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Sustained Attention in Children with Primary Language Impairment: A Meta-Analysis

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Abstract

Purpose—This study provides a meta-analysis of the difference between children with primary or specific language impairment (LI) and their typically developing peers on tasks of sustained attention. The meta-analysis seeks to determine if children with LI demonstrate subclinical deficits in sustained attention and, if so, under what conditions.

Methods—Articles that reported empirical data from the performance of children with LI, in comparison to typically developing peers, on a task assessing sustained attention were considered for inclusion. Twenty-eight effect sizes were included in the meta-analysis. Two moderator analyses addressed the effects of stimulus modality and ADHD exclusion. In addition, reaction time outcomes and the effects of task variables were summarized qualitatively.

Results—The meta-analysis supports the existence of sustained attention deficits in children with LI in both auditory and visual modalities, as demonstrated by reduced accuracy compared to typically developing peers. Larger effect sizes are found in tasks that use auditory and linguistic stimuli than in studies that use visual stimuli.

Conclusions—Future research should consider the role that sustained attention weaknesses play in LI, as well as the implications for clinical and research assessment tasks. Methodological recommendations are summarized.

Keywords

attention; specific language impairment; meta-analysis; cognition

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Children with primary language impairment (LI) appear on clinical caseloads and in the research literature under a variety of names including specific language impairment (SLI), language disorders and language-based learning disabilities. Consistent with a growing number of researchers, we prefer the term primary language impairment here as it encompasses the subtle nonlinguistic processing weaknesses that exist alongside the defining deficits in language, yet maintains the distinction between this diagnostic category and language impairment attributed to frank sensory, cognitive or neurological disorders (e.g., Kohnert, Windsor, & Ebert, 2009; Tomblin, Zhang, Buckwalter & O'Brien, 2003). For children with LI, several areas of language may be affected including vocabulary,

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morphosyntax, discourse, written language, and social language (see Leonard, 1998 and Schwartz, 2009 for reviews).

Although poor performance on language tasks, in the face of otherwise typical development, is considered the critical marker of LI, subtle processing inefficiencies extend beyond language to the general cognitive domain. Mounting empirical evidence points to at least three general areas of cognitive processing inefficiency in children with LI: working memory, speed of information processing, and attention (see Gillam, Montgomery, & Gillam, 2009 and Windsor & Kohnert, 2009 for reviews). The extent of these subclinical, cognitive processing weaknesses and their relationship to the more obvious language deficits in children with LI is not yet clear. Our concern here is with attention. The high comorbidity rate between language disorders and clinical disorders of attention is robustly supported (e.g., Willinger et al., 2003). However, the connection between delayed or inefficient language and attention may extend beyond comorbidity to more subtle deficits.

We present a meta-analysis and narrative summary of the empirical literature assessing one subtype of attention, sustained attention, in children with LI. Our purpose is to synthesize the evidence that supports or refutes the existence of sustained attention deficits in children with LI. This information is needed to guide future investigations which will, in turn, pave the way for advances in both language theory and clinical practice. To provide the context for this systematic review, we first consider the major conceptual approaches to attention and the theoretical basis for connections between attention and language development. We then discuss the rationale for focusing specifically on sustained attention. Finally, we motivate the use of a meta-analysis to consider the evidence related to this potential component of the LI profile.

Models of Attention and Links to Language

Attention is a basic cognitive skill that underlies performance on most information processing tasks. The breadth and importance of this skill has lead to several distinct conceptualizations of attention, many of which directly link attention and language. We will review three of the most common conceptualizations of attention. These three conceptualizations are not mutually exclusive; however, each has distinct predictions regarding the impact of attention skills on language development. Thus we consider each model, with its implications, separately.

In the first major model, the key division of attention is between automatic (or unconscious) and controlled (or conscious) information processing. Controlled attention requires the effortful maintenance of a goal in mind and is thus closely related to executive functions (Miyake, Friedman, Shah, Rettinger, & Hegarty, 2001). It can be assessed through higher level cognitive tasks as well as working memory tasks. Controlled attention is implicated in language acquisition because a language learner must successfully focus on relevant auditory input in the face of distracting stimuli. Conscious attention to the relevant linguistic input may then activate unspecialized neurons, assisting with the learning process (see Windsor & Kohnert, 2009, for review). In addition, children with LI may demonstrate impairments in controlled attention (Marton, 2008). The relationship between controlled attention and LI may be mediated by a common association with working memory and higher level cognitive tasks: controlled attention can be assessed through higher level cognitive tasks and working memory tasks (Miyake et al., 2001), and evidence strongly indicates that weaknesses in working memory and higher level cognitive tasks are a component of the LI profile (Kohnert et al., 2009; Montgomery, 2002).

The second model conceptualizes attention as a limited-capacity system. In this model, an individual's attentional resources are allocated to tasks as needed but problems arise when task demands exceed the individual's attentional capacity (Montgomery, Evans, & Gillam, 2009). Because the working memory system is often also conceptualized as a limited-capacity system (Just & Carpenter, 1992), attention is again closely related to working memory in this model. Language acquisition and attention are linked within this theory as well, because language learners must allocate their attentional resources to incoming linguistic stimuli in order to process it. Evidence within both the working memory (Montgomery, 2002) and attention frameworks (Montgomery et al., 2009) indicate that children with LI demonstrate notable capacity limitations.

A third major approach to conceptualizing attention is to divide it into components (e.g., Gomes, Molholm, Christodoulou, Ritter, & Cowan, 2000; Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991). The purpose of such an approach is to characterize the functioning of distinct pieces of the complex attention system more precisely, allowing for more accurate identification of points of breakdown in attentional problems. In addition, neuroanatomical evidence indicates that distinct brain regions are associated with each component of attention (Mirsky et al., 1991). Component approaches differ somewhat in the way they conceptualize the critical pieces of attention. Mirsky et al. (1991) argue that there is both behavioral and neuroanatomical evidence for four distinct components of attention: *focus*, in which information is selected for processing; *sustain*, in which this focus is maintained over time; *shift*, in which attentive focus is moved to new information; and *encode*, in which information is mentally registered.

All components of attention have a role in language acquisition (Gomes et al., 2000). A language learner must focus on relevant linguistic input and ignore irrelevant input. He or she must sustain this focus in order to take in complete input for processing. When the source of language input shifts, the language learner must also shift his or her attention to avoid missing relevant input. Finally, he or she must attend to encoding the information in order to make it available for future use.

As with the first two attention models reviewed, empirical evidence also links weak attention skills to LI in the component model. Initial evidence suggests that attentional shifting may be intact in children with LI (Schul, Stiles, Wulfeck, & Townsend, 2004). However, recent studies indicate that children with LI have deficits in sustained attention (Finneran, Francis, & Leonard; Spaulding, Plante, & Vance, 2008); in focus, or selective attention (Stevens, Fanning, Coch, Sanders, & Neville, 2008); and in encoding, which is similar to working memory.

Thus, from each distinct perspective the contribution of attention to language acquisition can easily be hypothesized. In other words, it is likely that attention skills combine with other cognitive constructs (such as memory) to facilitate language learning (Windsor & Kohnert, 2009). In addition, converging evidence suggests that weak attention skills play a role in LI. These patterns support a closer analysis of subtle attention deficits as a component of the LI profile, joining more established cognitive processing deficits such as speed of processing and working memory. However, this brief discussion of attention also underscores the difficulty of capturing the diverse conceptualizations of attention in a single, operational definition. Such an operational definition is necessary for conducting a sound systematic review and meta-analysis, as systematic reviews must focus on a concise question (Schlosser, Wendt, & Sigafoos, 2007). Thus narrowing our view of attention to a single perspective, and even further to a particular subtype of attention, facilitates synthesis of a portion of the evidence for attentional deficits in LI.

In the current study, we adopt a component theory of attention and consider the specific dimension of sustained attention. The component theory of attention is designed to break attention down into discrete potential areas of deficit which can be assessed separately (Mirsky et al., 1991). In contrast, both controlled attention and limited-capacity attention are inextricably intertwined with the concept of working memory, making assessment of attention and not working memory very difficult.

Sustained Attention

Within the component theory of attention, we focus on sustained attention as a starting point because there is reason to believe it is problematic in children with LI. Mirsky et al. (1991) define sustained attention as “the capacity to maintain focus and alertness over time, or vigilance” (p. 112). The authors of at least two separate studies have claimed to observe impaired vigilance in children with LI, with a resulting impact on task performance. Stark and Montgomery (1995) observed that children with LI who were completing a sentence processing task “would sometimes gaze around the test room, play with the headphones, or slump, glassyeyed, while the sentences were being presented.” (p.150). In addition, Helzer, Champlin, and Gillam (1996) found that children with LI and their typically developing peers had remarkably similar auditory temporal resolution skills. However, the children with LI required more trials to achieve a threshold. Because this reflects inconsistency in responses, the authors interpreted this difference as a reflection of poorer sustained attention skills among the LI group. However, sustained attention was not measured directly in either of these studies.

There has also been indirect evidence indicating that weak sustained attention skills play a role in treatment gains. Results from a large randomized trial suggest that language gains following intensive treatment programs may be related to gains in sustained attention. Gillam et al. (2008) assigned over 200 school-age children with LI to one of four treatment conditions. All participants attended treatment for 3.5 hours per day, but participants in one condition received a control treatment not specific to language. Significant but equivalent language gains were found across the four groups, leading Gillam et al. (2008) to question whether the intensive treatment conditions caused participants to improve their information processing skills, including sustained attention (p. 113). Implicit in this claim is the premise that children with LI have impaired sustained attention skills prior to the intervention. Two single-subject experimental design treatment studies (Ebert & Kohnert, 2010; Gillam, Crawford, Gale, & Hoffman, 2001) make very similar inferences, hypothesizing that intensive intervention may boost language in part through sustained attention improvements. It is important to note that these two studies used a design that limits the ability to generalize to the population, and thus make weaker claims than Gillam et al. (2008). However, an even more important limitation of all three studies is that they lack a direct measure of attention either before or after intervention and therefore cannot provide direct evidence either of weak attention skills in LI or of attention skill improvements with treatment.

In addition, several recent studies have directly investigated the presence of subclinical sustained attention deficits in children with LI (e.g., Bishop & Norbury, 2005; Finneran et al., 2009; Spaulding et al., 2008). These publications highlight increasing interest in the potential relationship between sustained attention and LI. In summary, both indirect and direct evidence suggest that sustained attention skills are potentially subtly impaired in children with LI. However, single studies provide conflicting results and are not strong enough to definitively establish the presence or characteristics of such deficits. A systematic review of the topic is warranted.

A Systematic Review and Meta-Analysis of Sustained Attention in LI

The purpose of a systematic review is to identify and synthesize evidence relevant to a specific question in a transparent and unbiased manner (Dollaghan, 2007). Systematic reviews are an essential tool for directing future research and for guiding clinical decision making (Schlosser et al., 2007). In this case, a synthesis of the evidence regarding potential sustained attention deficits in children with LI would inform the LI profile for both researchers and clinicians. Meta-analysis, a subtype of systematic review, is often valued over other types of systematic reviews because of the quantitative nature of the results (Dollaghan, 2007).

The primary purpose of this meta-analysis is to synthesize the evidence for and against sustained attention deficits in children with LI. If robust evidence of sustained attention deficits LI is found, a secondary purpose of the review is to characterize them. Thus we address two specific questions:

1. Do children with LI demonstrate deficits on tasks of sustained attention?
2. What are the methodological circumstances under which these differences are most evident, in terms of task, participant, and outcome variables?

To answer these questions, we conducted a search for articles in which both children with LI and typically developing peers completed a task of sustained attention. We defined children with LI using conventional criteria for LI/SLI (e.g., Leonard, 1998). To define a task of sustained attention, we adopted the suggestion by Mirsky et al. (1991) that the standard task for assessing sustained attention is a Continuous Performance Task or CPT (cf. Williams, Stott, Goodyer, & Sahakian, 2000). The CPT assesses vigilance or sustained attention by requiring the participant to monitor a series of stimuli over time for specific target stimuli

(Corkum & Siegel, 1993). Adopting a narrow definition of a sustained attention task allowed us to avoid confusing cognitive weaknesses already associated with LI, such as working memory and executive function, with sustained attention weaknesses.

Method

Inclusion Criteria

Prior to initiating the search, several inclusionary criteria for articles were established. To avoid publication and language bias (Schlosser et al., 2007), the search targeted published articles as well as unpublished theses and dissertations in the public domain, in any language. It was determined that articles would be included in the review only if they:

1. Included at least one group of participants with LI. A variety of terms for LI were accepted (e.g., Specific Language Impairment or SLI, developmental language delay, dysphasia, etc.) as long as the participants met conventional criteria for LI, including: nonverbal IQ within the average range, as demonstrated by a standardized test or author report; normal hearing; no identified neurological or behavioral disorders; and delayed language development in comparison to peers that is not restricted exclusively to the phonological domain of language (i.e., speech concerns may be present but should not be the only area of language affected). Exact criteria for the definition of delayed language development differed across studies; means of meeting this criterion included using a clinical diagnosis, requiring scores on one or more standardized language tests to be well below age expectations (e.g., > 1.25 SDs below the mean), and requiring a significant discrepancy between standardized language and nonverbal IQ scores. We included studies as long as they made a case for notable delays in language development, in order to accommodate studies that spanned a wide range of both time and geography.

   In addition, some studies reviewed did not explicitly state a method for excluding children with attention deficit hyperactivity disorder (ADHD) from their LI sample (see the section on moderator analyses for more detail). However, studies in which all LI participants also were diagnosed with ADHD (e.g., Oram-Cardy, Tannock, Johnson, & Johnson, 2009) were excluded.

2. Reported new empirical data from the administration of a behavioral task. Articles that reported data only from parent or teacher observations of behavior were excluded on the grounds that such checklists subjectively assess overt characteristics of inattention, such as those seen in ADHD. The purpose of this review was to look for objective evidence of subtle attention deficits in children with LI.

3. The behavioral task must assess sustained attention using some form of a CPT, although these tasks may be referred to with other names (e.g., go/no-go task, sustained attention task, auditory or visual monitoring task, etc.). Specifically, we restricted our review to tasks that required the participant to monitor a stream of stimuli. Studies in which attention was assessed using more complex cognitive

tasks, such as the Wisconsin Card Sorting Test or Tower of London (Marton, 2008), were excluded on the grounds that performance may reflect more complex executive functions (Kohnert et al., 2009) rather than the subcomponent of sustained attention. Similarly, in order to avoid rereviewing evidence that children with LI have deficits in working memory capacity, attention tasks that were framed as assessments of processing capacity (e.g., the Competing Language Processing Task) were not reviewed.

4. Reported results must compare the performance of participants with LI to the performance of a group of typically-developing (TD) peers without LI on at least one outcome measure from the task. Some authors (e.g., Finneran et al., 2009) argue that a true measure of sustained attention must capture the decrement in performance over time during an extended task, and thus simple measures of accuracy or response time from a CPT measure only selective attention. However, this strict definition of sustained attention appears to be adopted by a small minority of authors, and its application to language-impaired populations remains rare: we located only two studies that reported a measure of performance decrement over time. Thus we adopted a more lenient criterion for acceptable outcome measures. Physiological outcome measures such as ERP waveforms were not included in the review on the grounds that such measures of attention do not compare to behavioral measures of attention in a straightforward way.

5. When more than one outcome measure was reported for a single task administration, the first or primary measure reported by the authors was chosen for inclusion in the review. For example, Hanson and Montgomery (2002) report both hit and false alarm rates for the same sustained attention task; they describe the hit rate as the “primary” dependent variable (p. 84), and therefore only the hit rate data was included in our review. This step was adopted to avoid overemphasizing data from a single task in the review’s conclusions.

Literature Search

A systematic search for empirical articles addressing sustained attention in children with LI was conducted in January and February 2010. Databases searched include ERIC, Google Scholar, Highwire Press, Medline, PsychInfo, and Web of Science. The search term combinations *language impair* and attention* and *language disorder and attention* were applied to titles, keywords, and abstracts in each database.

A total of 1030 articles were identified in these searches. In the first round of article evaluation, abstracts were reviewed to exclude articles that clearly did not meet the search criteria established above. In other words, articles were discarded if they did not contain participants with LI (e.g., participants had acquired aphasia, autism, or another language disorder distinct from LI), did not contain empirical data, or did not report behavioral results from a task that potentially assessed sustained attention. Any article that may have contained a task meeting search criteria, including those tasks labeled using terms other than “sustained attention,” were retained for further review. Duplicate articles were also excluded

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during this stage. Following the first round of article evaluation, a total of 45 articles were identified for further review.

The full text of these 45 articles was obtained. In the second round of article review, the first author reviewed the text of each to verify that the article did meet all search criteria. Five articles were written in languages other than English (three in Spanish and two in German). The English and Spanish articles were reviewed by the authors and the German articles were reviewed by a consultant fluent in German. Following the full article review, 17 articles were identified for inclusion in the analysis. These 17 articles reported performance data from both children with LI and TD peers on 33 separate sustained attention tasks. All 33 tasks reported accuracy data; 10 tasks also reported reaction time (RT) data. Table 1 lists these 17 studies along with a summary of participants, task characteristics, and results.

Reliability—A portion of the search was reconducted by the second author in order to establish its replicability. The second author, who did not take part in the initial search, reviewed 18% of randomly selected results from the search. Agreement with the first author over whether or not the article met search criteria was 98% for these articles, prior to conferring.

Analysis

In order to perform the meta-analysis, effect sizes for each contrast of interest (i.e., children with LI vs. TD children) were calculated for the task accuracy data from each of the 33 tasks that met search criteria. The standardized mean difference between groups (Cohen's *d*; Cohen, 1988) was calculated from reported or graphically displayed group means and standard deviations when possible. Three studies (Greyerbiehl, 1981; Lum, Conti-Ramsden, & Lindell, 2006; McArthur & Bishop, 2004) subdivided the LI group; for these studies, we pooled data from all LI children to create the effect of interest. When the relevant means and standard deviations were not reported (i.e., Wiig and Austin, 1972) a reported *F* statistic was used to calculate effect size (Cooper, Hedges, & Valentine, 2009). One study (Noterdaeme, Amorosa, Mildenberger, Sitter, & Minow, 2001) containing four tasks of interest reported only group medians, statistics for a three-way group comparison including a group with autism, and a descriptive statement that the LI group performed significantly below the TD and autism groups on the tasks of interest. This study was judged not to provide enough information to accurately calculate *d*; it is included in qualitative portions of the review but was excluded from the meta-analysis.

These procedures generated 29 effect sizes for analysis. Visual inspection of the distribution of effect sizes indicated an obvious outlier with a *d* value nearly 3 times as large as the second-greatest effect size in the distribution (Wiig & Austin, 1972; $d = 3.41$). This study was also eliminated from the meta-analysis portion of the review.

Calculations were made assuming a fixed-effects model. We converted each of the 28 remaining effect sizes into Hedge's *g* to prevent bias from small sample sizes (Cooper et al., 2009), and used the inverse variance of each effect size to weight the relative contribution of each study to the overall effect size. The weighted average effect size across all studies was then calculated.

Moderator Analyses—We also conducted two moderator analyses. The first moderator analysis addressed the question of whether sustained attention deficits in children with LI are restricted to the auditory modality (Noterdaeme et al., 2001; Spaulding et al., 2009). Tasks were divided into three groups according to the type of stimuli employed: visual, auditory and linguistic, or auditory and nonlinguistic. We differentiated between linguistic and nonlinguistic stimuli in the auditory domain because by definition children with LI perform poorly on language-based tasks; a true weakness in sustained attention in the auditory modality should appear in studies that use nonlinguistic stimuli.

The second moderator analysis examined whether studies that state explicit criteria for ensuring that participants did not have ADHD differ from studies that do not. A number of studies found in the literature search described their participants as having no known neurological or behavioral disorders, but did not describe a test for ensuring that they did not have ADHD specifically. This group of studies was compared to those studies that described a procedure for excluding children with ADHD (e.g., a screening test, parent report, or teacher rating scale).

Finally, a qualitative synthesis of results was performed for two additional areas: RT results and task variables. In each of these areas, the number of studies that could be included in a meta-analysis was quite small. However, both areas were of interest a priori: RT differences between LI and TD children have been robustly supported in recent literature (Kohnert et al., 2009; Miller et al., 2006) and a previous review of CPT tasks (Corkum & Siegel, 1993) indicates that key task variables may be central to interpreting results from these tasks. Therefore, the data was extracted and analyzed qualitatively in these areas.

Results

Table 2 displays the results of the overall meta-analysis and the two moderator analyses. The weighted average effect size across all studies was 0.69. This result differs significantly from zero ($Z = 13.17$, $p < 0.001$), indicating that children with LI perform significantly below TD peers on sustained attention tasks. The test of homogeneity of variance among effect sizes was also significant ($Q = 59.16$, $p < 0.001$).

The moderator analysis for modality indicated that the weighted average effect size in each of the three modalities that were analyzed (visual, auditory-linguistic, and auditory-nonlinguistic) differed significantly from zero (auditory-linguistic: $g = 0.82$, $Z = 11.34$, $p < 0.001$; auditory-nonlinguistic: $g = 0.61$; $Z = 5.86$, $p < 0.001$; visual: $g = 0.47$, $Z = 4.24$, $p < 0.001$). The moderating variable explained a significant amount of variance in the effect sizes ($Q_b = 24.87$; $p = 0.02$). In other words, the modality of stimuli does affect LI deficits on sustained attention tasks. However, a significant amount of within-group variance remained in the auditory-linguistic ($Q_w = 23.34$, $p < 0.05$) and visual groups ($Q_w = 15.13$, $p < 0.05$). Thus, effect sizes in these two groups differed even after accounting for the effects of stimulus modality.

Post-hoc contrasts between the three modalities were conducted using Bonferroni correction. These analyses indicated that only the difference between the visual and auditory-linguistic means reached statistical significance at the $p < 0.05$ level.

The second moderator analysis examined the difference between studies with explicit ADHD exclusion criteria and those without. The between-groups heterogeneity statistic did not reach statistical significance ($Q_b = 0.59$), indicating no difference in effect size between these two groups of studies.

Reaction Time Outcomes

Reaction time data was reported for 13 of the 33 tasks that met search criteria, providing insufficient data for quality meta-analysis (Cooper et al., 2009). Children with LI demonstrated significantly slower reaction times than their typically developing peers on only one of these 13 tasks: the sustained auditory attention task reported by Noterdaeme et al. (2001). Taken at face value, this seems to indicate that speed of response on CPTs is unaffected by LI, a finding inconsistent with a growing body of literature indicating small RT differences for children with LI even on relatively simple perceptual-motor tasks (e.g., Kohnert et al., 2009; Miller et al., 2006). We return to this point in the *Discussion*.

Task Variables

Task differences may be the source of conflicting results in studies of sustained attention (Corkum & Siegel, 1993). Though all tasks within the reviewed studies met a relatively narrow definition of a sustained attention task, they differed along several dimensions. The key variables we extracted for comparison were the percentage of stimuli that are targets and the duration of the targets. These variables were selected for review because Corkum and Siegel’s (1993) review of CPTs shows that manipulation of the percentage of targets and duration of targets has a notable effect on results. Numerous other variables, such as the task duration or the interstimulus interval, have the potential to affect outcomes but clear and consistent patterns between these variables and task outcomes have not been established (Corkum & Siegel, 1993).

Table 1 presents task features, as well as dependent variables, for each of the 33 tasks reviewed. The duration of stimuli was reported for 22 of the 33 tasks. Stimuli ranged from 75 milliseconds to 2 seconds in duration. The percentage of stimuli that were targets ranged from 10% to 50% for the 23 tasks that reported the information.

Discussion

The results of the meta-analysis establish the presence of sustained attention deficits in children with LI in comparison to TD peers. The weighted average effect size across studies indicates that the task accuracy of children with LI fell more than half a standard deviation below that of their TD peers. The effect size does, however, indicate some overlap between the LI and TD populations on sustained attention tasks (Cohen, 1988).

Corrected effect sizes ranged widely across studies, from $g = -0.08$, indicating that LI children performed slightly better than TD children, to $g = 1.41$, indicating that children with

LI performed nearly 1.5 standard deviations below TD peers. We explained some of the variability among effect sizes by analyzing the role of stimulus modality on effect size. One of the prominent claims in the literature reviewed here is that children with LI demonstrate sustained attention deficits specific to the auditory rather than the visual modality (Noterdaeme et al., 2001; Spaulding et al., 2008). We differentiated between linguistic and non-linguistic stimuli in the auditory domain on the grounds that tasks using linguistic stimuli may be more indicative of language than attention deficits in the LI population. Results supported this distinction: though stimulus modality did play a role in effect size, only the difference between auditory-linguistic tasks and visual tasks reached significance. The average effect size for auditory-nonlinguistic tasks (g = 0.61) lies closer to the average effect size for visual tasks (g = 0.47) than for auditory-linguistic tasks (g = 0.82). We note, however, that all four of the studies that administered both visual and auditory tasks to the same children found deficits only on the auditory tasks (Dodwell & Bavin, 2008; Noterdaeme et al., 2001; Spaulding et al., 2008; Townsend & Tallal, 1989). It is possible that the difference between auditory-nonlinguistic and visual sustained attention tasks could reach significance with more data; such a result would provide compelling evidence of modality-specificity in sustained attention deficits in children with LI. In summary, there was clear evidence of poorer performance by participants with LI across all three sub-types of sustained attention tasks although the magnitude of this difference varied.

One potential limitation in the meta-analysis is that most of the reviewed studies investigated the attentional capacities of children with LI without ensuring that those children did not also have ADHD. Without any screening for attention disorders, samples of children with LI would be expected to contain more children with ADHD than samples of typically developing children, and children with ADHD would be expected to perform poorly on a task of sustained attention. The results of the second moderator analysis address this concern. The small value of the between-groups heterogeneity index indicates that studies with and without explicit ADHD exclusion do not differ substantially from each other. This result implies that other studies did in fact take steps to exclude children with ADHD but did not describe them in the manuscript, stating instead that children in the LI group did not have behavioral or neurological disorders. Thus the conclusion that children with LI demonstrate sustained attention deficits does not appear to be driven by the presence of children with comorbid ADHD in study samples.

Reaction Time

In contrast to the accuracy data, the RT results reviewed here provide little support for the claim that children with LI perform more slowly than typically developing peers on tasks of sustained attention. A number of factors temper this conclusion, however. First, RT measures are conventionally determined for accurate responses only. In a CPT, although both target and distractor trials can be used to calculate accuracy measures, only target trials can be used for RT calculations (because there is no response on a correct distractor trial). In some cases the number of targets on which valid measures of RT could be made was relatively small. For example, the percentage of targets in Spaulding et al. (2008) was 17% (16) per task. Finneran et al. (2009) included 40% targets yet given the very large group difference between LI and typically developing peers in accuracy, the number of stimuli on which valid calculations of RT could be calculated would be significantly reduced.

A second factor which limits the interpretation of RT results is the lack of statistical control for developmental effects in some of the studies. For example, Buiza-Navarrete, Adrián-Torres, and González-Sánchez (2007) found no significant between-group difference in RT on a visual sustained attention task for participants who ranged in age from 5;0 to 12;11 (see Table 1). The potential effect of age within each group was not investigated. It is quite possible that within-group variation related to age overwhelmed any potential between-group RT differences. In a study investigating simple and choice visual detection tasks in 8-to-13 year olds, Kohnert and Windsor (2004) found that age accounted for a significant 40% of the variance in RT for monolingual children with LI, and 39% for their typically developing peers. In addition, two of the four studies that report RT data have the youngest participants in the review. It is possible that high variability in this population contributes to the lack of significance in RT results (Spaulding et al., 2008). Finally, only four studies reported RT data for children with LI on a sustained attention task. Clearly, additional RT data is needed to confirm or refute the hypothesis that children with LI do not demonstrate reaction time deficits on tasks of sustained attention.

Based on the existing empirical literature, accuracy measures yield the most robust differences in sustained attention between children with LI and their typically developing peers. Furthermore, the finding of reduced accuracy on sustained attention tasks by children with LI indicates that limitations in sustained attention skills in this population are separable from more generalized slowing in information processing.

Task Variables

Additional methodological differences that may affect results are the duration of stimuli and the percentage of stimuli that are targets. These variables were not included in the meta-analysis because many studies did not report this information, and the information obtained could not always be easily compared (e.g., some stimuli durations were measured in syllables, and others in seconds). However, these variables may explain variability in outcomes and deserve consideration.

Corkum and Siegel (1993) suggest that tasks with shorter stimuli durations and higher percentages of targets place a greater demand on attentional resources and therefore discriminate better between children with impaired and intact attention. Corkum and Siegel review only tasks with visual stimuli and conclude that 50 to 200 milliseconds is an optimal stimulus duration for such tasks. In the current review significant results were obtained using stimuli that ranged from 75 milliseconds to 1 second in duration, suggesting that sustained attention deficits in LI are apparent under a range of task conditions. However, Corkum and Siegel's review may help explain patterns in the results that did not reach significance. At least 3 of the reviewed tasks using visual stimuli that did not find significant results employed stimuli durations of 1 to 2 seconds (an additional 3 tasks did not report stimuli durations). These durations fall well outside the range of 50–200 milliseconds and could have affected the power of those tasks to find sustained attention deficits.

The percentage of stimuli that are targets is another task variable with the potential to influence results. Corkum and Siegel (1993) argue that a higher percentage of targets increases task monotony and therefore increases the task's potency to detect sustained attention deficits. Percentage of targets does not appear to have a clear effect on the current results. Significant differences between LI and typically developing children were found across the range of percentage targets, from 10% to 50%. Studies with nonsignificant results also appear to be distributed across that range.

Finally, as noted in the results, another task variable -- such as task duration -- could affect outcomes. Significant within-group variability remained in two of the three groups of studies after accounting for the effect of stimulus modality. Either of the two task variables reviewed here could explain some of this variability, as could another variable that was not highlighted by Corkum and Siegel (1993). It will be important for future work in this area to describe all task parameters to illuminate the relationship between task variables and outcomes.

Potential Biases

The potential for source bias is a general concern with any systematic review (Schlosser et al., 2007). Publication bias is a particular concern; it is possible that the weighted average effect size found here is artificially inflated because studies that found smaller, non-significant effect sizes were not published. However, several considerations reduce the likelihood of significant publication bias in this study. Three of the 15 studies included in the final meta-analysis were in fact unpublished work (Greyerbiehl, 1982; Redey-Nagy, 2009; Townsend & Tallal, 1989). In addition, the sustained attention task was not the primary focus of many of the studies found in the literature search. Instead, the task was a component of a larger battery of tests (e.g., Arboleda-Ramirez et al., 2007; Buiza-Navarrette et al., 2007), a subcomponent of a single task (Lum et al., 2007), or an assessment used to predict performance on a separate task of interest (e.g., Dodwell & Bavin, 2008; McArthur & Bishop, 2004). Consequently, the publication status of these papers was unlikely to be driven by the significance of the sustained attention task, or lack thereof.

We also attempted to minimize language bias, as we sought studies published in any language, and source bias, as we searched a variety of databases. However, the possibility of relevant data that was not uncovered by the search must be acknowledged as a limitation.

Conclusions and Implications

We adopted the component theory of attention and selected evidence on a single subtype of attention within this theory to review. Based on this review it appears that deficits in sustained attention are part of the LI profile. The evidence for sustained attention deficits in children with LI affects both clinical practice and research. Clinicians should be aware of the potential for decreased attention to task over time when administering and interpreting assessments of children with LI. Test results obtained from lengthy sessions may be negatively affected by attention skills.

Researchers should also be aware of the potential impact of sustained attention deficits on task performance. Children with LI have been found to demonstrate deficits relative to nonimpaired peers on a wide variety of cognitive tasks. The vast majority of these tasks contain a component of sustained attention, in that performance will suffer if task vigilance is not maintained. Thus the presence of sustained attention deficits amongst participants with LI raises the possibility that poor task performance in LI groups is driven at least in part by attention. Given the theoretical basis for attention's impact on language learning, the possibility that attention weaknesses make a causal contribution to LI cannot be discounted. The claims that language gains following treatment may be driven in part by improvements in attention also support this possibility.

Results of this review provide a number of additional guidelines for future investigations of sustained attention in children in LI. Specific criteria for excluding children with ADHD should be articulated. Tasks should investigate both visual and auditory attention, using nonlinguistic stimuli to decouple basic cognitive functions from language demands. Additional RT data is needed to verify the apparent equivalence of LI and TD children in sustained attention RT; studies calculating RT should include enough target trials to obtain reliable RT means. In addition, statistical calculations in these studies should control for the contribution of participant age, particularly when they include children across a wide and very dynamic period of cognitive development.

Finally, it will be essential for future work to consider the skills of children with LI in other areas of attention. This review focused on a small subset of attention in order to facilitate feasibility, but the hypothesis that attention deficits in the LI population extend to other attentional components (such as *focus, shift*, or *encode*) remains untested.

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Table 1

Citation	**LI *n***	**TD *n***	**Age Range, LI group**	**Age Range, TD group**	**ADHD exclusion[a]**	**Modality**	**Stimuli**	**Stimuli Duration**	**Percentage Targets**	**Accuracy Dependent Variable**	**Significance and Effect Size[b]**	**RT Significance**
Arboleda-Ramírez et al. (2007)	51	49	6–16	6–16	No	Auditory	--	--	--	Errors	0.59**	NA
Bishop & Norbury (2005)	17	18	6–10	6–10	No	Auditory	Tones	--	6–67%	Scaled Score[1]	1.39***	NA
Buiza-Navarrete et al. (2007)	37	37	5;0–12;11	5;0–12;11	No	Visual	--	--	--	Hits	1.20***	NS
						Visual	-- (sequences)	--	--	Hits	0.65**	NS
Das & Äystö (1994)	60	163	7;7–19;2	8;4–19;0	No	Auditory	Words, gender of speaker	--	--	Hits – False Alarms	0.58**[c]	NA
						Auditory	Words, gender of speaker	--	--	Hits – False Alarms	0.90***[c]	NA
Dodwell & Bavin (2008)	16	25	6;1–7;0	6;0–7;2	No	Auditory	Words	1 syllable	20%	Errors	0.69*	NA
						Visual	Pictures	2 sec.	17%	Errors	0.33 NS	NA
Finneran et al. (2009)	13	13	4;5–6;10	4;6–6;11	Yes[d]	Visual	Shapes	400ms	40%	d’	1.06***	NS
Greyerbiehl (1981)	32	16	7;2–9;2	7;2–9;3	Yes[e]	Auditory	Syllables in Quiet	250ms	50%	Percent Correct	0.87**	NA
						Auditory	Syllables in noise, 40ms formant transition	250ms	50%	Percent Correct	1.15**	NA
						Auditory	Syllables in noise, 80 ms formant transition	250ms	50%	Percent Correct	1.26**	NA
Hanson & Montgomery (2002)	12	12	6–10	6–10	No	Auditory	Words	1 syllable	20%	Hits	0.25 NS	NA
Lum et al. (2006)[f]	26	14	--	--	No	Visual	Digits	80ms	7–13%	Hits	0.52***	NA
McArthur & Bishop (2004)	16	16	12–20	12–21	No	Auditory	Noises	345ms	--	Scaled Score[g]	−0.04 NS	NA
Montgomery (2008)	36	36	6;10–10;8	6;7–10;5	Yes[h]	Auditory	Words	1 syllable	20%	d’	1.31***	NA

Citation	LI *n*	TD *n*	Age Range, LI group	Age Range, TD group	ADHD exclusion[a]	Modality	Stimuli	Stimuli Duration	Percentage Targets	Accuracy Dependent Variable	Significance and Effect Size[b]	RT Significance
Montgomery et al. (2009)	26	26	7;1–10;6	7;0–10;5	Yes[h]	Auditory	Words	1 syllable	20%	d’	1.43***	NA
Noterdaeme[i] et al. (2001)	17	19	7;0–20;0	7;0–20;6	No	Auditory	Tones	--	--	Omission errors	**	NS
						Auditory	Tones	--	--	Omission errors in last 5 minutes – omission errors in first 5 minutes	***	**
						Visual	Symbols, screen location	--	--	Omission errors	NS	NS
						Visual	Symbols, screen location	--	--	Omission errors in last 5 minutes – omission errors in first 5 minutes	NS	NS
Redey-Nagy (2009)	11	10	5;0–10;3	5;5–10;11	No	Auditory	Tones	--	6–67%	Scaled Score[g]	0.60 NS	NA
Spaulding et al. (2008)	23	23	4;1–5;7	4;0–5;7	Yes[j]	Auditory	Words	1 sec.	16.7%	d’	0.19 NS	NS
						Auditory	Words, degraded	1 sec.	16.7%	d’	1.04**	NS
						Auditory	Noises	1 sec.	16.7%	d’	0.18 NS	NS
						Auditory	Noises, degraded	1 sec.	16.7%	d’	0.69**	NS
						Visual	Animated pictures	1 sec.	16.7%	d’	0.07 NS	NS
						Visual	Animated pictures, degraded	1 sec.	16.7%	d’	0.04 NS	NS
Townsend & Tallal (1989)	18	14	9–11	9–11	No	Auditory	Tones	75 ms.	10%	Hits	0.22*	NA
						Auditory	Tone sequences	75 ms.	10%	Hits	1.18**	NA

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Citation	LI *n*	TD *n*	Age Range, LI group	Age Range, TD group	ADHD exclusion[a]	Modality	Stimuli	Stimuli Duration	Percentage Targets	Accuracy Dependent Variable	Significance and Effect Size[b]	RT Significance
						Visual	Figures	75 ms.	10%	Hits	0.27 NS	NA
						Visual	Figure sequences	75 ms.	10%	Hits	0.49 NS	NA
Wiig & Austin (1972)[k]	13	13	6;4–7;11	--	No	Visual	Pictures	1 sec.	10%	Errors	3.41**	NA

Note. Consistent with the review's goal of comparing children with LI to typically developing peers, only typically developing comparison groups are included in the table. LI groups that were subdivided in the original study (Greyerbiehl, 1981; Lum et al., 2006) are unified here. All ages are reported as years; months, or in years only when the source did not report months. A single dependent variable was chosen from each study to prevent redundancy. Thus each line in the table represents data from a unique task. Dashed lines (--) indicate that the relevant information was not reported in the manuscript.

[a]Study reports a method for explicitly excluding individuals with clinical attention deficit. Studies that report participants had "no known neurological deficits" or the equivalent, but do not explicitly mention attention deficits, are marked "No" in this column.

[b]Effect size reflects the comparison between language-impaired and typically developing participants only. A negative effect size indicates that the LI group outperformed the TD group.

[c]Typically developing children in the Däs & Äystö (1994) study were significantly younger than their language-impaired counterparts, thus potentially underestimating effect size. The difference between the two tasks listed is in the conditions required for a target response.

[d]Typical scores on Connor's ADHD/DSM-IV Scales – Parent.

[e]Per teacher report.

[f]Lum et al. (2006) do not report an age range for participants but report an average age of 17;1 for the LI group and of 17;0 for the TD group, with a standard deviation of 0.4 years for both groups. Participants were required to report the value of the digit detected.

[g]From the Test of Everyday Attention for Children.

[h]By parent report.

[i]Authors do not report enough information to accurately calculate effect size; study was excluded from the meta-analysis.

[j]Did not have an ADD or ADHD diagnosis.

[k]Wiig & Austin (1972) report only that the TD group was age-matched to the LI group. This study was also excluded from the meta-analysis because it was an outlier.

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$.

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Table 2

Meta-Analytic Results

Variable		k	g	v	Z	95% CI		Q_w	Q_b
						Lower	Upper		
Modality	Auditory, Linguistic	12	0.82	0.0052	11.34***	0.96	0.68	23.34*	
	Auditory, nonlinguistic	8	0.61	0.0108	5.86***	0.81	0.41	13.76	
	Visual	8	0.47	0.0124	4.24***	0.25	0.69	15.13*	24.87*
Explicit ADHD criteria	Yes	12	0.74	0.0074	8.61***	0.91	0.57	37.14***	
	No	16	0.66	0.0043	9.99***	0.79	0.53	21.42	0.59
Overall		**28**	**0.69**	**0.0027**	**13.17*****	**0.79**	**0.59**	**Q = 59.16*****	

Note *k* = number of effect sizes; *g* = average weighted adjusted Hedge's *g* score across studies in the group; *v* = variance of *g*. A significant *Z* score indicates that *g* differs from zero. Q_W = within-group heterogeneity statistic; Q_b = between-groups heterogeneity statistic.

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$.