Identifying Attentional Shifting Weaknesses and Attentional Tendencies in Children with Developmental Language Disorder: A Potential First Step to Promoting Word learning

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Abstract

Identifying Attentional Shifting Weaknesses and Attentional Tendencies in Children with Developmental Language Disorder: A Potential First Step to Promoting Word Learning

Yara Aljahlan, Ph.D.

University of Connecticut, [2020]

**Purpose:** Studies to date investigating attentional shifting weaknesses in children with developmental language disorder (DLD) have reported mixed findings. Study 1 involved a meta-analysis designed to evaluate if differences in attentional shifting manifest for these children relative to age-matched, unimpaired, typical language (TL) peers, and if so, under what conditions. Study 2 investigated if preschool-age children with DLD exhibited reduced attentional capacity relative to (TL) peers by varying attentional shifting demands. Study 3 explored the attentional tendencies of preschool-age children with DLD compared to their TL peers during a word learning task, specifically examining the visual properties of object referents that capture their attention.

**Method:** For study 1, 20 studies were included in the meta-analysis. Task type, participant age, and the dependent variable of measure were explored as potential moderators. For Study 2, a behavioral task involving attentional shifting within and across multiple dimensions (auditory, linguistic, visual) was administered to 26 children with DLD and 26 TL children to assess their attentional shifting capacity. Demands on attentional shifting were increased based on input
dimension manipulations. In Study 3, 12 children with DLD and 12 TL children completed a novel name extension task in which they judged which of three visual characteristics of referent objects (movement, color, pattern) was most relevant during novel word-novel referent pairings.

**Results:** In Study 1 children with DLD performed worse than TL peers by 0.42 SD on average on attentional shifting tasks. There was significant heterogeneity, and task type was the only significant moderating variable explaining a portion of the variability across studies, with children with DLD performing worse on set-shifting tasks but not alternating tasks compared to TL children. In Study 2, attentional shifting weaknesses for children with DLD only manifested on the high attention-demanding condition. Children with DLD were just as accurate as those with TL but took longer to shift their attention, exhibiting greater RT switch costs. In Study 3, children with DLD were systematically different from their TL peers in which visual features of objects they attended to during nonword-novel referent pairings. They selected movement as the relevant feature of novel objects more often than TL children.

**Conclusion:** Children with DLD present with subtle deficits in attentional shifting which manifest only in high demanding conditions, specifically during set-shifting tasks and alternating tasks with high attentional shifting demands. During an important facet of language acquisition that is highly demanding, word learning during the preschool years, children are expected to shift their attention often. Given the attentional shifting weaknesses in children with DLD, it is important to gain an understanding of what they naturally attend to. The results suggest that preschool-aged children with DLD, unlike their TL peers, exhibit an attentional tendency towards movement when initially exposed to novel word-novel referent pairings. Implications for assessment and intervention will be discussed.
Identifying Attentional Shifting Weaknesses and Attentional Tendencies in Children with Developmental Language Disorder: A Potential First Step to Promoting Word learning

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Yara Aljahlan
Identifying Attentional Shifting Weaknesses and Attentional Tendencies in Children with Developmental Language Disorder: A Potential First Step to Promoting Word Learning

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Chapter 1

Introduction and Overview

Developmental language disorder (DLD) is a diagnosis given to children who are identified with having deficits in language functioning in the absence of a clear etiology (Bishop, 2006; Bishop, Snowling, Thompson, Greenhalgh, CATALISE consortium, 2016). In addition to linguistic deficits, recent research has documented widespread, yet in many cases, subtle attention challenges for many children with this disorder (e.g., Finney, Montgomery, Gillam, & Evans, 2014; Montgomery, Evans, & Gillam, 2009; Spaulding, Plante, & Vance, 2008). This work aims to: 1) further explore the attentional weaknesses in children with DLD, with a particular focus on attentional shifting, and 2) identify their attentional tendencies in a fast mapping, word learning task. Implications of their attentional tendencies and weaknesses for language acquisition, and word learning in particular, will be discussed.

Attention as Selective Processing Mechanism and a Limited Resource

When children are immersed in their natural environment, they are constantly inundated with a barrage of incoming sensory information. This is where attention, which appears to be critical for learning, comes into play. Attention is sometimes characterized as a process or mechanism that allows the child to ignore unimportant information within their sensory environment and to focus on what matters. In other words, children focus, concentrate on, or perhaps even prioritize a specific aspect or aspects of the environment at the expense of less-than-optimal processing of other sensory information that is present (e.g., Chun, Golomb, & Turk-Brownie, 2011; Desimone & Duncan, 1995). Under this conceptualization, attention is often considered as the allocation of attentional processing resources (e.g., Anderson, 2005; Shallice, 1988).
This allocation is necessary because individuals, including children, are not capable of simultaneously processing all sensory input in their environment. Given this, attention has also been characterized, not just as a process, but also as the resource itself for sensory processing (Wickens, 1980). The characterization of attention as a resource assumes that an individual’s attentional resources are allocated moment by moment according to the degree of attentional demand needed.

Regardless of whether attention is viewed as the allocation of processing resources or the resources themselves, attention is considered to be limited in capacity (Kahneman, 1973). This limitation refers to either the number of attentional resources available, the inefficient allocation of attentional resources, or some combination of the two (Kahneman, 1973; Lavie, 2005; Wickens, 2002). At any given moment, the demands on attention may exceed the child’s attentional capacity. When this occurs, individuals may not have enough attentional resources to attend to the relevant incoming input or they may have sufficient resources but be unable to allocate them effectively to process the information sufficiently and/or in a timely manner. It is worthy to note that paying attention to a specific aspect of environmental input does not necessarily require resource expenditure, per se, especially when attention allocation is automatic (e.g., Schneider & Shiffren, 1977); However, controlling attention in a top-down manner does consume attentional resources (e.g., Oberauer, 2019).

Whether attention is the allocation of attentional resources or considered the resources themselves, what is unclear is that given the vast amount of sensory input available for the child to process at any point in time, how do they decide, either overtly or covertly, what to attend to (select for processing, assign attentional resources to)? Let’s consider how it may work during an
important process occurring early in a young child development, the process of learning new words.

**Attention and Associative Accounts of Word Learning**

Associative accounts of word learning posit that children learn where to allocate their limited processing attentional resources over time, through experience with the linguistic input. Initially, young children attend to a wide variety of environmental cues (e.g., Jusczyk, Cutler, Redanz 1993; Nazzi, Jusczyk, & Johnsoson, 2000). Over time, they learn what information is relevant and allocate their attentional resources to the relevant cues, ultimately resulting in faster, more precise processing of the important, pertinent information. The relevancy determinations that young children posit during lexical acquisition, if sufficiently predictive, ultimately lead to word learning biases (e.g., Smith, 2000). These word learning biases are believed to be the result of children’s tracking of statistical regularities, or consistent properties in the input, that lead to the development of hypotheses and expectations during word learning (e.g., Gomez & Gerken, 1999; Kuhl, 2004; Smith; 2000a;2000b; Saffran, Aslin, & Newport, 1996). If these expectations are confirmed, in other words, are sufficiently predictive, these biases then manifest and at the time, appear to enhance word learning efficiency.

One illustration of a word learning bias posited as an outcome of attending to predictive statistical regularities in the input is the shape bias. Multiple sources of evidence, when combined, provide support that the shape bias emerges over time, with experience to the linguistic input, and is developed only if it results in predictive utility for word learning. For example, young children’s early lexicons are composed mainly of count nouns, or objects that have a particularly defined shape (e.g., Gershkoff-Stowe & Smith, 2004; Samuelson & Smith, 1999; Smith, 2000b). Second, toddler age children between 17 and 21 months exhibit increased
attention to shape as a relevant property in word learning as their expressive vocabularies increase (e.g., Gershkoff-Stowe & Smith, 2004), although they do not generalize novel labels using shape as the relevant cue until they are approximately 2 years of age and have an expressive vocabulary of 150 count nouns (e.g., Samuelson & Smith, 1999; Smith, Jones, Landau, & Gershkoff-Stowe, 2002). Finally, in a study by Smith et al., (2002), 17-month-old children who did not have a shape bias were randomly assigned to two groups. One group was taught nouns that were typical of those that children are expected to master in early development and in which shape was a relevant feature (count nouns), while the other group was taught nouns that were atypical and in which shape was not relevant (nouns that were non-solid substances). The first group developed a shape bias and exhibited accelerated future noun growth. The second group did not develop a shape bias and exhibited no such developmental improvement in their lexicons. While this body of work, when combined, supports the theory that children track statistical regularities in the input to form word learning biases, like the shape bias, it also signifies that development of a word learning strategy facilitates future efficient word learning.

While the emergence of attention skills and experience with the statistical regularities in the input mediate what cues children focus their attention on and use for word learning to enable word-referent pairing and generalization, word learners need to also be able to shift their attention among stimuli, among multiple aspects of the same stimuli, and ignore irrelevant information present in the word learning environment. For instance, if an adult slightly changes the verbal interaction with a child from playing with a “ball” to requesting the “red ball” in a visual field of different colored balls, the child must shift their attention from “shape” to the physical property of color. In the latter case, a word learning bias to shape is not predictive and
therefore no longer useful. In this case, it is even learning prohibitive. Attentional shifting is needed.

**Attentional Shifting Defined**

To successfully shift one’s attention, children must disengage from what is in current attentional focus, reallocate attentional resources to a different target of aspect of a stimulus, and engage and focus on the new target (Posner & Petersen, 1990). Attentional shifting occurs when attentional resources are reallocated to process a change in the stimulus input, to meet a task demand, or to attain a particular internally- or externally-driven goal. Because attentional shifting can be a consequence of any of these three triggers, attentional shifting can occur voluntarily or be more automatic in nature. When attentional shifting occurs automatically, such as in response to a stimulus that stands out in the environment (e.g., hearing one’s name spoken aloud in a previously unattended conversation), it is considered reflexive and not at the executive level (e.g., Frischen, Bayliss, & Tipper, 2007; Jonides, et. al., 1998; Mayer, Dorflinger, Rao, & Seidenberg, 2004). In contrast, attentional shifting is considered an executive function if this shifting is under volitional control. Volitional attentional shifting occurs when adjusting attention in a purposeful effort, typically to process information more efficiently. An individual evaluates previous knowledge, previous and current expectations, and previous and current goals in order to voluntarily decide whether or not to shift his or her attention in an effort to facilitate input processing (e.g., Blaye, Bernard-Peyron, Paour, & Bonthoux, 2006; Deák, Ray, & Pick, 2004; Luwel, Verschaffel, Onghena, & De Corte, 2003; Ravizza & Carter, 2008).

Inherent in investigations of attentional shifting is the understanding that the shifting of attentional resources from one stimulus to another results in a consequence, referred to as a
“cost” or “switch cost” (e.g., Logan & Bundesen, 2003; Monsell, 2003). This cost is reflected by a performance drop when attentional shifting occurs relative to when attentional shifting does not occur. In attentional shifting tasks, this performance drop is typically measured by either substantially more erroneous responses or substantially slower accurate responses in shifting relative to non-shifting experimental trials. Although all individuals are expected to manifest reductions in shifting speed and/or more erroneous responses when attentional shifting occurs relative to when it does not, individuals with substantially greater switch costs, measured by the difference in erroneous responses between switch and non-switch, repetition trials (or tasks) as well as the difference in response time between switch and non-switch, repetition trials (or tasks), are considered to be relatively poor attentional shifters. These poor attentional shifters may struggle to disengage from the original stimulus of focus, struggle to engage with the new stimulus, or fail to recognize that shifting is beneficial in a timely manner.

Importance of Attentional Shifting to Language Acquisition

Attentional shifting is relevant to the DLD population because attentional shifting appears to facilitate language acquisition in general (e.g., Finney et. al, 2014) and novel words learning specifically (e.g., Collisson, Grela, Spaulding, Rueckle, & Magnuson, 2015; Jones, Smith, & Landau, 1991; Landau, Smith & Jones, 1988; Samuelson & Smith, 2000; Smith, Jones, & Landau, 1996). Of particular importance to this dissertation is the role of attentional shifting in word learning, which has been documented in both children and adults (e.g., Collisson et al., 2015; Jones et al., 1991; Landau et al., 1988; Samuelson & Smith, 2000; Smith et al., 1996). For example, attentional shifting is needed for successful lexical cohesion, including linking referents (i.e., “It”) in “It happened so fast.”) and the concepts to which they refer (e.g., Deak and Narasimham, 2013; Fauconnier, 1997). In addition, in novel word learning experiments, adults
and children are known to shift their attention to different visual characteristics depending on the properties of objects. They attend to shape for artifacts (e.g., apple), material composition for nonsolid substances (e.g., liquids), and multiple properties, based on similarity, for animate objects (e.g., animals) (e.g., Samuelson & Smith, 2000; Smith et al., 1996).

Given the relationship between this attentional process and lexical acquisition, it is no surprise that the attentional shifting abilities of children with DLD have been of particular interest to researchers investigating this population. To date, however, the results stemming from these investigations have been equivocal (e.g. Farrant, Maybery, & Flecher, 2012; Henry, Messer, & Nash, 2012; Im-Bolter, Johnson, & Pascual-Leone, 2006; Kapa, Plante, & Doubleday, 2017; Roello et al. 2015; Yang & Gray, 2017). To gain a more comprehensive understanding of the attentional shifting abilities of children with DLD, a meta-analysis is warranted to synthesize the work conducted to date. A meta-analysis could determine if there is a difference in the attentional shifting abilities of children with DLD relative to their typically developing peers. If so, a meta-analysis would be useful in determining the magnitude of the difference and given the variability in study outcomes to date, evaluate factors which might contribute to the disparate research results. Consequently, Study 1 of this dissertation is a meta-analysis investigating the attentional shifting abilities of children with DLD relative to typically developing, age-matched peers.

The results of Study 1 of this dissertation provide further support for attentional shifting deficits in children with DLD; However, the magnitude of the deficits demonstrated by this meta-analysis appears to be subtle. Therefore, it is important to understand the conditions under which attentional shifting deficits in children with DLD manifest. Subtle attentional deficits in general can go undetected until demands on resources are high. Under demanding processing
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conditions, children with DLD often struggle to allocate sufficient resources to perform as well as their typically developing, age-matched peers. This has been documented on tasks assessing working memory (e.g., Dollaghan & Campbell, 1998; Edwards & Lahey, 1998; Ellis Weismer, Evans, & Hesketh, 1999), inhibition (e.g., Imbolter et al., 2006; Victorino & Schwartz, 2015), and selective attention (e.g., Spaulding et al., 2008). Whether children with DLD have insufficient attentional resources to allocate to demanding tasks that require a relative increase in attentional effort or whether they have sufficient attentional resources but fail to allocate them appropriately, at this point, is unknown. What is known, however, is that if demands on attentional shifting are low, deficits may remain hidden. In contrast, when demands on attentional shifting are high, the added attentional effort is apt to make deficits more apparent.

Study 2 was conducted to evaluate this possibility. Study 2 of this dissertation is a quasi-experimental study investigating attentional shifting in preschool children with DLD. This study specifically examined the impact of increased attentional demand, or load, on the speed and accuracy in which children with DLD shift their attention. The findings from both Study 1 and Study 2 suggest that children with DLD exhibit attentional shifting deficits when demands are high, but not when demands are low. This begs the question; how might this translate to their word learning challenges?

From a diagnostic perspective, children with DLD cannot be reliably distinguished from late talkers, the latter of whom grow out of their initial language delays, until preschool age (e.g., Greenslade, Plante, & Vance, 2009; Rescorla, 2002; Whitehurst & Fischel, 1994). While the preschool years represent an important time in morphological, syntactic, and pragmatic development, it is worthy to note that the demands on children’s word learning are particularly high during this time period. This is partially because the preschool years represent a time at
which rapid and efficient word learning is expected (e.g., Carey & Bartlett, 1978). To date, accumulating evidence supports that word learning during this period of time is more challenging for preschool children with DLD than their unimpaired peers (e.g., Alt, Plante, & Creusere, 2004; Gray, 2003; 2004; 2005; Kiernan & Gray, 1998; Rice, Burh, & Nemeth, 1990). Rapid, efficient word learning expectations likely place high demands on the children’s attentional processes, including attentional shifting.

Attention is particularly relevant for lexical acquisition because it serves as a filtering system for the over-whelming sensory input, honing in on the relevant features to enable efficient word learning. The relevance of attentional shifting ability comes into play because preschool children with DLD do not appear to attend to the relevant features to facilitate rapid and efficient word learning (Collisson et al., 2015). For example, Collisson et al. (2015) found that preschool children with DLD, unlike their typically developing language (TL) peers, do not attend to shape when exposed to novel count nouns. This is concerning as attending to shape promotes rapid count noun word learning (e.g., Smith et al., 2002).

Although teaching typically developing toddlers to attend to shape appears to promote rapid word learning (e.g., Smith et al, 2002), teaching preschool-age children with DLD to likewise shift their attention to relevant features, such as shape to facilitate count noun learning, may not be quite as easy. Based on Study 1 of this dissertation, preschool-age children with DLD are poor attentional shifters, and inhibiting what is the focus of their attention to switch them to attend to the relevant perceptual cues may be quite challenging given widespread research documenting their poor inhibitory control (e.g., Bishop & Norbury, 2005; Im-Bolter et al., 2006; Marton, 2007; Spaulding, 2010). What is apparent from Study 2 is that their ability to successfully switch their attention to a new focus under conditions of high demand is particularly
weak. Based on prior work (e.g., Alt et al., 2004; Gray, 2003; 2004; 2005; Kiernan & Gray, 1998; Rice et al., 1990), we have substantial evidence that many children with this disorder are likely to experience the word learning process as highly demanding. They struggle with word learning. Finally, there is a theoretical basis for suggesting that teaching children with DLD to shift their attention to other visual properties of the input may not be an efficacious intervention approach for children with DLD. This is because this process may exhaust their attentional capacity and leave few attentional resources remaining to actually learn the novel words. This depletion of resources available for learning has been referred to as a utilization deficiency (e.g., Clerc, & Miller, 2013; Clerc, Miller, & Cosnefroy, 2014). Given the limited cognitive capacity (e.g., Dollaghan & Campbell, 1998; Edwards & Lahey, 1996; Ellis Weismer et al., 1999), including for attentional processing (e.g., Aljahlan, & Spaulding, 2019; Spaulding et. al, 2008), observed in children with DLD, a utilization deficiency resulting from an attentional shifting focused approach to treatment is quite possible if attempting to get children with DLD to shift their attention to visual features that promote word learning in unimpaired children.

Rather than encouraging children with DLD to switch their attentional focus to what facilitates word learning for non-impaired populations (e.g., Smith et. al, 2002), shape for example for count nouns, Study 3 in this dissertation takes an innovative approach to circumvent a potential barrier to successful word learning in this impaired population, weak attentional shifting. Specifically, Study 3 of this dissertation investigates what preschool-age children with DLD naturally attend to when initially exposed to new words and their referents. Determining what children with DLD attend to naturally when exposed to new words is an important first step towards developing a treatment program which capitalizes on their attentional tendencies while minimizing the demand on their attentional weaknesses, in this case, attentional shifting.
To summarize, Study 1 is a meta-analysis of the attentional shifting ability of children with DLD. Study 2 investigates the attentional shifting capacity of preschool children with DLD. Study 3 investigates what captures the visual attention of preschool children with DLD when initially exposed to novel words, the phonological form, and its referents, the objects themselves. There are two goals of this work. The first is to identify attentional shifting weaknesses, including the conditions under which they manifest for this population. The second is to determine the attentional tendencies of these children during the language learning process, in this case during lexical learning. This work is based on the assumption that children with DLD have attentional weaknesses that accompany their language deficits and that these attentional weaknesses manifest when attentional capacity limits are reached. Because language learning is likely to exceed their attentional capacity limits, the current research also assumes more efficacious intervention can likely be provided to this population by adjusting treatment to accommodate their attentional tendencies.
Chapter 2

Attentional Shifting in Children with Developmental Language Disorder: A Meta-Analysis

Introduction

Developmental Language Disorder (DLD), a common disorder in childhood occurring in 7 - 8% of the population (e.g., Beitchman et al., 1986; Norbury et al., 2016; Tomblin et al., 1997), is diagnosed on the basis of exclusion. These children exhibit impaired language development with no intellectual disability, no primary physical disabilities, no frank neurological disorders, no primary sensory disabilities, and no emotional or behavioral disorders that could explain their language acquisition challenges (Leonard, 2014). Linguistic accounts for this disorder claim that children with DLD exhibit a language impairment in isolation, with no accompanying deficits in neuropsychological processes, to include attentional shifting (e.g., Gopnik & Crago, 1991; Rice & Wexler, 1996; Rothweiler, Chilla, & Clahsen, 2012; van der Lely, 2005). In contrast, the alternative account for DLD is that these children do indeed have neuropsychological deficits which accompany and may even contribute to their language challenges. These neuropsychological deficits include working memory (e.g., Archibald & Gathercole, 2000; Gathercole & Baddeley, 1990; Montgomery, Magimairaj, & Finney, 2010), auditory perception (e.g., Tallal & Peirce, 1973; Wright, Bowen, & Zecker, 2000; Ziegler, Pech-Georgel, George, Alario, & Lorenzi, 2005, and attention (e.g., leclercq, Majerus, Prigent, & Maillart, 2013; Montgomery, 2000; Spaulding, 2008). Supporting the latter account, meta-analyses conducted on these children to date have found working memory (e.g., Vugs, Hendriks, Cuperus, & Verhoeven, 2014), inhibition (e.g., Pauls, & Archibald, 2016), and sustained attention (e.g., Ebert & Kohnert, 2011) deficits in this population. However, clarity on an
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important attentional process, attentional shifting, is needed in this population due to the important role that attentional shifting appears to play in the language acquisition process.

Attentional Shifting Investigations in Children with DLD

Studies investigating attentional shifting in children with DLD to date have reported mixed findings (e.g., Dibbets, Bakker, & Joells, 2006; Farrant et al., 2012; Henry et al., 2012; Im-Bolter et al., 2006; Kapa et al., 2017; Lukács et al., 2016; Roello et al., 2015; Yang & Gray, 2017). For example, Roello et al (2015) investigated attentional shifting in preschool-aged children with DLD and TL. The authors presented children with sets of three pictures and asked them to first sort two pictures out of the three in each set that matched in one feature, and then to sort two pictures out of the three in the same set that matched in a different feature. The children with DLD struggled, relative to their typically developing peers, in successfully switching their attention with ease to the second shared feature in each set. Farrant, Maybery, & Flecher (2012) investigated attentional shifting in 4- to 6-year-old children with DLD and TL. They used the Dimensional Change Card Sort task (DCCS; Zelazo, Frye, & Rapus, 1996). Similar to the task used in the Roello et al (2015) investigation, the children were likewise to first select two pictures out of three that matched in one feature and then to select two pictures out of the same three based on a different matching feature. Similar to the prior study’s findings, the children with DLD exhibited more difficulty than their unimpaired peers in shifting their attention from a prior dimension sorting rule to a new dimension sorting rule. Yang and Grey (2016) also investigated preschool-aged children with DLD using the DCCS. They suggested that the linguistic weaknesses of the children with DLD may have impacted prior outcomes investigating attentional shifting using the DCCS, as the DCCS uses nameable objects (i.e., boat, bunny). For this reason, the researchers added another task that was similar in concept to the DCCS but used...
nameless shapes. They compared performance on the two to identify the potential contribution of linguistic demands to prior study outcomes. In their study, the preschool children with DLD performed worse than their age-matched peers on the DCCS, which was in line with previous work. However, the differences between the DLD and controls disappeared when the items used were not nameable. Interestingly, Kapa et al. (2018) also investigated attentional shifting in preschool-aged children with DLD and unimpaired age-matched peers, requiring them to name the objects in one version of their task and not requiring them to name them in the other. In conflict with the findings by Yang and Grey (2016), the surprising finding in this study was that the between group difference disappeared when children were expected to name the objects.

In contrast to the aforementioned studies, there are few investigations of attentional shifting of children with DLD that have been published that document consistent, comparable performance to their unimpaired peers on attentional shifting tasks (e.g., Henry et al., 2012; Im-Bolter et al., 2006). Henry et al. (2012) investigated attentional shifting in school-aged children with DLD using the Trail-Making Test which is a subtest of the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001). The children were expected to switch between connecting small circles with letters and numbers in sequence (A-1-B-2-C-3 through….16-P). This was compared to their performance sequencing letters in isolation and numbers in isolation. The performance of children with DLD did not differ from their typically developing peers. In addition, Im-Bolter et al. (2006) investigated attentional shifting in DLD and unimpaired children between 7- to 12-years of age. The school-age children completed a task in which they were to shift between two rules while responding to questions regarding value of digits on the screen (prompt: What Number?) and how many numbers were on the screen.
ATTENTIONAL SHIFTING WEAKNESSES AND TENDENCIES IN CHILDREN WITH DLD

(prompt: How Many?). The switch cost observed between switch and nonswitch trails was comparable between the two groups.

The results of investigations of the attentional shifting abilities of children with DLD are somewhat challenging to summarize in narrative form. This is largely due to the heterogeneity in study design. Whether or not children with DLD have a deficit in attentional shifting relative to their typically developing, similar aged peers, at this point, is unclear. Given the potential importance of attentional shifting to linguistic learning (e.g., Collisson et al., 2015; Deak & Narasimham, 2013; Fauconnier, 1997; Finney et. al, 2014; Jones et al., 1991; Landau et al., 1988; Samuelson & Smith, 2000; Smith et al., 1996), further clarity is needed on the attentional shifting abilities of children with DLD as their hallmark deficit is poor language acquisition. If attentional shifting weaknesses are present in children with this disorder, such deficits may contribute to the poor linguistic learning in this population.

Factors Which May Impact Equivocal Findings on Attentional Shifting in Children with DLD

Type of Attentional Shifting Task

One potential contributing factor that may account for variability in studies outcomes could be the type of attentional task employed. For example, some behavioral experimental paradigms use set-shifting tasks. In these types of tasks, individuals learn a rule and must modify their response set when the rule changes, whether informed of the rule change or through self-discovery from trial by trial feedback. In most of these tasks the target stimulus remains the same, but the sorting or selection rules change, and individuals must deduce the new rule from a cue or feedback. Stimulus items on these tasks are typically either bivalent or multivalent; that is, they have a sorting strategy relevant to each of the two or more rules, and the correct response
for one rule is incorrect for the other (e.g., Diamond, 2013). A successful attentional shift on these tasks happens when individuals switch from the old rule of which they have become accustomed to the new rule. Difficulty in attentional shifting is identified when individuals perseverate on the old sorting rule, interpreted as a struggle in the initial component of attentional shifting, disengaging attention.

Examples of widely used behavioral measures that apply this task design paradigm are the DCCS and the Wisconsin Card Sorting Task (WCST; Heaton, Chelune, Talley, Kay, & Curtis, 1993). In the WCST for example, participants use trial by trial feedback to determine the correct sorting strategy on multivalent cards. Once the participants discover and become accustomed to the sorting strategy that is considered correct, they begin receiving feedback on each trial indicating that this sorting strategy is no longer the correct one. Participants must deduce the new rule for sorting cards, based on trial by trial feedback, and shift their sorting strategy accordingly.

Attentional shifting is also measured using alternating tasks. In these tasks, participants are expected to shift their attention between two targets, while the rule remains the same. In these types of tasks, attentional shifting is either measured by comparing performance between two goals in the same task relative to a single goal in a different task to determine the “switch cost” of shifting between the two relative to attending to one alone (e.g., Henry et al., 2012; Im-Bolter et al., 2006; Mutch, 2001) or performance is compared on switch versus non-switch trials within the same task to ascertain the switch cost (e.g., Magimairaj & Montgomery, 2012). For example, in the +/- Task (Jersild, 1927) participants are expected to alternate their responses to each stimulus by performing alternate operations. They must add a certain quantity to the first stimuli, subtract the same quantity from the second stimuli, and continue in this alternating pattern.
Similar alternating tasks include the *Trail-Making Test*, the *Number-Letter Task* (Rogers & Monsell, 1995) and the Local/Global Task (Navon, 1977). In the *Trail-Making Test*, for example, participants are required to switch between connecting small circles with letters and numbers in alphabetical and numerical sequence respectively. Switch cost is measured by averaging participants’ performance on sequencing letters in isolation and numbers in isolation and comparing this to their performance when alternating between both letters and numbers. Consequently, in these types of tasks, the shifting rule remains the same, but the target is what changes.

To clarify, when studies employ a set-shifting paradigm to measure attentional shifting, children are expected to shift between two or more rules regarding a stimulus. For example, in the *DCCS*, children are asked to first sort two out of three pictures that match in color on a specific number of trials. In this case the child is learning the first rule, which is color, and is required to hold it in his or her working memory. Then the child is instructed to switch his or her sorting strategy to shape. So here a second rule is introduced that the child is required to learn and hold in his or her working memory within the same task. Furthermore, when the second rule (i.e. shape) is introduced, the child is expected to inhibit the first rule (i.e. color) that was learned on previous trials in order to respond correctly. This likely places demands on working memory and inhibition, both notably weak in children with DLD (e.g., Estes, Evans, & Else-Quest, 2007; Montgomery, 2005; Pauls, & Archibald, 2016; Spaulding, 2010; Vugs et al., 2014).

On the other hand, when studies use an alternating tasks paradigm, the rule does not change across the switching and the non-switch conditions, and the trials are repeated over and over. For example, in the *Trail-Making Test*, the rule that is introduced is “order”. Children are asked to first connect numbers in “order” on one trial, then connect letters in “order” on another...
trial, then alternate between letters and numbers while maintaining “order”. In alternating tasks, the participants are required to learn just one rule and to maintain this same rule throughout in working memory. When the rule is constant and does not change, logically there is likely relatively less demand on working memory and inhibition relative to the expectations inherent within set-shifting tasks.

**Dependent Variable of Interest**

Another potential explanation for these differences could be related to the different way attentional shifting performance is measured. Some studies report accuracy on attentional shifting measures (e.g., Kapa et al. 2017), while others report response time (RT) (e.g., Dibbets et al., 2006; Im-Bolter et al., 2006). The differences between children with DLD and their unimpaired peers may manifest in only one of these dependent variables, or the magnitude of difference may be larger in one compared to the other. One possibility is that there might be larger between group differences in studies that measure accuracy on attentional shifting measures when compared to studies that measured RT because some children may sacrifice RT for more accurate responses when tasks are challenging. Davidson, Amso, and Diamond, (2006) found that children and adults slow their responses to respond more accurately to challenging tasks. The ability to evaluate performance and slow down to respond accurately is apt to require a certain degree of inhibitory control. Children with DLD are known to have deficits in inhibitory control, unlike their typical peers, and they are less likely to slow down to improve performance (e.g., Spaulding, 2008). If TL children slow down and children with DLD do not, then greater between group differences in accuracy relative to RT may result. However, children with DLD are slower than their typical unimpaired peers to process different linguistic input (e.g., Lahey & Edwards, 1996; Montgomery & Leonard, 1998; Reynolds & Fucci, 1998) and
cognitive input (e.g., Johnston & Weismer, 1983; Sininger, Klatzky, & Kirchner, 1989).
Consequently, between group differences in RT may be, on the contrary, quite large. If children with DLD are slower to disengage from a prior focus of attention and engage with a new stimulus when expecting to shift their attention, then the differences in RT may be greater between children with DLD and children with typical language, and potentially even greater than accuracy disparities between this impaired and unimpaired population.

**Age of the Children with DLD**

In addition to the type of attentional task employed and the dependent variable of measurement, another potential factor contributing to the variability across studies of attentional shifting in children with DLD could be the age of the children in the investigations. Attentional shifting is, after all, a developmental skill.

The onset of attentional shifting has been observed in infants as young as 3 months of age via several approaches, including through eye gaze methodology. It is important to point out that while some researchers argue that gaze shifts across the age-span are involuntarily and reflexive in nature (e.g. Driver et al., 1999; Friesen et al., 2004), others provide evidence that shifting attention in response to a gaze cue begins as a reflexive behavior and develops into a voluntarily-controlled action (e.g. Kawai, 2011; Ristic & Kingstone, 2005; Vecera & Rizzo, 2006). Between 3-9 months of age, infants begin shifting their attention in response to a cue; However, these shifts of attention appear to be reflexive and peripheral in nature.

There is reliable evidence that intentional attentional shifting does not occur until at least later in child development. An investigation by Butler, Caron, and Brooks (2009) was one of the earliest studies to observe purposeful attentional shifting in response to eye gaze shifts in 14-18-
month-old infants. Their study showed that unlike 18-month olds, 14-month-old infants were still inconsistent with their purposeful shifting. Another line of research evaluated attentional shifting in infants has assessed perseverative errors, indicative of poor attentional shifting, in versions of A-not-B tasks (e.g., Diamond, 1985; Piaget, 1954; Thelen et al., 2001). In A-not-B tasks, infants are typically expected to retrieve a toy that is hidden under one of two identical boxes to the left and right of the infant’s midline. Once the infant retrieves the toy from side A after a couple of trials, the toy is hidden under side B and the infant is expected to shift his or her attention to retrieve it from the new location. Task difficulty is increased by extending the time delay between hiding and reaching at B until infants make the A-not-B error. Infants between 7-12 months of age begin to show a gradual increase in the delay they can tolerate before making the A-not-B error, and by 2 years of age, the majority of children showed no perseveration errors, indicating successful attentional shifting (e.g., Diamond, 1985; Carlson, 2005; Stahl & Pry, 2005; Thelen et al., 2001).

Investigations have also studied the development of attentional shifting through the preschool years. Some studies have used the DCCS to investigate the developmental changes in the attentional shifting of these children (e.g., Brooks, Hanauer, Padowska, & Rosman, 2003; Frye et al., 1995; Kirkham, Cruess, & Diamond, 2003; Zelazo et al., 1996). Studies that investigated children between 2-5 years of age have found that two-year-old children appear to be unable to sort successfully on their own even when they understood instructions. By 3 to 4 year of age, however, children begin to sort successfully by one dimension but have difficulty switching their attentional focus to a different dimension of the same object (e.g., Brooks et al., 2003; Frye et al., 1995; Kirkham et al., 2003; Zelazo et al., 1996). This failure in shifting to the new dimension and perseverating on the old dimension indicates that shifting abilities in children
of this age group is still underdeveloped. In one study, Frye and Colleagues (1995) found that 3- and 4-year-old children were able to follow instructions and sort accurately on pre-switch trials of the DCCS but perseverated on the pre-switch rule and struggled to switch to the new sorting rule on post-switch trials even when explicitly informed of the new rule. By 5 years of age, however, their attentional shifting ability improved as they succeeded in sorting correctly and switching to the new rule when expected to do so.

Other studies have found that attentional shifting continues to develop in the school years. Chelune and Baer (1986) found a reduction in perseverative errors on the WCST in 6-year-old children compared to preschool-age children. Similarly, Davidson et al. (2006) found an age-related linear improvement in attentional shifting skills using multiple experiments. In their study 6-year-olds continued to show improvement in attentional shifting, and even by 13 years of age, children were still not performing as accurately as adults.

Potential age-effects for children with DLD are likely, given the developmental nature of attentional shifting (e.g., Brooks et al., 2003; Frye et al., 1995; Kirkham et al., 2003; Zelazo et al., 1996). Several possibilities exist. First children with DLD could exhibit a delay in attentional shifting development. Differences could emerge early in development, such as during the preschool years, and grow wider once they reach school-age. Another possibility is that differences between children with DLD and their unimpaired peers may not emerge until the later school-age years when further attentional shifting skill is expected to develop. Finally, it is possible that differences between children with DLD and their unimpaired peers may be apparent during the preschool-age years, but when these children are given additional time to catch up to their unimpaired peers, such as during the school-age years, these differences may no longer manifest.
Relevant Meta-analyses to Date:

Understanding whether or not children with DLD present with attentional shifting deficits has been of recent interest in the literature. For example, Pauls and Archibald (2016) conducted a meta-analysis to explore if children with DLD do present with deficits in cognitive flexibility. Given that the term cognitive flexibility and attentional shifting have been used simultaneously in some literature (e.g., Diamond, 2013), it is important to draw important distinctions between the two. Pauls and Archibald (2016) viewed cognitive flexibility as an overarching term encompassing several functions including the ability to adapt or shift between tasks demands, to implement problem-solving strategies, and to carry out a new task in competition with the residual activation from previous tasks. Under this definition, they considered tasks of generativity or creative fluency as measures of cognitive flexibility. Important to the current investigation, the operationalization of attentional shifting used in the current study is the ability to disengage attention from a stimulus, then shift attention to another, and then re-engage attention to the new stimulus (Posner & Peterson, 1990). Consequently, not all of the studies included in the meta-analysis by Pauls and Archibald (2016) qualify under the definition of attentional shifting in the current investigation. Specifically, their meta-analysis included studies relevant to generative verbal fluency, not just alternating tasks and set shifting tasks. Generative verbal fluency tasks measure vocabulary size, lexical access speed, updating, and inhibition (e.g., Shao, et al. 2014; Troyer, Moscovitch, & Winocur, 1997), all of which are areas of deficit in children with DLD (e.g., Im-Bolter et al., 2006; Leonard, 2014; Spaulding, 2010).

In their meta-analysis, Pauls and Archibald (2016) found that children with DLD performed worse than their age matched typically developing peers by 0.2 standard deviations. The study also investigated if variations in study outcomes existed and if so, if the age of
participants, the linguistic demands of the task, and the severity of the language impairment in the DLD group contributed to disparities in study outcomes. Although this meta-analysis produced significant effect sizes, it did not show that there were differences among study outcomes; that is, their meta-analysis of heterogeneity statistic was zero. Considering the wide disparity among the ages of the study participants, the type of tasks, as well as the disparity in findings across studies, this absence of heterogeneity is confusing and may be a statistical or publication error. Despite this lack of heterogeneity specified at the statistical level, the authors explored potential contributions to heterogeneity. They investigated whether age of participants, linguistic demands of the task, and the severity of the language impairment in the DLD group moderated the results. None of these three moderator analyses were significant.

It is important to keep the comparison between the current study and this prior meta-analysis on cognitive flexibility within the context that they overlap in the inclusion of some tasks but are not equivalent. The current investigation does not include any studies or tasks of verbal fluency. These are omitted in the current analysis because studies of generative verbal fluency measure to what extent the child is flexible in generating clusters of nouns that belong to a specific category with time constrains, and then generating another cluster of nouns that belong to another category. Besides attentional shifting, this ability is based on a systematic memory search and the ability to flexibly change the search criteria. The specific contribution of attentional shifting to performance on these types of tasks is unknown.

Purpose of the Present Study
This meta-analysis was conducted to investigate the attentional shifting ability of children with DLD compared to their same-aged unimpaired peers. The aim was to determine if there are differences between children with DLD and their unimpaired, age-matched peers in their attentional shifting ability. If a difference is observed, the direction of this difference and the extent of this difference will be determined. Heterogeneity in attentional shifting study outcomes comparing children with DLD and their unimpaired peers was measured and moderators which may contribute to such heterogeneity were explored. The specific moderator variables of interest included the following: 1) task type (set shifting, alternating tasks); 2) dependent variable of interest (accuracy, response time), and 3) the age of the study participants (preschool-aged, school-aged). The research questions for Study 1 as follow:

(1) Is there a difference between children with DLD and their unimpaired, age-matched TL peers in their attentional shifting ability?

If differences in attentional shifting manifest,

(a) What is the direction of this difference?

(b) What is the magnitude of this difference?

(2) Is there significant heterogeneity across studies? If so, are the age of the participants (preschool-age, school-age), the dependent variable of measure (RT, accuracy), and/or the task type (set-shifting, alternating) significant moderating variables?
Method

A meta-analysis was used for this investigation. Meta-analysis enables results from studies using similar methodologies to be combined and, because of this, allows population parameters to be estimated with greater precision than single study designs (Borenstein, 2009; Card, 2015).

Literature Search


Study Inclusion and Exclusion Criteria

Studies included in the meta-analysis met the following criteria: (a) contained either a conventional operational definition that follows the lines of concordance evidence in identifying children with DLD (children who present with poor language skills that cannot be attributed to hearing impairment, neurological impairment, low IQ, or other diagnosis) or a clinical diagnosis of developmental language disorder (children who were identified by a speech-language
pathologist as having either a receptive and/or expressive language impairment); (b) included children with DLD in the age range of 3 to 17 years; (c) Used behavioral performance-based measures of attentional shifting (excluding tasks of verbal fluency); (d) reported adequate statistical results with computed effect sizes or that would allow for the computation of effect sizes.

Abstract screening of 604 studies resulted in identifying 161 studies that included a group of children with DLD. The full text of each of those studies was fully reviewed. Full text review lead to the exclusion of 124 studies of children with DLD that did not investigate attentional shifting or did not use an attentional shifting measure. Five studies were excluded because they were in a language other than English. Four more studies were excluded because the studies did not include a control group of typically developing, age-matched peers (e.g., Cane, 2008; Cuperus, Vugs, Scheper, Hendriks, 2014; Karasinski, 2011; Matson, 2003). One study was excluded because participants in the language impaired group did not meet the standard definition for DLD. In this case it did not exclude frank neurological impairment (Liss et al. 2001). One study was excluded for not reporting sufficient data to compute effect size (Noeterdaeme et al. 2000). Finally, two doctoral dissertations were excluded in favor of the peer-reviewed journal article of the same study. In the end, 20 studies were included for review in this meta-analysis. See Figure 2.1. for flow chart of study selection.

Data Coding

The following information was extracted from each study: (a) DLD inclusion criteria; (b) number of participants in the DLD and control groups; (c) mean ages of participant groups; (d) mean standard score and standard deviation of language and nonverbal test scores; (e) statistical
data reporting performance on attentional shifting tasks such as group mean and standard deviations, F values, and T values.

Additional variables to be used in moderator analyses were extracted and coded for each study. These included the age of the participants and the attentional shifting task type. For each study the mean age of the participants was categorized into preschool/kindergarten age (between 3;00-5;11) and school-age (between 6;00-17;11). In addition, attentional shifting behavioral tasks were then coded as either set-shifting tasks or alternating tasks. Tasks coded as set-shifting included a rule change with the same stimuli item. These included tasks such as the WCST and the DCCS. Studies were coded as alternating if the task employed in the study required participants to alternate between two targets, but the rule remained the same. These included, for example, The Trail-Making Task (Reitan, 1992) and the nonverbal fluency subtests of the D–KEFS (Delis et al., 2001). Finally, the dependent variable that was used to report data on the performance of children with DLD, RT if the study reported response time and Accuracy if the study reported either correct responses or incorrect responses, was also coded.

**Analysis**

The standardized mean effect size, $d$, was used in this study to compare group differences in performance between DLD and their unimpaired peers (TL) on measures of attentional shifting. The effect size $d$ is calculated by subtracting the mean of the DLD group from the mean of the TL group and dividing the result by the average pooled standard deviation. In this study, a positive effect size indicates that children with DLD performed better than children with TL on attentional shifting measures, and a negative effect size indicates that children with DLD performed worse. Effect size ($d$) was converted to Hedges’ $g$ to avoid the bias that may occur
when a study with a small sample size is given too much weight (e.g., Borenstein, Hedges, Higgins, & Rothstein, 2009; Card, 2015; Hedges, 1981). Thus, when the combined effect size is calculated using Hedges’ g, study contributions will be proportional based on each study’s sample size; that is studies with larger sample size will be being given more weight than studies with smaller sample size. Effect sizes of (0.2) are considered small, (0.5) are consistent with a medium effect size, and (0.8) are characterized as a large effect size (Cohen, 1988).

Analyses were conducted using Comprehensive Meta-Analysis (version 2, 2005). The homogeneity statistic $Q$ was calculated to determine the amount of variation in effect sizes among the studies included in the analysis. A chi-square test and resulting $Q$ value was conducted to evaluate the statistical significance of the heterogeneity across studies and the magnitude of the heterogeneity was determined using the $I^2$ value (Borenstein et al., 2009). $I^2$ describes the amount of variation between studies due to variation in effect sizes than sampling error alone (e.g., Card, 2015; Higgins, Thompson, Deeks, & Altman, 2003). Huedo-Medina and colleagues (2006) suggested that an $I^2 = 25\%$ is a small amount of heterogeneity, $I^2 = 50\%$ is a medium amount of heterogeneity, and $I^2 = 75\%$ is a large amount of heterogeneity. If significant heterogeneity was found, then the average effect size calculated is not an accurate measure of summary of effect sizes due to variation across study results. However, further investigation of factors that may be contributing to the variation among studies is warranted. If no significant heterogeneity was estimated, then the average effect size calculated by itself would be an accurate summary of the results. To estimate effect sizes when a single study contained multiple tasks and dependent variables, the shifting unit of analysis approach was employed (Cooper, 1998). Using this approach, multiple effect sizes within a study were averaged to yield one effect size for that study to ascertain the overall effect size. When comparing across levels of moderator
variables (i.e. task type, dependent variable of interest, chronological age), effect sizes were reported separately across these moderator variables. Then the multiple effect sizes were separated by level of the moderator variable (e.g., effect sizes for set shifting vs. alternating were kept separately when evaluating task type differences). To investigate moderator variables, the between group heterogeneity ($Q_{\text{Between}}$) resulting from subgrouping the studies by each moderator variable was examined. When there’s a significant between group heterogeneity, then this categorical moderator variable can be considered a reliable variable that contributes to the effect sizes found in the studies (Borenstein et al., 2014; Card, 2015).

**Hedges’ $g$ effect size:**

The effect sizes for each study are reported in Table 2.1 A random-effects analysis was carried out to estimate the overall standardized mean difference. The analysis estimated a standardized mean difference Hedges’ $g = -0.42$ ($SE = 0.08$, 95% CI [-0.58, -0.27]), which differed significantly from zero $Z = -5.35$, $p < .001$. The mean difference suggests that children with DLD performed worse than their age matching TL peers on attentional shifting tasks by almost half a standard deviation compared to typical control peers. As expected, there was a medium amount of heterogeneity, $Q = 31.66$, $p = 0.03$, $I^2 = 39.997\%$. See Figure 2.2. for a visual depiction of the forest plot.

**Publication Bias:**

One concern for meta-analysis is publication bias. Publication bias refers to tendency to published studies that have significant results rather than it’s theoretical or methodological quality. Pauls and Archibald (2016) suggest that this risk is unlikely as more studies published insignificant results in this area than significant results. To support this, an Egger’s test of the
intercept was conducted, in which the effect size is captured by the slope of a regression line \((B_1)\) and the bias is captured by the intercept \((B_0)\). In this case \((B_0)\) is -1.37, 95% CI [-3.40, 0.66], with \(t_{18}=1.41\). The \(p = 0.17\). This indicates that the changes in effect sizes are not associated with publication bias.

Sensitivity Analysis:

It was noted that the effect sizes of studies varied from -1.587 to 0.215. This variability brings the possibility that one study may be the reason that the average effect was statistically significant. Therefore, a one-study-removal analysis was conducted to investigate this. This analysis involved conducting separate analyses to assess the remaining impact on the overall effect size when each study was removed from the analysis. Removal of each individual study had limited impact on the magnitude of the average effect size or the confidence interval in this study as no individual study altered the average effect size sufficiently to result in a nonsignificant finding. The lowest average effect size obtained was −0.460, and the highest average effect size obtained was −0.374. Therefore, the results of this analysis showed that the average effect size was relatively stable.

Moderator Analyses:

Given the significant heterogeneity observed, moderator analyses were warranted. Moderator analyses were conducted to determine if they could explain some of this heterogeneity. An analysis following mixed-effects assumptions was conducted for age group (preschool, school age) as a potential moderating variable. This sub-group moderator analysis revealed that there were no significant effects of age, \(Q_{between} = 0.065, p = 0.80\). Therefore, it
could be concluded that age group as a moderator variable did not account for a significant proportion of the heterogeneity observed across the studies.

The second moderator analysis conducted was task type (set-shifting, alternating). Mixed effects analysis revealed a significant between condition difference \( Q_{between}=4.48, p < 0.03 \). In other words, task type moderated the performance of children with DLD relative to TL children on studies of attentional shifting. The within group analysis also revealed that the effect size of studies in set-shifting studies (Hedges’ \( g = -0.52 \), \( SE = 0.09 \), CI [ -0.70, -0.33 ]) resulted in significant between group differences, whereas there were no significant between group difference in studies that used alternating tasks, (Hedges’ \( g = -0.18 \), \( SE = 0.13 \), CI [ -0.43, 0.07 ]). See Table 2.2 for additional data from the moderator analysis of task type.

The final moderator variable investigated was the dependent variable that was used to measure attentional shifting. One study was excluded from this analysis (Yoo & Yim, 2018) because this investigation reported the combined score of both RT and accuracy. Sub-group moderator analysis revealed that there were no significant between group differences between studies that reported accuracy switch costs and studies that reported response time (RT) switch costs to capture attentional shifting ability, \( Q_{between} = 4.70, p = 0.09 \).

Discussion

The purpose of this study was to obtain empirical evidence that would help further the understanding of attentional shifting abilities in children with DLD compared to their age-matched, unimpaired peers. This study specifically aimed to document whether attentional
shifting deficits do exist for children with DLD, and if they do, to describe the magnitude of the difference. Data were compiled from studies measuring attentional shifting in children with DLD over the past 24 years. The main findings are highlighted below.

The results of the meta-analysis support the presence of attentional shifting deficits in children with DLD when compared to their age matched unimpaired peers, with the children with DLD performing, on average, worse than their unimpaired peers by almost half a standard deviation across attentional shifting measures. The effect size of this meta-analysis was medium in size which signifies that the attentional shifting deficits in children with DLD are not small enough to be negligible. This finding of attentional shifting weaknesses in children with DLD adds to the growing body of work documenting attentional deficits in this population (e.g., Finney et. al, 2014; Montgomery et. al, 2009; Spaulding et. al, 2008; Spaulding, 2010).

To further the understanding of this heterogeneity, a moderator analysis of task type was conducted. This moderator analysis was found to be significant, indicating that task type contributed to the heterogeneity observed among the studies. This finding provides evidence that the type of task used in studies to measure attentional shifting influences the magnitude of the between group differences observed in attentional shifting between children with DLD and TL. Most importantly, this analysis revealed that while differences were present between groups of children with DLD and TL across set-shifting tasks, there were no differences observed in attentional shifting between the DLD and the TL group in studies that used alternating tasks.

This finding may not be surprising. If set-shifting tasks place relatively more demand on other neuropsychological processes, like inhibition and working memory, compared to alternating tasks, the effect of task type would be expected. Recall that in set-shifting tasks,
stimulus items share a feature that can be related to either one of the shifting rules, and the child is expected to deduce which rule applies to the given task and if a new shifting rule is required based on explicit or trial by trial feedback. At the same time, the child is expected to inhibit a response to a rule that was previously established while switching to the second rule and hold this new rule in working memory (e.g., Huizinga, Dolan, & van der Molen, 2006; Miyake et al., 2000). In contrast, it is also no surprise that no between group differences were observed in tasks that are alternating. While these types of tasks are unlikely to be devoid of inhibition and working memory demands, they are apt to be less so than set-shifting tasks. This is because the rule never changes.

The second moderator analysis investigated was the dependent variable of interest that was supposed to encapsulate attentional shifting performance. The variability observed in the differences between the performance of children with DLD and TL across studies of attentional shifting in children was not related to the way attentional shifting was calculated. Studies that reported performance using RT data did not have greater or smaller between group differences when compared to studies that reported performance using accuracy data. This may appear to be a surprising finding because children with DLD are known to have generalized slowed processing across linguistic and cognitive domains (e.g., Johnston & Weismer, 1983; Lahey & Edwards, 1996; Montgomery & Leonard, 1998; Reynolds & Fucci, 1998; Sininger et al., 1989). That slowed processing could have been expected to make the between group differences in studies that reported RT greater than the between group differences of studies that reported accuracy. However, prior work has shown that preschool-age children with DLD do not appear to slow down their responses to improve performance, while TL children do (e.g., Spaulding,
This may have worked against finding comparatively large differences in RT between the two groups of children.

The findings of this last moderator analysis should be interpreted with some caution. This is because there was significant variability in studies that reported RT. While some studies calculated RT using task latency, or the time it took the participant to complete a task from its start to its finish (e.g., Im-Bolter et al., 2006), other calculations relied on switch costs (e.g., Henry et al., 2012). Another important point to add is that RT was usually reported for accurate responses only. Consequently, in tasks in which children with DLD exhibited lower accuracy, and hence more errors, than TL children, fewer trials were used to estimate their RT. The more trials in an estimation, the more accurate the estimation is. Finally, additional caution should be noted because there were fewer studies in the moderator analysis for RT than for Accuracy, which resulted in less power for identifying if the dependent variable of measure was a moderator should it truly be one.

The final moderator analysis investigated the age of the participants. The results revealed that age did not significantly influence between group differences. Although no clear prediction was suggested, this finding is somewhat surprising especially because developmentally, preschool children in general still tend to struggle with attentional shifting but begin to improve in the school-age years (e.g. Brooks et al., 2003; Chelune & Baer, 1986; Davidson et al. 2006; Frye et al., 1995; Kirkham et al., 2003; Zelazo et al., 1996). The lack of significant age effect means that the gap between the performance of children with DLD and TL on attentional shifting measures does not change from preschool-age to school-age. It also indicates that we do not have evidence that we can attribute the variability in the between group differences that is found in studies investigating attentional shifting in children with DLD to differences in the
developmental trajectories of the participants. The findings indicate that group differences on performance of attentional shifting tasks between children with DLD and TL remain stable as they get older; these differences do not get larger or smaller with age.

The lack of age effect observed in this meta-analysis is not however, by any nature, definitive. Age was explored as a categorical variable, with studies falling into either preschool-age or school-age. This type of approach inherently over-simplifies and under-estimates the variability in participants’ ages across investigations. For example, Marton (2008) investigated school-age children with DLD who had a mean age of 9.75 years, while Dibbets et al. (2006) investigated school-age children with DLD who had a mean age of 6.8 years. Despite the three years in age gap, both studies were placed in the school-age category and treated as if they investigated similarly-aged children. This may have contributed to the lack of age effects observed in this meta-analysis. One alternative, using the mean ages of the participants as a continuous moderating variable, was considered. However, similar means across studies was also somewhat misleading, failing to account for the range of ages within the studies themselves. For example, the mean age of the children in studies by Vicotrino (2011) and Schul, Stiles, Wulfeck, and Townsend, (2004) were quite similar (M=10;9 and 10;7 respectively), but children in the Victorino (2011) study ranged from 9;1 to 12;2 years in age, while children in the Schul et al. (2004) study ranged from 7;3 to 15;4 years of age.

Additional factors, which were not explored due to a lack of available information within the published studies or due to power limitations in the resulting data set, may account for the remaining variability found in the current study. First, the variability in attentional shifting deficits is likely attributable, in part, to the proportion of children with ADHD in the study samples. Afterall, children with ADHD exhibit attentional shifting deficits (e.g., Cepeda et al.,
2000; Marte, Nikolas, & Nigg, 2007). Their difficulties have been documented on both set-shifting (e.g., Cepeda et al., 2000) and alternating behavior task paradigms (e.g., Martel et al., 2007). Of relevance, DLD and ADHD evidence a high comorbidity (e.g., Cohen, Barwick, Horodezky, Vallance, & Im, 1998; Sciberras et al., 2014; Tirosh & Cohen, 1998), with studies finding that about 35–50% with ADHD have language impairments (e.g., Tannock & Schachar, 1996) and other studies finding that about 17% of children with DLD have ADHD (e.g., Benaisch et al., 1993). However, determining the relative contribution of the influence of ADHD comorbidity in studies of attentional shifting in children with DLD is challenging for a number of reasons. First, ADHD cannot be accurately and reliably identified until children are of school-age (e.g., Todd, Huang, & Henderson, 2008), and a large proportion of the studies in the current investigation were of preschool-age children. Second, studies investigating school-age children with DLD, who were of significant age to verify ADHD presence or absence, did not reliably implement a diagnostic measure to identify those who had ADHD in their study samples nor reliably implement a screening metric to attempt to exclude those with ADHD in their investigations.

In addition to ADHD comorbidity, the severity of language deficits in the samples of children with DLD may account for some of the variability across studies, particularly given the relationship between attentional shifting and linguistic acquisition. There are two ways to potentially determine severity of language impairment. First, severity of language deficits could be determined by measures which accurately differentiate language ability at different degrees of impairment. Across the investigations included in this meta-analysis, language impairment was typically determined by standardized, norm-referenced tests of child language and in some cases, confirmed through clinical referral or parent or teacher concerns. Unfortunately, at the current
point in time, there is no empirical evidence that severity of language impairment can be accurately determined by performance on any standardized, norm-referenced test of child language (see Spaulding, Swartwout Szulga, & Figueroa, 2012 for review). In fact, language impairment severity judgments differ depending on what test the children with DLD are administered (e.g., Spaulding, 2010). Furthermore, although there are no data supporting that children with parent or teacher concerns of their language development exhibit more severe language impairments than children with DLD whose parents and teachers are not concerned (e.g., Morgan et al. 2016; Scibberras et al., 2014; Wittke & Spaulding, 2018; Zhang & Tomblin, 2000), there is some evidence that children who are clinically referred for research investigations are likely to be more severely language impaired than those who are obtained via community samples (e.g., Zhang & Tomblin, 2000). However, for the current study, information was typically lacking on the specific procedures for participant recruitment. This lack of clarity combined with the fact that assuming that children who were clinically referred were more severely impaired than those who were not in their language functioning was a big assumption to make without definitive evidential support. Despite the difficulty in measurement, it is still likely that the heterogeneity in language skills of the children with DLD across study investigations contributed to some of the remaining variability left unexplained.

Finally, the current investigation categorized task type, without accounting for the variability inherent in the different tasks within set-shifting and within alternating task paradigms themselves. For example, within the set-shifting subgroup, some studies used the DCCS (e.g., Kapa et al., 2017; Reichenbach, Bastian, Rohrbach, Gross, & Sarrar, 2016; Yang & Gray, 2017), others used the WCST (e.g., Hughes, Turkstra, & Wulfeck, 2009; Weyandt, & Willis, 1994), and still others used tasks that were developed by the authors (e.g., Kapa et al, 2017; Yang, & Grey,
Conclusion:

Despite these limitations, some general interpretations from this meta-analysis can be concluded. Children with DLD appear to perform worse than their age-matched unimpaired peers on attentional shifting measures. However, the degree of deficit seems to depend on the type of task used to measure attentional shifting. This finding provides further evidence that careful consideration should be given to how we are measuring abstract concepts such as attentional shifting and to what extent other cognitive processes aside from attentional shifting could influence task performance. This is not a new concern. It has historically been recognized that behavioral measures purported to assess attentional shifting ability suffer from what is known as the “task impurity” problem (e.g., Burgess, 1997; Phillips, 1997). For example, the WCST, depending on the research publication, has been used as a measurement of attentional shifting, categorization, inhibition, problem solving, or some combination of these cognitive processes (e.g., Cane, 2007; Drewe, 1974; Hughes et al., 2009; Robinson, Heaton, Lehman, & Stilson 1980). It is a research and a clinical challenge. Measuring a behavior and inferring underlying cognitive processes that result in the behavioral manifestations that we observe is always a challenging undertaking.

Motivation for Study 2:

The findings presented in the meta-analysis from Study 1 provide support for attentional shifting deficits in children with DLD. The meta-analysis results also suggest that attentional
deficits are subtle and only present under certain situations, evidenced in set-shifting but not alternating attentional shifting tasks. The argument in Study 1 is that children with DLD exhibit deficits on set-shifting tasks because they are more demanding relative to alternating tasks on neuropsychological processes, which may include working memory and inhibition. Whether or not this is the case is unknown. What can likely be agreed upon, however, is that set-shifting tasks are more challenging than alternating tasks. If the demand on attention is what matters, and not necessarily the recruitment of other neuropsychological processes, then children with DLD would exhibit deficits on alternating tasks if and only if sufficient demands were reached on their attentional resources. This begs the question, is it possible to make alternating tasks more challenging, and if so, does this added challenge elucidate attentional shifting deficits in children with DLD? One way to explore the contribution of task difficulty to attentional shifting performance in children with DLD is to take a task that they generally do well on, such as an alternating task, and make it more demanding while attempting to minimize the contributions needed from other cognitive processes that are weak for children with this disorder, like working memory and inhibition. Study 2 is designed with this purpose in mind. Study 2 investigates attentional shifting in preschool children with DLD, specifically examining the impact of increased attentional demand, or load, on the speed and accuracy with which they shift their attention.
Chapter 3

Study 2: The Impact of Manipulating Attentional Shifting Demands on Preschool Children with Developmental Language Disorder

Although differences in the findings of studies investigating the attentional shifting skills of children with DLD could be for a number of reasons yet to be explored, the varying demands placed on the children’s attentional shifting capacity may contribute to the disparities observed among study outcomes. The premise here is that easier tasks are unlikely to place heavy attentional demands on children and may consequently fail to reveal attentional shifting challenges in children with DLD. For example, a child instructed to connect dots alternating between numbers and letters in a sequential order repeatedly may have an easier time on this task than a task in which they are to self-discover two different novel feature similarities on sets of three picture stimuli over time. The continued self-discovery of novel relevant features is likely more attention-demanding than merely following instructions and responding in a repeated pattern accordingly. Aside from logic, the data reported and not reported in studies of children with DLD may give some indication of the level of demand placed on attentional shifting. For example, Victorino (2011) and Mutch (2001) found attentional shifting deficits in children with DLD used alternating tasks. Both studies report response time (RT) switch costs and not accuracy switch costs. This may be because the number and type of errors are not sensitive in differentiating between those with and without language impairment (e.g., Klusman, Cripe, & Dodrill, 1989). Although it is unknown if accuracy ceiling effects were present in these two studies, ceiling performance would be consistent with low demand on the participants’ attentional capacity. The data reported in Kapa et al. (2017) lend some support to the possibility that more challenging tasks that place higher attentional shifting demand on children may reveal
Attentional shifting deficits in children with DLD, while less challenging tasks may not. In this investigation, no children with DLD reached ceiling performance on the nonverbal version of their task while ceiling performance was attained on the verbal version. The former revealed deficits in children with DLD while the latter did not.

**Attentional Capacity Limitation in DLD:**

What we do know is that when demands on an individual’s attentional capacity exceed their available attentional resources to respond to these demands, the ability to process incoming input suffers (Broadbent, 1958; Kahneman, 1973). Several researchers have suggested that children with DLD have, in general, reduced processing capacity relative to unimpaired peers. These include working memory capacity (e.g., Dollaghan & Campbell, 1998; Edwards & Lahey, 1998; Ellis Weismer et al., 1999), information processing capacity (e.g., Edwards & Lahey, 1996; Montgomery & Leonard, 1998), and relevant to this study, attentional capacity (e.g., Spaulding et al., 2008). Given the elevated comorbidity between disorders of language and disorders of attention (e.g., Willinger et al., 2003) and support for attentional capacity limitations in children with DLD without a clear attention disorder (e.g., Spaulding et al. 2008), it seems reasonable to conclude that attentional shifting capacity limitations may indeed be present in children with DLD. Under this conceptualization, attentional shifting tasks that exceed the attentional processing limitations of children with DLD may reveal deficits while those with lesser demands on their attentional capacity may fail to tap into attentional shifting disparities between the DLD and unimpaired populations. At the present time we do not know if this is the case as none of the above studies in the meta-analysis systematically manipulated attentional demand to investigate if this is a plausible explanation contributing to the variability in study outcomes.
If children with DLD have reduced attentional shifting capacity relative to their unimpaired peers, they may exhibit comparable switch costs to their unimpaired peers on attentional shifting tasks that require minimal attentional resources to shift their attention (low load tasks); In contrast, differences may manifest when attentional shifting demands increase (high load tasks). The impact of varying the attentional resources needed, or attentional load, on the attentional shifting performance of children with DLD can be determined by measuring the effect of increasing attentional shifting demand on their performance. In the current study performance will be measured by both error rates, the metric of accuracy, and response time (RT). Reporting both is important because as attentional demands increase, participants may choose to perform the attentional shifting task accurately by reducing the speed of their response selections or they may choose to perform the attentional shifting task quickly at the expense of making more erroneous responses.

How will attentional capacity limitations be explored? Through intra-and extra-dimensional shifting, which mirrors the attentional shifting processes inherent in language acquisition, including word learning. Intra-dimensional shifts involve switching attentional focus within the same dimension, for example when a child is expected to match a picture to a picture, the switching is from visual dimension to another within visual dimension. While extra-dimensional shifts involve switching attentional focus between or among different dimensions. For example, when a child is expected to match the sound that an animal makes to a set of picture choices of different animals, they are shifting extra-dimensionally. Relevant to the current study design, the language learning process necessitates successful attentional shifting not just within a sensory modality, but also across sensory modalities. For example, in order to learn the names of novel objects, children must not only process what the object looks like, but
also the linguistic term for this object, switching between the visual and auditory sensory modalities.

In fact, children take advantage of linguistic cues presented in the auditory modality to shift their attention to relevant visual features. For example, in novel word learning experiments, children exposed to the linguistic frame indicating count noun status (e.g., “This is a “DAX”). Find me another DAX”), will shift their attention to the visual dimension of shape compared to when count noun status is unclear (e.g., “Look at this; Find one that matches”) (e.g., Collisson, et al.2014; Jones, et al.,1991; Landau, et al.,1988). Likewise, when a young child is expected to learn the sounds associated with animals, they must shift their attention between the auditory stimuli (i.e., the sound of their dog barking) to the visual stimuli (i.e., the observance that their dog is making mouth movements) or between the auditory stimuli (i.e., the sound of a dog barking) to the linguistic form (i.e., their caregiver labeling the noise “dog”). Research has supported the important role of multisensory attentional shifting ability in the comprehension of language. Magimairaj and Montgomery (2012), for example, found that a composite measure of auditory and visual attentional shifting predicted children’s ability to understand verbal directions. The intra- and extra-dimensional shifting inherent in the process of linguistic acquisition will be used, albeit not in a learning task, to modify attentional demands on children with DLD.

The Present Study

Given the integral role of attentional shifting to the language learning process, comprehending the attentional shifting abilities of children with DLD, when attentional shifting is expected, is critical in order to understand the influence of potential deficits on their inefficient
language learning. In addition, exploring potential attentional capacity limitations in this population, with respect to attentional shifting, is needed in order to further our understanding of the disparity in findings on attentional shifting in DLD to date. The current study was designed to determine if preschool children with DLD exhibit difficulty with attentional shifting relative to preschool children who are typically developing. In addition, this study investigated whether children with DLD exhibit reduced attentional shifting capacity relative to their typically developing peers by manipulating attentional shifting load. The research questions for study 2 were as follows:

1. Do preschool children with DLD exhibit comparative attentional shifting performance to TL, age-matched controls?
2. If group differences emerge:
   a. Do they depend on whether attentional shifting costs are determined by performance accuracy or response time (RT)?
   b. Do they support attentional capacity limitations by manifesting only under elevated levels of attentional load?
   c. Do they depend on the metric of shift cost measurement (accuracy, RT) and attentional load condition (low, medium, high) interaction?

Method

Participants

Participants consisted of preschool children who were between 3 and 5 years of age. Twenty-six children diagnosed with DLD (DLD group) were matched with an equal number of children with typical language (TL group) based on age (+/- 3 months), sex, and socioeconomic
status. Maternal education level was used to indicate socioeconomic status. Children were recruited from rural, suburban, and urban preschools, educational centers, and daycare facilities across the state of Connecticut. See Table 3.1 for demographic characteristics for the DLD and TL groups.

All children were native, monolingual English speakers with normal or corrected to normal vision based on parent or guardian report. In addition, each participant passed a bilateral hearing screening with reliable responses at 25 dB HL for 500hz and 20 dB HL for 1000, 2000, and 4000hz. None of the participants exhibited intellectual disability based on receiving a standard score of 75 or higher on the Nonverbal Index of the Kaufman Assessment Battery for Children – Second Edition (KABC-II; Kaufman & Kaufman, 2004). Children were excluded from this study if they had a history of frank neurological impairment (i.e., stroke) or were diagnosed with a disorder (aside from language impairment for the DLD group) (i.e., autism spectrum disorder, seizure disorder, bipolar disorder) as reported by their parent(s) or guardian(s).

Parents/guardians of the children in the TL group reported a null history of motor, cognitive, hearing, speech, or language concerns for these children. Parents/guardians also reported that these children had no history of speech, language, special education, or other developmental services with the exception of one child in the TL group who received and had previously completed physical therapy as a result of an acquired acute injury to return to typical functioning. All children in the TL group received a standard score above 85 (< 1 SD below the mean) on the Clinical Evaluation of Language Fundamentals Preschool – Second Edition (CELF-P2; Wiig, Secord, & Semel, 2004). This cut-off results in an 82% specificity rate for identifying TL based on information provided in the CELF-P2 manual. In addition, a speech-
language pathologist blind to diagnosis of TL identified each of the children in the TL group as TL based on a one on one conversational exchange individually with each member of this group.

Children in the DLD group received a standard score at or below 85 (≥ 1 SD below the mean) on the CELF-P2. This cut-off is consistent with a sensitivity of 85% per the examiner’s manual. In addition to scoring in the impaired range on this standardized language test, parents/guardians or teachers of these children reported a concern regarding the children’s communication development. Additional confirmation of language impaired status was determined by a speech-language pathologist blind to diagnosis who identified each of the children in this group as having a language impairment based on a one on one conversational exchange with each child.

The Peabody Picture Vocabulary Test – Fourth Edition (PPVT-IV; Dunn & Dunn, 2007) was administered to all children in addition to the screening, cognitive, and language assessments reported above for the sole purpose of further describing the participants’ language skills. See Table 3.2. for norm-referenced assessment results.

Materials and Procedure

All language assessments, cognitive assessments, hearing screenings, as well as the administration of the versions of the experimental task took place in the participants’ home, school, or daycare setting in a quiet room over the course of 4 to 5 days. To minimize the impact of ambient environmental noise on the children’s performance, the participants wore noise cancellation headphones for the experimental task. Children were tested individually. For the attentional shifting experimental task, children listened to animal names, sounds the animals made, and watched animal animations presented one at a time on a laptop computer. The
children responded by pressing one of three button choices with a picture of one of each animal directly below each button on a button response box attached to a computer.

The three animals used in this task were a dinosaur, an elephant, and a bumblebee. The final selection of these three animals for this task, the selection of the sound each animal makes, the animal pictures used on the response box, and the animations of these animals were determined through a combination of pre-determined criteria and pilot testing on both adults followed by 10 three-year old children (range 3;0 to 3;4). First, the names of each animal needed to be three syllables in length, have the same syllabic stress pattern, and be similar in phoneme length. Second, based on pilot work with the 10 three-year-old children, these three animals and the sounds that these animals make were distinguishable enough to be accurately and rapidly labeled.

Preparation of Stimuli for Attentional Shifting Experimental Task.

The stimuli for the experimental task included animal names, animal sounds, and animal animations. Animal name stimuli were recorded and edited using Audacity 1.3 Beta. An undergraduate female student served as the speaker. She was a native English speaker and spoke with a Standard American dialect with no strong regional accent as judged by the authors. The 3 animal names for the attentional shifting task were pre-recorded in a quiet room using an Audio-technica AT-803 omni-directional condenser microphone that was positioned approximately 2 inches from the speaker’s mouth. Stimuli were spoken with the same stress location and same general affective tone. Each animal name was recorded to Audacity at a sampling rate of 44.1 kHz and with 16-bit quantization. The final animal names selected for use from the recordings
were judged to be approximately 1000ms in length each based on inspection of the acoustic waveforms.

Each animal name was normalized using the Audacity program so that the peak amplitude of each was constant across files. All other amplitude values in each waveform were adjusted by the same amount as the peak amplitude in order to preserve the dynamic range of the speech signal for each stimulus. Animal sounds stimuli were selected from http://www.findsounds.com. They were also edited in Audacity using the same procedure to be comparable in duration and amplitude to the animal name stimuli.

Animal animations were constructed from on-line clipart purchased with approval for use in this experiment. They were each animated using Macromedia Fireworks MX (Macromedia, Version 2004). The visual clipart animals were in color and animated by calibrating each into 7 frames of 125ms per frame for the first 6, and 250ms for the final frame, resulting in a total duration of 1000ms per animation. In an attempt to mimic the temporal evolution of the animal name and animal sound stimuli, the 7 frames appeared sequentially, with each prior frame remaining in view. Thus, each frame built on the former frames revealing iteratively more of the animal to form the complete picture of the animal. The animal animations were presented in a horizontal-orientation in the center of the computer screen within a high-contrast, plain white background at 160 px X 120 px.

General Procedures for Experimental Task.

The experimental task, including the training components, were run on portable Dell Latitude c840 15inch screen computers using the button box to record children’s responses. A Quest Model 215 sound pressure level meter was used to verify 65dB SPL presentation of
auditory stimuli prior to administration. The button response box had three horizontal blue buttons with laminated pictures of an elephant, a dinosaur, and a bumblebee each attached with velcro directly underneath each of the buttons respectively. The pictures were stills from the animations. These pictures remained underneath their corresponding buttons for the duration of the experimental task to reduce the potential influence of memory load. The assignment of the animal pictures to their corresponding buttons on the button response box was randomized across participants.

This was a simple three-choice discrimination task in which the children were to start from the start position (noted by two orange rectangles placed approximately 3 inches in front of the button box), to select one of the three buttons associated with the three different animals, and to return to the start position following the selection. Based on prior experiments in our lab with preschool-age children, it is important to train children to return their hand to the same start position between trials to obtain reliable response time data for comparison both within and across children. Participants were to select the button with the picture of the dinosaur directly underneath if they saw the dinosaur animation on the computer screen, heard the word “dinosaur”, or heard the sound a dinosaur makes. They were to select the button with the picture of the elephant if they saw the elephant animation on the computer screen, heard the word “elephant”, or heard the sound an elephant makes. Finally, they were to select the dinosaur button if they saw the dinosaur animation on the computer screen, heard the word “dinosaur”, or heard the sound a dinosaur makes. Participants’ button selection choices and their response time from stimulus onset were recorded by the DirectRT Precision Timing Software (Empirisoft, 2008) program.
Before beginning the experimental task, each participant completed two training phases. Training Phase 1 ensured that the participants readily identified the three animals based on the different stimuli (the animal names, the sounds the animals make, and the animal animation) in addition to ensuring that the participants understood the expectations regarding their response to the stimuli. In Training Phase 1, each participant was asked what each animal picture below each of three buttons on the button box was. If they correctly responded with each animal name without prompting (with the exception that prompting was allowed if the children presented a subordinate label), they were then provided the label of each animal, the visual animations of each animal, and the sounds of each animal, and asked to press the picture that matches each. If they correctly responded by pressing the appropriate picture that matched each of the 9 stimuli (3 animal animations, 3 animal names labels, 3 animal sounds), they passed Training Phase 1 and began Training Phase 2. All participants passed in their first attempt and proceeded to Training Phase 2.

Training Phase 2 involved training the children to begin and return their hands after the button press to the start position (noted by two orange rectangles placed approximately 3 inches in front of the button box) and to teach them to press the correct button in the time allotted when they encountered an animal animation, an animal name, or an animal sound. This training phase consisted of 9 trials, beginning with 3 animal animations, followed by 3 animal names, and finally 3 animal sounds. If the child correctly returned their hands to the starting position between button presses and correctly responded to a minimum 8 out of 9 trials with self-recognition that a button was pressed in error (either through verbal or nonverbal gestures) or 9 out of 9 trials correct, they were permitted to move on to the experimental task. Two
opportunities for the second training were permitted in order to progress to the experimental task. All the children met one of the two criteria in two opportunities.

Each child was than given general instructions for the experimental task. Each child was instructed to press the button corresponding to what they see or hear and to press the correct button as fast as they could. They were also reminded to return their hands to the orange squares after pressing a button. Before each trial, each child was oriented to the upcoming presentation of a stimulus by a combined visual and auditory ready cue. The time interval between the ready cue and stimulus presentation was 500ms. The participants were provided with a maximum 4000ms to respond from the onset of each stimulus, which lasted for 1000ms in duration.

To examine capacity limitations, demands on attentional shifting were increased based on differential impacts of intra-dimensional and extradimensional attentional shifting established in human discrimination literature (e.g., Gilbert-Gauntlett, Roberts, & Brown, 1999; Trobalon, Miguelez, & Mackintosh, 2003), with intra-dimensional shifts viewed as less demanding than extradimensional shifts. The low, medium, and high attentional load conditions each consisted of 3 blocks, with each block having 12 switch and 12 non-switch, repetition trials for a total of 36 switch and 36 non-switch trials per attentional load condition. The same number of switch and non-switch trials were used in each block to minimize the impact of learned irrelevance on attentional shifting performance. In addition, for each of the low, medium, and high attentional load conditions, non-switch trials involved a repetition of the same prior stimulus in the same dimension (i.e., dinosaur animation followed by dinosaur animation) with a correct response signified by a repeated press of the prior button. In contrast, for each of the attentional load conditions a correct response for shift trials involved selecting a different button from the prior button selection. Consequently, there were no instances in which the dimension of the stimulus
changed from the prior stimulus presentation, but the participants were to respond by pressing the same button (i.e., dinosaur animation followed by dinosaur name). Although each block in each attentional load condition was randomized across the participants, the association between each picture and its button choice selection, although also randomized across the participants, remained the same across each block in each attentional load condition for each participant.

What differed across the low, medium, and high attentional load conditions was the number of potential stimuli presented and whether or not the switch trials required an intra-dimensional or extra-dimensional shift. In the low attentional load condition, participants were exposed to only three different stimuli per block, and shift trials required an intra-dimensional shift in which the participants were to select a different button response from the prior selection. One block consisted of only hearing animal names. Consequently, there were only three potential stimuli in this block (the word elephant, the word dinosaur, and the word bumblebee). Another block consisted of only hearing animal sounds, again with only three potential stimuli in this block. The third consisted of only seeing animal animations, with three potential animations, one for each animal. A non-shifting trial in this low load condition involved a repetition trial of the same entity in the same dimension. A shifting trial in this low load condition involved shifting the entity, but not the dimension.

In contrast to the low attentional load condition, the medium load condition involved being ready to perceive and respond to 6 potential different stimuli in two different dimensions per block in three randomized blocks. In the medium attentional load condition, one block included the 3 animal animations and 3 animal sound stimuli, another involved the 3 animal animation and 3 animal name stimuli, and the third presented the 3 animal sound and 3 animal name stimuli. In addition, shifting trials involved an extra-dimensional shift (i.e., elephant...
animation to bumblebee name). Therefore, similar to the low load condition, a non-shifting trial involved a repetition trial of the same entity in the same dimension. Shifting in this medium load condition involved responding to a change in the entity and the other dimension.

Finally, in the high attentional load condition participants were exposed to 9 potential stimuli (the 3 animal names, the 3 animal sounds, and the 3 animal animations) across three dimensions within each block. Similar to the medium load condition, shifting trials involved an extra-dimensional shift that required a different button selection. However, this condition was viewed as having a higher attentional load than the medium load condition because there were 9 potential stimuli across three dimensions in each block, in comparison to the 6 potential stimuli across two dimensions in the medium load condition. Similar to the low load and the medium load conditions, a non-shifting trial involved a repetition of the same entity in the same dimension. In contrast, shifting in this high load condition involved shifting the entity and to one of the two other dimensions.

Participants were randomly assigned to the order of low, medium, and high load conditions, and randomly assigned to the order of blocks (block 1, block 2, block 3) within each condition. The frequency of entity presentations and dimensions were balanced across the low, medium, and high load conditions. In each of the attentional load conditions, shift cost was measured based on error rates and median response time differentials between shift and non-shift (repetition) trials to determine the shift cost under each attentional load.

During each trial, the children were to identify and respond to the stimuli by pressing the button corresponding to the stimulus on the three button response box. Response time, measured as latency in button pressing from the onset of each stimulus, was measured in milliseconds (ms).
Verbal encouragement was provided during the trainings and a countdown mechanism was provided prior to the commencement of the experimental blocks (after training 2) and between experimental blocks (i.e., a visual depiction of four stars, with one spinning, exploding, and then disappearing with the verbal, “three more to go”), to provide the children with guiding information as to when they would be finished with the computer task. No feedback was given during the experimental task regarding incorrect and correct responses. In addition, the experimenter sat behind the children in order to avoid distracting the children from the task and to ensure that no unintentional or incidental nonverbal feedback was provided to the children. When needed, the experimenter would remind the children to return their hands to the orange squares between button presses.

**Results**

*Data Preparation Procedures.*

To determine the presence of RT outliers and eliminate the possibility of these outliers from influencing the study results, all incorrect and correct RT responses greater than 3 standard deviations above the median of each participant’s responses for that particular condition (low load, medium load, high load) were excluded (see Kane & Engle, 2003). In addition, errors were not included in the RT analyses. Omissions were considered to reflect the loss of attention, and clearly were not measuring how fast a child shifts their attention. Commissions reflected inaccurate shifting, which could skew the RT results. In addition, RT data less than 200ms were excluded because these unusually short RTs likely reflected an uncooperative, uninterested participant who was either guessing fast or attempting to complete the study as fast as possible, and were not likely reflective of attentional shifting. Finally, if >25% of each participant’s
button press responses contained errors, the participants’ data were excluded from the RT analyses.

From the initial groupings of 26 DLD and 26 TL participants, 1 DLD participant was excluded because >25% of this participant’s button press responses were errors. Data from the corresponding TL participant originally matched to the excluded DLD participant was also removed from all data analyses.

**Error Rate Analyses:**

Due to the limited number of errors, both omission and commission errors were combined in this analysis. The combined error rate data exhibited a positive skew and consequently were not normally distributed. Given the skew and the ceiling performance for some participants, these data were subjected to a logarithmic (log 10 +C) transformation prior to inferential analyses.

The transformed number of errors was subjected to a Mixed ANOVA with group (DLD, TL) as the between-subjects variable and trial type (shift, nonshift) and attentional load (low, medium, high) as the within subjects variables. The summary data for each group are reported in Table 3.3.

The results of this analysis revealed a main effect of Group, $F(1,48) = 8.40, p = .006, n^2_p = .15$, with the DLD group exhibiting significantly more errors than the TL group on the experimental task. In addition to this between-subjects effect, there were also two within-subjects effects. There was a main effect of Trial Type, $F(1,48) = 33.05, p < .001, n^2_p = .41$, with participants in general exhibiting a higher proportion of errors in shift compared to non-shift,
repetition trials. There was also a main effect of Attentional Load, $F(2, 96) = 15.49, p < .001$, $n^2_p = .24$. Paired-t test post-hoc analyses were conducted to further describe this effect and revealed that while there was no difference between the number of erroneous responses in the low load and medium load conditions, $t_{49} = -1.14$, $p = .26$, there were more erroneous responses in the high load compared to the low load conditions, $t_{49} = -4.66$, $p < .001$ and also more errors in the high load compared to the medium load condition, $t_{49} = -4.44$, $p < .001$. There were no significant two-way interactions and the three-way interaction was also not significant. Consequently, 15% of the between-subjects variance was accounted for by Group, whereas Trial Type accounted for 41% of the Trial Type plus Error variance and Attentional Load accounted for 24% of the Attentional Load plus Error variance.

**Response Time Analyses:**

Unlike the accuracy data, the RT data evidenced no such skew. A Mixed ANOVA with group (DLD, TL) as the between-subjects variable and trial type (shift, nonshift) and load (low, medium, high) as the within subjects variables was conducted for this dependent variable. The RT results are displayed in Table 3.4.

The RT analyses revealed a main effect of Group, $F(1,48) = 15.88, p < .001$, $n^2_p = .25$, with the DLD group exhibiting longer RTs than the TL group. There was also a main effect for Trial Type, $F(1,48) = 140.63, p < .01$, $n^2_p = .75$, with participants in general exhibiting longer RTs during switch compared to non-switch trials. There was no Trial Type x Attentional Load interaction, $F(2,96) = 3.00, p = .06$, $n^2_p = .05$. This indicates that the RT differences between switch and nonswitch trials, for all participants combined, were consistent across the three attentional load conditions. There was a significant Group x Attentional Load interaction,
\( F(2,96) = 15.78, p < .001, \text{ } \eta^2_p = .25 \). This signifies that the RT differences between the DLD and TL groups, when all switch and nonswitch trials were combined, were not consistent across the three conditions. Based on these results, 25% of the between-subjects variance in RT was accounted for by Group. In addition, the Group x Attentional Load interaction accounted for 25% of the Group x Attentional Load interaction plus Error variance.

There was also a significant Group x Attentional Load x Trial Type three-way interaction \( F(2,96) = 3.29, p = .04, \text{ } \eta^2_p = .06 \). This result signified that the Group x Attentional Load x Trial Type interaction accounted for comparatively smaller, 6% of the Group x Attentional Load x Trial Type interaction plus Error variance, albeit significant. Post-hoc analyses revealed that the DLD group exhibited larger differences in RT on switch compared to non-switch trials relative to the TL group for the high attentional load condition \( t_{48} = 4.366, p < .001 \), but not for the medium \( t_{48} = 1.66, p = .10 \) or low \( t_{48} = .428, p = .67 \) attentional load conditions. See Figure 3.1. for RT switch cost results by Group for each attentional load condition.

**Discussion**

Prior investigations of attentional shifting in children with DLD, in general, have resulted in mixed findings (e.g., Farrant et al., 2012; Henry et al., 2012; Im Bolter et al., 2006; Kapa et al., 2017; Noterdaeme, Amorosa, Mildenberger, Sitter, & Minow, 2000; Roello et al., 2015; Schul, Stiles, Wulfeck, & Townsend, 2004; Roello et al. 2015; Yang & Gray, 2017). The meta-analysis, study 1 of this dissertation, found that some of the variability among the study outcomes was attributable to the type of behavioral task. Deficits were observed on set-shifting but not alternating tasks. In the studies, set-shifting tasks appeared to be more demanding than alternating tasks. The current study was designed to determine if deficits typically observed in
set-shifting tasks would also manifest on an alternating task if it was sufficiently challenging. Because breakdowns in attentional shifting may manifest only when demands exceed individuals’ available attentional resources (Broadbent, 1958; Kahneman, 1973), this investigation manipulated attentional load to determine if differences in attentional shifting between children with DLD and their peers manifest broadly or only under conditions in which attentional shifting demands increase and potentially exceed their available attentional capacity. To ensure that a potential impact of increased attentional demand was measured, this study examined the impact of increasing attentional shifting demands (or attentional load) on the participants’ error rates and response speed.

Because this was a new laboratory-derived task to measure attentional shifting, it was important to determine if the data supported that this task measured attentional shifting skill. Evidence of attentional shifting would come from significantly longer RTs in shifting relative to non-shifting, repetition trials. This additional RT would manifest in shifting trials because they require extra time to disengage from the previous focus of attention, reallocate attention to the new information, and process, encode, and respond to the new information. Further evidence would also come from higher error rates in shifting relative to non-shifting repetition trials. The RT results supported the validity of this task as the RT for shifting trials was significantly longer for the participants in general than the RT for non-shifting, repetition trials. Likewise, the error rates for the participants were higher in shifting relative to non-shifting, repetition trials. The differential impact to both RT and accuracy on shifting versus non-shifting trials increased our confidence that we were measuring and could compare participants while they were and were not engaged in attentional shifting.
It was also important to determine if the attentional load manipulation did indeed have a differential effect on the participants. The participants in this study exhibited significantly more errors on the high compared to the medium attentional load condition and the high compared to the low attentional load condition. In contrast, the participants, when combined, exhibited no differential impact of the different attentional load conditions on RT. The finding of more errors on the high attentional load condition relative to the remaining conditions suggests that the condition designed to place the highest load on the participants was indeed the most demanding. However, the lack of difference in between the medium load and the low condition, when measured by either error rates or RT, suggests that the medium load condition was not any more challenging to the participants than the low load condition. In other words, the preschool-age participants were equally capable of performing this task when presented with 6 different stimuli in which half the trials necessitated an extra-dimensional shift as they were when presented with 3 different stimuli in which half the trials required only an intra-dimensional shift. This is surprising given prior work finding that extra-dimensional shifting is generally more demanding than intra-dimensional shifting (e.g., Gilbert-Gauntlett et al., 1999; Trobalon et al., 2003).

The finding that the medium load condition really had no more impact on the participants’ performance than the low load condition may be partially because when designing the experimental task, efforts were made in an attempt to minimize potential contributions of semantic knowledge, working memory, and inhibition to participants’ performance. The participants could readily name the animal sounds and animations to minimize the impact of differential semantic knowledge on performance given the finding by Yang and Gray (2017) which suggests that their sample of typically developing children may have harnessed their intact linguistic abilities to facilitate performance on their attentional shifting task. Furthermore, given
the working memory deficits of children with DLD (see Montgomery, 2005 for review), working memory load was kept low by keeping the association between the response button and the animals with their corresponding pictures consistent across the trainings and the different attentional load conditions. In addition, many tasks documenting attentional shifting deficits in children with DLD required problem-solving to think of an alternative option for shared features, for example, and inhibition of a dominant response. Because of documented inhibition and problem solving deficits in children with DLD (e.g., Cane, 2007; Drewe, 1974; Hughes, 2006; Hughes et al., 2009; Kamhi, Ward, & Mills, 1995; Robinson et al., 1980; Spaulding, 2008), the effect of inhibitory control and problem solving on attentional shifting performance in the task was controlled by having an equal number of shifting and non-shifting trials while also having no expectation of self-discovery. While this is not an argument that the contribution of other processes aside from attentional shifting ability on participant performance in the experimental task was eliminated, the attempt to address the task impurity problem (e.g., Burgess, 1997; Phillips, 1997) in its design may have contributed to the failure in making the medium load condition any more taxing on the participants than the low load condition. Regardless, the impact of attentional demand on attentional shifting can still be examined because the data do support that the high load condition is relatively more demanding.

Turning to the major purpose of this investigation, to explore group differences, it is apparent that the preschool children with DLD performed more poorly on this attentional shifting experimental task compared to their unimpaired peers. Compared to the TL controls, the children with DLD exhibited more errors as well as longer RTs. Importantly, this does not mean that the children with DLD exhibited poorer attentional shifting ability than their unimpaired peers. Recall that the experimental task included both shifting and non-shifting trials. The
results do signify, however, that despite its simplistic nature, the experimental task was more challenging for the DLD group than their TL peers. Furthermore, the finding of comparatively longer RTs for the children with DLD does provide further support for the growing body of evidence of general slowing in individuals with this disorder. Children with DLD, regardless of age, appear to struggle to process input as efficiently as their unimpaired peers across language-based (e.g. picture naming and word identification tasks) and cognitive-based tasks (e.g. memory scanning, mental rotation) (e.g., Johnston, & Ellis Weismer, 1983; Lahey & Edwards, 1996; Montgomery & Leonard, 1998; Reynolds & Fucci, 1998; Sininge et al., 1989).

Evidence of impaired attentional shifting in children with DLD would be represented not by poorer performance on the experimental task, but instead by a greater switch cost in performance on shifting compared to non-shifting trials relative to the TL group. When examining switch cost errors, the results suggest that the children with DLD were not any more affected by the need to shift their attention than the controls. When examining RT, the same appears to be true, except in one important circumstance. While the children with DLD were similarly affected by having to shift their attention in the low and medium (although arguably similar in load) conditions, they exhibited a greater switch cost in RT in the high load condition. In other words, when needing to shift their attention, in order to avoid what would be an even greater drop in accuracy on shift compared to non-shift trials as their unimpaired peers in the attentional load condition which placed the greatest demands on their attentional shifting capacity, they took longer to respond.

One way to control performance on any task is to strategically decide to slow down responses in order to enhance performance accuracy. Whether or not the children with DLD strategically sacrificed RT for accuracy is unknown. Prior work on how preschool children with
DLD and TL controls respond to feedback regarding their own errors found that the TL children slowed down their subsequent responses while the DLD children did not (e.g., Spaulding, 2008). This suggests that, in this study, the hit to RT in the high attentional load condition may not have been strategic for the DLD group. However, because in this study no feedback was provided on the accuracy of participant responses, it is not possible to determine if the children with DLD self-recognized the errors that they were making and strategically sacrificed RT for accuracy in this experimental task.

Despite an inability to determine this, the results of this investigation are meaningful for a number of reasons. First, they indicate that children with DLD exhibited longer RTs and higher error rates relative to their unimpaired peers to process and respond to incoming stimuli, regardless of whether or not processing and responding requires attentional shifting. This continues to support a growing body of research documenting general slowed processing in children with DLD (e.g., Johnston & Weismer, 1983; Kail, 1994; Lahey & Edwards, 1996; Miller, Kail, Leonard, Tomblin, 2001; Montgomery & Leonard, 1998; Reynolds & Fucci, 1998; Sininger et al., 1989) with the implication is that children with DLD need substantially more time than unimpaired children to process and respond to incoming information in general. In addition, attentional shifting appears to be impaired in children with DLD, but only manifests when attentional shifting demands are high. This is evident by their greater speed decrement, relative to their unimpaired peers, on shifting compared to non-shifting trials in the high attentional load condition—the condition in which they made more errors than the control group. This finding suggests that children with DLD can handle the need to shift their attention to a certain extent, but when the demand on their attentional shifting increases, they exhibited reduced efficiency in shifting their attention to process the novel stimuli.
Finally, as is the case with many studies investigating preschool age children, it was not possible to determine how many children in either the DLD or TL groups had comorbid ADHD. However, it is unlikely that children in the TL group had ADHD given parent and teacher reports of no historic nor present developmental concerns. In addition, the attentional shifting task was particularly long in length. It is likely that if any of the preschool-age children had comorbid ADHD, their young age combined with unidentified ADHD status would have prohibited them from being able to complete the attentional shifting tasks. Regardless, whether or not there was the presence of ADHD in either the DLD or TL groups is currently unknown.

**Conclusion**

In conclusion, the results of this study suggest that there are difficulties in attentional shifting in preschool children with DLD as compared to their typical language peers. However, these challenges appear to only manifest when attentional shifting demand is elevated sufficiently enough to tap into the upper limits of their attentional capacity. From a research standpoint, studies may fail to find attentional shifting deficits or under-estimate such deficits in this population depending on the extent to which these tasks exceed the participants’ attentional capacity. Studies should report both accuracy and RT switch costs to facilitate this determination.

**Motivation for Study 3:**

The findings from Study 1 and 2, when considered together, support attentional shifting weaknesses in children with DLD under conditions of high effort. The word learning process itself is considerably effortful for children with DLD. Given the attentional shifting deficits of
this population, it is likely beneficial to know what children with DLD attend to when learning new words because, based on associative accounts of word learning, differences in the allocation of attention likely alter any word learning biases or strategies that they develop. In addition, if systematic attentional tendencies are present in preschool-age children with DLD, then these attentional tendencies can be potentially capitalized on in a treatment program to highlight relevant referents. Accommodating their attentional tendencies while minimizing demands on their attentional shifting weaknesses may be a fruitful therapeutic approach with this population.
Chapter 4

Study 3: Does movement contextually cue attention during novel word exposure: A Comparison of Preschool Children with Developmental Language Disorder and with Typical Language

Word learning is a complex process that takes place over time. It requires the word learner to attend to and establish links among different lexical, semantic, and contextual features of the word and its referent. The features that the young word learning child attends to can facilitate, or in some cases, hinder their word learning success (e.g., Clerkin, Hart, Rehg, Yu, & Smirth, 2017; Horst & Simmiring, 2015; Riley & McGregor, 2012; Fisher, Godwin, & Seltman, 2014). Important to this particular investigation, at different stages in development, children attend to different perceptual cues when engaged in word learning. Aside from social cues, movement in particular is a perceptual feature that appears to capture the attention of young, toddler-age word learners (e.g., Benedict 1979; Eiteljoerge, Adam, Elsner, & Mani, 2019; Gogate & Bahrick, 2001; Gogate, Prince, & Matatyaho, 2009; Nelson 1973; Scofield, Miller, & Hartin, 2011; Werker, Cohen, Lloyd, Casasola, & Stager, 1998). Although movement is no longer a dominant perceptual cue for preschool-age children (e.g., Scofield et. al. 2011), it may still be a prominent perceptual cue that captures the attention of preschool children with developmental language disorder (DLD), who demonstrate delayed word learning similar to younger, typically developing children. This investigation was designed to explore if this is the case.

The Word Learning Process
Word learning is a process that occurs over an extended period of time. It begins when children map an auditory signal onto its referent. In fact, young children are able to associate an auditory signal, or word form, with its referent after only one exposure to the novel word (e.g., Dollaghan, 1985; 1987). This phenomenon, representing the beginning of the word learning process, is referred to as “fast mapping” (Carey, 1978). Although young word learners are capable of fast-mapping after only one exposure to the word and its referent, at this point the word learner establishes only a fragmented, rudimentary, incomplete representation of the novel word-novel referent pairing (Carey, 1978). Through repeated exposure over time, a phenomenon known as “slow mapping occurs”, during which children gain a more refined semantic understanding of the word by acquiring a more detailed representation of the word’s form, a more thorough representation of the referent, and a strong association between the two (e.g., Carey, 1978; Deák & Wagner, 2003; Swingley, 2010). However, a child is not capable of obtaining a comprehensive understanding of a word until he or she has established at least a rudimentary grasp on the word and its referent by engaging in the fast-mapping process.

**Importance of Object-Oriented Attention in Early Word Learning**

How is attention important to word learning? Attention serves as a filtering system for handling the barrage of overwhelming sensory input, honing in on (or spotlighting) the relevant features of the input to enable efficient, rapid word learning. Studies documenting the importance of attention to word learning have found strong associations between object-directed attention and the words that these children acquire (e.g., Kannass & Oakes, 2008; Yu & Smith, 2012). For example, Kannass and Oakes (2008) investigated the correlation between the attention skills and language growth in infants at 9 and 31 months of age. They found that infants who had longer attention directed towards objects at 9 months of age, compared to those with
weaker object-oriented attention, had better vocabulary growth at 31 months of age. The link between attention to the objects and word learning was further exemplified in a study by Yu and Smith (2012). In parent-child play interactions, 18-month-old infants were exposed to novel objects and their associated novel labels. At times, the infants were attending to the objects when they were labeled and, at other times, they were not attending to the objects when the labels were provided. To test the ability of these infants to associate a novel word with its referent, a head turning preference procedure was used. The results revealed that the infants were able to match the label with the objects that they had been attending to at the time of initial exposure to its name; In other words, they were able to make the association between the novel labels and their corresponding referents. In contrast, the infants were unable to identify the objects when given the labels for items that they were not attending to at the time when the novel names were provided. This work emphasizes that attention to the referents during novel name exposure is important to their word learning.

Attention to Movement and Word Learning

While attending to a referent when provided with its label is important to word learning, what is also important is the perceptual features, including physical states, of the referent that capture the children’s attentional focus. Of particular interest to the current investigation, several studies of young children have found that referent movement facilitates their novel word learning (e.g., Benedict 1979; Eiteljoerge, Adam, Elsner, & Mani, 2019; Gogate & Bahrick, 2001; Gogate, Prince, & Matatyaho, 2009; Nelson 1973; Scofield, Miller, & Hartin, 2011; Werker, Cohen, Lloyd, Casasola, & Stager, 1998). For example, toddler-age children learn more words of objects they can move relative to objects that they cannot manipulate themselves (e.g., Benedict 1979; Hennon, Rocroi, & Chung, 1999; Nelson 1973). Further support for the importance of
movement to word learning comes from additional studies which have shown that young children’s comprehension of objects that move appears to be superior to their comprehension of objects that do not (e.g., Gogate & Bahrick, 2001; Gogate, Prince, & Matatyaho, 2009). Gogate and Bahrick (2001) demonstrated that young word learners do not have to be the ones moving the objects to demonstrate this movement advantage. The authors investigated word learning in infants during a synchronized naming task in which mothers in one condition provided the label for objects that they were moving at the time and in another condition, would provide the label of objects that they ensured were stationary during naming. The infants demonstrated significantly better learning for words that were moving at the time of label provision relative to the words for objects that were not moving when named.

Finally, additional support exemplifying the importance of movement to early word acquisition comes from research literature that centers on animacy. Animates are a specific classification of noun entities that are capable of self-generating movement (i.e., a bird). In contrast, inanimates are not capable of self-generated movement (i.e. a table) (e.g., Mandler, 2000; Opfer & Gelman, 2011; Rakison & Lupyan, 2008). Opfer and Gelman (2011) specified that for children to make this classification in distinguishing between animates and inanimates, they depend on certain feature characteristics which suggest a high likelihood of being able to self-generate movement. The predictive likelihood of various features for either animate or inanimate properties of objects is potentially the result of statistical learning (see Chapter 1). Regardless of the mechanisms involved in children’s ability to distinguish animates from inanimates, the research work in this area highlights the importance of animacy to early word learning. For example, Aslan and John (2016) investigated the influence of features depicting animacy on recall and recognition of novel names in children between the ages of 4 to 11 years.
The children completed a task in which they were exposed to novel words paired with additional
detail to coincide with either animate (e.g. an object with a claw) or inanimate visual properties
(e.g. an object with a lid). They were asked to rate each novel word for its animacy. After
completing a word recall task, the researchers found that the children recalled novel words that
were paired with animate properties better than novel words that were paired with inanimate
properties. The results from a recognition task also yielded a similar finding; novel objects with
animate features were recognized better than novel objects with inanimate features.

Although many cues can be used to facilitate word learning throughout development
(e.g., Juscyk et al., 1993; Nazzi et al., 2000), the relative importance of movement for word
learning appears to occur early in child development. Werker et al. (1998) examined the age at
which children establish word-object association in the absence of social cues. The investigators
found that by 14 months of age, toddlers learned the associations between words and their
referents when the referents were moving at the time of exposure, and not when the referents
were stationary. This finding suggests that movement is given relative attentional priority in the
word learning of young, toddler-age children. Although movement becomes less of a priority for
word learning as children age, if movement is the only reliable cue, they will capitalize on it.
Scofield, Miller, and Hartin (2011) introduced 3- and 4-year-old children to novel objects that
moved in the presence of other novel stationary objects. The children associated the labels of
novel words to the moving objects and associated novel facts to the moving objects as well. The
results suggest that preschool-age children will hypothesize that the referent for novel names and
novel facts is the object that is moving when other cues, such as lexical cues and social cues, are
notably absent.

Word Learning and Children with DLD:
In addition to other areas of linguistic deficit, most children with DLD struggle with word learning (e.g., Alt, Plant, & Creusere, 2004; Alt & Plante, 2006; Dollaghan, 1998; Edwards & Lahey, 1998; Kan, & Windsore, 2010; Leonard, Davis, & Deevy, 2007; Rice, Cleave, & Oetting, 2000). One potential contributing factor to their word learning challenges may be in the visual domain. Supporting this, a number of studies have found that children with DLD fail to process visual properties of referents as well as their typically developing, similar-aged peers (e.g. Alt, 2013; Alt & Plante, 2006; McGregor & Appel, 2002; McGregor, Newman, Reilly, & Capone, 2002). Some studies have found that the deficits in word learning in this population may be partially attributed to limited processing of relevant semantic information in context (e.g., Alt, Plant, & Creusere, 2004; Alt & Plante, 2006; Leonard, Davis, & Deevy, 2007). For example, Alt, Plante, and Creusere (2004) investigated the ability of preschool-aged children with DLD to learn the visually-based semantic features associated with novel words. They found that the children with DLD learned fewer visual features than their peers. This signifies that children with DLD do attend to some semantic features when learning new words, indicating that certain features captured their attentional focus. Whether or not they attended to less relevant features, however, cannot be deduced because the design did not differentiate relevant from irrelevant features; All were equally relevant. Support for the possibility that children with DLD fail to attend to the important, relevant features comes from work by Collison et al. (2015). The researchers found that preschool-age children with DLD, unlike their unimpaired peers, failed to map the pertinent visual characteristics for associating a novel word and its referent, which involved attending to shape when exposed to count nouns. Failing to attend to relevant features, like shape to count nouns, has been shown to hinder word learning (e.g., Smith et al., 2002). Given the relevance of attention to word learning, it is a surprise to see the paucity of work
directly examining the relationship between the attention skills and word learning abilities of children with DLD.

Of the studies that have investigated attention and word learning in preschool-age children with DLD, the focus has been on their associations of the phonetic form of the novel words and the visual properties of the contextual environment. The latter will be elaborated upon given the relevance to the current investigation. Tenenbaum, Amso, Abar, and Sheinkopf, (2014) investigated whether patterns of visual attention, for example “attention to the speaker’s mouth” predicted language outcomes in preschool-age children with language delays. To determine this, the relationship between scores on behavioral standardized test of language were compared to eye-tracking findings derived from children’s attention to the speaker’s mouth during a word learning task. After controlling for age, children with language delays showed a negative correlation between attention to the speaker’s mouth and language tests scores. This signifies that the preschool children with language impairment who fixated on the speaker’s mouth longer had lower language test scores. Although the findings may be because these children needed the visual input from the speaker’s mouth to facilitate their ability to determine the auditory signal with greater precision, this is unlikely as the McGurk effect is notably absent in young children with language impairment (Norrix, Plante, & Vance, 2007). Alternative explanations, therefore, are worthy of consideration. First, it is important to note that, unlike the findings of this study, attention to the mouth is usually a positive predictive factor of language development in younger infants and toddlers (e.g., Lewkowicz & Hansen-Tift, 2012). The negative relationship, however, documented in the Tenenbaum et al. (2014) study suggests that it may present as a barrier to successful word learning for the preschool-age population with language delays. If this is the case, then preschool children with DLD may be attending to visual features in their environment
during the word learning process that are in alignment with what captures the attention of younger, typically developing children. In addition, the finding that those with language delays focused on the speaker’s mouth during word learning signifies that they are attending to part of their visual environment that is moving----as the speaker’s mouth moves during speech production. This could mean that preschool-age children with DLD, unlike their unimpaired, similar aged peers, are still naturally attending to movement when exposed to novel words.

While it is important to gain a more comprehensive understanding of the attentional deficits in children with DLD, evidenced from Studies 1 and 2 of this dissertation, it is equally important to understand how the attentional tendencies of this population relate to their linguistic learning challenges. Younger, typically developing children tend to attend to movement when learning new words (e.g., Benedict 1979; Eiteljoerge, Adam, Elsner, & Mani, 2019; Gogate & Bahrick, 2001; Gogate, Prince, & Matatyaho, 2009; Nelson 1973; Scofield, Miller, & Hartin, 2011; Werker, Cohen, Lloyd, Casasola, & Stager, 1998). Because many studies have found that children with DLD, in many areas of linguistic learning, are similar to younger, typically developing children (e.g., Eyer et al., 2002; Rice et al., 1990), then it may be no surprise if preschool-age children with DLD also tend to gravitate to focusing on movement when learning new words, even if movement is not more relevant than other visual characteristics of the novel words. While this may not be a problem for younger children, it may pose a problem for preschool-age children, as they are expected to learn many words in which movement is not predictive.


Purpose of the study:

Study 3 was designed to determine if preschool children with DLD, compared to the chronological age-matched TL peers, prefer movement as a relevant cue to word learning above and beyond other potential visual-based properties of the referents, specifically color and pattern.

Prior work by Collison et al (2015) found that, when exposed to the novel names of count noun objects, preschool-age children with DLD did not reliably attend to shape, color, nor texture properties of the referents. They exhibited no systematicity in their responses. Furthermore, prior work shows that children with DLD are like their younger TD peers in fast mapping strategies (e.g., Eyer et al., 2002). Therefore, Study 3 is designed to determine if a systematic response will appear for children with DLD when a movement response option is provided, as this appears to be a cue that younger children gravitate towards. Rather than cross sensory boundaries, by providing texture as an option and by allowing the manipulation of the objects, as seen in prior work investigating children with DLD (e.g., Collison et al., 2015), the current study substituted pattern for texture as an option and prevented manipulation of the objects by providing the options in 2-dimensional rather than 3-dimensional space.

The research questions for Study 3 were as follows:

1. Are there differences in how preschool-age children with DLD and TL, age-matched controls extend a nonword to novel referents depending on the visual perceptual dimensions of the referent to include its color, pattern, and movement?

2. When exposed to nonword-novel referent pairings, are there differences between preschool-age children with DLD and TL controls in their frequency of movement responses as the relevant visual perceptual dimension of referent objects?
(3) Does the propensity for a movement bias, a movement advantage, depend on age? Is there a negative relationship between chronological age and the propensity for a movement bias?

(4) Does the propensity for a movement bias, a movement advantage, depend on receptive vocabulary knowledge? Is there a negative relationship between receptive vocabulary knowledge and the propensity for a movement bias?

**Method Study 3**

*Participants:* This is consistent with Study 1 in identification, recruitment procedures, and group classification. See Tables 4.1 for demographic characteristics for the DLD and TL groups and 4.2 for norm referenced assessment results.

*Materials:* The stimuli for the Novel Name Extension Task consisted of two-dimensional abstract colored pictures and animations depicting artifacts with no readily associated semantic label. These artifacts were previously used in the Collisson et al. (2015) study. These artifacts were modified from original use for pattern, color, and size using Microsoft Publisher, Microsoft Word, and Paint and were animated using the [https://en.bloggif.com/](https://en.bloggif.com/) website. for the purposes of the current experiment.

Movement effects were created by converting the images of the stimuli to a graphics interchange format (gif) via the [https://en.bloggif.com/](https://en.bloggif.com/) website. The graphics selected for use were “shaking”, “zooming”, “rotating”, “weathervane”, “mirror”, and “exploding”. For the “shaking” effect, rapid effects were set to 15 ms. The “zooming” effect, power to zoom was set...
to 5, and rapid effects were set to 10 ms. For the “rotating” effect, the rotation direction was changed to clockwise, and the rapid effect was set at 10 ms. The “weathervane” effect was also set at 10 ms rapid effect, the “mirror effect” was set at 60 ms with 0 ms for pausing. For the “exploding” effect, explosion power was set to 1 and the rapid effects were set to 10 ms.

Color modification to the original stimuli used in the Collison et al. (2015) study was conducted to ensure that no two novel objects had the same color. Additional modifications included the removal of color of the original stimuli for the response options that matched the exposure stimuli in movement and that matched the exposure stimuli in pattern. In all cases a black border remained to keep shape constant. These modifications were created by using Microsoft Publisher, Paint and Microsoft Word.

Pattern effects included the addition of spots and stars as well as the addition of striped, checkered, and dashed lines that were created by Microsoft Word and edited via Paint. Pattern changes to the original Collison et al. (2015) stimuli included removing the pattern from the response selection options that matched the exposure stimuli in movement and that matched the exposure stimuli in color.

See Appendix A. for still file examples of movement effects as well as color effects and pattern effects included in this study.

Six of the stimuli served as exposure stimuli. For each of the exposure stimuli, three stimulus response options were presented matching the exposure stimuli in shape and one other visual perceptual dimension. One of the three selection options matched the exposure stimulus in the presence and consistency of movement but differed from the exposure stimulus in that it had no pattern nor color. One of the three selection options matched the exposure stimulus in pattern
but differed from the exposure stimulus in that it had no color and no presence of movement. The remaining selection option matched the exposure stimulus in color but differed from the exposure stimulus in that it had no pattern and no presence of movement. Each of the stimuli and response options objects were 4x4 inches in diameter and were presented on a solid black background.

Audio stimuli accompanied the visual presentations. The audio stimuli consisted of the following six cvc novel words: /dɪb/, /fɪp/, /næm/, /muf/, /tɪd/, and /pɪf/. They were recorded and edited via Audacity 2.1.2 software. A native English speaker that spoke with Standard American Dialect with no strong regional accent served as the speaker. The instructions and novel words were prerecorded in a quiet room using an Audio-technica AT-803 omnidirectional condenser microphone that was positioned approximately 3.5 inches from the speaker’s mouth. Each novel word and instruction phrase were recorded to Audacity at a sampling rate of 44.1 kHz and with 16-bit quantization. Then the audio stimuli were normalized using Audacity so that the peak amplitude of each stimulus was constant across files. Visual presentations were presented on a Microsoft Surface Pro 3 computer with a 12-inch screen and auditory presentations were emitted through noise cancellation speakers.

**Procedures:**

**Novel Name Extension Task**

For this task, children were introduced to a moving novel object and were asked to make a forced choice to extend the animated novel object to one of three response options which match in movement, color, or pattern to the novel object. There were a total of three trials for each of the six animated novel objects, resulting in 18 total trials throughout the experimental task. The
order of the presentation was randomized across participants via the DirectRT program. Each novel object was presented on three trials, and the total number of trials was 18. During this task, the examiner pointed to an animated novel object label on the computer screen and the child heard “This is [dɪb]”. The child viewed this animated novel object with the examiner pointing to it for 5 seconds. Following this the novel object disappeared and three response options were presented in linear, horizontal order on the computer screen. The child was prompted; “Point to [dɪb]”. The examiner waited until the child has selected an option from the three response options before continuing to the next trial. Each of the response options were identical to the target in either movement, color, or pattern. The linear presentation of the three test items matching in different dimensions to the target and were counterbalanced in order of presentation to prevent children from associating a response option to a predictable location.

The examiner was sitting at the right of the child facing the computer screen to facilitate examiner pointing. An external keyboarded was attached to the laptop to avoid invading the child’s personal space and the examiner used it to code each response made by the child on the screen as “M” if the child selected the movement match, “C” if the child selected the color match, and “P” if the child selected the pattern match. The examiner’s input of the children’s responses was recorded and scored by the DirectRT Software. No feedback was given to the child to avoid differential response to feedback effects; However, children were verbally reinforced for paying attention and staying on task with phrases such as, “nice job pointing” and “you’re doing great!”.

For reliability purposes, an undergraduate double scored a subset of the participants’ experimental task and standardized, norm-referenced assessment performance.
reliability was calculated at 95.7%. Discrepancies were rectified via discussion, and when relevant, referring to the automated data collection data from the Direct RT program.

**Results**

*Group-Level Comparisons*

Mean frequency counts of shape, texture, and color matches in the experimental task are presented in Figure 4.1 A Freeman-Halton extension of the Fisher Exact Test was used to determine if the pattern of responses for the TL group was independent of the pattern of responses for the DLD group. The results were significant, $p = .02$. This indicates that there is a difference in the proportions of responses across feature categories between the TL and DLD groups.

It was important to determine the locus of the differences in patterns of responses between the TL and DLD groups. Since the theoretical questions for this investigation centered on the rate of movement responses, movement responses alone were analyzed using an independent t-test with Group (TL, DLD) as the independent variable and mean count of movement responses as the dependent variable. Selecting only movement responses for analysis relieved the constraints on statistical procedures which arise when including the remaining choice options (color and pattern). Importantly, when analyzing movement responses there was no violation of equal variances and the Kolmogorov-Smirnov Tests of Normality for both the TL and DLD groups were not significant, with $p = .11$ and $p = .54$ for the TL and DLD groups respectively. The results of the independent t-test were significant, $t_{11} = 3.40; p = .003$. The TL group selected movement less often (Mean = 3.83, SD = 5.91) than the DLD group (Mean =
11.33, SD = 4.85). See Table 4.3 for frequency of choices in novel name extension task by group.

**Individual Differences**

In addition to analyzing mean frequency counts, it was also important to examine potential feature biases in response selections for children in the TL and DLD groups at an individual level. Children were classified as having a propensity for a movement bias, a color bias, or a pattern bias based on the feature they selected most often. In the TL group, 3 children displayed a movement bias, 3 children displayed a pattern bias, and the remaining 6 in this group exhibited a color bias. In the DLD group, 10 children exhibited a movement bias, 2 presented with a color bias, and 0 children in this group displayed a pattern bias. Since 3 out of 12 TL children exhibited a movement bias, this indicates that 25% displayed a movement bias (33.33% is chance). In contrast, 10 out of 12, or 83.33% of the children in the DLD group presented with a movement bias. An odds ratio was conducted comparing the two groups on the odds of having a movement bias relative to the other biases, color and pattern, combined. Compared to the children in the TL group, those in the DLD group were 15 times more likely to exhibit a movement bias relative to the other biases, $z = 2.65$, $p = .008$, [CI = 2.03 – 111.18]. See Table 4.4 for the profiles of children in the DLD group and TL group who exhibited a movement bias and Table 4.5 for the profiles of participants in the DLD group and TL group who did not exhibit a movement bias. There were 10 males and 3 females who exhibited a movement bias compared to 6 males and 5 females who did not. The mean age of those with a movement bias was 47.84 (SD = 8.47) while the mean age for those who did not was 53.91 (SD = 7.61). In addition, for the participants who exhibited a movement bias, their nonverbal IQ score mean on the KABC-II Nonverbal Index was 104.69 (SD = 0.80), their overall language score on the CELF-P2 was
84.30 (SD = 15.36), and their receptive vocabulary score on the PPVT-IV was 95.92 (SD = 13.55). In contrast, for those children who did not exhibit a movement bias, their nonverbal IQ score mean on the KABC-II Nonverbal Index was 106.18 (SD = 9.28), their overall language score on the CELF-P2 was 93.36 (SD = 11.91), and their receptive vocabulary score on the PPVT-IV was 102.09 (SD = 12.23). See Table 4.4 for characteristics of individual study participants who showed a movement bias and Table 4.5 for characteristics of individual study participants who did not show a movement bias.

**Relationship Between Age and Propensity for a Movement Bias**

To examine the potential for a relationship between a propensity for a movement bias and age, the two groups, TL and DLD, were collapsed. This was important to do as the limited number of participants per group restricted the ability to detect this relationship, should it exist, at an individual group level due to limited power. In this analysis, chronological age was determined by number of months since birth and the propensity of a movement bias was calculated as the proportion of movement selection responses for each child. A Pearson product moment correlation was used. The results revealed a significant negative relationship between chronological age and the propensity for a movement bias, $r^2 = -0.52, p < .01$. Based on these results, 27.35% of the variability in propensity for a movement bias could be accounted for by the chronological age of the child participants. See Figure 4.2 for a scatterplot representation of the relationship between age and proportion of movement response selections.

**Relationship Between Receptive Vocabulary Knowledge and Propensity for a Movement Bias**

For this analysis, like the one prior, the two groups were collapsed. Receptive Vocabulary Knowledge was calculated from the standardized, norm-referenced scores of the

Standardized scores were used, as opposed to raw scores, to parcel out the contribution of age. Propensity for a movement bias was calculated via the proportion of movement response selections. A Pearson product moment correlation was used, the results were not significant, $r^2 = -.20$, $p = .35$. See Figure 4.3 for the scatterplot depicting the lack of relationship between PPVT-IV scores, the index of receptive vocabulary knowledge, and children’s propensity for movement response selection.

**Discussion**

The main purpose of the study was to determine if preschool children with DLD exhibit a movement bias when learning new words. Because preschool-age children with DLD have similar linguistic profiles as younger, typically developing children (e.g., Eyer et al., 2002) and because younger, typically developing children frequently rely on movement as a prime relevant cue during word learning (e.g., Benedict 1979; Eiteljoerge, et.al, 2019; Gogate & Bahrick, 2001; Gogate, et. al., 2009; Nelson 1973; Scofield, et., al., 2011; Werker, et. al., 1998), the hypothesis was that preschool-age children with DLD would also rely on movement as a predominant cue during word learning and that their age-matched, unimpaired peers would not. The assumption underlying this prediction is that typical language, age-matched peers would have outgrown their reliance on movement as the relevant visual cue during word learning to fast map the semantic meaning of novel words while their peers with DLD would not have at this point in development.

In order to evaluate if participants exhibited a movement bias during the fast mapping word learning task, it was important to ensure that movement was no more relevant than the other response options, in this case, color and pattern. Consequently, the experimental task was
designed so that none of these cues were more or less predictive than the others. In addition, unlike prior work investigating word learning biases in children (e.g., Samuelson & Smith, 1998, 2000, Yu & Smith, 2011, 2012), including preschool-age children with DLD (e.g., Collisson et al., 2015), the response categories remained in two-dimensional space and did not add tactile input as a possible contributor to study results. This was done to ensure that differences in multisensory processing ability did not impact study results, which has been found between children with DLD and with TL (Magimairaj & Montgomery, 2012). This allowed for focusing on potential group differences in processing visual features, or properties, of the input. While prior work has shown that children with DLD attend to fewer visual features of the input (e.g., Alt & Plante, 2006), little research has been conducted on what visual features they attend to, particularly when forced to choose only one. This is important to determine as attending to certain visual properties of novel objects over others may, in some cases, hinder their word learning.

The results of this study indicate that children with DLD are fundamentally different from their TL peers in the visual features they gravitate to when associating novel words with novel objects in a case when no visual features are predictive. On average, preschool-age children with DLD relied on movement as the most relevant cue more often than preschool-age children who had typical language. This was the case whether results were analyzed on a group level based on mean proportion of movement responses or were analyzed on an individual level by categorizing the participants based on what visual property (movement, color, or pattern) they responded to most often.

Group differences in the propensity for a movement bias were quite apparent. While 83.33% of the DLD group could be categorized as movement-biased, only 25% of the
participants in the TL group could be categorized as such. This signifies that preschool age children with DLD were 15 times more likely to exhibit a movement bias than children in the TL group. Although this appears large, the confidence interval surrounding this estimate was quite wide, ranging from 2.03 to 111.18. This means that we can be 95% confident that children with DLD are between 2 times and 111 times more likely to exhibit a movement bias relative to children with TL. Although this confidence interval does not cross 0, indicating that it is a significant finding, the odds ratio estimate lacks precision. This is partially attributable to a particular weakness in this study, the small sample size.

Regardless of the lack of specificity in the odds of having a propensity for a movement bias whether you have DLD or TL, the study findings do support that children with DLD are more likely to exhibit a movement bias than their unimpaired, typically developing, same-aged peers. This is in alignment with the predicted hypothesis, that children with DLD, despite being of preschool-age, would rely on movement as a relevant feature when engaged in the initial process of word learning, even when it was not helpful for their word learning outcomes.

Importantly, the results of this investigation show that although children with DLD are not 100% consistent in what feature they gravitate to, they are more systematic than not. This finding is actually in conflict with prior work showing that preschool-age children with DLD exhibit no systematicity of responses when the properties of novel objects are not predictive (e.g., Collisson et al., 2015). For example, when prompted with, “Find me another.”, preschool-aged children with DLD did not reliably select shape, color, or texture. Even when a particular cue was more relevant, for example the visual property of shape when hearing a linguistic signal indicating count noun status (e.g., “This is a dax. Find me another dax”), Collisson and colleagues (2015) continued to show that children with DLD still exhibited no systematicity in
their responses. What may explain differences in systematicity findings between the current study and that by Collison et al. (2015) is that, in the current study, movement was offered as one of the response options while in the Collisson et al. (2015) study, it was not.

Why might this matter? This may be important because no prior studies have found that either color or texture (or even pattern) response options captured the attention of children at any point in development. In contrast, a large body of research has found that movement captures the attentional focus of children early in development (e.g., Benedict 1979; Eiteljoerge, Adam, Elsner, & Mani, 2019; Gogate & Bahrick, 2001; Gogate, Prince, & Matatyaho, 2009; Nelson 1973; Werker, Cohen, Lloyd, Casasola, & Stager, 1998), and if relevant, continues to capture the attention of children during the preschool years (e.g., Scofield, Miller, & Hartin, 2011).

Consequently, the current investigation permitted the determination of if preschool-aged children rely on a cue that is used by younger unimpaired children even when it is no longer particularly useful to their word learning to do so.

While the preschool-age children with DLD exhibited a propensity for a movement bias, even when it was not particularly relevant, their TL peers did not. This finding is not surprising. It is in alignment with previous work documenting that TL children fail to exhibit systematicity in the responses to characteristics of novel objects without predictive utility in the linguistic frames or the characteristics of the novel objects themselves to do so (e.g., Collisson et al., 2015). While it signifies that preschool-aged children with TL do not appear to gravitate towards particular visual properties of input consistently when it is not in their best interest to do so, it also suggests that they have potentially outgrown the attentional tendency to focus on movement as the most relevant cue when exposed to new words and their object referents. It is important to
note, however, that the lack of inclusion of a younger, typically developing group makes this latter interpretation far from definitive.

Inclusion of a typically developing, younger, chronologically-aged group in future work would not only facilitate determining if a movement bias is outgrown in typically developing, preschool-aged children, it would also assist in making comparative interpretations of interest for the DLD group. Future work comparing preschool-aged children in the DLD group to younger, typical language, language-matched peers would help to determine if the propensity for a movement bias shown by the majority of children in the DLD group is consistent with that observed in younger unimpaired children. This would signify that children with DLD are following a developmental protracted projectory and that their propensity for a movement bias may dissipate as their language skills improve.

Additional findings from the current investigation both support and may appear to provide evidence against this possibility. First, there was a significant negative correlation between chronological age and propensity for a movement bias. As children in this study got older, their tendency to rely on movement as a relevant cue when learning to associate novel objects with novel labels decreased. The results indicated that 27.35% of the propensity for a movement bias could be attributable to the chronological age of the study participants. Given the limited age of the participants, who were between 3 and 5 years, the finding of a significant correlation was somewhat surprising given the restricted range. What it does indicate, however, is that there appears to be a lot of change during this period of prime word learning development. Children may have a movement bias early in development because it is helpful to their lexical acquisition and gravitate away from this movement bias as they age because it is no longer as useful to their vocabulary learning.
The additional correlational analysis findings, however, may lead individuals to the opposite interpretation. Recall that there was not a significant relationship between receptive vocabulary knowledge, measured by standardized scores on the Peabody Picture Vocabulary Test-Revised (PPVT-R, Dunn & Dunn 2004) and the propensity for a movement bias demonstrated on the experimental task. One way to interpret this lack of significance is that, unlike what was expected, at the preschool-age, having a movement bias does not hinder receptive vocabulary acquisition. Consequently, the finding that children with DLD had a greater propensity for a movement bias than their unimpaired peers may be spurious and not meaningful to their lexical learning. However, an alternative interpretation of this finding is possible. If having a movement bias initially in early development promotes word learning (e.g., Eiteljoerge, Adam, Elsner, & Mani, 2019; Scofield, Miller, & Hartin, 2011; Werker, Cohen, Lloyd, Casasola, & Stager, 1998), and only later (including at preschool-age) hinders word learning, then we wouldn’t expect to observe a negative relationship between the propensity for a movement bias and receptive vocabulary knowledge at preschool-age because these children spent years in which a movement bias was facilitative and potentially years in which it was not. The helpfulness of a movement bias combined with its later hindrance would likely cancel each other out.

In addition, it is worthy to consider that the lack of a significant correlation may also be because the standardized, norm-referenced test of receptive vocabulary knowledge includes items in which movement is a relevant feature and many items in which it is not. Consequently, children’s scores are a collapse of both. Future work could consider conducting an item-level analysis on PPVT-IV data. The degree of propensity for a movement bias may be positively associated with correct responses on items associated with movement and fewer correct
responses on items not associated with movement. If this were the case, it would support both
the facilitative and barrier effects of the movement bias for the natural navigation of word
learning in children.

While there is much that remains unclear, what we do know from the current
investigation is that the majority of children with DLD appear to be exhibiting a movement bias
during the preschool years while engaged in the early stage of fast-mapping. We also know from
prior work that they do not typically attend to the right cues to facilitate their word learning (e.g.,
Collison et al., 2015). Finally, there is evidence that they can’t attend to as many visual features
of objects when learning their names as unimpaired children do (e.g., Alt & Plante, 2006; Alt et.
al., 2004). If they tend not to attend to the right cues, and they can’t attend to as many visual
features, then clinically it may be useful to know what they typically attend to and use this
feature to highlight and draw their attention to what they are expected to learn. The current
study’s results indicate that serious consideration should be given to movement as a relevant
candidate.
Chapter 5 – Summary and Conclusion

The importance of attention in processing the relevant information in the environment, including during word learning, should not be ignored. This is because attention highlights the important information within the environment, which changes as time progresses, to enable individuals to handle the mountains of incoming input. Word learners need to allocate their attention to the right input at the right moments in time, and given the rapid changes in the natural environment, do so efficiently and with ease. The allocation of attention to the relevant properties in the input is particularly poignant for a population of children who struggles with word learning, specifically individuals with DLD. Prior research has shown that they need more exposures to word-referent pairings to learn words (e.g., Gray, 2003, 2004; Rice et al., 1994). This may be because they fail to attend to relevant cues which promote rapid word learning (e.g., Collisson et al., 2015). In order to attend to the relevant cues during vocabulary acquisition, they need to be able to shift their attention to properties of the input that are pertinent at different points in time and to do so relatively quickly.

Unfortunately, based on the meta-analysis findings of Study 1, children with DLD tend to be weak attentional shifters. Across attentional shifting tasks, they performed, on average, .42 standard deviations lower than their unimpaired, age-matched TL peers. While their relatively weak attentional shifting ability is significant, it is not grossly apparent, particularly in comparison to their linguistic deficits. In other words, their attentional shifting challenges are relatively subtle. There are three important implications of this. First, the documented deficits in attentional shifting identified in this meta-analysis provide evidence against pure linguistic accounts of DLD; Rather, neuropsychological-based accounts of DLD, which purport that deficits in neuropsychological processes, like attention, accompany and may potentially even
contribute to the language learning challenges of this population, are supported (e.g., Archibald & Gathercole, 2000; Leclercq et. al., 2013; Montgomery, 2000; Spaulding, 2008; Ziegler et. al., 2005). The second implication is not theoretical, but rather clinical in nature. Because the attentional shifting deficits of children with DLD are not marked, they are unlikely to be readily identified. If they do contribute to their linguistic learning challenges, which some neuropsychological accounts suggest, then their lack of identification may ultimately hinder the application of important therapeutic approaches to address their linguistic deficits. The third and final implication of the results from Study 1 stems from the finding that children with DLD exhibit attentional shifting challenges in some situations, but not others. In this case, attentional shifting deficits were noted on set-shifting but not alternating tasks, both of which are commonly employed to measure attentional shifting ability across neurotypical and neuroatypical populations.

Why do they manifest attentional shifting deficits on set-shifting but not alternating task designs? It may be because attentional shifting tasks are not necessarily only measuring attentional shifting. This interpretation is consistent with the task impurity issue previously identified when researchers attempt to quantify neuropsychological processes (e.g., Burgess, 1997; Phillips, 1997). Given the expectations inherent within the set-shifting tasks, processes including working memory, inhibition, problem-solving, and others may also have been tapped to perform well. However, the discrepancy in results between set-shifting and alternating performance may also be because set-shifting tasks are more challenging, requiring the allocation of more attentional resources, which may be deficient or not allocated appropriately in children with DLD. Deficient attentional capacity has been suggested by prior work investigating this population (e.g., Finney et. al, 2014; Montgomery et. al, 2009; Spaulding et. al, 2008).
To explore the latter possibility, Study 2 was designed to determine if children with DLD would exhibit attentional shifting deficits on a task that they typically perform well on, alternating tasks, if and only if there was more demand on the children’s attentional resources. Based on the limited capacity framework originally proposed by Broadbent (1958), and refined by Kahneman (1973), attention, a limited capacity system, and effort are intrinsically linked. In essence, the theoretical argument is that the more challenging a task is, the more effort is required, and consequently more attentional resources need to be allocated to perform well. If the needed attentional resources exceed an individual’s attentional capacity, performance suffers. Therefore, deficits in attentional shifting would only be observable if demands were sufficiently high enough to exceed the available attentional resources and/or their successful allocation. If preschool-age children with DLD and their similar aged TL peers have the same attentional capacity, they would perform comparably to their TL peers regardless of the demand on their attentional resources. In contrast, if they have reduced attentional capacity, either in the number of attentional resources or in their successful allocation, deficits would be revealed if and only if attentional demands exceeded their capacity limitations.

Based on the findings of Study 2, preschool-age children with DLD do appear to have reduced attentional capacity, particularly in the area of attentional shifting. They exhibited comparable performance when expected to shift their attention intra-dimensionally among linguistic or among auditory or among visual dimensions alone but struggled when increased attentional demand was required to shift their attention extra-dimensionally among all three. This finding, when combined with the meta-analysis results from Study 1, provide additional support for the likelihood that children with DLD only struggle with attentional shifting when engaged in tasks that require relatively high levels of effort. What is clear is that
preschool-age children with DLD struggle in shifting their attention under high demands, such as when engaged in set-shifting tasks which are taxing by design or during alternating tasks which are manipulated to likewise place heavy demands on attentional shifting. They may indeed struggle because of reduced attentional capacity relative to their TL peers. The findings from both Study 1 and Study 2 are in alignment with prior research on attentional functioning of children with DLD (e.g., Finney et. al, 2014; Montgomery et. al, 2009; Spaulding et. al, 2008), and provide further support for the limited capacity theory of children with DLD as it relates to the attention domain.

Interestingly, based on the results of the quasi-experimental investigation in Study 2, it is important to note that preschool-age children with DLD did not falter completely under the high attention-demanding attentional shifting condition. Rather, they maintained comparable accuracy switch costs to the TL group regardless of attentional load and exhibited similar RT shift costs to the TL group in the low and medium load conditions. The only notable difference in Study 2 in attentional shifting was the RT shift costs in the high load condition. The DLD group exhibited greater hits to their RT on shifting relative to non-shifting trials relative to the TL group in this high load condition. In other words, they required substantially more time to respond in shifting trials relative to non-shifting trials. Why is this the case? It is possible that children with DLD may have sacrificed response efficiency for response accuracy in a scenario in which they were unable to do both well. In other words, they were inefficient, but because they were provided with enough time to respond, were ultimately successful at performing the task at a comparatively high level of accuracy as unimpaired children. Regardless as to whether or not the substantially slowed responses on shifting relative to non-shifting trials compared to the TL group was purposeful on the part of the DLD participants, what is clear is that the DLD group
was not able to respond both accurately and in a timely manner when expected to shift their attention under high demand. This suggests not only reduced attentional capacity, but specifically reduced capacity as it pertains to efficient resource allocation. The children with DLD appeared to have a sufficient number of attentional resources to perform as accurately as TL children on shifting relative to non-shifting trials in this high demanding condition. It just took them more time to shift their attention, suggesting that allocation not resource quantity was the issue.

It is important to mention, however, that while Study 1 found no differences in attentional shifting for children with DLD compared to their TL peers whether attentional shifting was measured by RT or accuracy, Study 2 did. Recall that in Study 2, attentional shifting issues for the DLD group only manifested when assessing RT and were not apparent when measuring accuracy. Consequently, while the results of Study 1 suggest that it does not matter whether attentional shifting is measured by RT or accuracy, Study 2 provides evidence that it does. There are a number of potential explanations for these seemingly disparate results. First, there were very few studies that reported RT in the meta-analysis, specifically 6 compared to the 13 studies that reported accuracy metrics. The limited power resulting from the small number of studies for RT in the moderator analysis may have restricted the ability to find meaningful differences. Second, the p-value for the moderator analysis was .09, which suggests that there is a 9% probability that the null is true, that there are no differences in attentional shifting if measuring RT or accuracy. This signifies that there is a 91% chance there is a difference, given the resulting data. Again, the limited number of studies, particularly those that measured RT, limits the ability to determine if this would reach significance and fall below the alpha level of .05 or move away from significance to make a clearer interpretation. Finally, another reason why there may have
been no significant difference observed in studies that assessed RT and those that assessed accuracy in the meta-analysis may have been because none of the studies included in the meta-analysis measured RT on an attentional shifting measure in preschool-aged children. This could explain the disparate finding in Study 2 which was conducted with children of preschool age.

Regardless of this seemingly disparate finding between Study 1 and Study 2, what is clear is that both studies revealed attentional shifting difficulties in children with DLD. While statistically significant, is it consequential? It may indeed be consequential when they are engaged in vocabulary acquisition.

One area of linguistic acquisition that children with DLD are well-known to exhibit inefficiency is in the area of word learning, with numerous studies providing evidentiary support. For example, they acquire their first words later than their TL peers (e.g., Trauner, Wulfeck, Tallal, & Hesselink, 2000). In addition, relative to TL peers, they learn novel words more slowly (e.g., Alt & Plante, 2006; Dollaghan, 1987; Gray, 2003, 2004, 2005; Leonard et al., 1982; Rice et al., 1992; Rice, Oetting, Marquis, Bode, & Pae, 1994). This inefficiency even extends to words that are already in their vocabulary repertoire. For example, Edwards and Lahey (1996) found that they were slower to receptively identify words, while other studies have found that they were also slower to expressively provide the names of the words that they can successfully identify at the receptive level (e.g., Rubin & Liberman, 1983; Wiig, Semel, & Nystrom, 1982).

Their relatively slow vocabulary acquisition may be partially attributable to failing to attend to the optimal cues that promote robust, efficient vocabulary acquisition. Relevant to the current work, the lack of robustness is apparent in their visual representation of referents. They learn fewer visual features of the referents when exposed to novel words (e.g., Alt & Plante,
2006; Alt et. al., 2004) and demonstrate reduced visually-informed semantic knowledge, the latter evidenced by their lack of visual detail when asked to draw pictures of what particular words signify (e.g., McGregor & Appel, 2002; McGregor, Newman, Reilly, & Capone, 2002). These findings, combined with prior work documenting that they do not attend to the most relevant visual cue that would likely promote more efficient word learning (e.g., Collisson et al., 2015), suggest that it may be important to focus the attention of children with DLD on important visual cues to enhance their word learning efficiency.

However, caution is needed when considering this approach. This is because the findings from Study 1 and Study 2 suggest that children with DLD struggle with shifting their attention in cases that require a high degree of effort, and thus attentional resource allocation. Based on the accumulating body of research to date, word learning is effortful for many children with DLD. Therefore, asking children with DLD to shift their attention to relevant visual cues during word learning may deplete all of their attentional resources and leave few or none remaining to actually dedicate to learning the novel words. This would be consistent with a utilization deficiency, which is a scenario that often presents itself when children learn to successfully execute what is expected of them but derive little or no benefit from it. What I am currently suggesting is that children with DLD may learn to successfully shift their attention to relevant cues but fail to learn the new words because of the added effort they use up to shift their attention to the relevant input. Utilization deficiencies have been previously suggested when strategies which facilitate linguistic learning in TL children have resulted in little to no success in children with DLD (e.g., Alt & Spaulding, 2011; Campanelli & Scheuer, 2014).
Before attempting to therapeutically treat the word learning deficits of children with DLD by adopting word learning biases (or strategies) that are successful for children with TL and applying them to children with DLD, it was important to determine what children with DLD naturally attend to when learning new words. If children with DLD systematically attend to a particular visual feature of novel objects, this may prove to be a more useful starting point when attempting to promote word learning in this population. If attention is indeed a limited resource, and if they naturally attend to certain properties of the input, there is the possibility that they would expend fewer attentional resources during this allocation. Study 2 provides evidence that the demand on attentional resources matters for preschool-age children with this disorder because they appear to exhibit a limited attentional capacity. If children with DLD systematically allocate their attention to certain feature properties of the input, then this could be potentially used therapeutically to help to highlight the words to be learned for these children, potentially without tapping into their reduced attentional capacity.

Study 3 was designed to determine what visual features of novel objects capture the attention of children with DLD when engaged in an early process of word learning, fast mapping. Because there is substantial evidence that children with DLD struggle to determine what is predictive when learning language (e.g., Evans, Saffran, & Robe-Torres, 2009; Lammertink, Boersma, Wijnen, & Rispens, 2017; Plante, Gomez, & Gerken, 2002), this impact was controlled by having no visual features any more predictive than the others in the study design. While color and pattern matches were consistent response options for the participants, movement was the response option that was of particular interest in this investigation. This was given particular emphasis in the analyses because younger, TL children appear to attend to movement when exposed to novel words (e.g., Benedict, 1979; Eiteljoerge et al., 2019; Gogate &
Bahrick, 2001; Gogate et al., 2009; Scofield et al., 2011; Werker et al., 1998). Because children with DLD appear like younger, TL children in their vocabulary acquisition (e.g., Eyer et al., 2002; Rice et al., 1990), they may, like younger TL children, naturally attend to the movement of objects when exposed to novel word-novel referent pairings.

The findings stemming from the final investigation, Study 3, were that children with DLD exhibited a fundamentally different pattern of responses than their age-matched TL peers when determining the relevant visual properties of novel objects during novel word-novel object pairings. When examining movement in particular, it was clear that the children with DLD attended to this characteristic as a particularly relevant feature when exposed to novel word-novel referent pairings and did so considerably more often than children with TL. In fact, 10 of the 12 children with DLD, compared to 3 out of 12 TL children, predominantly selected movement as the relevant cue. Movement captured the attention of the children with DLD.

Why does this matter? The vast majority of preschool-age children with DLD are attending to referent movement when exposed to nonword-novel referent pairings at a time in which attending to movement is typically outgrown. There is good reason to no longer rely on movement when exposed to new words. In order to learn most words that children are expected to acquire during the preschool years, movement does not serve as a reliable, predictable cue. Using a cue that was once beneficial but is no longer so is likely to inhibit the word learning process as it no longer serves in a facilitatory role.

Vocabulary acquisition is a common target in treatment for clinicians working with the DLD population. While proficient word learners, like TL children, demonstrate the capacity to shift their attention across multiple stimuli and multiple features of the same stimuli, children
with DLD are neither proficient word learners nor strong attentional shifters. Consequently, it is beneficial to know what children with DLD attend to when learning new words. Preschool-age children with DLD, or at least the vast majority of them, appear to attend to referent movement.

**Clinical Implications**

There are several clinical implications stemming from this work. First, the results of these studies suggest that in particularly challenging situations, children with DLD may need additional time to shift from previously relevant input to newly relevant input in order to be as ready as their unimpaired peers to process the new information. Therefore, it is important to determine what would be difficult and attention-demanding for children with DLD. Based on their hallmark deficit in linguistic functioning, learning language is particularly challenging for children in this population. Consequently, this may represent an important time during which their reduced attentional shifting capacity manifests. Parents, guardians, caregivers, teachers, speech language pathologists, and others attempting to enhance the skills of children with DLD should be aware of the additional time these children may need to process incoming information and to transition to new input. Providing these children with the time they need may be integral for ensuring that they are as ready to process and learn as are their unimpaired peers.

This is particularly relevant for speech language pathologists who work with children with DLD because, whether clinicians are engaged in assessment or intervention efforts with these children, both are challenging for the DLD population. Consequently, it is a time period in which these children are apt to exhibit subtle, potentially sub-clinical deficits in attention including attentional shifting. Speech language pathologists need to be aware of their expectations for speedy attentional shifting when engaged in assessment and intervention efforts.
as these children will likely need more time to shift amongst incoming stimuli. For example, during the administration of a standardized, norm-referenced assessment, children are typically expected to shift their attention in a timely manner between what the clinician says and visual stimulus items before making a response. While the deficits in attentional shifting might be subtle in this population, and may only manifest as RT delays in shifting amongst the stimuli, verbal instructions, and potential response options, the presence of attentional shifting challenges may negatively influence the child’s performance on these language assessment measures, independent of language ability. It is entirely possible that in some instances, clinicians are inadvertently measuring a combination of language ability and attention ability, including attentional shifting.

In addition, understanding the link between attention and language learning could also inform our intervention with this population of children. Because attentional shifting plays an important role in language learning includes the learning of new meanings, inferencing, and sentence structure (e.g., Deak and Narasimham, 2013; Jones et al., 1991; Magimairaj & Montgomery, 2013; Smith et al., 1996), designing an intervention approach that focuses on improving attentional shifting while also targeting their poor linguistic functioning may be more beneficial to accelerating language growth than focusing on language alone. Intervention studies incorporating other types of attention, including divided attention, have found that working on attention in addition to language in individuals with language disorders has been beneficial compared to working on language skills in isolation (e.g., Albert, Helm-Estabrooks, & Connor, 2000; Ebert & Kohnert, 2009; Khan, 2013). Whether or not the same holds true for targeting attention, including attentional shifting in preschool-age children with DLD, is unknown but potentially a worthy avenue of exploration.
Given the weakness that children with DLD have in attentional shifting, however, it may be useful to take a different approach entirely or at least until a time in which their attentional shifting ability substantially improves. Specifically, it may be beneficial to take advantage of what children with DLD naturally attend to when exposed to language and to tailor intervention programs for this clinical population based on what captures their attention. When in the early stages of novel word learning, the vast majority of children with DLD attend to referent movement. If movement increases the saliency of the referent for children with DLD, because it captures their attention, this can potentially be used therapeutically to scaffold the attention of children with DLD to relevant referents in the environment in order to draw adequate attention to the target to enable successful word-referent pairings. Given the attentional shifting challenges of children with DLD, and their reduced attentional capacity (including attentional shifting capacity), they might benefit from such scaffolding.

Limitations

There are several limitations to each of the studies in this dissertation that need to be considered. For Study 1, although the tasks were categorized based on their methodological design, it is worth mentioning that there were also a number of within tasks variations that might also contribute to the differences in the children’s performance across studies of attentional shifting. For example, some set-shifting studies used the DCCS (e.g., Kapa et al., 2017; Reichenbach et al., 2016; Yang & Gray, 2017), others used the WCST (e.g., Hughes et al., 2009; Weyandt, & Willis, 1994), and others used tasks that were developed by the authors (e.g., Kapa et al, 2017; Yang, & Grey, 2016). An insufficient number of studies prevented an analysis at the specific task level. Similarly, variations across studies in whether the tasks required linguistic
processing such as reading, naming, and/or categorization, and whether the tasks required verbal or manual responses across studies prohibited an analysis at the specific verbal and linguistic demand level. Also, while subtle attentional shifting deficits were documented within this study for children with DLD, it is not known if the constitution of the DLD sample contributed to this finding. For example, given the inability to reliably and accurately identify children with Attention Deficit Hyperactivity Disorder (ADHD) in preschool-age children, it is possible that the preschool samples of children with DLD included children with comorbid ADHD. This would necessarily contribute to a finding of attentional shifting deficits for the DLD population. Even at the school-age level, a time period in which the diagnostic sensitivity and specificity for ADHD drastically improves, the vast majority of studies did not provide a valid and reliable procedure for excluding children with comorbid ADHD from their study sample. In addition, it is entirely possible that some children with DLD had oral-only language deficits, while some studies included children with DLD with co-morbid dyslexia. The same issues regarding the inability to identify in the preschool-age and the lack of exclusion of comorbid dyslexia for children in the DLD group, even at the school-age level, prevented an analysis to provide clarity on the degree to which dyslexia comorbidity contributed to the variability in study outcomes.

For Study 2, it is important to note that the condition designed a priori to be of medium attentional load did not appear to be any more demanding than the condition considered to be of low attentional load, evidenced with a lack of accuracy switch cost and RT switch cost differential. This limits the interpretations of the results to the discussion of the impact of the high attentional shifting demand condition (high load) compared to low attentional shifting demand condition (low load) on participant performance.
In addition to the design of Study 2, there are some limitations in the interpretations that could be derived from the results. First, the control group was matched to the DLD group on chronological age. Consequently, it is not feasible to disentangle if the increased RT switch costs of children with DLD relative to the TL group in the high load condition was due to a delay or deviance from typical progression in attentional shifting ability with development. Given the link between attention and language acquisition (e.g., Deak and Narasimham, 2013; Jones et al., 1991; Magimairaj & Montgomery, 2013; Smith et al., 1996), additional work investigating attentional shifting comparisons between children with DLD and younger, typically developing children matched for language skills would help to determine whether or not the attentional capacity limitation is consistent with younger children, and therefore represents a delay, or deviates from that expected from children with similar language levels. It is a possibility that the current findings represent a delay in attentional shifting ability given prior work documenting similar attentional shifting ability between older, school-age children with DLD and their typically developing peers when using alternating designed attentional shifting tasks (e.g., Dibbets et al., 2006, Henry et al. 2012; Im-Bolter et al., 2006). At this point, however, this is unknown.

In addition to the limitations for Study 1 and Study 2, there are a number of limitations for Study 3. The main issue centered on the small number of participants, which resulted in limited power to conduct further analyses and to make additional interpretations. For example, there was not enough power to examine within group comparisons to determine patterns of responses as well as between-group comparisons to ascertain if differences were apparent in the groups’ tendencies to make other visual feature response selections, including pattern and color. In addition, because of power restrictions no analyses were included to compare each group’s
pattern of responses to chance. Finally, correlational analyses were conducted on the groups combined because of the small number of participants. It is entirely possible that different findings would emerge if the opportunity had arisen to include enough participants in each group to be analyzed separately.

Conclusion

Despite these limitations, conclusions can still be made. The results of Study 1 and Study 2 indicate that children with DLD have attentional shifting deficits that manifest under high demanding conditions. Their deficits in attentional shifting are particularly concerning as they are subtle enough to not be readily identified and potentially large enough to impede their efficient language learning. Efficient learning challenges are particularly apparent for children with DLD when engaged in word acquisition, which requires efficient and accurate novel word-novel referent pairings. Based on Study 3, when exposed to novel word-novel referent pairings, preschool-age children with DLD, unlike their peers, appear to attend to referent movement as a relevant cue despite its lack of predictive utility. Because referent movement appears to capture the attention of DLD when engaged in fast-mapping, an early part of the word learning process, this feature of attentional capture may be worthy to consider when exploring ways to promote the word learning of children from this population. Instead of shifting their attention to relevant properties of the input, given their attentional shifting weaknesses, serious consideration should be given to compensating for their attentional shifting deficits by using movement to enhance referent saliency and potentially facilitate their word-referent pairings.

Future Directions:
There are a number of future studies that could help to clarify interpretations from Study 1 and Study 2, both of which measured attentional shifting in children with DLD compared to TL age-matched controls. First, while an argument was made in Study 1 that set-shifting paradigms are more taxing on other executive functions, like inhibition and working memory, compared to alternating paradigms, this was not assessed. Future work could help determine if this is the case by providing empirical evidence on the role of inhibition and working memory processes in both of these types of attentional shifting tasks. This would help in providing further clarification on this possibility. In addition, future work could determine the relative contribution of ADHD and dyslexia comorbidities to attentional shifting performance, particularly during the school-age years as this is a time period in which the presence or absence of these impairments can be reliably and accurately determined. This is important because, the differences in attentional shifting between the children with DLD and the TL controls could have been driven by a small portion of children in the DLD groups who had co-morbid yet unidentified ADHD and may not be representative of the broader DLD population. In addition, it is possible that the differences in attentional shifting could also have been a result of a small number of children in the DLD groups who had comorbid dyslexia. Prior research has found attention challenges in the dyslexia population (e.g., Facoetti, et al., 2003; Heiervang, & Hugdahl, 2003; Visser, Boden, & Giaschi, 2004). Consequently, it would be important to determine if the differences were driven by the dyslexia, the DLD, or their comorbidity. Furthermore, although attentional shifting deficits were noted for children in the DLD group, this deficit could not be clearly differentiated as a delay or deviancy. Additional work in attentional shifting which includes a language-matched, younger, TL control group could help determine which is the case. Finally, it’s also important to conduct additional research to determine the
relative contribution of attentional shifting to assessment results and to the interpretation of intervention outcomes for the DLD population, given their identified attentional shifting deficits and the likely role that attentional shifting plays in these children’s performance on assessment measures and clinical intervention protocols.

There are also important avenues of direction for future work examining the attentional tendencies of children with DLD when engaged in language acquisition. To date, the importance of attentional shifting in language learning for children with DLD has received relatively little exploration. Future work could help to examine other stages of word learning besides the initial fast-mapping stage and examine the role of attentional tendencies for the hallmark linguistic deficit of children with DLD, specifically morphosyntax learning. In addition, future work should expand upon the current study by recruiting more participants to increase power and to also compare the performance of children with DLD to younger, language-matched controls to determine if their attentional tendency, like their attentional shifting weaknesses, are or are not comparable to younger typically developing children of similar language ability.

All 3 studies, when combined point to two possible avenues of intervention research assuming that differences in attentional shifting and attentional tendencies influence language learning for children with DLD. First, it may be worthy to investigate if targeting these attentional shifting weaknesses in treatment would be beneficial and facilitative of language learning. Second, it would also be interesting to investigate if circumventing the attentional shifting weaknesses altogether is a better approach. Instead of working on attentional shifting deficits, it may be better to focus on what children with DLD naturally attend to, which in the case of word learning appears to be referent movement, and use this as a facilitative predictive
cue when teaching them new words. Treatment approaches which successful enhance word learning efficiency in children with DLD are definitely needed.
References


language. *Journal of Speech, Language and Hearing Research, 47*, 407-420


Appendix A. Animal Picture Choices on Button Response Box
### Appendix B: Novel Labels For Movement Bias Task With Associated Movement Description and Picture Stimuli

<table>
<thead>
<tr>
<th>CVC Label</th>
<th>Associated Movement</th>
<th>Associated Picture Stimuli</th>
</tr>
</thead>
<tbody>
<tr>
<td>/dɪb/</td>
<td>Shaking</td>
<td>![Image of a Plane]</td>
</tr>
<tr>
<td>/fɪp/</td>
<td>Zoom</td>
<td>![Image of a Flashlight]</td>
</tr>
<tr>
<td>/næm/</td>
<td>Rotating</td>
<td>![Image of a Box]</td>
</tr>
<tr>
<td>/tɪd/</td>
<td>Weathervane</td>
<td>![Image of a Weather Vane]</td>
</tr>
<tr>
<td>/mʌf/</td>
<td>Explodes</td>
<td>![Image of a Bomb]</td>
</tr>
<tr>
<td>/pɪf/</td>
<td>Mirror</td>
<td>![Image of a Mirror]</td>
</tr>
</tbody>
</table>
### Table 2.1 Attentional Shifting Between Group Effect Sizes by Study

<table>
<thead>
<tr>
<th>Study</th>
<th>DLD</th>
<th>TL</th>
<th>Task Type</th>
<th>Age Group</th>
<th>Dependent Variable</th>
<th>Hedges’ g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dibbets et al. (2006)</td>
<td>4</td>
<td>7</td>
<td>Set-S</td>
<td>School</td>
<td>Accuracy</td>
<td>-1.53</td>
</tr>
<tr>
<td>Dibbets et al. (2006)</td>
<td>4</td>
<td>7</td>
<td>Set-S</td>
<td>School</td>
<td>RT</td>
<td>-1.63</td>
</tr>
<tr>
<td>Evans et al. (2018)</td>
<td>60</td>
<td>87</td>
<td>Alt</td>
<td>School</td>
<td>Accuracy</td>
<td>-0.41</td>
</tr>
<tr>
<td>Farrant et al. (2012)</td>
<td>30</td>
<td>30</td>
<td>Set-S</td>
<td>Pre-school</td>
<td>Accuracy</td>
<td>-0.66</td>
</tr>
<tr>
<td>Henry et al. (2012)</td>
<td>41</td>
<td>88</td>
<td>Alt</td>
<td>School</td>
<td>RT</td>
<td>0.10</td>
</tr>
<tr>
<td>Henry et al. (2012)</td>
<td>41</td>
<td>88</td>
<td>Set-S</td>
<td>School</td>
<td>Accuracy</td>
<td>-0.22</td>
</tr>
<tr>
<td>Hughes et al. (2009)</td>
<td>21</td>
<td>21</td>
<td>Set-S</td>
<td>School</td>
<td>Accuracy</td>
<td>-0.82</td>
</tr>
<tr>
<td>Im-Bolter et al. (2006)</td>
<td>45</td>
<td>45</td>
<td>Alt</td>
<td>School</td>
<td>RT</td>
<td>-0.04</td>
</tr>
<tr>
<td>Im-Bolter et al. (2006)</td>
<td>45</td>
<td>45</td>
<td>Set-S</td>
<td>School</td>
<td>Accuracy</td>
<td>-1.41</td>
</tr>
<tr>
<td>Im-Bolter et al. (2006)</td>
<td>45</td>
<td>45</td>
<td>Set-S</td>
<td>School</td>
<td>RT</td>
<td>-0.11</td>
</tr>
<tr>
<td>Kapa et al. (2017)</td>
<td>26</td>
<td>26</td>
<td>Set-S</td>
<td>Pre-school</td>
<td>Accuracy</td>
<td>-1.19</td>
</tr>
<tr>
<td>Kapa et al. (2017)</td>
<td>26</td>
<td>26</td>
<td>Set-S</td>
<td>Pre-school</td>
<td>Accuracy</td>
<td>-0.24</td>
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<tr>
<td>Kiernan et al. (1997)</td>
<td>15</td>
<td>13</td>
<td>Set-S</td>
<td>Pre-school</td>
<td>Accuracy</td>
<td>-0.23</td>
</tr>
<tr>
<td>Authors</td>
<td>Sample Size</td>
<td>Age</td>
<td>Setting</td>
<td>Condition</td>
<td>Measure</td>
<td>Effect Size</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------</td>
<td>-----</td>
<td>---------</td>
<td>-----------</td>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>Lukács et al. (2016)</td>
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<td>31</td>
<td>Alt</td>
<td>School</td>
<td>Accuracy</td>
<td>0.21</td>
</tr>
<tr>
<td>Marton (2008)</td>
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<td>25</td>
<td>Set-S</td>
<td>School</td>
<td>Accuracy</td>
<td>-1.16</td>
</tr>
<tr>
<td>Mutch (2001)</td>
<td>8</td>
<td>10</td>
<td>Alt</td>
<td>School</td>
<td>RT</td>
<td>0.09</td>
</tr>
<tr>
<td>Reichenbach et al. (2016)</td>
<td>27</td>
<td>30</td>
<td>Set-S</td>
<td>Pre-school</td>
<td>Accuracy</td>
<td>-0.13</td>
</tr>
<tr>
<td>Rodríguez et al. (2015)</td>
<td>29</td>
<td>29</td>
<td>Set-S</td>
<td>School</td>
<td>Accuracy</td>
<td>-0.31</td>
</tr>
<tr>
<td>Roello et al. (2015)</td>
<td>60</td>
<td>58</td>
<td>Set-S</td>
<td>Pre-school</td>
<td>Accuracy</td>
<td>-0.36</td>
</tr>
<tr>
<td>Schul et al. (2004)</td>
<td>15</td>
<td>90</td>
<td>Alt</td>
<td>School</td>
<td>Accuracy</td>
<td>-0.84</td>
</tr>
<tr>
<td>Victorino (2011)</td>
<td>15</td>
<td>15</td>
<td>Alt</td>
<td>School</td>
<td>RT</td>
<td>-0.42</td>
</tr>
<tr>
<td>Weyandt &amp; Willis (1994)</td>
<td>34</td>
<td>45</td>
<td>Set-S</td>
<td>School</td>
<td>Accuracy</td>
<td>-0.15</td>
</tr>
<tr>
<td>Williams et al. (2000)</td>
<td>10</td>
<td>10</td>
<td>Set-S</td>
<td>School</td>
<td>Accuracy</td>
<td>-0.09</td>
</tr>
<tr>
<td>Yang &amp; Gray (2016)</td>
<td>19</td>
<td>28</td>
<td>Set-S</td>
<td>Pre-school</td>
<td>Accuracy</td>
<td>-0.77</td>
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<td>Yang &amp; Gray (2016)</td>
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<td>28</td>
<td>Set-S</td>
<td>Pre-school</td>
<td>Accuracy</td>
<td>-0.57</td>
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<tr>
<td>Yoo &amp; Yim (2018)</td>
<td>15</td>
<td>20</td>
<td>Set-S</td>
<td>School</td>
<td>-</td>
<td>-0.69</td>
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</table>
### Table 2.2. Moderator Analysis of Task Type

<table>
<thead>
<tr>
<th>Type of Task</th>
<th>k</th>
<th>Hedges’ g</th>
<th>SE</th>
<th>95% CI</th>
<th>Z-value</th>
<th>P-Value</th>
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</thead>
<tbody>
<tr>
<td>Set-Shifting</td>
<td>15</td>
<td>-0.52</td>
<td>0.09</td>
<td>[-0.70, -0.33]</td>
<td>-5.51</td>
<td>0.00</td>
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<td>Alternating</td>
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<td>0.14</td>
<td>[-0.40, 0.16]</td>
<td>-1.39</td>
<td>0.16</td>
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</table>

Note: $k =$ Number of studies in each group; SE = Standard error. Negative effect size means that children with DLD performed worse than their age-matched typical peers.
Table 3.1. Demographic Characteristics of the Participants by Group

<table>
<thead>
<tr>
<th>GROUP</th>
<th>DLD (n=26)</th>
<th>TL (n=26)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Months)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M )</td>
<td>50.69</td>
<td>49.88</td>
</tr>
<tr>
<td>( SD )</td>
<td>5.32</td>
<td>5.61</td>
</tr>
<tr>
<td>Range</td>
<td>(44-61)</td>
<td>(42-59)</td>
</tr>
<tr>
<td>Sex (n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Females</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Mother’s education level (Years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M )</td>
<td>13.89</td>
<td>14.13</td>
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<tr>
<td>( SD )</td>
<td>2.04</td>
<td>1.98</td>
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<td>Range</td>
<td>(10-18)</td>
<td>(12-18)</td>
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<td>Ethnicity (n)</td>
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<td>Not Hispanic</td>
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<td>Hispanic</td>
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<td>6</td>
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<td>Not reported</td>
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<td>5</td>
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<td>Race (n)</td>
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<tr>
<td>White</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Black/African American</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Multiracial</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Asian</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Not reported</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: TL = typical language and DLD = developmental language disorder; M = mean, SD = standard deviation, n = number of participants
**Table 3.2 Group Performance on Norm-Referenced Assessments**

<table>
<thead>
<tr>
<th>Behavioral measure</th>
<th>TL</th>
<th>DLD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M(SD) Range</td>
<td>M(SD) Range</td>
</tr>
<tr>
<td><strong>CELF-P2</strong></td>
<td>106.96 (10.09) 90-123</td>
<td>78.38 (06.65) 65-83</td>
</tr>
<tr>
<td><strong>PPVT-IV</strong></td>
<td>110.31 (09.52) 92-126</td>
<td>93.19 (06.65) 75-112</td>
</tr>
<tr>
<td>KABC-II</td>
<td>108.12 (08.40) 94-127</td>
<td>105.88 (07.41) 92-120</td>
</tr>
</tbody>
</table>

Notes. TL = typical language; DLD = developmental language disorder; CELF-P:2 = Clinical Evaluation of Language Fundamentals Preschool-Second Edition (Wiig, Secord, & Semel, 2004); K-ABC-II = Kaufman Assessment Battery for Children – Second Edition (KABC – II; Kaufman & Kaufman, 2004); PPVT-IV = Peabody Picture Vocabulary Test – Fourth Edition (PPVT-IV; Dunn & Dunn, 2007); ** = significant difference at p<.01; * Standard scores with a mean of 100 and a standard deviation of 15.
### Table 3.3. Transformed Mean Errors by Group, Attentional Load, and Trial Type

<table>
<thead>
<tr>
<th>Load</th>
<th>TL Nonshift</th>
<th>TL Shift</th>
<th>DLD Nonshift</th>
<th>DLD Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$ (SD)</td>
<td>$M$ (SD)</td>
<td>$M$ (SD)</td>
<td>$M$ (SD)</td>
</tr>
<tr>
<td>Low</td>
<td>.202 (.232)</td>
<td>.253 (.292)</td>
<td>.365 (.325)</td>
<td>.435 (.282)</td>
</tr>
<tr>
<td>Medium</td>
<td>.211 (.262)</td>
<td>.392 (.337)</td>
<td>.347 (.279)</td>
<td>.479 (.348)</td>
</tr>
<tr>
<td>High</td>
<td>.312 (.312)</td>
<td>.457 (.380)</td>
<td>.588 (.357)</td>
<td>.737 (.288)</td>
</tr>
</tbody>
</table>

Note: TL = typical language; DLD = developmental language disorder; Nonshift = nonshifting, repeated trial; Shift = shifting trial; $M$ = mean, $SD$ = standard deviation.
Table 3.4. Mean Response Time in Milliseconds by Group, Attentional Load, and Trial Type.

<table>
<thead>
<tr>
<th>Load condition</th>
<th>TL Nonswitch $M$ (SD)</th>
<th>TL Switch $M$ (SD)</th>
<th>DLD Nonswitch $M$ (SD)</th>
<th>DLD Switch $M$ (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1786.44 (411.24)</td>
<td>2143.56 (343.64)</td>
<td>1868.88 (412.91)</td>
<td>2288.48 (393.12)</td>
</tr>
<tr>
<td>Medium</td>
<td>2093.56 (314.20)</td>
<td>2263.64 (313.99)</td>
<td>2141.88 (411.84)</td>
<td>2463.68 (349.54)</td>
</tr>
<tr>
<td>High</td>
<td>2145.24 (324.99)</td>
<td>2357.20 (424.50)</td>
<td>2475.52 (343.25)</td>
<td>3178.00 (398.33)</td>
</tr>
</tbody>
</table>

Note: TL = typical language and DLD = developmental language disorder; M = mean, SD = standard deviation
Table 4.1. Demographic Characteristics of the Participants by Group

<table>
<thead>
<tr>
<th>GROUP</th>
<th>DLD (n=12)</th>
<th>TL (n=12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Months)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>50.31</td>
<td>50.83</td>
</tr>
<tr>
<td>SD</td>
<td>8.37</td>
<td>8.63</td>
</tr>
<tr>
<td>Range</td>
<td>(38-66)</td>
<td>(39-65)</td>
</tr>
<tr>
<td>Sex (n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Females</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Mother’s education level (Years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>14.5</td>
<td>15</td>
</tr>
<tr>
<td>SD</td>
<td>1.62</td>
<td>1.73</td>
</tr>
<tr>
<td>Range</td>
<td>(10-18)</td>
<td>(12-18)</td>
</tr>
<tr>
<td>Race (n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Black/African American</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Multiracial</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Asian</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Not reported</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: TL = typical language and DLD = developmental language disorder; M = mean, SD = standard deviation, n = number of participants.
Table 4.2 Group Performance on Norm-Referenced Assessments

<table>
<thead>
<tr>
<th>Behavioral measure</th>
<th>DLD</th>
<th>TL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M(SD)</td>
<td>Range</td>
</tr>
<tr>
<td><strong>CELF-P2\textsuperscript{a}</strong></td>
<td>75.85 (5.15)</td>
<td>90-123</td>
</tr>
<tr>
<td><strong>PPVT-IV\textsuperscript{a}</strong></td>
<td>90.15 (7.99)</td>
<td>75-106</td>
</tr>
<tr>
<td>KABC-II\textsuperscript{a}</td>
<td>101.85 (7.99)</td>
<td>92-118</td>
</tr>
</tbody>
</table>

Notes. TL = typical language; DLD = developmental language disorder; CELF-P:2 = Clinical Evaluation of Language Fundamentals Preschool-Second Edition (Wiig, Secord, & Semel, 2004); K-ABC-II = Kaufman Assessment Battery for Children – Second Edition (KABC – II; Kaufman & Kaufman, 2004); PPVT-IV = Peabody Picture Vocabulary Test – Fourth Edition (PPVT-IV; Dunn & Dunn, 2007); ** = significant difference at p<.01; \textsuperscript{a} Standard scores with a mean of 100 and a standard deviation of 15.
Table 4.3 Mean Frequency Count of Movement, Color, and Pattern:

<table>
<thead>
<tr>
<th>Selection</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DLD</td>
<td></td>
<td>TL</td>
<td></td>
</tr>
<tr>
<td>Selection</td>
<td>M(SD)</td>
<td>Range</td>
<td>M(SD)</td>
<td>Range</td>
</tr>
<tr>
<td>Movement</td>
<td>11.33(4.85)</td>
<td>90-123</td>
<td>3.83(5.91)</td>
<td>65-83</td>
</tr>
<tr>
<td>Color</td>
<td>4.33 (4.18)</td>
<td>75-106</td>
<td>8.00(7.00)</td>
<td>92-124</td>
</tr>
<tr>
<td>Pattern</td>
<td>2.42 (1.73)</td>
<td>92-118</td>
<td>6.08(6.36)</td>
<td>89-127</td>
</tr>
</tbody>
</table>

Notes. TL = typical language; DLD = developmental language disorder; M= mean frequency count; SD= Standard deviation.
Table 4.4 Profiles of Children Who Exhibited a Movement Bias:

<table>
<thead>
<tr>
<th>Group</th>
<th>Age</th>
<th>Sex</th>
<th>Categorization</th>
<th>KABC-II</th>
<th>CELF-P2</th>
<th>PPVT-IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLD</td>
<td>38</td>
<td>F</td>
<td>Movement</td>
<td>113</td>
<td>75</td>
<td>93</td>
</tr>
<tr>
<td>DLD</td>
<td>41</td>
<td>F</td>
<td>Movement</td>
<td>95</td>
<td>82</td>
<td>94</td>
</tr>
<tr>
<td>DLD</td>
<td>58</td>
<td>F</td>
<td>Movement</td>
<td>96</td>
<td>69</td>
<td>75</td>
</tr>
<tr>
<td>DLD</td>
<td>42</td>
<td>M</td>
<td>Movement</td>
<td>106</td>
<td>82</td>
<td>88</td>
</tr>
<tr>
<td>DLD</td>
<td>44</td>
<td>M</td>
<td>Movement</td>
<td>102</td>
<td>84</td>
<td>100</td>
</tr>
<tr>
<td>DLD</td>
<td>44</td>
<td>M</td>
<td>Movement</td>
<td>106</td>
<td>75</td>
<td>91</td>
</tr>
<tr>
<td>DLD</td>
<td>49</td>
<td>M</td>
<td>Movement</td>
<td>102</td>
<td>79</td>
<td>88</td>
</tr>
<tr>
<td>DLD</td>
<td>52</td>
<td>M</td>
<td>Movement</td>
<td>92</td>
<td>68</td>
<td>88</td>
</tr>
<tr>
<td>DLD</td>
<td>55</td>
<td>M</td>
<td>Movement</td>
<td>104</td>
<td>73</td>
<td>89</td>
</tr>
<tr>
<td>DLD</td>
<td>66</td>
<td>M</td>
<td>Movement</td>
<td>94</td>
<td>80</td>
<td>91</td>
</tr>
<tr>
<td>TL</td>
<td>39</td>
<td>M</td>
<td>Movement</td>
<td>109</td>
<td>115</td>
<td>126</td>
</tr>
<tr>
<td>TL</td>
<td>41</td>
<td>M</td>
<td>Movement</td>
<td>115</td>
<td>106</td>
<td>116</td>
</tr>
<tr>
<td>TL</td>
<td>53</td>
<td>M</td>
<td>Movement</td>
<td>127</td>
<td>108</td>
<td>108</td>
</tr>
</tbody>
</table>

Table 4.5 Profiles of Children Who Did Not Exhibit a Movement Bias:

<table>
<thead>
<tr>
<th>Group</th>
<th>Age</th>
<th>Sex</th>
<th>Categorization</th>
<th>KABC-II</th>
<th>CELF-P2</th>
<th>PPVT-IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLD</td>
<td>39</td>
<td>F</td>
<td>Color</td>
<td>118</td>
<td>72</td>
<td>91</td>
</tr>
<tr>
<td>DLD</td>
<td>49</td>
<td>M</td>
<td>Color</td>
<td>104</td>
<td>75</td>
<td>78</td>
</tr>
<tr>
<td>TL</td>
<td>50</td>
<td>F</td>
<td>Color</td>
<td>89</td>
<td>102</td>
<td>124</td>
</tr>
<tr>
<td>TL</td>
<td>56</td>
<td>F</td>
<td>Color</td>
<td>100</td>
<td>100</td>
<td>109</td>
</tr>
<tr>
<td>TL</td>
<td>57</td>
<td>F</td>
<td>Color</td>
<td>100</td>
<td>88</td>
<td>100</td>
</tr>
<tr>
<td>TL</td>
<td>65</td>
<td>F</td>
<td>Pattern</td>
<td>106</td>
<td>96</td>
<td>92</td>
</tr>
<tr>
<td>TL</td>
<td>44</td>
<td>M</td>
<td>Color</td>
<td>120</td>
<td>94</td>
<td>99</td>
</tr>
<tr>
<td>TL</td>
<td>57</td>
<td>M</td>
<td>Color</td>
<td>108</td>
<td>90</td>
<td>108</td>
</tr>
<tr>
<td>TL</td>
<td>57</td>
<td>M</td>
<td>Pattern</td>
<td>98</td>
<td>94</td>
<td>103</td>
</tr>
<tr>
<td>TL</td>
<td>59</td>
<td>M</td>
<td>Pattern</td>
<td>114</td>
<td>112</td>
<td>111</td>
</tr>
<tr>
<td>TL</td>
<td>60</td>
<td>M</td>
<td>Color</td>
<td>111</td>
<td>104</td>
<td>108</td>
</tr>
</tbody>
</table>

Figure 2.1. PRISMA Flow Chart of Study Selection Indicating Data Inclusion and Exclusion At Each Stage of The Literature Search Procedure:

- **Identification**: Records identified through database searching (n = 2,425)
- **Screening**: Records after duplicates removed (n = 2271)
  - Records after irrelevant citation removed (n = 606)
- **Eligibility**: Records titles and abstracts screened (n = 606)
- **Included**: Full-text articles assessed for eligibility (n = 163)
- **Excluded**: Full-text articles excluded (n = 143)
  - Did not measure attentional shifting: 126
  - Studies written in languages other than English: 5
  - Did not include a TL control group: 3
  - Only used BRIEF to assess executive function: 5
  - Doctoral dissertations excluded in favor of the peer-reviewed journal article of the same study: 2
  - Study participants do not meet definition of DLD: 1
  - Study did not report sufficient data to compute an effect size: 1

**Studies included in qualitative synthesis (n = 20)**

- Adult studies: 21
- Autism studies: 210
- ADHD studies: 84
- Down syndrome studies: 13
- Dyslexia studies: 25
- Hearing Impairment studies: 21
- Stuttering studies: 20
- Bilingual/second language learning studies: 49
Figure 2.2. Forest Plot:

<table>
<thead>
<tr>
<th>Study name</th>
<th>Hedges's g and 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dibbets et al. (2006)</td>
<td></td>
</tr>
<tr>
<td>Evans et al. (2018)</td>
<td></td>
</tr>
<tr>
<td>Farrant et al. (2012)</td>
<td></td>
</tr>
<tr>
<td>Henry et al. (2012)</td>
<td></td>
</tr>
<tr>
<td>Hughes et al. (2009)</td>
<td></td>
</tr>
<tr>
<td>Im-Bolter et al. (2006)</td>
<td></td>
</tr>
<tr>
<td>Kapa et al. (2017)</td>
<td></td>
</tr>
<tr>
<td>Kiernan et al. (1997)</td>
<td></td>
</tr>
<tr>
<td>Lukács et al. (2016)</td>
<td></td>
</tr>
<tr>
<td>Marton (2008)</td>
<td></td>
</tr>
<tr>
<td>Mutch (2001)</td>
<td></td>
</tr>
<tr>
<td>Reichenbach et al. (2016)</td>
<td></td>
</tr>
<tr>
<td>Rodriguez et al. (2015)</td>
<td></td>
</tr>
<tr>
<td>Roello et al. (2015)</td>
<td></td>
</tr>
<tr>
<td>Schul et al. (2004)</td>
<td></td>
</tr>
<tr>
<td>Victorino (2011)</td>
<td></td>
</tr>
<tr>
<td>Weyandt &amp; Willis (1994)</td>
<td></td>
</tr>
<tr>
<td>Williams et al. (2000)</td>
<td></td>
</tr>
<tr>
<td>Yang &amp; Gray (2016)</td>
<td></td>
</tr>
<tr>
<td>Yoo &amp; Yim (2018)</td>
<td></td>
</tr>
</tbody>
</table>

Note: Negative effect size means that children with DLD performed worse than their age-matched typical peers. The diamond is the overall effect size of the studies. Each line represents a study, and the squares represents the effect size of each study, the size of the square reflects the weight of the study. When lines cross zero, there is no significant difference between the TL and DLD groups in the performance on the attentional shifting tasks.
Figure 3.1. Response Time Shift Cost for Groups Based on Attentional Load
Figure 4.1 Frequency of Choices in Novel Name Extension Task by Group
Figure 4.2 Correlation Between Age and Proportion of Movement Responses
Figure 4.3 Correlation Between PPVT-IV Scores and Proportion of Movement Responses