children in the TD group ($M$ = 72.81, $SD$ = 5.31, range = 62–80). There was no effect for rate, $F(1, 24) = 3.37$, $p = .079$, and the Rate × Group interaction was not significant, $F(1, 24) = 0.004$, $p = .95$. These findings suggest that the children with SLI were not only more impulsive but also less attentive on the sustained attention task (see Figure 3). The findings also indicate that the rate manipulations did not have a significant effect on the number of hits for either group. An analysis of the total number of responses for each group (hits and false alarms) revealed that the children in the SLI group ($M$ = 149, $SD$ = 30, range = 113–195) did not differ significantly from those in the TD group ($M$ = 157, $SD$ = 11, range = 140–172), $t(24) = 0.84$, $p = .41$.

**Figure 3.** Mean number of hits and mean number of false alarms by group. Error bars indicate standard error of the mean.




*Accuracy and language.* Given the finding that the children with SLI performed at a lower level of accuracy than the children in the TD group, an analysis was conducted to determine if there was a correlation between accuracy scores on the sustained attention task (mean $d'$ scores for each child) and the standard scores on the Peabody Picture Vocabulary Test–Third Edition (PPVT-III; Dunn & Dunn, 1997). This receptive vocabulary test was used in the correlation, as it was not used to determine inclusion in the SLI or TD language groups. A Pearson product–moment analysis using the nontransformed $d'$ data revealed a moderate correlation of .56, $t(24) = 3.21$, $p < .01$, suggesting that there may be an association between sustained attention and receptive vocabulary skills.

## Effects of Repeated Administrations

The RT data and accuracy data for the slow event rate were analyzed to determine whether repeated administrations of this task had a significant effect on performance.

*RT.* Mean RT was calculated for each of the four slow event rate sessions per child. The data were analyzed in a mixed factorial ANOVA, with group (SLI, TD) as the between-subjects variable and day (1–4) as a within-subjects variable. There was no effect for group ($M_{\text{SLI}}$ = 842, $SD$ = 216, range = 435–1,327; $M_{\text{TD}}$ = 749, $SD$ = 141, range = 517–1,159), $F(1, 24) = 2.41$, $p = .13$, nor for day, ($M_{\text{Day 1}}$ = 763, $SD$ = 178, range = 526–1,160; $M_{\text{Day 2}}$ = 785, $SD$ = 204, range = 439–1,258; $M_{\text{Day 3}}$ = 796, $SD$ = 169, range = 474–1,240; $M_{\text{Day 4}}$ = 838, $SD$ = 198, range = 512–1,327), $F(3, 72) = 1.74$, $p = .17$, and the Group × Day interaction was not significant, $F(3, 72) = 0.53$, $p = .67$. The results of these analyses did not change in statistical significance when log-transformed values, rather than nontransformed RT values, were analyzed.

*Accuracy.* Mean accuracy ($d'$) was calculated for each of the four slow event rate sessions per child. The data were analyzed in a mixed factorial ANOVA, with group

(SLI, TD) as the between-subjects variable and day (1–4) as a within-subjects variable. There was an effect for group, $F(1, 24) = 13.39$, $p = .001$, $\eta^2 = .36$, in which accuracy for the children in the SLI group ($M = 2.50$, $SD = 0.75$, range = 0.60–3.48) was significantly lower than that for the TD group ($M = 3.18$, $SD = 0.40$, range = 2.15–3.48). There was no effect for day ($M_{\text{Day 1}} = 2.74$, $SD = 0.65$, range = 2.27–3.48; $M_{\text{Day 2}} = 2.89$, $SD = 0.76$, range = 2.51–3.48; $M_{\text{Day 3}} = 2.82$, $SD = 0.64$, range = 2.61–3.48; $M_{\text{Day 4}} = 2.90$, $SD = 0.72$, range = 2.15–3.48), $F(3, 72) = .66$, $p = .58$, and the Group × Day interaction was not significant, $F(3, 72) = 0.29$, $p = .83$. The results of these analyses did not change in statistical significance when square-root-transformed values, rather than non-transformed accuracy values, were analyzed.

## Examiner Feedback

The tapes for the 26 children included in the study were later reviewed, and instructor feedback (with time of occurrence, in ms) was logged. The total number of instances of examiner feedback was then calculated for each 1-min epoch for each of the 26 children. The data were analyzed in a mixed factorial ANOVA, with group as the between-subjects variable and rate (fast, slow) and epoch (1–5) as within-subjects variables. (The 1 child that was missing one taped session due to the video camera malfunction was excluded from this analysis.) There was a main effect for group, $F(1, 23) = 6.80$, $p = .016$, $\eta^2 = .23$, in which the children in the SLI group received more feedback overall ($M = 2.3$, $SD = 3.07$, range = 0–58) as compared with the children in the TD group ($M = 0.73$, $SD = 1.47$, range = 0–33). There was no effect for rate, $F(1, 23) = 2.90$, $p = .10$, nor for epoch, $F(4, 92) = 1.92$, $p = .33$, and there were no significant interactions: Rate × Group, $F(1, 23) = 0.03$, $p = .86$; Rate × Epoch, $F(4, 92) = 0.77$, $p = .54$; Epoch × Group, $F(4, 92) = 1.96$, $p = .14$; Rate × Epoch × Group, $F(4, 92) = 0.81$, $p = .52$. These results indicate that the children with SLI received more feedback overall than the children in the TD group but that there were no significant differences in the amount of feedback either group received across input rate conditions or epochs.

# Discussion

Three predictions were made at the start of this study: (a) The children with SLI would demonstrate poorer sustained attention with slower and less accurate responses than the TD children; (b) both groups would demonstrate a sustained attention decrement across the five 1-min epochs where accuracy ($d'$) would drop and responses (RT) would slow, but the children with SLI would present with a greater decrement in sustained attention as compared with the TD children; and (c) performance (RT, $d'$) would be best in the fast rate condition for both language groups.

## Group

The first prediction addressed group differences. Analysis revealed that although the children with SLI were not slower than the TD children, they were consistently less accurate (i.e., the children with SLI demonstrated poorer sustained attention) across both epoch and rate manipulations. Several considerations are discussed with regard to the presence or absence of significant group effects.

*Performance and nonverbal IQ scores.* As noted previously, the children in the SLI group had significantly lower nonverbal IQ scores as compared with the children in the TD group. There are inconsistent findings in the literature regarding the relationship between intelligence and sustained attention, although there is some evidence of a positive relationship between these two factors in preschool-age children (for reviews, see Berch & Kanter, 1984; Corkum & Siegel, 1993). Nonverbal IQ scores were therefore entered as a covariate in the analyses for both the RT and accuracy data in order to determine whether IQ, rather than language status, might better predict performance on the sustained attention task for each data set. Results indicated that IQ did not predict performance as measured by RT or by accuracy on this sustained attention task.

*Accuracy and receptive vocabulary scores.* There was a moderate correlation between accuracy on the sustained attention task and receptive vocabulary scores, suggesting that there may be an association between the children's performance on this nonverbal test of attention and receptive vocabulary abilities (although a causative relationship cannot be determined from the analysis).

*Children not included in the study.* As discussed previously, of the 10 children who were discontinued from the study, 8 were children who had qualified for the SLI group but had been discontinued because they failed the attention screener (4 children) or demonstrated significant difficulty with the task (4 children). The behaviors demonstrated by these children during the sustained attention task (e.g., disengaging from the task) or reported by parents on the CADS-P (e.g., easily frustrated) are typically associated with attentional difficulties. It seems possible, then, that there would have been an even greater difference in accuracy between the two language groups if these 8 other children had completed the task. As is, even with the conservative criteria used for inclusion (including equivalent attention scores on the CADS-P across the two language groups), the children with SLI still demonstrated reduced sustained attention as compared with their TD peers. This suggests that children with SLI appear to demonstrate subtle deficits in sustained attention that may not be reflected in broader measures of attention such as the CADS-P.

*Accuracy and inhibition.* There is evidence that children have difficulty inhibiting habituated responses as compared with adults (e.g., Harnishfeger & Bjorklund, 1994) and that children with SLI have even greater difficulty inhibiting their responses than their peers on tasks of verbal working memory (e.g., Marton, Kelmenson, & Pinkhasova, 2007; Marton & Schwartz, 2003). Although the present task was not explicitly designed to assess response inhibition, the false alarm data were analyzed as a rough measure of impulsivity in order to determine whether the children with SLI had demonstrated greater impulsivity in responding as compared with the TD group. Analyses revealed that there were more false alarms for the SLI group than the TD group. Analysis of the hit data revealed, conversely, that there were fewer hits for the SLI group than the TD group. These findings suggest that, as a group, the children with SLI demonstrated increased impulsivity and greater inattention.

The set of all children had a higher number of false alarms in the fast rate condition than in the slow rate condition. This is consistent with previous findings that children with and without attention deficits made fewer false alarms when the rate of stimuli presentation was slower (and, thus, the ISI was longer; see Corkum & Siegel, 1993, for a discussion on factors that influence performance on sustained attention tasks).

*RT.* It was predicted that the children with SLI would demonstrate reduced sustained attention in the form of slower reaction times as well as reduced accuracy. Analysis revealed no significant group differences, however. The lack of RT differences between groups may be surprising in light of the literature that reports generalized slowing in processing speed in SLI (e.g., Kail, 1994; Miller, Kail, Leonard, & Tomblin, 2001). However, there is evidence that children with SLI may not demonstrate reduced RTs as compared with their peers, and this may be especially true with respect to attentionally demanding tasks. For example, Im-Bolter et al. (2006) found no group differences in RT between children with SLI and TD children on a variety of tests of executive function and attentional inhibition. Similarly, in one recent study on sustained selective attention in SLI, Spaulding et al. (2008) reported that there were no RT differences between a group of preschool-age children with SLI and TD peers.

## Epoch

The second prediction addressed the hypothesized sustained attention decrement. It was expected that both groups would demonstrate a performance decrement (reduced accuracy, increased RT) across the five 1-min epochs in both rate conditions but that the children with SLI might show a greater decrement over time than would the TD children. Analysis revealed that, on average, children in both groups were fastest in Epoch 1, followed by a trend of slowing RT, and another significant decrement at Epoch 4. Alternatively, accuracy levels were consistently maintained across all five epochs for both rate conditions. These findings reveal that the children slowed but did not lose accuracy as the 5-min task progressed. This slowing of responses may have reflected increasing difficulty with sustaining attention over time.

These findings generally support the initial prediction of a performance decrement, although a significant decrement was not observed across all five epochs. It is important to note that although the decrement is well documented in adults, it is not consistently documented in children (see Berch & Kanter, 1984, and Corkum & Siegel, 1993, for a discussion). This may be due in part to the abbreviated nature of the CPTs used with children. Whereas adult research uses CPTs that can vary in duration from 10 min (Ballard, 2001) to up to 40 min (Smit, Eling, & Coenen, 2004) or more, studies with children typically use abbreviated monitoring tasks (e.g., Rose et al., 2001; see Corkum & Siegel, 1993, for a review). As discussed previously, a 5-min CPT was used in the current study because there is evidence that children of this age are able to complete a visual CPT of this length (Levy, 1980), and it was expected that the population tested would have difficulty completing anything significantly longer.

Another possible age-related reason for the absence of a significant decrement across the 5-min task relates to the need for instructor feedback during the task. The children who had participated in this study were younger than those tested by Rose et al. (2001). These younger children in the current study had required some amount of feedback to participate in and complete the sustained attention task. This type of feedback was not reported to be used by Rose et al. and is not typically used in adult studies of sustained attention. It is possible that although there was not a significant increase in feedback across the five 1-min epochs, the presence of feedback in the five epochs may have facilitated performance to the degree that any decrement in performance over time was reduced in magnitude.

As discussed previously, a number of children were discontinued from the task as a result of behaviors (reported or observed) that are typically associated with attentional difficulties. Given this, it is also possible that there would have been a more significant decrement in performance across the five 1-min epochs if these children had completed the task. Finally, it is possible that the absence of a significant decrement across the 5-min task may not be an artifact of the task but, rather, may reflect an aspect of the developmental trajectory of sustained attention.

## Rate

The third prediction addressed the effect of event rate on performance. Rose et al. (2001) had reported that young school-age TD children performed best (i.e., faster RTs, higher accuracy) in the fast rate condition. The effect of event rate was examined in the current study in order to determine how event rate affects the performance of younger children with and without language impairments. It was predicted that performance would be best in the fast rate condition. There were no specific predictions with regard to a Group × Rate Condition interaction, as it was not clear which event rate would better facilitate performance for these children.

Analyses revealed that both groups responded faster in the fast rate condition, although they were more accurate in the slow rate condition. These findings are consistent with the adult literature in which an inverse relationship between event rate and performance accuracy in sustained attention tasks is well documented (Leclercq, 2002; Warm & Jerison, 1984). This suggests that this pattern of behavior may be associated with the experimental task and was not a consequence of the participants' age or language status.

In the adult literature, researchers have attempted to explain the inverse relationship between event rate and performance accuracy in a number of ways. It has been proposed that improved accuracy with a slower event rate may be a direct result of having fewer signals to detect overall, leading to improved ability to distinguish signals from distractors (Guralnick, 1973, as cited by Warm & Jerison, 1984, p. 40). It has also been proposed that a slower event rate allows for more time to make a decision (supported by the observation of longer RTs), thus improving accuracy (Leclercq, 2002; Warm & Jerison, 1984).

There were no significant Group × Rate Condition interactions. The Rate × Group interaction approached significance for the RT data, but a post hoc analysis revealed no significant differences of interest (i.e., the two language groups did not differ significantly in either rate condition). Thus, it appears that the event rate manipulations did not have a differential effect on RTs according to language status. It should be noted that there was also not a significant difference in RT between the two groups overall. As previously discussed, the lack of significant group differences in RT is consistent with the findings of Spaulding et al. (2008) in their study of sustained selective attention. These findings may be taken to suggest that on tests of sustained attention, the measurement of RT may not consistently differentiate children with LI from their TD peers.

## Summary

In the present study, the children with SLI demonstrated reduced visual sustained attention as compared with their TD peers. The findings of the present study are significant in several ways. For one, it adds to the body of literature that suggests the presence of attentional limitations in children with LI who do not demonstrate behaviors associated with clinical attention deficits. More specifically, the findings indicate that children with SLI may, in fact, have difficulty with sustained attention to visual stimuli as well as to auditory stimuli (Spaulding et al., 2008).

The finding of difficulties in visual sustained attention, in conjunction with the reported difficulties in auditory sustained attention tasks (Spaulding et al., 2008), supports the proposal that the general processing deficits in SLI may be associated with concurrent limitations in sustained attention. It is not clear whether the language processing problems and attentional limitations have a causal relationship or whether they both result from an underlying neurodevelopmental deficit. Although the limited nature of the present results, derived from a single experiment with a small number of children from two relatively homogeneous cohorts, makes it difficult to do more than speculate in general terms, current understanding of the role of attention in language learning suggests that the present results are consistent with the following hypotheses regarding the potential role of sustained attention limitations in SLI.

Given that working memory models typically associate the limited nature of information processing with limitations in the availability of attentional resources such as selective (e.g., Conway, Cowing, & Bunting, 2001) and sustained attention (e.g., Engle et al., 1999), it seems possible that any constraints on these attentional mechanisms, such as limitations in the ability to sustain focused attention, would therefore constrain information processing. Thus, limitations in attentional resources (such as the ability to sustain attention) could contribute to deficits in information processing capacity or speed which, in turn, could constrain language learning. Following this line of reasoning, limitations in sustained attention could, over time, contribute to the development of language deficits by virtue of their interference with information processing systems necessary for normal language development.

## Clinical Implications

Attentional factors—particularly, subclinical limitations in attentional capacity—have not yet received much examination in the SLI literature. The current findings suggest that children with SLI may, in fact, demonstrate limitations in their ability to sustain attention, even in the absence of clinically diagnosable attention deficits. Given the fundamental role of attention in language processing, the results of this study support the hypothesis that subclinical limitations in attention might be a part of the SLI profile.

It is notable that the children with SLI in this study demonstrated significantly reduced sustained attention in an environment controlled for distraction where they were explicitly instructed to attend to the stimuli. It seems likely that if these children demonstrated reduced sustained attention in this more optimal, if more artificial, environment, then they might demonstrate the same or even greater levels of difficulty in more natural settings. It is important, therefore, to be sensitive to the impact that limitations in sustained attention may have on developmental language problems even in the absence of clinically diagnosable attention deficits.

Based on the findings of the current study, it may be possible to facilitate sustained attention in learning environments. When clinicians and educators design tasks to teach specific skills or knowledge, they may improve the child's performance and learning by (a) controlling the rate of information that is being presented; (b) reducing the amount of time in which the children must sustain attention to a task (e.g., shortening task length, increasing the frequency of breaks within a task, increasing active child participation); and (c) providing feedback to facilitate participation and, possibly, the level of sustained attention to the task.

## *Conclusion*

This study provided evidence that subclinical limitations in sustained attention may be one underlying component of developmental language disorders. Further research on the relationship between attentional capacity and language acquisition will help to broaden our understanding of how attentional factors may contribute to language difficulties. Specifically, more investigation is needed into the roles that the various forms of attention (e.g., sustained, divided) play in language learning and how limitations in these attentional mechanisms may impede learning about different aspects of language (e.g., phonological, semantic, syntactic). Given that sustained attention improves with age (see Berch & Kanter, 1984, for a discussion), further research is also needed to examine how the relationship between attention and language learning changes over time in children with LI. This better understanding of the role of attention in language learning in SLI may then be applied by clinicians and educators to the assessment and treatment of children with SLI.

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