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How Word Characteristics Affect Language-Mediated Eye Movements in Preschoolers With Varying Language Ability

Shelby Nicole Slocum
Brigham Young University

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Shelby Nicole Slocum

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Kathryn Cabbage, Chair
Steven Luke
Connie Summers

Department of Comunication Disorders

Brigham Young University

ABSTRACT

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Shelby Nicole Slocum
Department of Communication Disorders, BYU
Master of Science

Children with lower language abilities, including children with Developmental Language Disorder (DLD) are at risk for persistent reading difficulties. Previous studies have demonstrated that children with lower language abilities display eye movements different from their typically developing peers while hearing nouns in a naturalistic storybook reading context. This study examined how language ability and various lexical characteristics interact with 4- and 5-year-olds' eye movements during a naturalistic storybook reading task. We used eye-tracking technology to measure eye movements of 49 preschoolers with variable language skill. The children looked at storybook pictures on an eye tracking computer while they listened to a narration of the story. Target areas of each illustration corresponded to verbs in the text (i.e., images of the subjects and objects referred to by the verb). Results revealed that all children, regardless of language ability, were more likely to be looking at the target images while a target verb was being spoken than when a different word was being spoken. This relationship grew stronger as language ability increased. Additionally, lexical variables (age of acquisition, number of syllables, concreteness, frequency, and occurrences in the story) also impacted the likelihood that children were looking at the target images. Because the interaction of each lexical variable, language ability, and time was different, clinical implications suggest that speech-language pathologists, early childhood educators, and parents should be aware of these interactions in selecting storybooks with specific word stimuli. Such careful consideration of word stimuli may help children identify what illustrations are important during shared storybook reading.

Keywords: language disorder, eye-tracking, verbs, storybooks, reading

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DESCRIPTION OF THESIS STRUCTURE AND CONTENT

This thesis, *How Word Characteristics Affect Language-Mediated Eye Movements in Preschoolers With Varying Language Ability,* is written in a hybrid format, which combines traditional thesis requirements with a format that is often used for journal publication. To meet the university submission requirements, these preliminary pages have been included. This thesis is presented as a journal article, conforming to the length and style requirements for submitting journal articles to academic research journals. The contents of the appendices are as follows: the participant recruitment flyer in Appendix A, the participant consent form in Appendix B, and an annotated bibliography in Appendix C.

Introduction

Language is one of the defining features of humanity. It allows individuals to communicate with one another and interact with their surrounding environment. As such, typical language development has been analyzed and studied for nearly a century. Identifying, diagnosing, and treating language disorders is part of the unique specialty of speech-language pathologists (SLPs). As the field of speech-language pathology has continued to evolve, additional research has focused on what characterizes a language disorder, as well as examining the far-reaching implications of atypical language development. In this study, we used eye-tracking methodology to investigate how language ability impacts where preschool-aged children are looking while being read a storybook. That is, this study aims to determine what children are attending to in real-time and whether this differs depending on a child's language skill. We further examined how lexical characteristics of words influenced where children focused their eye movements in real-time and whether this varied by language ability. Results of this study have the potential to inform clinical decisions when working with children of varying language skill.

One of the main diagnoses for children who experience language difficulties in development is Developmental Language Disorder (DLD). Although referred to historically as Specific Language Impairment (SLI), this disorder will consistently be referred to as DLD throughout this paper to reflect the current terminology regardless of whether or not the reference paper used DLD or SLI. According to previous studies, 7.4% of kindergarten children will receive a diagnosis of DLD (Tomblin et al., 1997), and for these children language deficits are not a result of injury or biomedical etiologies (Bishop et al., 2017). There are also many children whose language development presents atypically, although they are not diagnosed with DLD.

This may be due to a different known biomedical etiology, injury, or the fact that their language deficits are not significant enough to solicit a formal diagnosis, despite experiencing functional difficulties with their language.

Language difficulties often have long lasting implications. Studies show that children with language impairment in kindergarten are at an increased risk for reading difficulties in 2nd-4th grade (Catts et al., 2002). Catts and colleagues (2002) concluded, however, that children who had improved their language abilities by 2nd grade had better reading outcomes later in elementary school than did the children whose language impairments persisted. Thus, language intervention early in a child's education is crucial for literacy development as well. For language intervention to successfully combat potential reading deficits, at-risk children (i.e., those with language impairment or lower-language abilities) should be identified prior to the commencement of formal reading instruction (Catts et al., 2002). It is important to note that children with DLD are not the only group of children who may be at-risk for later reading disabilities; children with non-specific language impairment (NLI), which is different from DLD in that children with NLI have general language difficulties in addition to a low nonverbal IQ while children with DLD have language difficulties in the absence of a low nonverbal IQ (Tomblin & Zhang, 1999), are at an even higher risk for reading disabilities than children with DLD. In the past, children with NLI have not been considered appropriate candidates for language treatment, but not all support this notion (Cole et al., 1990; Fey et al., 1994). Children with DLD and NLI, as well as children without a specific diagnosis but who are exhibiting lower language abilities should be considered at-risk for developing literacy difficulties.

Language Functioning of Children With Language Deficits

To determine which children may benefit from language intervention, as well as what that intervention should specifically target for each child, we examine common characteristics and hallmarks of typically developing language. Among children with language deficits, word learning difficulties are common, contributing to smaller vocabularies and also impacting morphosyntactic abilities (Borovsky et al., 2013; Storkel et al., 2017). Studies have also shown that children with DLD often have lower processing speeds (Borovsky et al., 2013). For example, Borovsky and colleagues conducted a study in which they concluded that adolescents with DLD do not differ from their typically developing peers in how quickly they draw on lexical information to predict sentence meanings, but the DLD group did differ in that they were less able to update their overall schema of a sentence online (Borovsky et al., 2013). This may relate to many researchers' suggestions that children with DLD experience impairments in nonverbal cognitive processing factors as the main underlying issue behind their language difficulties (e.g., Gillam et al., 1998; Hoffman & Gillam, 2004; Leonard et al., 2007; Montgomery & Evans, 2009).

To date, it has been challenging to develop effective interventions to treat word learning difficulties, despite the prevalence of this deficit among children with DLD. However, shared and interactive book-reading has proven to be one effective intervention for word learning (Storkel et al., 2017). There have also been sufficient amounts of evidence to suggest that children with DLD require increased exposure to words as compared to their typically developing peers in order to associate meanings with the new words (Borovsky, 2017). With this comes the difficulty of learning and applying semantic features of words. Further understanding

of how children with low language skills associate words with illustrations in storybooks may help inform naturalistic interventions to support word learning.

Research regarding development of noun concepts far exceeds what is known about development of verb concepts in childhood language. However, studies have generally shown that verbs are acquired slower and later than are nouns (Behrend, 1990; Bishop, 1979; Rice et al., 1995), although the process of exactly how children learn verbs is not well understood. There is some evidence that typically developing children between the ages of 3- and 4-years-old utilize verb inflection to match novel verbs with their meaning. For example, children selected images of events that maintained a given activity when they heard verbs inflected with present progressive -ing, whereas they selected events that maintained the result when they were presented with past tense -ed verbs. While this was a commonality among typically developing preschoolers, children with DLD did not use the verb inflection to appropriately match the verbs to the corresponding images (Carr & Johnston, 2001). This suggests that children with DLD, and perhaps lower language abilities in general, may differ from typically developing children in their bootstrapping abilities specifically pertaining to verbs.

Children with DLD have also been observed to possess less of an understanding of novel verbs when heard in a storybook context as compared to their typically developing age-matched peers. Not only do children with DLD have greater difficulty learning the semantic content of verbs, but also with phonological aspects of word learning, which was demonstrated when children were administered five different tasks to determine what they had learned about the new words after hearing them in a storybook context several times (Nash & Donaldson, 2005).

In addition to part of speech (e.g., nouns versus verbs), other word characteristics may be influencing comprehension of words, especially in children who present with lower language

abilities. Such word characteristics may include the age at which the word is acquired, the number of syllables that the word contains, the concreteness of the word, and the frequency with which the word is used in the child's environment. Word frequency has long been considered one of the most important word characteristics in word processing research (Brysbaert & New, 2009; Ferrand et al., 2011; Kuperman et al., 2012). The corpus from which one draws frequency data must be large to ensure accuracy. Corpora that are indeed adequate in size have been effective as a means to control words (Brysbaert & New, 2009; Ferrand et al., 2010; Keuleers et al., 2010; Keuleers et al., 2012). Words used at a higher frequency are often able to be both produced and perceived more quickly than words with lower frequencies (Brysbaert & New, 2009; Jescheniak & Levelt, 1994; Rayner & Duffy, 1986). Likewise, word processing speed increases as word length decreases, so utilizing word length either measured in characters or syllables has been important to word processing research (Kuperman et al., 2012).

While the frequency and the word length have traditionally been two of the most commonly used controls in research, it has been argued that age of acquisition should also be used as a control for word stimuli (Kuperman et al., 2012). The speed at which children can access representations of different words is impacted by the order in which they learn those words, despite the frequency at which they have been exposed to a given word (Kuperman et al., 2012). Frequency data is typically compiled using materials that are predominately accessed by adults, necessitating employment of additional word controls when a study involves child language (Kuperman et al., 2012). Additionally, concreteness may be an informative characteristic to examine, as concrete words are easier to learn than abstract words because they involve "perceptual memory codes" rather than just "verbal codes" (Brysbaert et al., 2014). This is important to keep in mind when evaluating word characteristics in the context of literacy, as

some words are acquired following tangible experiences while others are primarily encountered in text (Brysbaert et al., 2014). The present study will examine several word characteristics as a parameter upon which to compare eye behaviors between children across a continuum of language abilities.

Eye-Tracking

Although prior research has sought to determine how children with varying language skill are impacted by various word characteristics, such as part of speech (noun versus verb), little is known in regards to how processing speed and lexical deficits manifest in real-time comprehension. In order to observe and analyze children's real-time reactions to word characteristics of language stimuli, eye-tracking technology has been utilized to determine how children respond to and more so *differ* in their response to words corresponding to picture stimuli. When looking at images corresponding to verbs versus nouns, children with DLD are slower than their typically developing peers to gaze at the target image, especially when the target image corresponds to a verb rather than a noun (Andreu et al., 2011). Additionally, the type of verb changes the speed at which children are able to identify the corresponding picture target. That is, the more complex the verb, the longer it takes both typically developing children and children with DLD to attend to the appropriate image (Andreu et al., 2011).

Eye-tracking technology has also been able to show the predictive nature of certain words (Altmann & Kamide, 1999; Nation et al., 2003). For instance, verbs can be used to guide an individual's eye movements to the target object before the word corresponding to the target has been spoken. Children begin to eliminate certain pictures as candidates if they would not commonly be used with a given verb (Altmann & Kamide, 1999). Likewise, both children with typically developing language and "less-skilled comprehenders" have been shown to make

anticipatory eye movements based on the verb (Nation et al., 2003). For example, after listening to two sentences such as, “Jane watched her mother choose a cake” and “Jane watched her mother eat the cake,” where the first sentence utilizes a neutral verb (not specific to the target noun) and the second sentence utilizes a supportive verb (specific to the target noun), children demonstrated earlier looks to the target image upon hearing the sentence with the supportive verb. However, although children with both average and low language abilities used the verb to make predictions about the end of the sentence, the children with greater comprehension difficulties spent less time overall looking at the target image as they looked back and forth from the target image to other irrelevant images in their view (Nation et al., 2003), further demonstrating the subtle differences in eye behavior between children with differing language abilities.

Children with higher or lower language skills differ from one another according to their eye movements in other ways. Toddlers with higher vocabulary have been observed to pay more attention to illustrations that depict key narrative events, and the toddlers that attend more to the illustrations of key narrative events performed better on a receptive test following the story (Kaefer et al., 2017). Thus, perhaps the primary deficit is not necessarily just poorer receptive language and comprehension, but also an increased difficulty in using the environment (i.e., illustrations in a storybook) to comprehend the verbal information they are taking in. Similarly, preschool children with lower language have been shown to reference storybook images to support a retell less than their age matched peers (Andreu et al., 2011).

Storybook reading, a naturalistic and familiar context for most young children, is an appropriate context for eye-tracking studies because it allows children to make linguistically-mediated eye movements as they look at the illustrations while receiving auditory language input

(Luke & Asplund, 2018). Recently, Nicholls (2020) used eye-tracking technology to determine whether or not preschool aged children with varying language ability differed in how long it took to fixate on noun phrases in an illustration while hearing a storybook read aloud. Nicholls (2020) found that although there were not statistically significant differences between the speed at which children looked at the relevant images, the time the children spent fixating on the relevant images differed significantly based on language ability. This demonstrates that language-mediated eye movements do differ in preschool-aged children according to their language ability, even in naturalistic settings such as storybook reading. The study only evaluated children's responses to nouns, however.

Statement of Purpose

The current study extends previous work (Nicholls, 2020) and was designed to determine whether preschool-aged children exhibit language-mediated eye movements for verbs when being read a storybook. We hypothesized that children with low language skill will demonstrate significantly different language-mediated eye movements in response to verbs as compared to children with higher language skill. Moreover, we investigated whether different lexical characteristics (i.e., age-of-acquisition, syllable length, concreteness, frequency, and occurrence in story) influenced eye behaviors in preschool aged children. This information may provide useful clinical insights and inform how clinicians are selecting word stimuli to use in treatment.

Research Questions

Our research questions are as follows:

1. Are language-mediated eye movements associated with verbs moderated by language ability?

Hypothesis: We hypothesized that children with lower language ability will have a lower proportion of fixations on the target images corresponding to verbs as they are spoken than their peers with higher language ability.

2. How do word characteristics of verbs interact with language ability for language-mediated eye movements?

   Hypothesis: We hypothesized that, because of what is known about how children with language impairment learn words differently, the eye behaviors will vary based on language ability. We also hypothesized that word characteristics will impact children's eye behaviors, but the impact will present differently for typically developing children than for those with lower language abilities. We expected that words that are earlier acquired, have a higher frequency, are more concrete, and are repeated throughout the story will be attended to more quickly, although the speed may vary according to language ability.

Method

The Institutional Review Board approved utilization of human subjects as participants for this study. A consent form that was signed by a parent or guardian for each child participant prior to commencement of the first session was collected by the researchers and a copy was provided to the parent upon request. The children were also asked for their assent upon being informed that they would be participating in several activities including looking at pictures in storybooks and looking at pictures on a computer screen while they listen to a story and have the computer watch his or her eyes.

Participants

Forty-nine preliterate children between 48 and 66 months of age participated in this study, with a mean age of 57.5 months. The children consisted of 26 males and 23 females, and all were native English speakers who had not begun kindergarten. Formal and informal language assessments were administered across two research sessions, and will be further described below. See Table 1 for a summary of the results of the assessments. Children with speech sound disorders were not excluded from this study unless their speech sound errors impacted their intelligibility so much so that their language samples could not be analyzed. Children with any comorbid conditions such as Autism Spectrum Disorder or seizure disorders were excluded from the study. Rather than assigning a group identity to the children based on language ability, a combination of standardized and informal measures was employed to describe each child's language ability. As determined by the criteria outlined in the instruments section, 32 children were found to demonstrate typically developing language skills, five children demonstrated language skills in the low-average range, and 12 children met criteria for DLD. However, this diagnostic information was primarily used to ensure that the study included children with varying language ability, as all of the participants were analyzed together with a continuous language variable based on a composite language score (outlined below in the Instruments section).

Participants were recruited from local preschools and through posted flyers and word of mouth. See Appendix B for a copy of the recruitment flyer. Additionally, children with lower language abilities and DLD were recruited through community-based SLPs who work specifically with preschool children. The SLPs were asked to share the recruitment information with the parents of children on their caseload with DLD or any type of language delay.

Table 1

Participant Scores on Formal and Informal Language Measures

Measure	Mean	SD	Min	Max	Max Possible
CELF-P2 Core Language Standard Score	99.33	19.06	45	133	N/A
CELF-P2 SS Raw Score	15.57	4.41	0	22	22
CELF-P2 WS Raw Score	15.04	6.87	0	24	24
CELF – P2 EV Raw Score	21.98	8.26	0	40	40
GFTA-2 Standard Score	95.06	20.82	40	119	N/A
PPVT-5 Standard Score	111.98	12.97	85	137	N/A
Print Concepts Percentage Correct	55.89	25.38	5	88.9	100
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	N/A
PEARL Responsiveness Score (0-4)	2.25	1.30	0	4	4

Note. CELF-P2 = Clinical Evaluation of Language Fundamentals-Preschool-2. CELF-P2 SS Raw Score = Raw score of the Sentence Structure subtest on the CELF-P2. CELF-P2 WS Raw Score = Raw score of the Word Structure subtest on the CELF-P2. CELF-P2 EV Raw Score = Raw score of the Expressive Vocabulary subtest on the CELF-P2. 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.

Settings

This study took place in two different university lab settings for each child participant. The first session for each child took place in a room inside the John Taylor Building at Brigham

Young University. Parents were allowed in the room with their child if that made them more comfortable. The child sat next to the examiner or examiners at a table or on the floor during administration of the assessments. The second session for each child took place in a room inside the Richards building at Brigham Young University. Again, parents were invited into the room to put their child at ease, if needed. The eye-tracking computer was set up in a 3-sided black tent to keep children's focus on the computer monitor screen, and in front of a high-backed booster car seat sitting in a chair to maintain support for the child's head and neck.

Instruments

A combination of diagnostic, descriptive, and experimental measures were used in this study, and each will be described in detail below.

Diagnostic Measures

The following two standardized assessments assisted in characterizing language by establishing the presence or absence of DLD or any language difficulties.

Clinical Evaluation of Language Fundamentals - Preschool 2 (CELF-P2). The CELF-P2 is intended to assess a young child's expressive and receptive language abilities and to diagnose language disorder (Wiig et al., 2006). The Sentence Structure, Word Structure, and Expressive Vocabulary subtests were administered to children in this study. The manual of the CELF-P2 reports a sensitivity of .85 and a specificity of .82. The average reliability of composite scores is reported as $r > .90$, and split-half reliability of each subtest ranges from .80 to .97 (Wiig et al., 2006).

In order to create a latent variable that combined the sub scores for the three CELF-P2 subtests administered, a factor analysis was conducted on the three sub scores prior to data analysis. Scores were entered into a principal components analysis with varimax rotation, using

the Princomp function in R (R Core Team, 2015. One factor with an eigenvalue greater than 1 was obtained, accounting for 82% of the total variance. The three CELF-P2 sub scores all loaded positively onto this factor with factor loadings of 0.57 - 0.59. We used this factor as a predictor of language ability in our analyses below.

Predictive Early Assessment of Reading and Language (PEARL). The PEARL is a criterion-referenced diagnostic language screener that examines the two parts of reading: decoding and oral language comprehension (Petersen et al., 2018). The Dynamic Assessment of Language subtest was used in this study. It uses a dynamic assessment model, measuring a child's ability to learn rather than measuring what they currently know, in an effort to reduce and differentiate between cultural and linguistic differences and previous exposure. The examiner reads the child a short narrative, has the child retell the story to the best of his or her ability, and then teaches the child how to tell more complete narratives using verbal and visual support. Then, the examiner re-tests the child using a new narrative. The PEARL yields a Responsiveness Score, which is rated by the examiner immediately following the teaching phase on a scale of 0 to 4, with 0 being difficult to teach and 4 being easy to teach. The manual for the PEARL reports that the pretest and posttest of the Dynamic Assessment of Language subtest have a correlation coefficient of .70 and that the internal consistency of this subtest is above .80 as calculated by Cronbach's alpha. Inter- and intra-rater reliability is at or above 90% and administration fidelity is at or above 95% (Petersen et al., 2018).

Receiving a Core Language Score of 78 or lower on the CELF-P2 corresponded to a child qualifying for a diagnosis of DLD. Additionally, receiving both a score of 7 or lower on two CELF-P2 subtests and a Responsiveness Score of 0 or 1 on the PEARL indicated an increased likelihood that a child may have DLD. Children who scored a core language score of

90 or lower on the CELF-P2 and a Responsiveness score of 2 or lower on the PEARL were characterized as having language abilities in the low-average range.

Descriptive Measures

The following 2 measures were used to further describe a child's language abilities and any emerging literacy skills, but were not used as diagnostic criteria for the presence or absence of DLD.

Woodcock Reading Mastery Tests - 3 (WRMT-3). The WRMT -3 Letter Identification Subtest is designed to examine basic letter knowledge (Woodcock, 2011). This is important because letter knowledge is an indicator of early and emergent literacy skills. The examiner showed the child a page of a flip-book that contained several letters in both upper- and lower-case and asked him or her to identify the letter that was stated by the examiner. The WRMT-3 Manual reports that for the age group included in this study, the split-half reliability ranges from .95 to .97 on the Letter Identification subtest. (Woodcock, 2011). The Letter Identification subtest raw score is used in this study as a measure of the participants' pre-literate abilities under the notion that literate children will perform differently on eye-tracking measures than will non-literate children.

Goldman Fristoe Test of Articulation - 2 (GFTA-2). The GFTA-2 includes a Sounds in Words subtest that was administered in this study. This subtest assesses a child's articulation for each phoneme in the English language in different word positions at the word level (Goldman & Fristoe, 2000). The number of errors made for the target phoneme in a given position of a specific word totals to equal the raw score. These results provided information about the participants' intelligibility and speech sound error patterns which was helpful in determining if grammatical morpheme errors on the CELF-P2 were speech or language related.

Supplemental Measures

The three measures that are described in this section were administered originally as descriptive measures, but were not used in the final data analysis. When submitted to a factor analysis, they loaded onto the components similarly to the CELF-P2 subtests, indicating that they were not further differentiating between the participants' language ability. Additionally, because data were missing for at least one participant for each of these three assessments, they were not included in the final composite score in order to increase statistical power.

Language Sample. The wordless picture book *Frog Where Are You?* (Mayer, 1969) was shown to each participant while the examiner told the story of a boy and his dog looking everywhere for their lost pet frog. Then the children were each asked to retell the story to the examiner while the examiner turned the pages of the book for the child to see. The *Systematic Analysis of Language Transcripts* (SALT) database contains norms on the *Frog Where Are You?* retell task, and was used to assist in analysis of the language sample once it had been transcribed and coded. Using SALT, an MLU was generated for each child, as well as their Type Token Ratio. If a child was unable to participate in the story retell task, an alternate language sample was elicited while the examiner engaged the child in a play context using a magnetic play set.

Peabody Picture Vocabulary Test - 5 (PPVT-5). The PPVT-5 is a receptive vocabulary assessment for individuals aged 2 years and 6 months through 90+ years (Dunn & Pearson, 2019). During this assessment, each child was shown pictures four at a time on a flip-book and was asked to point to the picture that corresponded with the word the examiner read. The manual for the PPVT-5 reports a split-half reliability as .94 - .95 (Dunn & Pearson, 2019).

Print Awareness Measure. Another measure that was used to assess emergent literacy skills in this study was the Print Concepts portion of the Preschool Word and Print Awareness

Assessment (PWPA), which also examines print concepts as described by Justice and Ezell (2001). The children's book *Nine Ducks Nine* (Hayes, 1990) was read to each child by the examiner. The examiner also asked questions while reading, such as "Where do I begin to read?", "Which way do I read?", and "Show me a capital letter", in order to gain information about the child's understanding of words in print (Justice & Ezell, 2001, pg. 215). A mean administration fidelity was reported as 99% for the PWPA (Justice & Ezell, 2001).

Experimental Measure

The following section provides information about the experimental measure which was compared against language ability in this study. The experimental procedures used by Luke and Asplund (2018) provide a model for the experimental procedures used here.

Eye-Tracking. The Tobii Pro Spectrum and Tobii Pro Lab software were used to gather the eye movement data. A low-intensity infrared light is sent from the eye-tracking computer to the child's eyes. The child's gaze patterns on the screen are determined by the light reflecting off the child's retina back into the camera.

The storybook used in this task was *The Happy Man and His Dump Truck* (Miryam & Gergely, 2005). Each page of the storybook was displayed as 1600 x 900 pixel images on the computer screen. Interest areas were identified for each page corresponding to subjects and objects associated with verbs in the text. Children listened to an audio recording of a native English speaker female voice reading at a natural rate. The onset and offset in milliseconds of each target verb was determined using Audacity software. The narrator's production of target verbs took an average of 352 milliseconds (SD = 82 ms; range 247 – 542 ms). Verb onsets averaged 2299 milliseconds apart (SD = 1585 ms; range 766 – 7066).

The Tobii Pro Spectrum in remote mode sampling at 1200 Hz recorded each child's eye movements from both eyes as he or she sat in the high-backed booster seat atop a chair facing the 24-inch LCD computer monitor, situated approximately 60 centimeters away so that the image substended 40 by 24 degrees of visual angle.

A 5-point calibration procedure preceded each story listening task to map each child's eye position to spatial points on the computer monitor screen. An attention-grabbing image would appear in each of the five screen quadrants sequentially, and the children were instructed to direct their eye gaze to the image as quickly as possible when they noticed that it had moved to a new location. Following the calibration, the first storybook page was brought up on the screen and the corresponding audio recording began after a 2-second delay. When each audio file ended and a new page was displayed, there was again a 2-second delay before a new audio file would begin. This continued in the same manner until each page of the storybook had been displayed and each corresponding audio file had been played. Because the eye-tracker is sensitive to excessive movement and there is always a chance that calibration was completed inaccurately (Luke & Asplund, 2018), each child participant listened and watched the storybook task in this same manner two times to ensure quality of data.

Stimuli Development

Each word in the storybook used in the experimental phase of the study (*The Happy Man and His Dump Truck)* was analyzed for the following: occurrence in the storybook, part of speech as used in the story, number of syllables, age of acquisition, concreteness, and frequency in the SUBTLEX corpus. Only the analysis for verbs in the storybook was included in this study, corresponding to the target verbs that were selected based on the presence of a corresponding

image in the illustrations. See Table 2 for a summary of the lexical characteristics of the target verbs.

Age of acquisition (AoA) values were obtained from a compilation by Kuperman et al. (2012), in which they outlined the AoA ratings for over 30,000 English lemmas, including nouns, verbs, and adjectives.

Likewise, concreteness ratings were obtained from a compilation by Brysbaert et al. (2014) based on nearly 40,000 English lemmas and two-word expressions. Concreteness ratings evaluate how well a word relates to a "perceptible entity" (Brysbaert et al., 2014), which is specifically related to this study in that the target verbs are those that corresponded to a specific illustration, whereas words that did not directly correspond to the illustrations were omitted. Participants in the concreteness compilation were instructed to utilize a 5-point rating scale from abstract to concrete to rate each word they were presented with; thus, words with a higher concrete value were assigned a higher rating.

The SUBTLEX corpus, created by Brysbaert and New (2009), was used to determine a frequency measure for the target words. This specific corpus was used because it is a spoken corpus in which the frequency values were compiled based on words used in television commercials (Brysbaert & New, 2009) rather than in text like many other frequency corpora. Because the participants in this study are children, a spoken corpus is more relevant than a written corpus.

Table 2

Descriptive Statistics of Lexical Characteristics

Lexical Characteristic	Mean	SD	Min	Max	N
Occurrence in Story	1.66	1.26	1	7	41
AoA	4.91	1.3	3	8	17
Syllables	1.1	0.3	1	2	41
Concreteness	2.92	0.96	1	5	33
Frequency in SUBTLEX Corpus	56615.85	99268.64	1	15503.12	41

Note. AoA = Age of acquisition listed in years.

Procedures

This study involved two separate sessions, each lasting approximately 60 minutes. The first session was used to administer a battery of language assessments in order to classify the children's language functioning. The second session was used to administer assessments that would further describe the children's language abilities and to conduct the eye-tracking experiment.

Session One

Upon arrival for session one, the examiner went over the consent form with the child's parent/guardian who then signed the form. The child and the parent were invited back to the laboratory room where the session was to take place. The Sentence Structure, Word Structure, and Expressive Vocabulary subtests of the CELF-P2 were administered. Following the CELF-P2, the Screener subtest of the PEARL was administered. Children were permitted to take a break at any time. Examiners tried to avoid breaks in the middle of subtests, but children were

not denied breaks when they were requested. The wordless picture book, *Frog Where Are You?* (Mayer, 1969), was used to elicit a narrative retell language sample, and then the GFTA-2 was administered to assess articulation abilities. After each task, children were given stickers and earned small prizes to keep them motivated.

Following this session, the children's scores on each assessment were analyzed in order to determine their level of language functioning. Any children that did not meet this study's criteria for inclusion were dismissed and not contacted for session two. Children who did meet the criteria were contacted to schedule their second session.

Session Two

For session two, participants were met in the parking lot of the BYU Richards Building and escorted to the laboratory room. The children were assisted in getting seated in a chair that was equipped with a high-backed car booster seat for head and neck support. The examiner moved the chair to the appropriate distance from the eye-tracking computer and remained with the child in the tent while a second research assistant ran the eye-tracking software on a computer monitor adjacent to the eye-tracking tent.

Calibration. The eye-tracking calibration task was conducted as previously described. The examiner instructed the child to move his or her eyes to the attention-grabbing animation as quickly as possible each time they noticed it had moved. If the calibration was successful, the task would end and the experiment would begin.

The Experiment. The storybook pages appeared one at a time on the computer monitor in front of the child and an audio recording of the text for each page was played. The children's eye movements were recorded as they looked at the storybook pictures. When this was finished, the Letter Identification subtest of the WRMT-3 was administered. Then, the eye-tracking

experiment was repeated following the same procedure as before, including another calibration. After the second reading of the eye-tracking storybook, children participated in the PPVT-5. Once more, the children were assisted into the eye-tracking seat where they completed a story retell task (the data from which is not analyzed in this study), and then they participated in the Print Concepts storybook assessment portion of the PWPA. Similar to the first session, children were allowed a break at any time and they were given stickers following each task to earn small prizes.

Data Analysis

Methods outlined by Luke and Asplund (2018) were used to guide analysis of the data for this study. In order to determine if and how language-mediated eye movements, such as time to fixation and probability of fixation, vary according to child characteristics (language) and word characteristics (occurrence in the storybook, part of speech as used in the story, number of syllables, age of acquisition, concreteness, and frequency in the SUBTLEX corpus), two linear mixed effects models were utilized. Language ability was examined on a continuum rather than dividing the children into two separate groups. As noted in the information regarding the CELF-P2 in the Instruments section, we created a composite CELF-P2 score using factor analysis. Because there was missing data for at least one participant for each of the other language measures and because those additional measures loaded onto the component similar to the CELF-P2 subtest scores, they were not included in the final composite score.

Results

The results to this study will be presented in this section, following a reiteration of our research questions and hypotheses:

1. Are language-mediated eye movements associated with verbs moderated by language ability?

   Hypothesis: We hypothesized that children with lower language ability would have a lower proportion of fixations on the target images corresponding to verbs as they are spoken than their peers with higher language ability.

2. How do word characteristics of verbs interact with language ability for language-mediated eye movements?

   Hypothesis: We hypothesized that, because of what is known about how children with language impairment learn words differently, the eye behaviors would vary based on language ability. We also hypothesized that word characteristics would impact children's eye behaviors, but the impact will present differently for typically developing children than for those with lower language abilities. We expected that words that are earlier acquired, have a higher frequency, are more concrete, and are repeated throughout the story would be attended to more quickly, although the speed may vary according to language ability.

Research Question 1

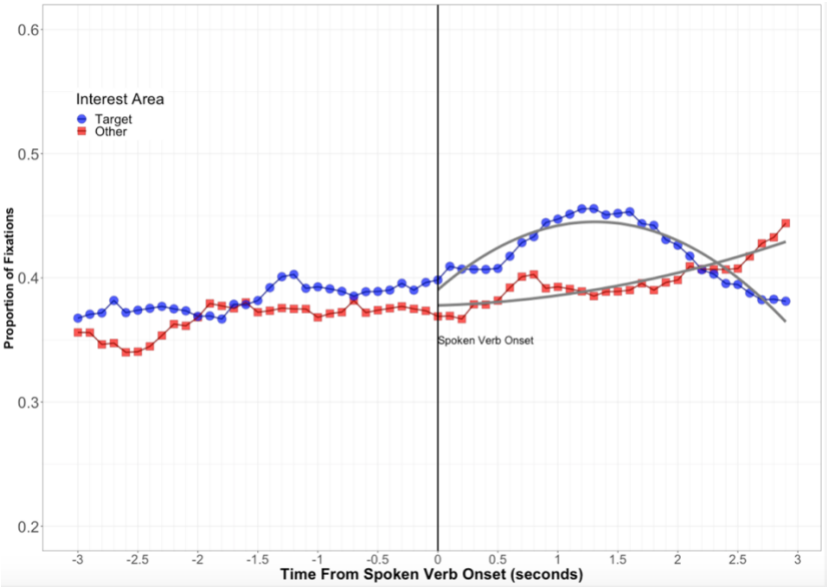
A linear mixed effects model was fitted to determine how the proportion of fixations to target images was influenced by language ability. As stated above, data analysis was completed using language ability along a continuum, and the children were not broken into dichotomous groups. Fixed effects were the CELF-P2 composite score (created with a factor analysis using the Word Structure, Sentence Structure, and Expressive Vocabulary subtests in a process which was outlined in the CELF-P2 section of the methods), whether the illustration was a target image or a control image, and the linear and quadratic functions for time. The fixation data were

divided into 60 100-millisecond bins, beginning three seconds before and ending three seconds after the onset of each spoken target verb in the story. The analysis focused on the three seconds starting with spoken target verb onset. Any image was considered to be a target during the time that its corresponding verb was narrated and the same image was matched to a time two seconds earlier, which served as the control condition. Interest areas were defined for illustrations of both subjects and objects corresponding to each target verb, and fixations on either the subject or the object were combined for the analysis. Random effects included random by-participant intercepts and random intercepts for subject versus object interest areas.

The results (see Table 3) demonstrated that preschool children's eye movements are language-mediated during a storybook reading task. Growth curve analysis showed that the children's proportion of fixations on an image was related to the verb being narrated regardless of language ability (see Figure 1). A quadratic relationship was shown between time and fixation proportion on the target image, but this same relationship was not present for the control illustrations, indicating that the eye behaviors were language-mediated.

Figure 1

Probability of Fixating on Verb-Related Interest Areas as a Function of Time



Adding the CELF-P2 composite score based on the three subtests to the analysis demonstrated statistically significant differences across children with differing language skills. As the composite language score increased, the children exhibited more contrast between target and control condition. That is, the quadratic relationship between time and fixation proportion on the target image grew stronger. Thus, the participants demonstrated evidence of language-mediated eye movements regardless of language ability, but those with higher language ability were more responsive to spoken verbs than children with lower language ability.

Table 3

Growth Curve Analysis of Proportion of Fixations

Fixed Effect	*b*	*SD*	*t*	*p*
Intercept	0.44	0.1	4.35	0.14
Language Skill	-0.015	0.0098	-1.52	0.13
Reference Condition = Target	0.025	0.0018	14.1	< 0.0001
Time (Linear)	5.83	0.66	8.85	< 0.0001
Time (Quadratic)	1.9	0.66	2.89	0.0038
Language Skill x Reference Condition = Target	0.0029	0.0018	1.62	0.11
Language Skill x Time (Linear)	1.74	0.66	2.66	0.0079
Language Skill x Time (Quadratic)	1.8	0.66	2.75	0.0059
Reference Condition = Target x Time (Linear)	-7.14	0.93	-7.67	<0.0001
Reference Condition = Target x Time (Quadratic)	-13.1	0.93	-14	<0.0001
Language Skill x Reference Condition = Target x Time (Linear)	-2.93	0.93	-3.14	0.0017
Language Skill x Reference Condition = Target x Time (Quadratic)	-2.33	0.93	-2.5	0.013

Research Question 2

For the second analysis, a linear mixed effects model was fitted as described by results to Question 1, with two modifications. First, fixed effects for this model included the CELF-P2 composite score, the linear and quadratic functions for time, and centered and standardized effects for the following lexical characteristics: occurrence in the story, age of acquisition, number of syllables, concreteness, and SUBTLEX frequency. For each of these lexical characteristics, we modeled the interaction with language skill, the interaction with time, and the 3-way interaction. As before, random effects included random by-participant intercepts and

random intercepts for Subject versus Object interest areas. The results of this analysis are shown in Table 4. The meaningful results will be described below.

Table 4

Analysis of Lexical Variables

	b	*SD*	*t*	*p*
Intercept	0.46	0.12	3.96	0.15
Language Skill	-0.0099	0.011	-0.91	0.37
Time (Linear)	-0.66	0.45	-1.45	0.15
Time (Quadratic)	-7.8	0.45	-17.3	< 0.0001
Language Skill x Time (Linear)	-0.72	0.45	-1.59	0.11
Language Skill x Time (Quadratic)	-0.29	0.46	-0.65	0.52
Occurrence in Story	-0.015	0.00098	-15.5	< 0.0001
Occurrence in Story x Language Skill	0.00059	0.00099	0.6	0.55
Occurrence in Story x Time (Linear)	2.62	0.36	7.25	<0.0001
Occurrence in Story x Time (Quadratic)	1.82	0.36	5.03	<0.0001
Occurrence in Story x Language Skill x Time (Linear)	-0.42	0.37	-1.14	0.25
Occurrence in Story x Language Skill x Time (Quadratic)	0.57	0.36	1.56	0.12
Age of Acquisition	0.065	0.0014	46.8	<0.0001
Age of Acquisition x Language Skill	0.0094	0.0014	6.81	<0.0001
Age of Acquisition x Time (Linear)	1.37	0.51	2.67	0.0075
Age of Acquisition x Time (Quadratic)	5.14	0.51	10	<0.0001
Age of Acquisition x Language Skill x Time (Linear)	0.69	0.51	1.34	0.18
Age of Acquisition x Language Skill x Time (Quadratic)	0.8	0.51	1.56	0.12
Syllables	0.26	0.0053	48.7	<0.0001
Syllables x Language Skill	-0.00041	0.0053	-0.79	0.43

Table 4 – continued

	b	*SD*	*t*	*p*
Syllables x Time (Linear)	23.2	1.96	11.9	<0.0001
Syllables x Time (Quadratic)	14	1.97	7.12	<0.0001
Syllables x Language Skill x Time (Linear)	4.74	1.9	2.45	0.015
Syllables x Language Skill x Time (Quadratic)	5.15	1.95	2.64	0.0084
Concreteness	0.0064	0.0014	4.71	<0.0001
Concreteness x Language Skill	-0.0026	0.0014	-1.9	0.058
Concreteness x Time (Linear)	-1.19	0.5	-2.36	0.018
Concreteness x Time (Quadratic)	-3.23	0.5	-6.41	<0.0001
Concreteness x Language Skill x Time (Linear)	-2.85	0.5	-5.69	<0.0001
Concreteness x Language Skill x Time (Quadratic)	-0.48	0.5	-0.97	0.33
Frequency	0.055	0.0014	39.8	<0.0001
Frequency x Language Skill	-0.0062	0.0013	-4.67	<0.0001
Frequency x Time (Linear)	2.37	0.51	4.67	<0.0001
Frequency x Time (Quadratic)	-2.31	0.51	-4.56	<0.0001
Frequency x Language Skill x Time (Linear)	-0.99	0.5	-2	0.045
Frequency x Language Skill x Time (Quadratic)	-0.72	0.5	-1.45	0.15

Age of Acquisition

There was a significant effect of age of acquisition (AoA), indicating that as AoA increased, there was a greater proportion of fixations on the interest areas. There was also an interaction of AoA and language skill such that as language skill increased, the effect of AoA on proportion of fixations increased. The interaction between AoA and time was significant and indicated that as AoA increases, the curve becomes less peaked and more spread out, demonstrating less focused language-mediated attention. However, the analysis showed that the

3-way interaction between AoA, language, and time, was not significant indicating the shape of the growth curve was that regardless of language ability, children took longer to fixate on words with higher AoAs.

SUBTLEX Frequency

There was an effect of frequency, indicating that as frequency from the SUBTLEX corpus increased, so too did proportion of fixations on the interest areas. Additionally, there was a negative interaction of frequency and language skill, showing that as language skill increased, the effect of frequency on proportion of fixations decreased. The interaction of frequency and time shows that as frequency goes up, the shape of the curve becomes more peaked, indicating more language mediation for higher-frequency words. Again, the 3-way interaction between frequency, language, and time was non-significant, indicating that all children with differing language abilities demonstrated quicker fixation on words with higher frequencies.

Concreteness

There was a significant effect of concreteness such that as concreteness increased, there was a greater proportion of fixations on the interest areas. There was also an interaction of concreteness and time indicating that as concreteness increased, eye movements became more language-mediated, demonstrated by a more curved peak. However, there was not an interaction of concreteness and language skill nor was the 3-way interaction between concreteness, language skills, and time significant, indicating that all children regardless of language ability demonstrated more focused attention on the interest areas corresponding to words with higher concreteness ratings.

Occurrence in Story

There was a significant negative effect of occurrence in the story, indicating that the greater number of times a word occurred in the story, the lower the proportion of fixations on the interest areas. An interaction of occurrence and time indicated that more occurrences of a word in the story results in less language mediation. In other words, the children demonstrated less focused attention on words that were mentioned multiple times. The interaction between occurrence in the story and language skill was non-significant, and the 3-way interaction between occurrence in the story, language skill, and time was also non-significant. Thus, regardless of language ability, all children fixated on the interest area less the more times a word was repeated.

Number of Syllables

There was a significant effect of number of syllables, such that as the number of syllables in a word increased, the proportion of fixations on the interest areas also increased. There was also an interaction of number of syllables and time, indicating less language mediation for longer words. While there was not a significant interaction of number of syllables and language skill, the 3-way interaction between number of syllables, language skill, and time was significant, demonstrating that increased language skill increases the effect of number of syllables on time.

In summary, children showed similar eye behaviors while listening to verbs read aloud in a story as they did in previous studies with noun phrases (Nicholls, 2020). That is, children fixated on illustrations corresponding to the verbs that were being spoken. The strength of the language-mediated eye movement increased as language ability increased in the children in this study. Additionally, lexical characteristics of verbs impacted children's eye movements. The

differing impacts of the lexical characteristics examined, and their relationship to language ability, will be discussed below.

Discussion

The purpose of conducting this study was to determine whether preliterate preschool-aged children exhibited language-mediated eye movements for verb stimuli. We also aimed to determine whether the lexical characteristics of the target verbs influenced preschoolers' eye movements and how language ability interacted with the lexical characteristics. The results of the study revealed 4-year-old children looked to the subject or object corresponding to the verb as the verb was being talked about in a storybook context. Additionally, it was found that different lexical characteristics (e.g., occurrence in story, age of acquisition, syllable length, frequency, and concreteness) influenced children's eye movements, and importantly, language ability contributed to many of these related eye behaviors.

Language-Mediated Eye Movements Associated With Verbs Are Moderated By Language Ability

The results of this study replicated previous studies by Nicholls (2020) and Luke and Asplund (2018), demonstrating that children look at illustrations that correspond to the words being read aloud. While the previous studies found this to be true for noun phrases, this study found that children similarly fixate on images corresponding to the subject and object of spoken verbs. Likewise, when the verb was not being talked about in the storybook, the children were less likely to be looking at the target images in that moment. This relationship was stronger for children with higher language skill. That is, for 4-year-old children, the higher the language skill, the more likely they were to be looking at the target interest area at that moment. It is important to note that this study examined subjects and objects of the verbs together in order to increase

statistical power rather than comparing the children's fixations on the subject versus the object while the verb was being spoken.

These results are consistent with previous literature which has demonstrated that language-mediated eye movements associated with noun phrases also differ according to language ability (Nicholls, 2020). While Nicholls (2020) found that children across all language ability looked at the relevant illustrations when the corresponding noun phrases were being read aloud, children with lower language abilities spent less time overall looking at the relevant images and more time looking at the irrelevant images when compared to peers with higher language abilities.

The results of the current study demonstrated children's ability to fixate on illustrations corresponding to the objects of the target verbs while the verb was being spoken, rather than waiting until the object was spoken. This is consistent with results from Altmann and Kamide (1999) and Nation et al. (2003) which showed children used verbs to make anticipatory eye movements to predict the end of the sentence by looking at the image of the object while the verb was being read and before the object was read aloud.

How Word Characteristics Of Verbs Interact With Language Ability for Language-Mediated Eye Movements

The lexical characteristics that were examined for each target verb will be discussed individually below.

Age of Acquisition

The results demonstrated that as the AoA of a given verb increased, so too did overall looks to the image(s) corresponding to the target verb. While this was true of all children regardless of language ability, the influence of AoA was stronger for children with higher

language skill. Thus, although all children demonstrated a novelty factor in looking to items they were less familiar with, individuals with higher language skill may have been more readily aware of words they did not know and demonstrated more visual interest in those items. That is, children with higher language skill exhibited eye movements that were more sensitive to differences in AoA. Not surprisingly, there was less focused language-mediated attention on images corresponding to verbs with higher AoAs. It is possible that this is because it took the children more time to determine what it was they should be attending to and what image corresponded to the later acquired verbs, showing a pattern of more distributed rather than focused attention across all children. Andreu et al. (2011) similarly found that different types of verbs caused children to be able to identify the corresponding image at different speeds. They found that it took both typically developing children and children with DLD longer to fixate on the target image of more complex verbs. It is possible findings of the current study demonstrate a similar effect with later acquired verbs, which are often also more complex. Notably, in this study, we were unable to determine AoA values for several verbs in the storybook so we recommend interpreting these results with caution. Future work should seek to include more verbs for which AoA values can be reliably calculated.

SUBTLEX Frequency

Interestingly, the spoken frequency of a given verb showed a different interaction with language skill than did AoA. Although looks to the target images increased as frequency increased for all children, this relationship was actually weaker for children with higher language skill. It is possible that for children with greater difficulty with language, the difference between high and low frequency words is much more influential to their eye behaviors. Conversely, children with higher language skill do not rely as heavily on their familiarity with verbs from

hearing them more frequently in order to attend to them in a storybook context. However, for children of all language abilities, an increased frequency of the target words allowed them to locate and fixate on the target image with increased focus than words with lower frequencies. Again, this is in line with findings from Andreu et al. (2011), as discussed previously. It is possible that more complex verbs (e.g., higher AoA) are used less frequently, causing children's' eye movements to behave similarly when hearing less complex (i.e., low AoA) and more frequent words.

Concreteness

Regardless of language skill, overall looks to the target increased as concreteness ratings increased. Likewise, children demonstrated more focused language-mediation for illustrations that corresponded to verbs with higher concreteness ratings. Although a trend was observed for children with lower language ability to depend on concreteness more so than children with higher language ability, the relationship was not statistically significant. For all children, concrete words are easier to learn than abstract words, because concrete word learning is reinforced by tangible experiences (Brysbaert et al., 2014). Thus, familiarity of the concrete verbs likely influenced their eye movements.

Occurrence in Story

The more times a word was repeated in the storybook, the fewer overall looks to the image the children made. However, this was not moderated by language proficiency. Regardless of language ability, it seems that increased repetition of a verb yields less interest in the corresponding images.

This brings up several questions about selecting storybooks for intervention that contain predictive and repetitive text. Storkel et al. (2019) found that while repetition of words in a

storybook increase word learning to a certain extent, after 36 repetitions in any combination (e.g., 6 repetitions of a word per story, repeated story reading six times or nine repetitions of a word per story, repeated story reading four times) word learning did not continue to increase with increased repetition. Because we did not manipulate or control for the number of times the verbs were repeated throughout the story, the conclusions that can be drawn about the effectiveness of repetition in word learning is limited, but this would be interesting to explore in future work. It is also possible that verbs with higher occurrences were looked at less in the moment the verb was being read aloud, but more right before the verb was spoken. If this were the case, it would show that increased repetition of words in a storybook reading may cause a certain amount of predictability for the children and cause them to look to the target images before the target word is spoken.

Number of Syllables

The analysis showed that as the number of syllables increased, looks to the target image also increased. However, the majority of the words in the story were only one syllable in length, with the mean number of syllables in the verbs in the storybook being 1.1 syllables in length. This, again, limits the conclusions we can make regarding the effect of the number of syllables on language-mediated eye movements. It is also noted that words with a higher number of syllables have, by definition, a longer duration, thus it is possible that because longer words are more distributed over time, the proportion of fixations was artificially increased.

Limitations

It is important to note possible limitations of this study. As mentioned, the composite language score used in the analysis included only subtests from the CELF-P2, and although that is in part due to the fact that other assessment scores and measures loaded onto the component

similarly, it was also because there was missing data for at least one participant for each of the other assessments. To increase statistical power and include as many participants as possible in the final analysis, assessments for which there was missing data were removed from the composite score. In addition to missing data for some participants' language assessments, the sample size for several of the lexical characteristics was limited by the databases used. For example, only 17 out of the 41 target verbs were listed in the AoA database, decreasing the number of verbs that were used in the AoA analysis in total. Thus, the reader is advised to interpret some results with caution.

There were also other limitations in the lexical characteristics examined. The SUBTLEX corpus is an adult word frequency corpus rather than a corpus of child word frequency. It was chosen because it is a spoken corpus rather than a written corpus, but nonetheless it is not specific to children. As this study investigates 4-year-olds' eye movements upon hearing the verbs in the story, it may be beneficial to analyze the interaction between a child word frequency corpus and language ability. Another possible limitation is that because the book that was selected for the eye-tracking experiment has a very simple language structure in which we did not manipulate the words, there are some questions that cannot be answered. For example, we did not manipulate the number of times different words were repeated in the story in order to adequately control "occurrence in the story." Additionally, most of the verbs in the story only had one syllable, which likely limited the degree to which we could fully examine the impact of word length on language-mediated eye movements.

Other limitations result from our largely homogenous sample of children. They were all monolingual English speakers whose parents volunteered them to participate in the research

study at Brigham Young University. Because of this, it is possible that the results are more generalizable to children from middle or high socioeconomic backgrounds.

Implications for Future Research

Future studies should use a more consistent measure of predictability that could include words that are controlled for occurrence in the story or an alternate measure of predictability such as a predictability rating compiled from a survey. It would also be beneficial to examine the lexical characteristics of target nouns as well to determine if they interact the same with nouns as they do with the verbs in this study. This study could be replicated using a child-specific frequency corpora, in order to confirm the conclusions drawn about the interaction of frequency with language ability. This study only included participants that were 4- and 5-years old, and future research should seek to discover if lexical characteristics are used differently for younger and older children. Importantly, the current study was not an intervention study, so future research should seek to determine whether specific techniques can be employed during storybook reading tasks to alter how and where children with low language ability attend to pictures during a storybook reading task. It would further be interesting to determine whether such techniques may impact word learning and/or comprehension processes in children with low language ability. Future work should also include a larger sample size of children with DLD. Ultimately, future intervention studies would benefit from using eye-tracking to determine whether children with lower language can learn to more closely mirror the language-mediated behaviors of children with higher language skill.

Clinical Implications

This study provides clinical implications regarding word stimuli used in treatment. Specifically, it shows that regardless of language ability, preschool children use AoA, frequency,

number of occurrences in the story, concreteness, and number of syllables to determine what to look at during a storybook reading. However, children with lower language skill rely more heavily on frequency and less on AoA than their peers with higher language skill, and they used concreteness, number of occurrences, and number of syllables in the same manner as children with higher language skill. Understanding the way in which children with lower language ability use lexical characteristics of verbs to dictate what they visually explore in reading activities allows clinicians to select books based on these different lexical characteristics to maximize word learning. Some children may need explicit instruction on what images they should be attending to during a storybook reading, requiring parents, teachers, and SLPs to point out where to look as they are being read to.

Conclusion

This study showed that, while being read a storybook, preschool children look at parts of the illustrations that refer to the verbs (subjects and objects) as the verbs are being spoken. This is similar to what has been found for noun comprehension (Luke & Asplund, 2018; Nicholls, 2020), and it is true regardless of language ability. However, children with higher language ability are more likely to be looking at the relevant images in the moment the target words are spoken than are children with lower language abilities. Additionally, lexical characteristics of the verbs, such as age of acquisition, frequency, concreteness, number of times the words occur in the story, and number of syllables in each word, impact the likelihood that the children are looking at the relevant images as the words are being spoken. Importantly, these lexical characteristics all interact differently with the children's eye behaviors, allowing clinicians to carefully select word stimuli for intervention based on what they are trying to achieve.

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APPENDIX A

Recruitment Flyer

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

Children and Reading
cablabbyu@gmail.com
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cablabbyu@gmail.com
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cablabbyu@gmail.com
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cablabbyu@gmail.com
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cablabbyu@gmail.com
Children and Reading
cablabbyu@gmail.com

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

Altmann, G. T., & Kamide, Y. (1999). Incremental interpretation at verbs: Restricting the domain of subsequent reference. *Cognition*, *73*(3), 247-264.

Objectives: This study seeks to understand whether or not verbs can direct someone's attention to a certain object based on the semantic information provided by that verb prior to the object being spoken.

Methods: 24 native English speakers from the University of York wore a head mounted eye-tracker as they looked at pictures accompanied with two sentences each. The two sentences only varied in the verb they contained. For example, there was a picture of a boy sitting on the floor with a toy train, a toy car, a balloon, and a birthday cake around him. The accompanying sentences for this image were "The boy will move the cake" and "The boy will eat the cake" where the verb "move" corresponds with all of the objects while the verb "eat" only corresponds with the cake. Each participant was asked to judge whether or not the sentence they heard could apply to the image they saw, but the eye-tracker data was showing when they actually looked at the target item. A second experiment was conducted and they followed the same procedure except the participants were informed that each picture would be shown while a sentence was read that may or may not be relevant to the image. This was intended to eliminate the explicit metalinguistic judgement task that is not necessarily a part of daily conversation.

Results/Conclusions: This study concluded that the verb can be used to guide someone's eye movements towards the appropriate object. Even the second experiment demonstrated these anticipatory eye movements, although they were slightly delayed.

Relevance to Current Study: The current study is similar in that it utilizes eye-tracking technology in order to determine how the verb allows for anticipatory eye movements to specific objects in a visual scene.

Behrend, D. A. (1990). The development of verb concepts: Children's use of verbs to label familiar and novel events. *Child Development*, *61*(3), 681-696.

Objectives: There is some evidence indicating that action verbs are developed earlier than result verbs. Study 1 in this article seeks to replicate and extend this evidence pertaining to action versus result verbs. The objective of study 2 is to see how children label events using verbs that they just learned, and to determine if there are any biases present in verb learning.

Methods: Study 1 - Researchers assigned an appropriate action verb, a result verb, and an instrument verb with events that would be watched on videotape by the participants. The participants were asked to label that event. The participants were 24 3-year-olds, 24 5-year-olds, 24 7-year-olds, and 24 adults between the ages of 18;8 and 26;4. In each videotape, there were 18 events in which an action was shown that included a change of state. After they labeled the action, they watched the video again and were asked if they could think of any more words to label the action. Study 2 - Novel verbs were taught to children and then they had to use the verbs they learned as labels for events in situations where the instrument, action, or result had changed from the event that was used to teach the verb to the participant. The subjects were 10 3-year olds, 10 5-year-olds. And 10 adults between 18;6 and 20;6. Each event was novel, meaning that it showed an unfamiliar instrument being used in an unfamiliar manner to yield a specific result. A nonsense word was taught to the participant as a label for this event. The

participants watched an event and the examiner taught them the novel verb. Then they watched another video clip that had changed in some way and they were asked if this was portraying the verb they just learned or something else. They were also asked to provide a definition of what they thought the novel verb meant after watching videos of it.

Results/Conclusions: The results included not only the first verb that each child used to label each event but also all the verbs that were used to label each event after they were asked if there were any more words they could use to label the events. Age was a significant predictor to determine which types of verbs they used as their first label. 3-year-olds used fewer instrument verbs out of all of the other ages and adults used more instrument verbs than any other age. The opposite of this is true for action verbs, in that 3-year-olds used the most and adults used the fewest. There were no significant differences in the number of result verbs used with age. Study 2 - The results demonstrated that changes to the result had the largest impact on participants using the novel verb in the second event, and action changes had the second greatest impact while instrument changes had the least amount of impact. Age did not make a significant difference. Producing definitions for the novel verbs increased with age. Study 1 concluded that though used less frequently by younger children, instrument verbs were the most common verbs used and they were most often used as first verbs. 3-year-olds used more action verbs and adults used result verbs and instrument verbs more often. Study 2 found that individuals of all ages are less likely to use a verb they just learned if the result of the event is different than the result of the event in which they learned the verb.

Relevance to Current Study: "It is certainly true that research on the development of verb concepts has lagged far behind that for noun concepts." Previous research studies have demonstrated that when compared to nouns, children develop verbs slower and later. There is still much to be learned about verb learning and acquisition in typically developing children before we can fully understand how that differs in children with language impairment. The current study seeks to determine how differences in verb knowledge between typically developing kids and kids with language impairment impact their pre-literacy skills, so we first must understand what verb learning is like in typically developing children.

Carr, L., & Johnston, J. (2001). Morphological cues to verb meaning. *Applied Psycholinguistics*, *22*(4), 601-618.

Objectives: This study intended to further investigate the results of the first study and see if they applied to children with SLI.

Methods: In the first study, 21 children were broken into two groups. One group contained children between 3;6 and 4;3 and the other group was made up of children between 4;5 and 5;2. The participants listened to novel verbs that were inflected with -ed or -ing and they were instructed to select a corresponding event. Some of the events maintained the activity and some maintained the result. In the second study, there were nine children between the ages of 4 and 5 with Specific Language Impairment. These children participated in the same task that was described in the first study.

Results/Conclusions: In the first study, children in the younger group used the verb inflection in order to choose the appropriate event. They selected events that maintained the activity when they heard -ing verbs and events that maintained the result

when they heard -ed verbs. Children in the older group selected events that maintained the result regardless of inflection. In Study 2, the group of children with SLI showed that they did not use the same strategy as the younger children or the older children in the first study. This study demonstrated that earlier in development, children will use the inflection of a verb to infer its meaning, whereas when they are older, they replace that strategy with a same-result bias. However, while this is true of typically developing children, kids with SLI do not follow the same pattern.

Relevance to Current Study: The current study is seeking to determine how verbs may allow children to anticipate events in storybook contexts. This is related to the Carr and Johnston study in that they were trying to determine how children use morphology to supplement their verb knowledge, and how typically developing children differ from children with SLI in their bootstrapping abilities.

Kaefer, T., Pinkham, A. M., & Neuman, S. B. (2017). Seeing and knowing: Attention to illustrations during storybook reading and narrative comprehension in 2-year-olds. *Infant and Child Development*, *26*(5), e2018. https://doi.org/10.1002/icd.2018

Objectives: This study had three primary purposes. They sought to find out if toddlers demonstrated story comprehension after a single reading. They also asked the question of whether or not toddlers comprehension is impacted by their vocabulary knowledge, prior reading experiences, and attention to key images corresponding to key narrative events. The last question they asked was whether or not toddler's prior reading experience and vocabulary knowledge influences their attention to the key narrative events.

Methods: 68 children between 23 and 36 months listened to *Tom and Pippo and the Bicycle* (Oxenbury1994) while they looked at the illustrations. Tobii eye-tracking

technology was used to record their eye movements while they listened to the story. Following the storybook reading, the children were administered a receptive test in which they looked at illustrations that included the target image and two foils. They were asked to point to the target item that answered a question about a key story event. Their expressive vocabulary was also measured using the MacArthur-Bates Communicative Inventories.

Results/Conclusions: The toddlers with higher vocabulary scores had a tendency to attend to more illustrations that depicted key narrative events, and the toddlers who attended more to those key narrative event illustrations demonstrated greater memory for those events on the receptive test.

Relevance to Current Study: Like the current study, this study examined children's eye behaviors during a storybook reading. The current study is intended to draw conclusions about a child's comprehension based on which storybook illustrations they are attending to.

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.

Objectives: The objectives of this study were to determine if preschool children's eye movements during shared storybook reading are language-mediated and if their eye movements are predictive as compared to the adult controls.

Methods: 41 children between the ages of 3 and 5 participated in this study. All of the children were preliterate native English speakers. 41 adults participated as the control group, who were native English speaking college students at Brigham Young University. The storybook used for this study was *The Happy Man and His Dump Truck (*Miryam &

Gergely, 2005), and it was chosen because it had a high number of noun phrases that were depicted by visual illustrations in the book. The book was scanned in order to be presented on a computer screen. Interest areas were created for each page that corresponded to noun phrases in the text (e.g., the man, the pig, a farm, etc.) for a total of 2-8 interest areas per page. Audio files were created of a female native English speaker reading the text at a normal speaking rate. For the adults, the text of the storybook was deleted from the picture files so they could not read along instead of looking at the illustrations. The adults' and children's' eye movements were recorded while they sat 60 cm away from the screen. The children participants sat in a booster car seat for extra head and neck support. A calibration task occurred before the storybook task, and participants' eye movements were re-calibrated each time they got out of the booster seat and got back in. After calibration, the storybook pages began to appear with their corresponding audio files playing. Each child participant watched and listened to the storybook two times to ensure accurate data collection; however, the adults only completed the task once.

Results/Conclusions: Parent survey information indicated that the child participants had easy access to books at home, the children have been read to from an early age (5.4 months of age on average), and that the children are interested in storybook reading. The study also revealed that preliterate children focus primarily on the illustrations of the storybook, not the text. No differences were observed between the adults and the children.

Relevance to Current Study: Shared storybook reading provides a natural context for children to exhibit language-mediated eye movements. We already know that shared storybook reading can contribute to child language development, but our current study

seeks to find out what is different between kids with typical language and kids with lower language skills when they are engaged in shared storybook reading.

Nash, M., & Donaldson, M. L. (2005). Word learning in children with vocabulary deficits. *Journal of Speech, Language, and Hearing Research*, *48*(2), 439–458. https://doi.org/10.1044/1092-4388(2005/030)

Objectives: This study was intended to examine the way word-learning difficulties present in children with Specific Language Impairment, as well as determining if the way new words are presented to children impacts their overall word-learning difficulties.

Methods: 16 children with SLI and 32 children with typically developing language participated in this study. The children all heard some novel verbs in a storybook context and some in a teaching task. Then, the children were administered five different tasks to determine what they had learned about the new words after hearing the word six times and then after 12 more repetitions of the words.

Results/Conclusions: Overall, the kids with SLI demonstrated less of an understanding of the words than the chronologically age matched children but similar to the vocabulary matched children. The study concluded that children with SLI not only have greater difficulty with learning the semantic content of novel verbs, but also phonological aspects of word learning.

Relevance to the Current Study: The current study seeks to compare kids with lower language abilities to their typically developing peers on the premise of how word knowledge impacts their ability to predict which word will complete a sentence in a storybook context.

Nation, K., Marshall, C. M., & Altmann, G. T. (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.

Objectives: Nation and colleagues seek to determine if children's comprehension abilities impact their ability to use verbs to predict an appropriate visual object.

Methods: 11 "less-skilled comprehenders" aged 10 and 11 and 11 age matched control children were shown four clip art images where 1 quadrant contained the target noun and the other three were distractor items. The children heard two sentences which differed only by the verb. For example, the two sentences could have been "Jane watched her mother choose a cake" and "Jane watched her mother eat the cake" where the first sentence contains a neutral verb (meaning that verb isn't specific to the target noun) and the second sentence contains a supportive verb (meaning that verb is specific to the target noun). The participants were seated in front of a touch screen monitor displaying the images, and they wore a head mounted eye-tracker. They were instructed to touch the image when they heard the name of the corresponding picture, and the eye-tracker data showed at which point they were actually looking at the target item.

Results/Conclusions: The study supported findings from Altmann and Kamide (1999) and demonstrated that the supportive verb allowed for earlier looks to the target object than did the neutral verb. It also showed that both "less-skilled comprehenders" and their typically developing peers make anticipatory eye movements based on the verb. Less-skilled comprehenders actually made more separate glances to the target image, but interestingly, when the total amount of time spent looking at the target was added up, the less-skilled comprehenders spent less time looking at the target object. This indicates that

the less-skilled comprehenders would look at the appropriate object, but they would not focus their gaze on that object like their typically developing peers.

Relevance to Current Study: This is similar to the current study in that it was examining the differences between eye movements of typically developing children versus their peers with lower language abilities. They used eye-tracking technology to see if the verb causes anticipatory eye movements, similar to the current study.

The following sources were used to compile lexical characteristics for each target word in the storybook:

Brysbaert, M., & New, B. (2009). Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods*, *41*(4), 977-990.

SUBTLEX-US Corpus: The number reported from this corpus is the frequency count. In other words, it is the number of times the word appears in the corpus.

Brysbaert, M., Warriner, A. B., & Kuperman, V. (2014). Concreteness ratings for 40 thousand generally known English word lemmas. *Behavior Research Methods*, *46*(3), 904-911.

Concreteness Ratings: It is theorized that concrete words are easier to learn and remember than abstract words. These concreteness ratings were obtained by having participants assign a rating of 1-5 going from abstract to concrete. Concreteness was defined as able to be experienced directly through at least one of the five senses.

Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012). Age-of-acquisition ratings for 30,000 English words. *Behavior Research Methods*, *44*(4), 978-990.

Age of Acquisition Ratings: Participants were asked to report at what age they had

learned the target words. In this case, learned was defined as having the ability to understand the word when used by someone else even if the participant themselves was not using the word in his or her language output.