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Language-Mediated Eye Behaviors During Storybook Reading as aFunction of Preschool Language Ability

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A thesis submitted to the faculty of
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ABSTRACT

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Children with Developmental Language Disorder (DLD) are at risk for reading disability and academic failure, and there remains a lack of scientific consensus about the underlying deficits that may explain their language difficulties. This study examined how language ability predicts preschoolers' eye movements during a naturalistic storybook reading task, a possible indicator of comprehension processes in real-time. We used eye-tracking measures to examine comprehension processes in 49 preschoolers with wide-ranging language abilities, using language skill as a continuous predictor variable. Participants viewed and listened to a storybook presented on an eye-tracking computer. Portions of each illustration that corresponded with a noun phrase in the text were considered target images during the time course of the spoken referent. Eye-tracking analyses revealed that children had similar latency to target images regardless of language level. However, language ability was a significant predictor of proportion of fixations; children with higher language skills had more fixations on target images and less fixations on control images than children with lower language skills. These results suggest that children with lower language abilities attended to the story but did not sufficiently sustain attention to relevant images and continued to attend to extraneous images after the onset of spoken noun phrases. Speech-language pathologists and early childhood educators should be aware that children with language difficulties may need help identifying what is most important to attend to during shared storybook reading.

Keywords: developmental language disorder, eye-tracking, inhibition, comprehension

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DESCRIPTION OF THESIS STRUCTURE AND CONTENT

This thesis, *Language-Mediated Eye Behaviors During Storybook Reading as a Function of Preschool Language Ability,* is written in a hybrid format. The hybrid format combines traditional thesis requirements with formats typically used for journal publication. The preliminary pages of this thesis meet the university submission requirements. This report is presented as a journal article, conforming to the length and style requirements for submitting research articles to academic journals. The participant recruitment flyer is included in Appendix A. The participant consent form is included in Appendix B. Appendix C contains an annotated bibliography.

Introduction

Children's language skills are an essential part of their ability to interact with others and learn about the world. However, not all children develop language on a typical trajectory. One major role of a speech-language pathologist (SLP) is to diagnose and treat language disorders in children. To this end, many researchers have sought to identify what characterizes a language disorder in individuals from infancy through adulthood. This introduction will summarize how Developmental Language Disorder (DLD) is currently understood and discuss some of the remaining unknowns surrounding this diagnosis. A discussion of the advantages of eye-tracking research and what is known about the connection between eye-tracking behaviors and language will follow.

Developmental Language Disorder

Developmental language disorder (DLD) is a diagnosis given to children who have difficulty acquiring and using language in the absence of known biomedical etiologies that would account for significant language deficits (Bishop, Snowling, Thompson, & Greenhalgh, 2017). This disorder has also been referred to as language impairment (LI) and specific language impairment (SLI; Stark & Tallal, 1981). The recommended term is now DLD because it emphasizes that language problems occur in these children during development, not as a result of an injury or biomedical condition (Bishop et al., 2017). Although DLD is the most current term, this introduction will reference the various labels for language disorder as they appear in the literature cited.

Between three to seven percent of children have DLD (Bishop et al., 2017). These children may be delayed in achieving early language milestones, such as the first fifty expressive words and basic word combinations (Ellis, Borovsky, Elman, & Evans, 2015). Children with

DLD continue to present with a number of language learning problems into the school years, including difficulties with grammatical tense, vocabulary, complex syntax, and spoken and written language comprehension (Borovsky, Burns, Elman, & Evans, 2013). Elementary school students with DLD are at heightened risk for literacy difficulties. A longitudinal study found that 50% of fourth graders with a history of LI could also be diagnosed with reading disability (Catts, Fey, Tomblin, & Zhang, 2002). Importantly, these individuals are also likely to have weak language skills in adulthood, which can impact social, educational, and vocational success (Leonard, 2014).

Diagnosing DLD is difficult because of the complexity of language and the range of ways a language disorder may manifest (Caulfield, Fischel, DeBaryshe, & Whitehurst, 1989; Thal & Tobias, 1992). It is especially challenging to identify young children with this disorder; some toddlers with signs of delayed language development "catch up" by the school years, while others do not (Caulfield et al., 1989; Dale, Price, Bishop, & Plomin, 2003; Roos, & Weismer, 2008; Thal & Tobias, 1992). The current gold standard for diagnosing DLD entails a comprehensive battery of language assessments given by an SLP. Children are typically assessed across multiple language domains and modalities; namely, vocabulary, grammar, narrative, and receptive and expressive language (Catts et al., 2002). Commonly accepted criteria for diagnosing DLD include low standard scores (e.g., 1.5-2 standard deviations below the mean) on more than one norm-referenced language assessment or subtest, with deficits appearing in more than one area (Catts et al., 2002). Although a discrepancy between verbal and nonverbal IQ was previously considered a key factor in the diagnosis of SLI, at present, low nonverbal intellectual ability does not exclude a diagnosis of DLD (Bishop et al., 2017).

There is a lack of scientific consensus regarding the underlying deficits or causes of DLD. Researchers have theorized about whether DLD is limited to the specific domain of language, or whether it is mediated by differences in more general cognitive processes. The classic view of DLD, previously called SLI, centers on the language-specific deficits these children demonstrate, especially in certain morphological and syntactical forms (Rice, Wexler, & Cleave, 1995). Many early SLI studies focused on markers of language disorder such as inconsistent use of regular and irregular past-tense forms, reduced expressive vocabulary, and difficulty comprehending and producing subordinate clauses (Bishop, 1979; Rice et al., 1995). This research focus may be partially attributable to the recently discontinued definition of the disorder as having language difficulties despite typical nonverbal intelligence (Bishop et al., 2017). Although these language deficits may be more readily apparent than underlying cognitive processes, there is a growing appreciation that other domains are impacted in DLD (Hoffman & Gillam, 2004; Leonard et al., 2007).

In contrast to the perspective that this is a specific language disorder in the face of otherwise typical cognition, other theories associate DLD with broader, domain-general deficits. Researchers investigating domain-general processes and DLD have implicated speed of processing, capacity of processing, and working memory as potential mechanisms of the disorder (Hoffman & Gillam, 2004; Leonard et al., 2007). Leonard et al. (2007) examined how children with LI perform on linguistic and nonlinguistic cognitive processing tasks. Nonlinguistic processing tasks included asking children to scan visual arrays for a predetermined item and indicate its presence or absence with a keyboard click, indicate whether two figures were identical or mirror images, and determine whether two pictures matched in category, name, etc. Verbal processing measures involved tasks such as identifying rhyming words and listening to statements about pictures and judging them to be true or false. Children with SLI showed limitations on both linguistic and nonlinguistic processing tasks compared to typically developing peers. These findings suggest that children with language disorders experience cognitive processing deficits that are not limited to the domain of language (Leonard et al., 2007).

Hoffman and Gillam (2004) compared children with SLI to same-age peers on both verbal and nonverbal working memory measures. The participants viewed and attempted to recall various combinations of numbers, colors, or the spatial location of Xs presented sequentially on a screen. The children with SLI performed significantly below controls on the verbal recall and nonverbal visuospatial recall tasks, again suggesting that differences in processing and working memory were not limited to linguistic tasks (Hoffman & Gillam, 2004). What remains unclear is whether working memory and processing limitations in these children are symptomatic of LI, causing LI, or simply common but unrelated comorbidities (Leonard et al., 2007).

An alternate domain-general theory suggests that individuals with poor language abilities have inefficient suppression of irrelevant stimuli (Borovsky et al., 2013; Gernsbacher & Faust, 1991). While inhibition is considered a core executive function, it is a complex topic and its subcomponents are not clearly defined across researchers or disciplines. Diamond (2013) made a distinction between voluntary inhibition and interference control. Voluntary inhibition involves the ability to override strong dispositions or environmental lures to do what is expected or necessary (Diamond, 2013). This inhibition of action has also been referred to as inhibition of a prepotent response (Spaulding, 2010). Interference control differs because it is less conscious and can occur at the level of perception; it allows individuals to focus their attention on what is necessary in incoming information and suppress what is irrelevant (Diamond, 2013). In this discussion, the terms suppression of irrelevant stimuli and interference control will be used interchangeably to refer to this inhibitory process.

There is emerging evidence of a relationship between language level and inhibition abilities (Bishop & Norbury, 2005; Gernsbacher & Faust, 1991; Gernsbacher & Robertson, 1995; Spaulding, 2010). Bishop and Norbury (2005) compared groups of children with autism, pragmatic language impairment, and SLI with typically developing controls on inhibition of a prepotent response. This form of inhibition was measured by same/opposite tasks and a stop/go task. Children first performed a task in which they followed a simple command (i.e., trace your finger along a paper lined with ones and twos, read each number aloud), then they would repeat the task after being instructed to do the opposite of what they did before (i.e., say “two” when pointing to one). Next, the stop/go task required children to perform an action when they heard a certain sound and inhibit the action when a warning tone was played. The go sound was played repeatedly, making it difficult to stop when a warning tone sounded. The results indicated that inhibitory deficits were not strongly associated with one disorder category in the study; rather, children with SLI, pragmatic language impairment, and autism all had difficulty with these tasks. The authors concluded that there is an association between low language levels, inattention, and inhibition abilities (Bishop & Norbury, 2005).

In addition to difficulties with voluntary inhibition, there is evidence to suggest that individuals with low language have reduced interference control abilities. Gernsbacher and Faust (1991) found that adults with poor comprehension skills were less able to suppress incorrect meanings of ambiguous words in text, incorrect forms of homophones, and typical but absent objects in visual displays. For example, participants read a sentence such as “She dropped the plate" and then saw a related or unrelated word such as "BREAK" and judged whether the word fit the meaning of the sentence (Gernsbacher & Faust, 1991, p. 7). In some trials, the word was similar in meaning to a homophone in the sentence. For example, the sentence may read "He had lots of patients," followed by the word "CALM," where "CALM" was related to the homophone "patience" but not to the meaning of the sentence (Gernsbacher & Faust, 1991, p. 7). Both typical and poor comprehenders experienced distractor interference when the word to be rejected was related to a homophone, as evidenced by a slower reaction time compared to non-homophone trials. However, the typical controls suppressed this homophone activation within one second, where the less skilled comprehenders were still unable to reject the unrelated word after this time delay. The visual suppression task required the subjects to look at a visual display of objects, such as a farm scene. After viewing the scene, subjects read words and indicated whether or not each item had been present. Poor comprehenders were more likely to respond that an expected object (e.g., a tractor in a farm scene) was present when it was not. The authors concluded that the poor comprehenders may have used context to enhance correct meanings appropriately but failed to suppress the activation of related but extraneous information efficiently (Gernsbacher & Faust, 1991; Gernsbacher & Robertson, 1995).

More recently, Spaulding (2010) studied interference control and voluntary inhibition in preschoolers with and without LI. The research tasks were designed to have simple linguistic directions and few demands on attention and memory to emphasize inhibitory performance. The voluntary inhibition task required children to click on an on-screen dinosaur when they heard "dinosaur" or a butterfly when they heard "butterfly," unless the word was immediately followed by "stop." The interference control task was a computer game in which children were directed to feed a cow ice cream when requested, but not pizza. Prior to the onset of the directions, various auditory, verbal, and visual distractors were presented. Children had to resist the distractor input in order to follow the directions correctly. The results of both tasks showed that preschoolers with LI had poorer interference control in the presence of distractors and less voluntary inhibition relative to typically developing controls (Spaulding, 2010).

Eye-Tracking

Overview. There is an established, though poorly understood, relationship between DLD and interference control. However, there is limited research on how this deficit may manifest in natural everyday tasks. The present study seeks to use eye-tracking technology to observe the online comprehension processes of preschool children with DLD during storybook reading, which may provide insight into interference control processes in young children. Eye-tracking is a valuable research tool for comprehension-related questions and observing in real-time what children are attending to and what they are ignoring (Luke & Asplund, 2018; Rayner, Chace, Slattery, & Ashby, 2006). More specifically, high-precision eye-tracking technology can reveal eye movements that are sensitive to spoken language processing variables when a participant is presented with verbal stimuli and a related visual display on a computer screen. Basic analyses of eye-tracking data may include the amount of time it takes a participant to look at a target image after hearing the stimuli and whether the participant focuses their gaze on the image, revealing information about the speed and robustness of their comprehension (Luke & Asplund, 2018; Rayner et al., 2006), and their ability to ignore irrelevant stimuli (Nation, Marshall, & Altmann, 2003).

Relevant eye-tracking research. Eye-tracking research revealed that typically developing pre-reader children do not attend to printed text during shared storybook reading (Evans & Saint-Aubin, 2005; Luke & Asplund, 2018). Given pre-readers' tendency to focus on illustrations, Luke and Asplund (2018) explored whether the eye movements of preschool children are language-mediated during storybook reading. Forty-one pre-reader children ages three to five and 57 adult controls had their eye movements tracked while looking at and listening to a simple storybook. The results showed that children fixated on target pictures corresponding to the noun phrase in a similar, language-mediated fashion to the adult participants. That is, the young children and adults demonstrated storybook comprehension by gazing at certain parts of illustrations as related words were read (Luke & Asplund, 2018).

Eye-tracking has also been used to study language-mediated eye movements in individuals with DLD (Andreu, Sanz-Torrent, & Guårdia-Olmos, 2011; Andreu, Sanz-Torrent, Guårdia-Olmos, & Macwhinney, 2011; Borovsky et al., 2013; McMurray, Samelson, Lee, & Tomblin, 2010). This technology grants insight into online language comprehension processes without requiring verbal input from the participant, thus removing a level of difficulty for participants with poor language skills. In the following sections, relevant eye-tracking studies involving individuals with low language or DLD from infancy through adolescence will be reviewed.

Infancy. Ellis et al. (2015) used eye-tracking to determine whether late-talking toddlers had different lexical processing abilities than children with typical language development. Late-talking toddlers and cognitive-level matched typically developing toddlers were trained on several novel word-picture pairs. After training, children’s eye movements were recorded while they heard the novel words and saw the corresponding image plus a distractor image. Based on traditional eye-tracking measures, both groups of toddlers accurately identified the target image in similar manners. However, fine-grained analysis of the eye-tracking results showed that the typically developing group made a distinction between the target and distractor image by focusing their gaze on the correct image after a certain time point, but the late-talker group did not. The late-talker children shifted their gaze between the target and distractor without favoring the target. This could be due to a lack of word-learning depth or an inability to focus attention on one image in the face of distractor interference (Ellis et al., 2015). This study exemplifies the level of sensitivity eye-tracking has to detect subtle differences in online processing. It further indicates that signs of DLD may be detectable at a very young age, and that these children may have difficulty filtering extraneous information such as the distractor images.

Preschool. Andreu, Sanz-Torrent, Guàrdia-Olmos, and Macwhinney (2011) observed the eye-tracking behaviors of Spanish- and Catalan-speaking preschool children with and without LI during storybook comprehension and narrative retell. The children looked at storybook illustrations on a computer equipped for eye-tracking while listening to a narration. The children then looked at the same illustrations while attempting to retell the story. For both tasks, children's proportion of fixations to semantically relevant areas of the illustration were measured. No significant between-group differences were found in the storybook comprehension task based on the eye-tracking data point of proportion of looks to semantically relevant areas throughout the reading. However, the children with LI performed poorly on the narrative retell portion and did not look at semantically relevant areas of the illustration to support their memories as frequently as the controls (Andreu, Sanz-Torrent, Guàrdia-Olmos, & Macwhinney, 2011).

Elementary school. Andreu, Sanz-Torrent, and Guàrdia-Olmos (2011) found that five- to eight-year-old children with LI were slower than age-matched peers to look at target images relating to the nouns and verbs they heard in sentences, especially in three-argument verb sentences. The children with LI were also compared to typically-developing children who were younger in chronological age but matched on mean length of utterance (MLU). No significant differences were found between the eye-tracking results of the children with LI and their MLU controls. The children with LI showed equivalent visual processing speed when compared to age-matched controls in an eye-tracking task that was not language-mediated, demonstrating the linguistic component of the observed gaze pattern differences (Andreu, Sanz-Torrent, & Guàrdia-Olmos, 2011).

Nation et al. (2003) used eye-tracking to determine that children, like adults, can use verb selection predictions and visual context to predict the object of the verb. Ten- and eleven-year-old children were grouped as typical or low comprehenders and tasked with listening to sentences while looking at related illustrations. In conditions that supported inferencing, both groups of children had anticipatory eye movements to the target illustration corresponding to the final noun (e.g., "Jane watched her mother eat the cake," where "eat" supports inferencing of the word "cake;" Nation et al., 2003, p. 314). However, the low comprehender group showed a higher number of fixations toward the target and spent less total time looking at the target. These results may indicate a difficulty suppressing irrelevant stimuli, as evidenced by the low comprehenders continuing to distribute looks among the target and distractor images past the time the control group had differentiated the target (Nation et al., 2003).

Adolescence. Similarly, eye-tracking research indicates that adolescents with LI may not be as effective at lexical integration as their typical peers due to difficulty suppressing irrelevant stimuli (Borovsky et al., 2013; McMurray et al., 2010). Adolescents with and without LI had their eye movements tracked while looking at pictures related to simple transitive sentences. Unlike the typically developing group, the teenagers with LI did not show increased fixations to action-related images after the word was read and continued to distribute fixations among the target and distractor items (Borovsky et al., 2013).

McMurray et al. (2010) also concluded that adolescents' language levels were associated with language-mediated visual fixations. In this study, groups of teenagers with SLI (specific language impairment with typical nonverbal IQ), NLI (non-specific language impairment with low nonverbal IQ), and typical development underwent eye-tracking while hearing a target word and viewing four images. One image depicted the target word, two depicted phonologically related distractors, and one was a phonologically unrelated distractor (e.g., target: "candle," cohort: "candy," rhyme: "handle," phonologically unrelated: "button;" McMurray et al., 2010, p. 6). Eye-tracking analyses revealed that participants with SLI and NLI did not demonstrate a sufficiently strong activation of the target word and were delayed in achieving peak activation of the target compared to the control group. The overall pattern showed that listeners with low language abilities did not activate the target word efficiently and may have had increased activation for related competitor words, as evidenced by excessive looks to distractors compared to typical controls (McMurray et al., 2010).

Statement of Purpose

The present study seeks to fill a gap in the literature regarding how children with low language skills process language during storybook reading. Eye-tracking technology may provide key insight into these children's comprehension processes which may warrant further research on targeted intervention.

Because eye-tracking research shows that children with low language skills may initially look at the target image, but then continue to look at distractors after this initial identification, it is relevant to study these eye movements over time and in relation to the spoken story narration

(Borovsky et al., 2013; Ellis et al., 2015). Andreu, Sanz-Torrent, Guàrdia-Olmos, and Macwhinney (2011) concluded that preschoolers with and without DLD did not show significant differences in proportion of looks to semantically relevant areas during online storybook comprehension. However, this study used a global eye movement measure that was not time-locked in relation to the spoken language. That is, the researchers examined children's fixations on target illustrations irrespective of when they heard particular phrases. The application of a time-locked analysis may yield differences that do not appear in a global eye-tracking analysis, as other researchers have found (Ellis et al., 2015; Nation et al., 2003). The present study will examine indicators of comprehension processes during a similar storybook reading task; namely, the probability that children will look at a target within a designated time frame after the word is read. Based on the literature cited in this introduction, we hypothesize that the children with low language skills in this study may demonstrate difficulty with interference control during storybook reading. This may manifest as the children continuing to look at semantically irrelevant areas more frequently than their typically developing peers as the story is read. If this finding is confirmed, it will provide significant clinical insight into what preschool children with language difficulties gain, or do not gain, from early literacy activities.

Research Questions

Therefore, our research questions are the following:

1. Do preschool-age children differ in the time to fixation on illustrations associated with spoken referents as a function of language skill?

Hypothesis: We hypothesize that children with lower language skills will take longer to fixate on the illustration that corresponds to the spoken word being read to them, as compared to their peers with higher language skills.

2. Do preschool-aged children differ in the proportion of fixations on an illustration as a function of language skill?

Hypothesis: We hypothesize that children with lower language skills will spend less time overall fixating on the illustration that is associated with the spoken word being read as compared to their peers.

Method

The following sections will describe the study participants, research settings, instruments, procedures, research design, and planned data analysis. The Institutional Review Board at Brigham Young University granted approval for the recruitment of human subjects and the execution of this study. Forty-nine preschool children were recruited for participation. To ensure a wide variety of language skills, we recruited subjects from the BYU preschool in the Child and Family Laboratory, preschool educators and SLPs in local school districts, and SLPs in private practice. Additional participants were recruited through emails, flyers, and word of mouth. Informed consent forms were read and signed by the parent prior to the beginning of the first session. Consent forms were then collected by the researcher with a copy provided to the parent upon request.

Participants

The participants were 49 preschool children: 26 males and 23 females. All participants were native English speakers between 48 and 66 months of age, with a mean age of 57.5 months. These children had not started kindergarten or learned to read. Children with autism or a seizure disorder were excluded from this study. Every attempt was made to include children with speech sound production errors in this study. However, children with speech sound production errors that significantly reduced their intelligibility such that a reliable language sample could not be gathered or analyzed were excluded.

Children's language skills were assessed using a variety of standardized and informal language testing performed in the first research session. To represent the variable nature of language skill, language was treated as a continuous variable rather than a basis for dichotomous groupings. See Table 1 for a summary of results from the descriptive assessment measures, demonstrating the broad range of language abilities included in this study. Twelve of the participants were clinically diagnosed with DLD and five participants were labeled low language (see group criteria in instruments section). Thirty-two participants fell into the typically developing range for language skill.

Table 1

Participant Scores on Formal and Informal Language Measures

Measure	Mean	SD	Min	Max	Range
CELF-P2 Core Language Score	99.33	19.06	45	133	88
GFTA-2 Standard Score	95.06	20.82	40	119	79
PPVT Standard Score	111.98	12.97	85	137	52
Print Concepts Percentage Correct	55.89	25.38	5	88.9	83.90
WRMT-3 Letter ID Raw Score (0-17)	11.04	6.52	0	17	17
Mean Length of Utterance (FWAY)	5.51	2.24	1	9.22	8.22
PEARL Responsiveness Score (0-4)	2.25	1.30	0	4	4

Note. CELF-P2 = Clinical Evaluation of Language Fundamentals-Preschool-2. GFTA-2 = Goldman-Fristoe Test of Articulation-2. PPVT-5 = Peabody Picture Vocabulary Test-5. The Print Concepts score comes from an informal print awareness task (Justice & Ezell, 2001). WRMT-3 = Woodcock Reading Mastery Tests-3 assessment. FWAY = narrative sample based on retelling of *Frog, Where Are You?* (Mayer, 1969). PEARL = Predictive Early Assessment of Reading and Language.

Instruments

All instruments used in this study are described in this section. These include diagnostic, descriptive, and experimental measures.

Diagnostic measures. These formal measures were used to determine the presence or absence of DLD and to characterize overall language skills.

Clinical Evaluation of Language Fundamentals-Preschool-2. The Clinical Evaluation of Language Fundamentals-Preschool-2 (CELF-P2) is designed to evaluate a child’s general language ability and determine the presence of a language disorder (Wiig, Secord, & Semel, 2006). Three subtests of the CELF-P2 were used: Sentence Structure, Word Structure, and Expressive Vocabulary. The individual scaled subtest scores and core language score, which combines the results of the three subtests, were used to confirm the presence or absence of a language disorder. The CELF-P2 manual reports the average reliability of composite scores as $r > .90$. Split half reliability from the subtests range from .80 to .97. The CELF-P2 has sensitivity of .85 and specificity is .82 (Wiig et al., 2006). This test was included as a diagnostic measure because it is one of the most commonly used assessments for this purpose and has good psychometric properties (Denman et al., 2017).

Predictive Early Assessment of Reading. The Predictive Early Assessment of Reading and Language (PEARL) is a language test that employs dynamic assessment to measure how easily a child learns in the domains of decoding and academic language (Petersen, Gragg, & Spencer, 2018). Subtest 2: Dynamic Assessment of Language was used in this study. This subtest involves the examiner reading the child a brief narrative, asking for a retell, coaching the child to tell the story more completely using visual and verbal cues for support, then retesting the child with a new story. Immediately after the teaching portion of the test, the examiner rates the child on a responsiveness scale that describes how easy or difficult it was for the examinee to learn (ranging from 0 to 4, with 0 being difficult and 4 being easy). The PEARL manual reports at or above 90% inter- and intra-rater reliability and fidelity of administration at or above 95%. The pretest and posttest of the language subtest have a correlation coefficient of .70. The internal consistency of this subtest, calculated as Cronbach's alpha, is above .80 (Petersen et al., 2018).

Diagnostic criteria. The presence or absence of DLD was determined from the aforementioned assessments. A core language score of 78 (1.5 standard deviations below the mean) or lower on the CELF-P2 qualified a child for a DLD diagnosis. Otherwise, two CELF-P2 subtest scores of 7 or lower, or a responsivity score of 0-1 on the PEARL indicated a probability of DLD. Children were considered low language participants if they received a CELF-P2 core language score of 90 or lower and responsivity score of 2 or lower on the PEARL.

Descriptive measures. These measures further described and characterized each child's language abilities and early literacy skills.

Language sample. Each child participated in one of two methods of language sampling. The majority of children (n = 46) completed a story retell task using the wordless picture book *Frog, Where Are You?* by Mercer Mayer (1969), in which a little boy and his dog go on an adventure while searching for an escaped pet frog. The examiner turns the pages and models the story for the child and then asks the child to retell the story while looking at the pictures. This method provides needed scaffolding for young children to produce a narrative retell. The *Frog, Where Are You?* narrative task has norms on the Systematic Analysis of Language Transcripts (SALT) database and has been used extensively in narrative research (Miles & Chapman, 2002). However, a small number of children failed to comply with this story retell task (n = 3). To still obtain a narrative sample, these children instead participated in a more language sampling procedure which elicited language through play with a farm- or city-themed magnetic illustration set. Language samples were transcribed and coded for language structures used. Analysis using SALT software yielded MLU data.

Peabody Picture Vocabulary Test-5. The Peabody Picture Vocabulary Test-5 (PPVT-5) measures the receptive vocabulary of children and adults (Dunn & Pearson, 2019). This assessment was used to characterize children's receptive vocabulary knowledge. For this assessment, participants are shown four pictures at a time and must point to the picture that represents the word read by the examiner. This test yields a standard score. The PPVT manual reports split-half reliability as .94-.95 on average (Dunn & Pearson, 2019).

Woodcock Reading Mastery Tests-3. The Woodcock Reading Mastery Tests-3 (WRMT-3) Letter Identification subtest measures a child's basic letter knowledge, which is an important indicator of early literacy skills (Woodcock, 2011). Children are asked to identify letters in uppercase and lowercase forms. The raw score from the Letter Identification subtest was used in this study because some participants were too young for the norms (Woodcock, 2011).

Goldman-Fristoe Test of Articulation-2. The Goldman-Fristoe Test of Articulation-2 (GFTA-2) Sounds in Words subtest measures a child's ability to articulate each English phoneme at the single word level in a variety of word positions (Goldman & Fristoe, 2000). The raw score corresponds with the total number of errors made across all phonemes in all eligible positions of words. The results were used to assess participants' speech sound production and provide information to help with intelligibility.

Print awareness measure. To further measure emergent literacy skills and knowledge of print concepts, participants were given the Print Concepts portion of the Preschool Word and Print Awareness Assessment (PWPA) as described by Justice and Ezell (2001). This informal print awareness task centers on the picture book *Nine Ducks Nine* by Sarah Hayes (1990). The examiner reads the book with the child while asking questions designed to probe his or her understanding of words in print and the relationship they have to spoken language (e.g., "Where do I begin to read?," "Which way do I read?," and "Show me a capital letter;" Justice & Ezell, 2001, p. 215). This subtest yields a raw score. Justice and Ezell reported a mean administration fidelity score of 99% for the entire PWPA.

Experimental measure. This section describes the experimental measure which will be compared against language skill. The experimental setup and procedures will reflect those used by Luke and Asplund (2018).

Eye-tracking. The eye movement data were acquired using the Tobii Pro Spectrum and Tobii Pro Lab software. The eye tracker sends a low-intensity infrared light into the participant's eyes. The light reflects off retina of the eye, allowing the camera to identify the location of the child's gaze on the screen.

The storybook used was *The Happy Man and His Dump Truck* (Gergely, 2005). Each page was displayed on a computer screen as a 1600 x 900 pixel image. Two to eight interest areas were selected for each page as they corresponded to noun phrases in the text. An audio recording of a female native English speaker reading at a natural rate was prepared. Audacity editing software was used to identify the onset and offset of each target noun phrase in milliseconds (e.g., "the man," "the dump truck"). The narrator's production of target noun phrases took an average of 534 milliseconds (standard deviation = 169 ms; range 281 – 1290 ms). Noun phrase onsets averaged 1,281 milliseconds apart (standard deviation = 655 ms; range 374 – 3404).

Eye movements were recorded via the Tobii Pro Spectrum eye tracker in remote mode sampling at 1,200 Hz. Participants sat in a booster seat approximately 60 cm away from a 24-inch LCD computer screen with a display resolution of 1,600 x 900, so that the image subtends 40 by 24 degrees of visual angle. Eye movements were recorded from both eyes.

Each story reading began with a five-point calibration procedure that maps eye position to spatial points on the computer screen. The calibration procedure entailed instructing the child to look at an attention-getting image that appeared sequentially in each of five screen quadrants. Once calibrated, the child saw the first pages of the story on the screen and heard the audio after a two-second delay. There was also a two-second delay after each audio file finished playing. Each page of the story was presented in this way. Participants were eye-tracked while listening to the story two times through to ensure data quality, since the eye-tracker is sensitive to excessive head movement, poor calibration, etc. (Luke & Asplund, 2018).

Procedures

Children participated in two sessions for this study. During the first session, they underwent a battery of formal and informal language assessments to determine language abilities. The second session included descriptive assessment measures and the experimental measure.

Session one. The first session occurred in a child-friendly space that was convenient for the participant. This may have been an on-campus laboratory, the child's home, or the child's preschool or daycare. The purpose of this session was to administer standardized speech and language testing to determine further study eligibility and general language ability. The parent gave consent and the child gave assent before proceeding. Three subtests of the CELF-P2 were administered first. Next, the screener subtest of the PEARL was given as further, dynamic language testing. Then a language sample was gathered via the *Frog, Where Are You?* task or magnetic farm/city set. Lastly, articulation was assessed using the GFTA-2. This session typically lasted approximately 60 minutes. Throughout testing, children received stickers to earn small prizes for continued motivation. Children also received breaks as often as needed. After session one, standardized measures from each child were scored to determine further eligibility. Those who did not meet the criteria for the study were dismissed from further participation. Children who met the criteria were invited to participate in a second research session.

Session two. The second session occurred in room 221 of the BYU Richards Building. This room is equipped for recording eye movement with an eye-tracking camera. The eye-tracking computer was set up inside a three-sided black tent to help children focus their attention on the computer screen. Children sat on a high-backed car booster seat attached to a chair to support the head and neck.

Calibration. Before the experiment, each child underwent the eye-tracking calibration procedure previously described. Children were instructed to look at the attention-getting image each time it moved. After successful calibration, the eye tracker mapped each child's eye movements to specific locations on the screen.

The experiment. After calibration, the children had their eye movements recorded as they looked at each page of the storybook and listened to the audio recording of the text. This task was repeated a second time, after children completed the Letter Identification subtest of the WRMT-3. After eye-tracking was complete, children were given the PPVT-5. Finally, the children participated in the Print Awareness storybook assessment. Again, children received stickers to earn small prizes throughout the session, which lasted approximately one hour.

Data Analysis

The eye-tracking data analysis consisted of some of the methods used by Luke and Asplund (2018). Rather than dividing the children into groups, language level was used as a dichotomous variable for these analyses. To determine the relationship between language skill and time to fixation, we performed an onset-contingent analysis to see how quickly participants looked to targets after the onset of a spoken noun phrase. Next, language mediation of eye movements was examined using a growth curve analysis to see if the proportion of fixations on a given picture was influenced by the noun phrase being spoken. Linear mixed effects models were used to examine the relationship of the continuous CELF-P2 scores to these variables in both analyses (Luke & Asplund, 2018).

Results

This section will outline the statistical results for our research questions, restated:

1. Do preschool-aged children differ in the time to fixation on illustrations associated with spoken referents as a function of language skill?

Hypothesis: We hypothesize that children with lower language skills will take longer to fixate on the illustration that corresponds to the spoken word being read to them, as compared to their peers with higher language skills.

2. Do preschool-aged children differ in the proportion of fixations on an illustration as a function of language skill?

Hypothesis: We hypothesize that children with lower language skills will spend less time overall fixating on the illustration that is associated with the spoken word being read as compared to their peers.

Question 1

To determine whether fixation time to illustration was influenced by language skill, we performed an onset-contingent analysis. The dependent variable was fixation latency, which is the time between the onset of the spoken noun phrase and the participant's first fixation on the illustration of interest. The fixed effects were referent status (whether the illustration was in the target or control condition) and the CELF-P2 score of the participants. Each illustration was in the target condition starting at the onset of its corresponding spoken noun phrase, and the same illustration was in the control condition during a randomly matched non-corresponding spoken noun phrase. Instances where participants were already looking at the target image before the onset of the noun phrase were excluded from the analysis.

The relationship between referent status and fixation latency was similar to that found by Luke and Asplund (2018). Participants looked to illustrations more quickly during the reading of the corresponding noun phrase than at other times (see Table 2). Language skill was not found to be a significant predictor of fixation latency (see Table 2). Children looked to the target image after the onset of spoken noun phrases in a similar manner regardless of the CELF-P2 Core Language Score.

Table 2

Results of Onset-Contingent Analysis

	B	*SE*	*t* value	*p*-value
Intercept	916.30	19.58	46.80	< 0.001
Referent Status	-53.53	23.33	-2.30	0.03
CELF-P2 Scaled Score	0.08	15.58	0.01	0.99

Note. CELF-P2 = Clinical Evaluation of Language Fundamentals-Preschool-2.

Question 2

To determine how the proportion of fixations to target illustrations was influenced by language for both groups of children, we fitted a linear mixed effects model where the dependent variable was the proportion of fixations on a particular illustration. Fixed effects were the CELF-P2 Core Language Score (centered and z scored), whether the illustration was in the target or control condition, and the linear and quadratic functions for time. The fixation data were divided into 60 100-millisecond bins, beginning 3 seconds before and terminating 3 seconds after the onset of each spoken noun phrase in the narration. Each target image served as its own control; a given image was in the target condition during the timeframe that its corresponding noun phrase was read aloud. The same image was randomly matched with a different noun phrase time windows (a noun phrase that did not correspond with the image) to serve as the control condition. The fixation probabilities to control and target images during these noun phrase time windows were computed in the same manner.

Excluding the variable of language skills, the results replicated the key finding from Luke and Asplund (2018) that children's eye movements are language-mediated during storybook reading. Growth curve analysis showed that participants' proportion of fixations on a given illustration was related to the noun phrase being spoken; that is, children in both groups tended to look at the image that was being spoken about (see Table 3). There was a quadratic relationship between time and fixation proportion on the target image, but not for the control images, indicating that eye movements are language-mediated.

With the addition of the CELF-P2 core language score, the data showed significant differences between children with higher and lower language skills. As CELF-P2 scores increased, the proportion of fixations on the control image decreased (see Table 3). A significant interaction with illustration condition indicated that as CELF-P2 scores decreased, the contrast between the control and target condition lessened (see Figure 1). Thus, children with lower CELF-P2 scores demonstrated a smaller proportion of fixations to the target image and an increased proportion of fixations to the control image. Children showed evidence of language-mediated eye movements regardless of language skill, but children with higher language abilities were more responsive to spoken noun phrases than those with lower language abilities.

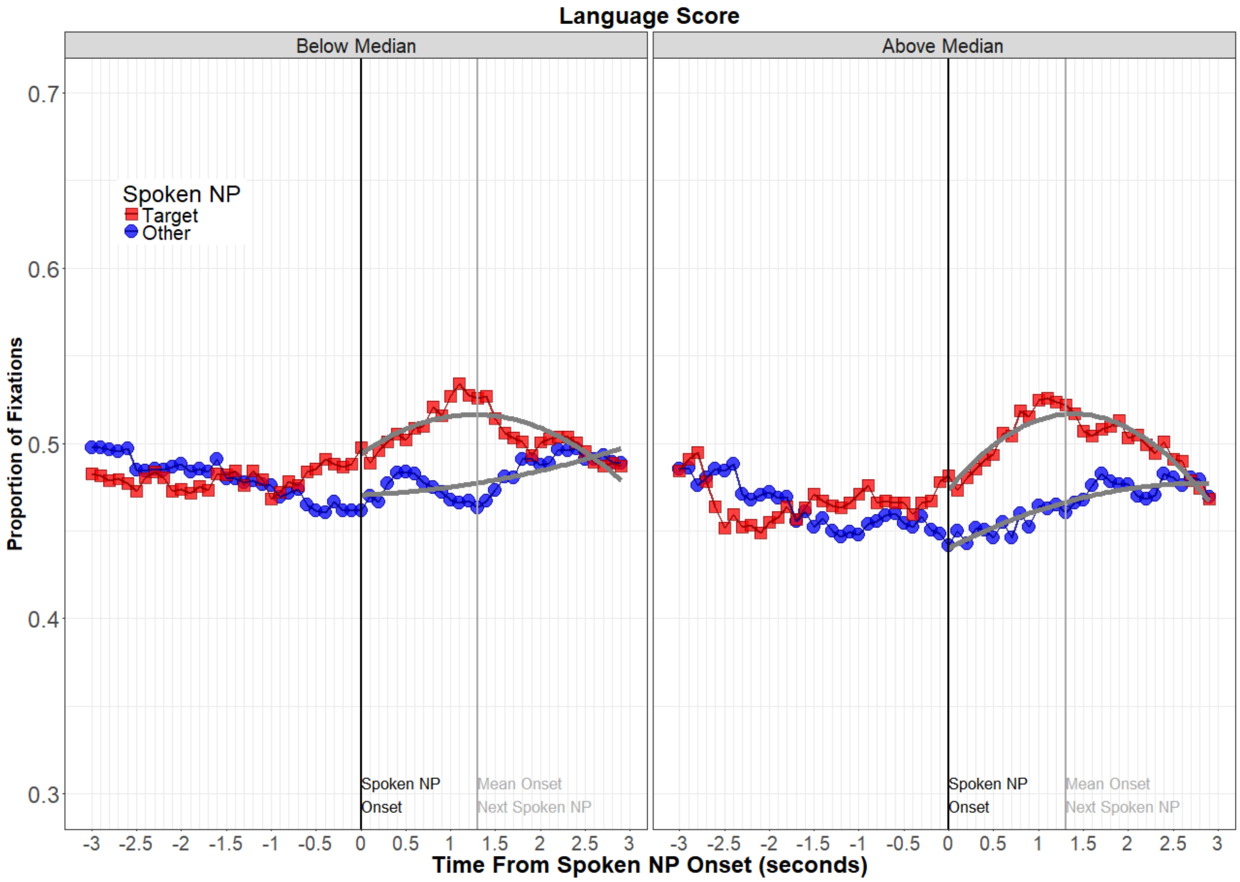

Figure 1. Probability of fixating illustration during spoken target noun phrase vs. control noun phrase. NP = Noun Phrase. For the purpose of this visual representation of differences in eye-tracking behaviors, children were split into two groups of lower language vs. higher language based on the median Clinical Evaluation of Language Fundamentals-Preschool-2 Core Language Score. Children with scores below the median are represented on the left, and children with language scores above the median are represented on the right. For both groups, the proportion of fixations to the control image fit a line, and proportion of fixations to the target image fit a curve. However, this representation shows that the below the median group had fewer fixations to the target image and more fixations to the control image when compared to the above the median group.

Table 3

Results of Linear Mixed Effects Model Examining Proportion of Fixations to Illustrations

	b	*SE*	*t* value	*p*-value
Intercept	0.48	0.01	59.45	< 0.001
CELF-P2 Scaled Score in Control Condition	-0.02	0.01	-2.49	0.02
Referent Status	0.03	0.00	20.28	< 0.001
Linear Function Control Condition	0.70	0.14	5.02	< 0.001
Quadratic Function Control Condition	-0.03	0.11	-0.27	0.79
CELF-P2 Scaled Score Target Condition	0.01	0.00	3.37	< 0.001
Linear Function Target Condition	-0.97	0.11	-8.99	< 0.001
Quadratic Function Target Condition	-0.84	0.11	-7.75	< 0.001

Note. CELF-P2 = Clinical Evaluation of Language Fundamentals-Preschool-2.

In summary, children showed similar timing of initial looks to target images regardless of language skill. When examined over time, however, children with lower language skills had significantly different proportions of fixations to control and target images. Lower language participants spent more time looking at control images and less time looking at target images than higher language participants.

Discussion

The purpose of this study was to determine the relationship between preschoolers' language skills and their language-mediated eye-tracking behaviors during shared storybook reading. We hypothesized that children with lower language skills would be slower to look at the target image after the onset of the spoken noun phrase than their typically developing peers. We further hypothesized that children with lower language skills would spend less total time fixating on the target image than children with higher language. Preschoolers with DLD, low language, and typical language skills had their eye movements tracked while viewing and listening to a storybook. An onset-contingent analysis was performed to determine how quickly children looked at the target image once the corresponding noun phrase was read aloud. Additionally, a proportion of fixations analysis was used to determine the likelihood that children were looking at a target or control image during a given time frame. This section will discuss two key findings.

Do preschool-aged children differ in the time to fixation on illustrations associated with spoken referents as a function of language skill?

Language skill did not have a statistically significant effect on fixation latency to the target image. Thus, regardless of language level, children looked at the target image after the onset of the spoken noun phrase at similar speeds. This is consistent with findings from Ellis et al. (2015), who did not find significant differences between late-talking and typically developing toddlers in fixation latency during a novel word-learning task. Our findings also align with Nation et al. (2003), who found that young school-age children with lower language skills used language input to make predictive eye movements at similar speeds to their typically developing peers. These findings thus demonstrate that the fixation latency results from our preschool age participants are consistent with those of both younger and older children with language deficits.

Furthermore, we demonstrated this finding in a naturalistic storybook reading task, which is a task young children commonly engage in during their daily interactions with parents and preschool educators. This demonstrates that, even with a very passive experience such as listening to a storybook, preschool-aged children evidence language-mediated eye movements. Taken together, these between-group similarities across age groups suggest that children with language difficulties are not failing to attend to language input; conversely, they are identifying semantically relevant images as quickly as their typically developing peers.

Andreu, Sanz-Torrent, and Guàrdia-Olmos (2011) did find differences in fixation latency when comparing sentence structure comprehension in children with and without SLI. Their results demonstrated that children with SLI were slower to look at the target images relating to nouns and verbs in spoken sentence stimuli, especially when a three-argument verb structure was presented (Andreu, Sanz-Torrent, & Guàrdia-Olmos, 2011). This finding may arise from the sentences being in Spanish and Catalan, and the use of more complex stimuli. The storybook task used in our study is a much simpler and more familiar task for children.

Do preschool-aged children differ in the proportion of fixations on an illustration as a function of language skill?

While the timing of the initial look to target images did not differ as a function of language skill, the amount of time spent on target images differed significantly between children with low and high language skills. The proportion of fixations analysis revealed a strong interaction between language skill and eye-tracking behaviors over time. Participants with higher language skills attended more to target images and less to control images than the participants with lower language skills. Stated differently, children with lower language skills did not attend to target images or suppress attention to control images as strongly as their typically developing counterparts. Andreu, Sanz-Torrent, Guàrdia-Olmos, and Macwhinney (2011) did not find differences between children with SLI and typical language skills in proportion of fixations during storybook reading. However, this may have been due to the global eye-tracking analysis they performed. Andreu, Sanz-Torrent, Guàrdia-Olmos, and Macwhinney (2011) compared how often children with and without SLI looked at parts of the illustration that were deemed most semantically relevant; however, children's fixations on these images were not studied in relation to the timing of the spoken referents. It is established that children with poor language skills are capable of language-mediated eye movements; but clinically notable differences arise in these eye movements over time and in relation to the timing spoken language. This explains why our time-locked analysis yielded different results.

Previous psychological research demonstrated that individuals with poor language skills also have weaknesses in suppressing irrelevant stimuli (Gernsbacher & Faust, 1991; Spaulding, 2010). Strikingly, this difficulty with interference control appeared in a variety of eye-tracking studies with different research tasks and participant characteristics. Despite initially looking at the target image during a novel word-learning task, late-talking toddlers continued to distribute looks between target and distractor images after typically developing toddlers focused their attention on the target (Ellis et al., 2015). Correspondingly, school-age children with poor language comprehension showed heightened activation of distractor images during a sentence comprehension task (Nation et al., 2003). This aligns with findings that adolescents with language disorders demonstrated increased activation for distractor images and lower activation for target images than control participants during language-mediated eye-tracking tasks (Borovsky et al., 2013; McMurray et al., 2010). Our study found the same inefficient suppression of irrelevant stimuli in preschool age children with low language abilities, even during the simple task of passively listening to a storybook reading. Even in an everyday language task that is familiar to preschool children, the low language participants in our study showed inefficient suppression irrelevant stimuli by giving increased looks to control images after the onset of each spoken noun phrase. This study adds to the body of evidence that preschool-aged children with DLD and borderline language levels are not inhibiting their attention to distractor information, which may impact comprehension of more complex language as compared to their peers.

Limitations

We note several potential limitations in the current study. First, we chose to use language as a continuous variable in the model as opposed to a dichotomous distinction between DLD and non-DLD children. While this may limit the conclusions we can draw about language-mediated eye movements in an exclusive population of children with DLD, we emphasize the clinical practicality of using language as a continuous variable for this analysis. First, this approach allowed us to include children who have borderline language skills that are low, but not low enough to merit a clinical diagnosis. There is much debate in the DLD literature regarding which clinical tests can reliably detect and diagnose true DLD (Bishop et al., 2017). By including a large number of descriptive language measures as well as using a language measure as a continuous variable, we aimed to determine the role of language skill on language-mediated eye movements in all children, regardless of DLD status. Another limitation of this study was the use of a single language variable, the CELF-P2, in our eye-tracking analyses. The CELF-P2 is a common language measure, but it is a static measure of discrete language skills such as vocabulary and basic morphological knowledge and therefore does not provide a complete description of language ability, such as narrative skills. Each participant was assessed on an array of early literacy and language skills, but these measures were not included in this preliminary analysis. The CELF-P2 was selected as the initial language measure for analysis because it is commonly used and has good evidence of psychometric quality (Denman et al., 2017). Additionally, our results are limited by the lack of a story comprehension measure after the presentation of *The Happy Man and the Dump Truck* (Mayer, 1969).

There are also limitations to generalizing the results of this study due to the participants included. Our relatively homogeneous sample of children were all monolingual English speakers and participated after parents opted to bring their child to the research laboratory for participation. As a result, we may have overrepresented children from middle or high socioeconomic backgrounds which may more readily facilitate research participation.

Implications for Future Research

Future work should investigate how specific language constructs correlate with eye-tracking behaviors. Specifically, the other formal, informal, and dynamic language measures of each participant should be included in future analyses to discover if any particular language or literacy construct is most predictive of eye-tracking behaviors. Additional research should also include a story retell analysis. Some of the children in this study participated in a story retell task while their eye movements were recorded, but these data have not been analyzed yet. In the future, it would be beneficial for similar studies to include a comprehension measure after the storybook reading to more deeply examine the relationship between suppression of irrelevant stimuli and language comprehension. A formal inhibition measure on the participants may also be informative. Finally, future work should incorporate more diverse populations.

Clinical Implications

The results of this study add to the body of evidence that children, adolescents, and adults with low language skills present with inefficient cognitive suppression of irrelevant stimuli.

More specifically, this study indicates that preschoolers with DLD or low, subclinical language levels have difficulty activating only what is relevant even in a simple storybook reading task. Shared storybook reading is commonly recommended by SLPs and early education professionals to facilitate early language skills and literacy readiness. However, this research suggests that children with language difficulties may not be gaining as much as their typically developing peers during traditional shared storybook reading. Some logical adjustments to the activity may help these children know what is most important to attend to. For example, clinicians or parents may slow their speech rate as they read and point out the semantically relevant images while reading to children with low language. More generally, individuals of varying ages who receive treatment for language skills may need help and even explicit instruction to identify the most relevant parts of linguistic information for improved comprehension.

Conclusion

In this study, we investigated the relationship between preschoolers' language abilities and eye-tracking behaviors during a storybook reading task. We found that children looked at the relevant part of the illustration as the corresponding words were spoken in similar manners regardless of language skill. Differences arose in how long children spent looking at relevant images over time; those with lower language skills spent less time looking at relevant images and more time looking at irrelevant images than children with higher language skills. This may be due to inefficient suppression of irrelevant stimuli in children with poor language abilities. Speech-language pathologists should be aware that children with language difficulties may have poor interference control and may need help identifying what linguistic information is most important in language comprehension tasks.

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APPENDIX A

Recruitment Flyer

Institutional Review Board
11-1-2018 11-12-2019
Approved Expires

Research Study:
Children and Reading

Pre-K Children ages 4-5 needed for reading study

We are seeking pre-kindergarten participants with and without language delays who are between the ages of 4-5. Parents will need to be in attendance as well.

We are studying how children move their eyes when they are first learning to read. Your child will participate in up to two research sessions. In the first session, they will complete a variety of speech and language tasks. In the second session, they will listen to a story, identify objects and letters, and view pictures on a computer screen while his/her eye movements are monitored.

Participants will be paid $15 for each 60-minute session.

If interested, email cablabbyu@gmail.com for more information

APPENDIX B

Consent Form

Introduction

This research study is being conducted by Steven G. Luke, Ph.D., a faculty member in the Brigham Young University Psychology department and Kathryn Cabbage, Ph.D., a faculty member in the Brigham Young University Communication Disorders Department. The purpose of this study is to determine what children look at when they are being read to. You were invited to have your child participate because your child is a native English speaker with normal (or corrected-to-normal) vision.

Procedures

The experiment will take place in two sessions. The first session will take place at a location convenient to you and your child (a quiet room at home, your child's preschool/daycare, or on BYU campus). During the session, you will complete a brief Developmental History Questionnaire and your child will complete a series of speech and language tasks. If you have difficulties completing this Questionnaire, please tell the experimenter. If you agree to let your child participate, the tasks completed by your child will involve looking at pictures, talking about pictures, and answering questions. Your child will be provided small prizes (e.g., stickers, small toys) throughout the session. Your child will be given breaks as often as needed to maintain interest and motivation. This session will take approximately 1 hour to complete.

If your child meets the criteria for the next stage of the study based on his/her speech and language performance, you and your child will be invited to participate in the second session.

The second session will take place on BYU campus, in room 1144 (11th floor) of the Spencer W Kimball Tower (SWKT). During the session, you will fill out a short survey about your child's reading experience and ability. If you have difficulties completing this survey, please tell the experimenter.

During this session, your child will complete two tasks. First, your child will have their eyes tracked as **a picture book** is read to them. If you agree to let your child participate, your child will be seated in front of a computer screen and a small sticker will be placed on his/her forehead to assist the camera in finding the eyes. Eye movement data will be acquired using the SR research Eye Link 1000 desktop mount and Experiment Builder software. The eye tracker works by shining a low intensity infrared light, which reflects off the retina of the eye and allows the camera to see where the eyes are looking on the computer screen. This infrared light is well below the standards set by the United States Occupational Safety and Health Administration and is not visible. The experiment will begin with a blank screen for calibration. A small image will appear at the center of the screen and will then move to various places, and your child should move his/her eyes to look at the center of the image each time it moves. This important procedure helps the eye-tracker learn to map eye movements to locations on the screen, so it is important that your child follows the experimenter's instructions carefully during the calibration. After this calibration phase, the experiment will begin. Your child will see pages from a children's book on the computer screen and listen to an audio recording of the text being read.

During this time, the eye tracker will record where your child is looking and for how long. Your child will then complete a short picture and letter identification task. After this, your child will listen to the same picture book again while their eyes are tracked for a second time. Your child will then be asked to tell the story back while looking at the pictures and having their eyes tracked for a third time. Upon completion of the eye-tracking tasks, your child will complete a book reading activity to examine how he/she interacts with books. The entire session should be approximately 60 minutes.

Following this part of the experiment, a short reading proficiency test will be sent out when your child reaches first grade. If you choose to participate, you will be asked to administer this test and report the results.

Risks/Discomforts
This research involves looking at pictures and words on a computer screen and listening to stories, something your child does frequently at home and school, so the risks are minimal and no greater than those encountered in everyday life. Since the session will last for approximately 30 minutes, it is possible that your child will become fatigued. To help prevent this, the researcher will indicate to you and your child which stage of each task is the best point to take a break, and your child is encouraged to take a break or breaks when and if you or your child desire. Also, if you notice that your child appears upset or uncomfortable, please let the experimenter know and a break can be taken.

Benefits
You will receive no direct benefits from your participation in this study. This study has the potential to benefit society by advancing and informing theories of how children transition from pre-readers to readers, how we control where our eyes look, and what benefits reading to children have.

Confidentiality
At the beginning of the experiment, your child will be assigned a participant ID code. The data from this experiment, which will be stored on a password-protected computer for up to 10 years, will be marked with this code and not your child's name or your name or any other identifying information. Any document that contains names or other confidential information will be stored in a locked file cabinet, inside a locked room, to which only the experimenters will have access. When the results of this study are published, no identifying information will be included in the published report; only aggregate data or, if necessary, participant ID codes will be published.

Compensation
You will receive $15 for each session, to be paid at the end of each session. If you decide to withdraw your child from the study without completing the full session, you will still be compensated for your participation.

Participation
Participation in this research study is voluntary. You and your child have the right to withdraw at any time or refuse to participate entirely without jeopardy to class status, grade, or standing with the university

Questions about the Research
If you have questions regarding this study, you may contact Steven Luke at steven_luke@byu.edu or Kathryn Cabbage at kcabbage@byu.edu for further information.

Questions about Your Rights as Research Participants
If you have questions regarding your rights as a research participant contact IRB Administrator at (801) 422-1461; A-285 ASB, Brigham Young University, Provo, UT 84602; irb@byu.edu.

Statement of Consent
I have read, understood, and received a copy of the above consent and desire of my own free will to allow my child to participate in this study.

Your child's name: ________________________________

Your Name:__________________ Signature:___________________Date:__________________

We would also like to investigate how children's eye-movements when being read to are related to their later reading development. To accomplish this, we would like to contact you when your child is in 1stgrade. We would send a short survey for you to complete and a brief reading assessment to administer to your child. If you are willing to complete this survey in the future, please provide us with an e-mail address on the line below.

Email: ____

APPENDIX C

Annotated Bibliography

Andreu, L., Sanz-Torrent, M., Guàrdia-Olmos, J. (2011). Auditory word recognition of nouns and verbs in children with specific language impairment (SLI). *Journal of Communication Disorders, 45*(1), 20-34. doi:10.1016/j.jcomdis.2011.09.003

Objectives: This study investigated the differences between online processing of spoken verbs and nouns in children with and without language impairment.

Methods: The participants were 25 Spanish-speaking children ages 5-8 with language impairment and 50 typically developing children ages 3-8. Two experiments were carried out. The first examined whether there were differences in eye-gaze behaviors between the two groups. The children were eye-tracked while listening to spoken stimuli and looking at related pictures. The children saw one target picture with three distractor pictures as the spoken stimuli was presented. Images corresponded to verbs or nouns in the sentence, and sentences contained one, two, or three argument verbs. The next experiment investigated whether differences between these groups were due to reduced linguistic processing speed or visual and motor processing limitations. The visual setup was similar to the first experiment, but there was a red dot in one of the four quadrants and the children were instructed to look at the red dot as quickly as possible.

Results: In both groups, images that showed people performing an action received more looks than objects. No differences between groups were found in the suppression of this effect. This is referred to as the "animacy effect." In experiment one, the children with LI were slower to look at the target image than age-matched peers but no differences were found between the children with LI and the MLU-matched controls. The children with LI were especially slow in looking at the target when listening to a three-argument verb sentence. All groups of children recognized nouns faster than verbs. In experiment two, there were no significant differences between the two groups in visual/motor speed.

Conclusion: Young children with and without language impairment were both visually drawn to images depicting people doing things more than images depicting objects. Children with language impairment were slower to look at target images than their age-matched peers, especially in the three argument verb condition. This may be due to impoverished semantic representations of verb argument structure, leading to increased processing time for these children. The children with language impairment and the controls showed no differences in a visual speed task that was not language-mediated, eliminating a visual-motor processing deficit as an explanation for the differences in experiment one.

Relevance to our study: This study demonstrated differences in the eye-tracking behaviors of young children with language impairment. It also showed that the differences in eye-tracking behaviors between children with and without language impairment are not motoric in nature.

Bishop, D. V. M., & Norbury, C. F. (2005). Executive functions in children with communication impairments, in relation to autistic symptomatology. *Autism, 9*(1), 29-43. doi:10.1177/1362361305049028

Objectives: This study examined the relationship between executive functions and the symptoms of autism, as compared to children with language impairment and pragmatic language disorder.

Methods: Four groups of children ages 6-10 participated: 14 children with high functioning autism, 25 children with pragmatic language impairment (who did not meet the full diagnostic criteria for autism), 17 children with specific language impairment (SLI), and a typically developing control group of 18 children. The children were given subtests from the Test of Everyday Attention for Children. These tasks included the 'same world' task compared to the 'opposite worlds' task, which measures inhibition of a prepotent verbal response. The other was the 'walk don't walk' task, which examines the ability to sustain attention to one's own actions and intentions without requiring a verbal response.

Results: Only the pragmatic language impairment group scored significantly below the control group on the same world task. All three groups performed below the control on the opposite world subtest. The three groups all did poorly on both tasks overall, and their performance declined significantly in the opposite word condition (which required inhibition). The pragmatic language impairment group showed the most difficulty with inhibition. Several children did not complete the walk don't walk task, but available data showed that the three clinical groups performed poorly on this task and did not differ significantly from each other. Errors included both impulsive and unduly slow responses. This task looked at sustained attention and showed that all three groups were impaired in this area.

Conclusion: Poor inhibition was not specifically associated with autism on the verbal or non-verbal tasks. The only measure significantly related to the sustained attention task was non-verbal ability. Executive function deficits may not be specifically associated with autism but instead associated with a range of developmental disorders. Another theory is that inner speech may be an important part of some executive tasks, and children with low language skills have difficulty verbalizing the rules of tasks to themselves, especially in non-verbal response tasks. However, deficiencies on inhibition tasks were seen in children with poor language regardless of response-type. These results add to the evidence that response inhibition is not a specific problem with autism. Executive functions may be mediated by verbal abilities, but this is a very preliminary hypothesis. What is the role of language in rule-governed behavior?

Relevance to our study: This discusses the relationship between LI and executive functions such as response-inhibition. It suggests that there is a connection between poor language skills and executive functions.

Borovsky, A., Burns, E., Elman, J. L., Evans, J. L. (2013). Lexical activation during sentence comprehension in adolescents with history of specific language impairment. *Journal of Communication Disorders, 46*(5), 413-427. doi:10.1016/j.jcomdis.2013.09.001

Objectives: This study looked at whether there was a difference in real-time sentence comprehension between adolescents with language impairment and same-age typically developing peers.

Methods: Twenty-six adolescents participated in the study, 12 with language impairment and 14 typically developing. The participants were eye-tracked and shown pictures while listening to related simple transitive sentences. Four pictures were shown concurrently; one was related to the target (the final word of the sentence), one to the agent, one to the action, and one was a distractor.

Results: Both groups of adolescents were equally fast at fixating on the picture relating to the sentence's final item. However, the group with language impairment did not show increased fixations to action-related items after the action word was read (when compared to the control group).

Conclusion: Adolescents with LI may not be as effective at lexical integration, resulting in the failure to consider alternate meanings of sentences.

Relevance to our study: This study assesses language-mediated eye movements using an eye-tracker in an adolescents with language impairment. It supports our hypothesis that the children with language impairment in our study will look to the target pictures initially but will have continued fixations on irrelevant stimuli as well (inefficient suppression hypothesis).

Other points: lexical processing model, visual world eye-tracking paradigm

Ellis, E. M., Borovsky, A., Elman, J. L., Evans, J. L. (2015). Novel word learning: An eye-tracking study. are 18-month-old late talkers really different from their typical peers? *Journal of Communication Disorders, 58*, 143-157. doi:10.1016/j.jcomdis.2015.06.011

Objectives: SLPs have a very limited set of predictors of LI in very young children and infants. This study seeks to determine if lexical processing abilities of late talkers (18-24 months) differ from those of typically developing children, and if these lexical processing differences can indicate future LI.

Methods: A group of 14 late-talking toddlers and an age and cognitive-level matched typical group of toddlers were presented with a novel word learning task while being eye-tracked. The novel word learning task exposed the children to images of fictional objects and paired these images with nonwords. The children were then shown images of two of these objects, one a distractor and one paired with the auditory stimuli. These groups were also given standardized cognitive and vocabulary testing before the eye-tracking session began.

Results: There are some differences between late-talking and typical 18-month-olds regarding novel word learning and interpretation. The results of traditional measures (e.g., accuracy, reaction time) did not show significant differences between the group, but more fine-grained measures (e.g., gaze divergence) did show differences. The late talker group looked at both the target and distractor, but did not show distinction between the two pictures. The typical group showed more distinction between the two pictures and distinguished the target picture earlier on. This may be interpreted as a difference in the depth of learning of the new word between groups.

Conclusion: Gaze divergence is not a traditional measure of novel word learning, but it may be significant because it differed between the late talker and typical groups (divergence point is the moment in time when someone's overall pattern of looking shifts between the two images). This difference could be explained in a number of ways; it could be that the late talkers are not as familiar with the novel word and have not mastered it at the same level as the typical children, or it could be that the late talker group had more difficulty focusing their attention on one image. Further research on the fine-grained processing of novel word learning, and the differences children with LI may exhibit in these tasks, is warranted.

Relevance to our study: This study supports the usefulness of using eye-tracking to study very young populations with and without language disorders. It also indicates the need to identify children with LI as early as possible to optimize intervention and support ("Infant vocabulary levels combined with factors such as socioeconomic status (SES) and family history of impairment have low sensitivity and specificity in correctly classifying children as having SLI at age five, and correctly identify less than 30% of LTs who will have SLI."). Finally, it demonstrates that late talkers (who are are at risk for LI) demonstrate differences (and some interesting similarities) in lexical processing compared to their typically speaking age-matched peers.

Evans, M. A., & Saint-Aubin, J. (2005). What children are looking at during shared storybook reading. *Psychological Science, 16*, 913-920. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16262779

Objectives: "Determine the extent to which young children fixate on the print of storybooks during shared book reading."

Methods: Children's storybooks with a variety of print and illustration styles were shown on a computer screen and read to a child by a teacher or parent. Some books had vibrant pictures, others had simple black-and-white drawings. Some books had more interesting, colorful text. The children wore an eye tracking headband to record eye movement during the reading.

Experiment 1: 5 children ages 46 to 61 months participated (native French speaking). 5 books with varying text and illustration styles were read to the children while they wore SR Research EyeLink II eye tracking headbands.

Experiment 2: Same as experiment 1, but with 10 children and the addition of a probe looking at the "extent to which children's fixations on the different parts of the illustrations could be manipulated" by alterations to the story.

Results: "Preschool children engage in minimal exploration of the print during shared storybook reading."

Experiment 1: For all 5 books, the children almost never fixated on the text. No pattern in the text fixations.

Experiment 2: The results unequivocally replicated the findings of experiment 1, again demonstrated that preschool children do not look at the printed text during shared storybook reading. Additionally, it was found that visual fixations on details in the pictures were increased when the text was altered to highlight those details. This shows that the children's visual attention depended at least in part on the accompanying text. However, when the unaltered version of the text was read and certain details were not highlighted, the children's attention to the illustration seemed to be less affected by the plotline.

Conclusion: The effect of shared storybook reading on print knowledge is questionable. Preschool children spend little to no time actually looking at text during shared storybook reading. The stronger benefits of shared storybook reading include the expansion of vocabulary and other spoken language abilities.

Experiment 1: Preschool children scarcely fixate on text during shared storybook reading, focusing most attention on the illustrations. This is unaffected by the layout of the text or richness of the illustrations.

Experiment 2: Children's fixations on parts of the illustration are somewhat affected by the text.

Relevance to our study: This supports the part of our hypothesis that states that children with and without LI will attend more to the illustrations than the text. It establishes that prereaders spend very little time fixating on text during shared storybook reading.

Gernsbacher, M. A., & Faust, M. E. (1991). The mechanism of suppression. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*(2), 245-262. doi:10.1037/0278-7393.17.2.245

Objectives: This study looked at whether the cognitive mechanism of suppression explains differences in adult comprehension skill. Research has established that less skilled comprehenders are able to draw on context to make predictions; therefore, an inability to draw on auditory and visual context does not explain differences in comprehension. This study hypothesizes whether the component of comprehension driving these differences is inefficient suppression of irrelevant stimuli.

Methods: Five experiments relating to linguistic and general comprehension were conducted. The subjects were recruits from the US Air Force. They were divided in to typical and less skilled comprehender groups based on their performance on a Multi-Media Comprehension

Battery. The five experiments looked at suppression of the incorrect forms of homophones, suppression of visual information in scenic arrays, suppression of information across modalities, enhancement of the appropriate meanings of ambiguous words, and enhancement of typical objects in scenic arrays.

Results: Less skilled comprehenders do not efficiently suppress the inappropriate meanings of ambiguous words while reading, nor the incorrect forms of homophones. In the visual array experiment, it was found that less skilled comprehenders suppressed the typical but absent objects less efficiently than the control group. Less skilled comprehenders also suppressed information across modalities less efficiently.

Conclusion: Less skilled comprehenders fail to efficiently suppress various types of extraneous information that is activated during comprehension of linguistic and nonlinguistic material. Less skilled comprehenders do not enhance correct meanings less efficiently; in fact, they may benefit more from context than typical comprehenders.

Relevance to our study: This paper establishes that less skilled comprehenders shift from one focus to another more than typical comprehenders. This extends beyond linguistic comprehension to general comprehension. This underlies our hypothesis that the children with language impairment may shift their gaze more frequently and in a less focused manner than the control group.

Gernsbacher, M. A., & Robertson, R. R. W. (1995). Reading skill and suppression revisited. *Psychological Science, 6,* 165-169.

Objectives: This study explored whether less skilled readers might be better than more skilled readers at comprehending puns because they are not as effective at suppressing inappropriate meanings of words.

Methods: 80 university students were divided into equal groups of more skilled and less skilled readers based on a the reading section of a multimedia comprehension battery. The participants read a series of sentences and then saw a test word. The participants were then asked to judge whether to test word was related to a meaning of the final word of the sentence, but not the meaning implied by the sentence (e.g., “He dug with the spade,” test word: “Ace”). Half of the test items required the participants to accent an additional meaning, and half required them to reject an incorrect answer.

Results: More skilled readers more quickly accepted the meaning of a homonym not implied by the sentence context. More and less skilled readers did equally well at accepting the meanings of homonyms that were supported by the context.

Conclusion: More skilled readers are quicker to accept seemingly inappropriate meanings of homonyms because they have more efficient suppression (including of more appropriate meanings in the case of puns).

Relevance to our study: This adds to the evidence we have to support the inefficient inhibition theory.

Luke, S. G., & Asplund, A. (2018). Prereaders' eye movements during shared storybook reading are language-mediated but not predictive. *Visual Cognition, 26*(5), 351-365. doi:10.1080/13506285.2018.1452323

Objectives: To look at whether the eye movements of preschool children and adult control participants are language-mediated in shared storybook reading and whether prereaders and adults make predictive eye movements during storybook reading.

Methods: Forty-one prereader children between three and five years old and 57 adults participated in this study. The participants were eye tracked while looking at and listening to a book called The Happy Man and His Dump Truck. The text was included on each page for the children, but erased for the adults to insure fixation on the illustrations. The storybook was shown to each participant twice while being eye tracked.

Results: This result replicated previous research findings that children spend very little time looking at text during shared storybook reading. Furthermore, children fixated on target pictures that corresponded to the noun phrase being read in proportions similar to the adult participants. Children’s eye movements are similarly language mediated; however, adult eye movements were somewhat faster and more focused. No evidence for predictive eye movement was found in this study.

Conclusion: Prereader children look at pictures, not text, during shared storybook reading. Their eye movements are language-mediated, very similar to adult eye movements.

Relevance to our study: This is the parent study that our study continues from. It reviews all the relevant literature relating to prereader fixations during shared storybook reading and language mediation of eye movements in adults and children. It establishes that typically developing children look at the part of the illustration corresponding to what is read, establishing the foundation for our research question.

Leonard, L. B., Ellis Weismer, S., Miller, C. A., Francis, D. J., Tomblin, J. B., & Kail, R. V. (2007). Speed of processing, working memory, and language impairment in children. *Journal of Speech, Language, and Hearing Research, 50*(2), 408-428. doi:10.1044/1092-4388(2007/029)

Objectives: This study investigated the relationship between processing speed and working memory, and whether these two abilities are the underlying mechanisms of language impairment.

Methods: __ 14-year-old children with LI and ___ typical peers participated in processing speed and working memory tasks. Both groups were also given a comprehensive language examination.

Results: Processing speed and working memory accounted for 62% of the variance in children's language scores, with verbal working memory being the most significant contributor.

Conclusion: There is reason to believe that processing factors have a relationship with language disorders, although further research is warranted before more specific conclusions can be drawn.

Relevance to our study: This is a competing explanation of language impairment that goes against our hypothesis.

McMurray, B., Samelson, V. M., Lee, S. H., & Bruce Tomblin, J. (2010). Individual differences in online spoken word recognition: Implications for SLI. Cognitive Psychology, 60(1), 1-39. doi:10.1016/j.cogpsych.2009.06.003

Objectives: This study seeks to offer some insight into the competing theoretical models of the deficits in underlying processes in language impairment.

Methods: 93 adolescents of varying language and intellectual abilities participated in this study. There was a specific language deficit group and a general IQ impairment group. There was also a non-specific language impairment group and a typically developing control group. Participants were shown on-screen images depicting a target, a cohort competitor, a rhyme competitor, and a distraction object. They were instructed to click on the target. Eye movements were monitored with an eye-tracker.

Results: Language status was related to the fixations to the target, cohort, and rhyme. Adolescents with low language skills activated the target less and took longer to get to peak activation than the control group. It also appeared that the poor language skills group could not "fully suppress the competitor and had higher offset baseline activation than normal adolescents."

Conclusion: Variation in overall language ability may be associated with specific changes in word recognition. While there was individual variation, there was an overall pattern that showed listeners with poor language do not completely activate the target word and show increased activation for related competitors.

Relevance to our study: This is an eye-tracking study looking at language mediated eye movements of adolescents with language impairment. It adds to the evidence for our hypothesis about decreased suppression of irrelevant stimuli in children with language impairment.

Nation, K., Marshall, C. M., & Altmann, G. T. M. (2003). Investigating individual differences in children's real-time sentence comprehension using language-mediated eye movements. *Journal of Experimental Child Psychology, 86*(4), 314-329. doi:10.1016/j.jecp.2003.09.001

Objectives: This experiment set out to examine individual differences in children's online language processing (typical vs. poor comprehenders). Particularly, it looked at whether children use information from a verb to predict the upcoming object based on visual context.

Methods: Ten and eleven-year-old children were selected as typical or low comprehenders through a number of screening measures looking at their text accuracy, reading comprehension, decoding, and visuo-spatial abilities. Only children with normal nonverbal ability participated in this study. Eleven skilled comprehenders and eleven less-skilled comprehenders were eye-tracked while being auditorily presented with sentences containing verbs that were either neutral with respect to the illustrations or supportive. The supportive verbs aided inferencing by referring to one specific part of the illustration (e.g., the verb "eat" preceding the noun "cake," where cake is the only edible item in the picture).

Results: Both groups of children demonstrated anticipatory eye movements, with no difference in the time taken to direct eye movements to the target in either the supportive or neutral conditions. Both groups spent more time looking at the target in the supportive condition. The low comprehender group demonstrated a higher number of fixations towards the target; however, they spent less time looking at the target in both conditions.

Conclusion: Children, like adults, use verb selection restrictions in combination with visual context to predict the object of the verb (in the supportive condition). The low comprehender group was initially able to distinguish the visual target as quickly as the control group. However, there were differences in the eye movements of the low comprehenders. They had more eye movements overall and spent less time fixating on the target. This could be due to a number of factors, including visual or auditory memory problems, attention deficits, or difficulty filtering irrelevant stimuli.

Relevance to our study: This study, similar to ours, addresses auditory comprehension of children while looking at an online task. It also demonstrates the basis for our hypothesis- the low comprehender group showed differences in language mediated eye movement compared to the control group.

Rayner, K., Chace, K. H., Slattery, T. J., & Ashby, J. (2006). Eye movements as reflections of comprehension processes in reading. *Scientific Studies of Reading, 10*(3), 241-255. doi:10.1207/s1532799xssr1003_3

Objectives: The objective of this study was to demonstrate that eye movements are sensitive to discourse processing variables and that eye tracking can provide insight into online comprehension processes.

Methods: Experiment 1 looked at how eye movements change with passage difficulty. The participants were 16 native English speakers with normal vision and normal reading abilities. Participants were eye-tracked while reading a variety of passages varying in difficulty level.

Experiment 2 looked at how eye movements demonstrate readers' anaphor processing. The participants were 18 native English speaking adult skilled readers with normal vision. The readers were eye-tracked while reading paragraphs that contained some sentences with anaphors. Half of the passages contained anaphors that matched their antecedents, half had inconsistent anaphors. The distance between anaphor and antecedent was varied.

Results: In Experiment 1, the difficulty rating of each passage was positively correlated with average fixation duration, number of fixations, and total time spent reading. In Experiment 2, readers spent more time looking at the inconsistent anaphors, indicating an increased difficulty in processing. Distance did not affect the processing time.

Conclusion: This study concluded that eye movements are mediated by global text difficulty, and that an inconsistency between and anaphor and its prior antecedent is registered by the eye movement system. Perhaps most importantly, this study establishes that eye movement recording can be a valuable research tool for comprehension-related questions.

Relevance to our study: This study asserts that eye movement data can be valuable in assessing online comprehension processes.

Spaulding, T. J. (2010). Investigating mechanisms of suppression in preschool children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 53*, 725-738. doi:10.1044/1092-4388(2009/09-0041)

Objectives: This study examined mechanisms of suppression in preschool children with SLI, specifically their resistance to distractors and their inhibition of a prepotent response.

Methods: Forty-four preschool children participated; 22 had SLI and 22 were typically developing. They were presented with two inhibition tasks. The first task required them to suppress various nonverbal, verbal, and visual distractors while completing a goal-oriented task. The second task was a stop-signal paradigm that required the children to suppress a prepotent response.

Results: The SLI group demonstrated significant difficulty suppressing distractor interference and poor inhibitory control compared to the control group.

Conclusion: This study provides evidence that preschool children with SLI have difficulty with inhibition, specifically in "suppressing irrelevant and contradictory information."

Relevance to our study: This study provides evidence that preschool children with LI do have difficulty with the executive function of inhibition. Our study can contribute whether these difficulties arise in a very natural task (i.e., storybook reading).