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The Effects of Symbol Format on Receptive Syntax Outcomes of Children Without Disability

by

Jamie Zolkoske

A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Science in the Department of Communication Sciences and Disorders

Idaho State University

May 2021

Committee Approval

To the Graduate Facility:

The members of the committee appointed to examine the thesis of Jamie Zolkoske find it satisfactory and recommend that it be accepted.

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Human Subjects Committee Approval

April 22, 2020

Kristofer Brock
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RE: Study Number IRB-FY2020-216 : The Effects of Symbol Format on Receptive Syntax Outcomes of Children With and Without Disability

Dear Dr. Brock:

Thank you for your responses to a previous review of the study listed above. These responses are eligible for expedited review under OHRP (DHHS) and FDA guidelines. This is to confirm that I have approved your application.

Notify the HSC of any adverse events. Serious, unexpected adverse events must be reported in writing within 10 business days.

You may conduct your study as described in your application effective immediately. The study is subject to renewal on or before April 22, 2021, unless closed before that date.

Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Tom Bailey (208-282-2179; email humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen,
PhD, MPH, CIP
Human Subjects
Chair

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The Effects of Symbol Format on Receptive Syntax Outcomes of Children Without Disability

Thesis Abstract--Idaho State University (2021)

The foundation of augmentative and alternative communication (AAC) includes the combination of graphic symbols to create messages, but research has focused solely on static graphic symbol messages in spite of mainstream commercial technologies such as animation. This study investigated the effects of symbol format (animation and static) on identification accuracy and reading accuracy (labeling) of graphic symbol sequences (5-symbol) in 7- and 8-year-old children with typical development. Paired samples t-tests indicated significant differences between the symbol formats for both the four-choice identification task and the reading task. Animated sentences were identified and read with greater accuracy when compared to static sentences; however, response latency differences were negligible. Overall, animations facilitated identification accuracy and symbol sequence interpretation in this sample. Limitations and future directions are discussed.

Keywords: Augmentative and alternative communication animation; Animation, Graphic symbols; Identification; Receptive syntax

Chapter I: Introduction

It was estimated that 7.6% of children with developmental disabilities (e.g., autism spectrum disorder) have a communication and intellectual impairment so severe that they require an augmentative and alternative communication (AAC) system to replace or supplement natural speech (Keeney & Kogan, 2011). Moreover, AAC strategies or techniques, such as graphic symbols, can facilitate language learning for those with and without specific language impairment (Beukelman & Mirenda, 2013; Branson & Demchak, 2009; Diehm et al., 2020; Fujisawa et al., 2011). AAC is often a contentious topic among caregivers and professionals; specifically, some believe that AAC will hinder speech and language development (Schlosser, 2003; Schlosser & Wendt, 2008). However, the data are quite clear in that AAC positively impacts language development, including spoken language (Allen et al., 2017; Millar et al., 2006; O'Neill et al., 2018).

However, there are two areas in which the data are not clear: (a) application of animation technology to graphic symbols to support communication and (b) the accurate interpretation of multi-symbol sentences or sequences. First, research into animated symbol technology is in its infancy with the majority of work analyzing single symbol identification and naming. Second, there are no data concerning animated multi-symbol sequences. All of the research to date has investigated how children interpret relatively simple static symbol sequences (e.g., subject-verb-object), and the results are mixed (Binger et al., 2017; Sutton et al., 2010). Binger et al. (2017) found the 5-year-olds who required aided communication were able to construct subject-verb-object (SVO) symbol messages with ease while Sutton et al. (2010) found that 3-year-old children with typical development had difficulty constructing and interpreting similar symbol messages. Therefore, the purpose of this study is to investigate the effects of animated and static graphic symbol sequences on receptive syntax outcomes in children with typical language development.

Chapter II: Literature Review

Graphic Symbol Format

The majority of AAC users only have access to a single graphic symbol format to learn and interpret spoken language: static symbols (Allen et al., 2017). Research in the last three decades has primarily explored nouns depicted as static symbols because nouns are easily depicted graphically (Allen et al., 2017; Schlosser & Sigafoos, 2002). The ease with which nouns are depicted graphically can be explained by several principles such as word frequency (Bastiaanse et al., 2016), age of acquisition (Genter, 1978; Nelson, 1973), and iconicity (Fuller & Lloyd, 1992). Given that the purpose of this study is to compare two symbol formats (animated and static), the iconicity principle is rather important. Fuller and Lloyd (1992) defined a transparent symbol as one that depicts the visual relationship to its referent well, and therefore is more easily understood by looking at the symbol. The principle states that transparent graphic symbols are not only easier to teach, but are also acquired for communication purposes much sooner than translucent or opaque symbols (Fuller & Lloyd, 1992). In contrast, translucent symbols (i.e., the symbol and the referent must be paired by the clinician to understand their visual relationship) and opaque symbols (i.e., no visual relationship with the referent) require additional therapy time to teach the symbol-referent relationship. Most nouns tend to be transparent or translucent, therefore making them easier to teach; however, nouns offer very little for expanding an AAC user's communicative functions (e.g., informing, interacting, questioning, and requesting) or syntax. Verbs that are action-based are not as easily depicted graphically secondary to their inherent movement, but verbs do have the added benefit of activating a lemma (i.e., information associated with a concept) which includes semantic information, thematic roles, and argument structure (Levelt, 1989). For example, the verb *feed* takes additional arguments in the sentence, "The mom *[agent] feeds* lunch *[patient]* to her baby *[goal]*." Professionals can teach verbs and assist children with mapping additional words onto those verbs. Therefore, from a morphosyntactic perspective, verbs may be better treatment targets than nouns due to their potential for expanding communicative functions and syntactical structures. While research indicates that static symbols can be used effectively to support comprehension and expression across the domains of morphosyntax and semantics (Allen et al., 2017; O'Neill et al., 2018), there have been no studies comparing different symbol formats (static vs. animated) to determine the most effective symbol modality.

According to Bétrancourt and Tversky (2000), animation is defined as "any application which generates a series of frames, so that each frame appears as an alteration of the previous one, and where the sequence of frames is determined either by the designer or the user" (p. 313). Höffler and Leutner (2007) stated that animation conveys important movement-based information over time which provides an external mental representation of the word that may reduce the demands of working memory. Animation may therefore compensate for the complex task of creating a mental representation of the movement, which enhances comprehension of the concept. Previous research in multimedia learning has shown positive learning outcomes for typically developing adult populations when they are exposed to animation (Berney & Bétrancourt, 2016; Höffler & Leutner, 2007). Berney and Bétrancourt (2016) conducted a meta-analysis of hundreds of studies and found that animation may contribute to decreased cognitive load when learning new material. Similar results were found in another meta-analysis by Höffler and Leutner (2007) who reported that 71% of comparisons between animation and static graphics indicated an advantage for animations, resulting in a small to medium effect size.

While there is positive evidence on the effectiveness of animations, there are also some associated disadvantages. First, animation can create a shallow understanding of a concept. This illusion of understanding occurs when an individual believes that they fully comprehend a concept because of the use of animations (Schnotz & Lowe, 2003). Scholars have suggested that this may be due to a decreased allocation of cognitive resources to the information when provided with animations (Schnotz & Lowe, 2003). Other authors have discussed how animations may also result in information overload. Excess and complex information presented in conjunction with animation along with the transient nature of movement may reduce its effectiveness (Jones & Scaife, 2000; Lowe, 1999; Mayer & Moreno, 2002). However, a more comprehensive investigation is required to fully understand this concept. These disadvantages should be considered when deciding how animations can be used in populations with little to no functional speech. With the proliferation of consumer-level technologies, researchers have begun to investigate the effects of animated graphic symbols on the comprehension and expression of verbs and prepositions in the hopes of enhancing these once opaque word classes (Schlosser et al., 2014, 2019).

The research of animation technology within AAC is still in its infancy, but previous studies have demonstrated positive effects of animation at the single word level during naming and identification tasks (Fujisawa et al., 2011; Mineo et al., 2008; Schlosser et al., 2014, 2019). For example, previous studies found that children with ASD and those with typical development identified stimuli representing animated verbs given a spoken word more readily than their static counterparts (Mineo et al., 2008; Schlosser et al., 2019). In another study, Fujisawa et al. (2011) found that participants with intellectual disability named animated symbols more readily than their static counterparts in a single symbol naming task. Lastly, Choe et al. (2020) found that 5 participants aged 6 to 9 years with autism had a 52% accuracy rate when acting out a given animated symbol sequence. Unfortunately, no control condition (e.g., static sequences) was used to make a comparison between static and animated conditions. Although it is still unclear as to why, researchers believe that animations present clearer representations of the referent, increased attention to the stimuli, and an overall reduced demand on working memory (Thistle & Wilkinson, 2013). Moreover, the stimulus movement effect suggests that individuals may better understand these animated word classes because of the built-in priority for movement in our visual-perceptual system (Franconeri et al., 2004; Nealis et al., 1977). While these studies offer proof of concept, the experimental identification and naming tasks are not representative of most multi-symbol AAC systems, nor does it generalize to daily communication. However, the facilitative effects of animation at the single word level suggest that animation may be a method to improve comprehension and production of more complex syntactic language structures for individuals using AAC.

AAC and Receptive Syntax

Individuals who use AAC systems rely on graphic symbol sequences for their expressive communication and comprehension of spoken messages. Previous research has also prioritized expressive communication which subsequently created a large gap in the literature with respect to comprehension. Allen et al. (2017) noted that the AAC literature is devoid of intervention research focusing on receptive syntax outcomes. However, there are several processing studies investigating the effect of static symbol messages on receptive syntax. Specifically, researchers have studied receptive syntax using two- to four-static symbol sequences that were interpreted by typically developing individuals and individuals with developmental disabilities (ages 3 - 49 years) through various tasks: (a) act-out tasks in response to a video clip or spoken sentence (Trudeau et al., 2014), (b) forced-choice identification (Sutton et al., 2004; Sutton et al., 2010; Trudeau, Morford, et al., 2010; Trudeau, Sutton, et al., 2010), (c) act-out tasks in response to a graphic symbol sequence (Boyer et al., 2012; Choe et al., 2020; Trudeau et al., 2014), and (d) reading graphic symbol sequences (Boyer et al., 2012; Trudeau et al., 2014). Given the purpose of this study, only the identification and reading graphic symbol sequence tasks will be discussed in the following paragraphs.

One task that is often used in receptive syntax and AAC literature is forced-choice identification. Several studies have implemented two- and four-choice identification tasks in children and adults with and without disabilities. Previous research has explored this paradigm by evaluating the overall accuracy of responses as well as the consistency of responses to these stimuli. Overall, results indicated that participants had low accuracy when matching photographs to canonical and non-canonical sequences. Additionally, participants became more consistent responders as they got older. First, Sutton et al. (2004) provided a two-choice array along with reversible agent-action-patient sequences. They found that adult participants who used AAC for daily communication chose the photograph that represented the word order that most closely replicated spoken word order (e.g., N1 V1 N2 (V2) N3; "The girl pushes the clown who wears a hat") in 75% of responses. However, 19/25 participants did not consistently select differing word orders to represent object relative clause (OS) (e.g., “The girl pushes the clown who wears a hat”) and subject relative clause (SS) structures (e.g., “The girl who pushes the clown wears a hat”) which convey two different meanings. Sutton et al. (2010) studied the identification of SVO sequences in typically developing preschoolers given a four-choice array. The sequences were presented electronically with natural speech output. Across all participants and sentences, the correct response was chosen about 52% of the time.

Next, Trudeau, Morford, et al. (2010) investigated the consistency of responses to 3- and 4-symbol canonical and non-canonical symbol sequences in typically developing preschoolers through adults. In this study, participants demonstrated low consistency in their responses to these structures. Specifically, more participants became consistent responders across sentence types as their age increased, with an overall mean of 37% of preschoolers and 92% of adults being consistent responders (i.e., identified the correct response on 75% of trials). While preschoolers did not show a preference for specific interpretations, school-age children often assigned the agent to the first noun in the sequence regardless of whether the sentence was canonical (e.g., “girl push clown”) or non-canonical (e.g., “girl clown push,” “push girl clown”). On the other hand, teenagers and adults often assigned the agent to the first noun in canonical and 3- and 4-symbol verb-final sentences and to the second noun in 3- and 4-symbol verb-initial sentences. On 4-symbol sequences, these participants assigned the attribute (e.g., scarf or hat) to the noun immediately preceding it. These results also showed that individuals who have little experience with AAC can use word order strategies to assign meaning to graphic symbol sequences with the caveat that as participants got older, they relied on word order strategies more to interpret these sequences.

Trudeau, Sutton, et al. (2010) used similar methods to replicate Trudeau, Morford, et al.’s (2010) findings in individuals aged 8 to 49 years of age who used AAC. A participant was considered a stable responder if they chose the corresponding photograph in 75% of responses that matched the noun-verb phrase in simple sentences and the correct agent (i.e., subject) in complex sentences (i.e., noun-verb-noun sentence with added attribute to one of the characters). Overall, 54% of participants showed stability on all structures. Like the typically developing participants in Trudeau, Morford, et al. (2010), many participants who used AAC elected a word order strategy to assign meaning to the symbol sequence (e.g., assigning the attribute to the noun immediately preceding it). The low percentage of consistent responders in these studies show that graphic symbol sequences can be difficult to understand, often resulting in inconsistent interpretation across individuals.

Another common task that has been implemented in previous research is the reading, or labeling, symbol sequences task. Boyer et al. (2012) and Trudeau et al. (2014) used this task to measure 3- to 6-year-old typically developing participants’ comprehension of graphic symbol sequences. Both studies presented an SV or SVO symbol sequence and asked the children to read (label) the sequence aloud. Responses were considered correct if all symbols were stated in the correct order, but articles and conjugations were not required or scored if present. These two studies had differing results, with over 90% of all participants passing the reading task in the study by Boyer et al. (2012) and accuracy ranging from 35% in 3-year-old participants to 91% in 6-year-old participants in the study by Trudeau et al. (2014). Children who used conjugated verbs in their verbal responses for the reading task tended to perform more accurately on the act-out tasks in the same studies. This may be due to the child comprehending the sequence as a full sentence, rather than individual symbols that are unrelated. Participants' use of conjugated verbs increased with age. Data in this area are consistent in that younger, typically developing children may have more difficulty interpreting simple symbol sequences. This has direct implications for AAC users who may be chronologically or developmentally young.

One limitation to studies of AAC and receptive syntax is that animations have not been studied. Animations have shown positive effects for children with and without disabilities at the single word level. For children who do not assign meaning to the sequence and therefore have more difficulty interpreting these sequences (e.g., those who labeled the symbols rather than forming a complete sentence with conjugation), animations may be used to help these children connect the individual units to form meaning. Additionally, if animations can provide more context for opaque word classes (e.g., verbs and prepositions), like they have been seen to do in single words, their meaning will be more explicitly understood. This may result in a more complete understanding of these sequences and more consistent interpretations across all age groups.

In sum, animation is a promising method used to enhance labeling and identification of graphic symbols; however, previous animation research has focused on (a) the theoretical underpinnings, (b) typically developing child and adult populations, and (c) experimental tasks that do not reflect everyday communication challenges. To date, there are no data comparing the effects of symbol format (animated and static) on the comprehension of graphic symbol sequences in any population. These data are needed to understand the role of symbol format, specifically the use of animations, in AAC and receptive syntax. With a refined understanding about the benefits of animation in AAC, animation may be found to be a clinical tool to reduce the time spent teaching individual symbol meaning and improve individuals' understanding of more complex language structures. In turn, this facilitating effect could also provide clinicians with additional time to teach more complex academic constructs. Therefore, the purpose of this study is to determine the effects that symbol format (animated and static) has on the comprehension of graphic symbol sequences and response time; specifically, an identification and reading (e.g., labeling) task were implemented. While the term 'reading' is used to describe this task, it should be noted that this was more of a labeling task and it is not possible to confirm comprehension of the sequence labeled. Since there are currently no data regarding symbol format and receptive syntax, this research line will first focus on outcomes from typically developing children to explore proof of concept. The following research questions will be addressed:

1. What are the effects of symbol format on the identification accuracy of a photograph corresponding to a graphic symbol sequence in typically developing children between 7;0 and 8;11 years of age?
2. What are the effects of symbol format on the response time for identification of a photograph corresponding to a graphic symbol sequence in typically developing children between 7;0 and 8;11 years of age?
3. What are the effects of symbol format on the reading (e.g., labeling) of a graphic symbol sequences in typically developing children between-7;0 and 8;11 years of age?

Chapter III: Method

Participants

Children with typical development between 7;0 and 8;11 years of age were recruited for this study. Table 1 provides demographic information for all participants. Each child met the following inclusion criteria: (a) proficient in English or English as the primary language spoken in the home, (b) no history of speech, language, cognitive, motor impairments or uncorrected vision or hearing impairment, (c) standardized language assessment score within 2 standard deviations of the mean as indicated by the *Oral and Written Language Scales* (OWLS-2; Carrow-Woolfolk, 2011), and (d) 100% knowledge of all words used in this study as indicated by a screening task or caregiver confirmation.

Setting

All children were recruited from local school districts, daycares, and personal connections nationwide. The study was completed in quiet rooms within the home using Zoom video conferencing.

Experimenters

The experimenters included a certified speech-language pathologist researcher and graduate student research assistant.

Table 1

Participant Demographic Information

Participants	CA *M* (*SD*)	*OWLS* SS *M* (*SD*)	Gender	
24	94.3 (6.49)	106 (11.2)	12 M	12 F

Note. CA = Chronological Age in Months

Power Analysis

An a-priori power analysis was calculated using G*Power 3.1 (Faul et al., 2007). The dependent means (matched pairs) power analysis at alpha = .05 with an expected effect size of .5 indicated that a sample size of 34 participants is required. A large effect size was used secondary to the large differences found between animated and static conditions in previous studies (Harmon et al., 2014; Schlosser et al., 2014, 2019).

Research Design

A within-subjects design was used to determine the effect of graphic symbol sentence format (i.e., animation and static) on the identification accuracy of a corresponding photograph, response latency, and symbol sequence interpretation accuracy (i.e., reading/labeling out loud). The order of task presentation (identification and reading) and symbol format was counterbalanced across participants. The presentation of the symbol sequences was randomized twice, once for each condition and implemented in that order across participants. The time between each of experimental sessions was less than 3 weeks to control for developmental effects. Finally, this research was approved by the institutional review board.

Materials

Verbs, Prepositions, and Nouns

Transitive verbs, those that mandate a direct object, were used in this study. The 18 verbs used in this study included: *blow, bounce, catch, cover, close, cut, drop, eat, give, hit, kick, open, pick up, pull, push, ride, take,* and *throw*. Three additional verbs, *climb*, *hug*, and *draw*, were used in the familiarization task but were not included in the experiment or data analysis. Seven prepositions were used in this study: *behind, in, next to, off, out, over,* and *under*. Three additional prepositions, *on, between*, and *in front*, were used in the familiarization task but were not included in the experiment or data analysis. These verbs and prepositions were chosen because according to Huttenlocher et al. (1983), each emerges early in a child's lexicon (i.e., 3 years of age). Additionally, these verbs were selected from the *MacArthur-Bates Communicative Development Inventories* (Fensen et al., 2007). According to the SUBTLEXus word frequency database (Van Heuven et al., 2014), the frequency of each verb ranged from 9.84 to 1891.04 per million words with an average of 300.66. The frequency of each preposition ranged from 15.18 to 3865.31 per million words with an average of 1006.33. See table 2 for the word frequency per million words for each target verb and preposition in the study.

In addition to word frequency data, information was gathered for all verbs and prepositions used in the study about their imageability and concreteness. Imageability refers to the ease with which an individual can form a mental image of a word (Friendly et al., 1982). On a scale from 1.00 to 7.00, the imageability for each verb ranged from 3.65 to 6.13 with an average of 4.85. The imageability for each preposition ranged from 1.70 to 6.18 with an average of 3.68 (Brysbaert et al., 2014; Cortese & Fugett, 2004). Lastly, concreteness is how easily a word is perceived by the five senses (Friendly et al., 1982). On a scale from 1.00 to 5.00, the concreteness for verbs ranged from 2.83 to 4.55 with an average of 3.87. The concreteness for prepositions ranged from 2.46 to 3.67 with an average of 3.02 (Brysbaert et al., 2014). See table 2 for imageability and concreteness data for each target word.

Table 2

Target Verb and Preposition Word Frequency and Imageability Data

Target Word	Word Frequency (per Million Words)	Imageability	Concreteness
Blow	97.57	4.74	3.74
Bounce	9.84	5.19	3.86

Catch	135.51	4.44	4.11
Close	219.43	3.97	3.20
Cover	94.27	4.23	4.23
Cut	229.76	6.13	4.55
Drop	130.61	4.64	4.21
Eat	251.88	5.65	4.44
Give	1167.82	3.65	2.83
Hit	275.00	5.59	4.11
Kick	73.41	5.83	4.33
Open	320.41	4.49	3.21
Pick up/Lift	34.14	4.89	3.89
Pull	146.45	4.42	3.97
Push	70.55	5.06	4.21
Ride	135.37	5.42	3.75
Take	1891.04	3.89	3.06
Throw	128.82	5.09	4.04
Behind	187.86	4.25	3.48
Inside	211.27	1.70	3.67
Next to/Beside	15.18	3.30	2.59
Off	1179.51	2.60	2.79
Out	3865.31	6.18	2.73
Over	1323.29	3.59	2.46
Under	261.92	4.13	3.45

To create the sentence stimuli, 17 nouns were needed: *apple, ball, basketball hoop, bike, box, bubbles, cars, cat, chair, dog, house, ladder, paper, rock, spoon, tree,* and *wagon*. According to the SUBTLEXus word frequency database (Van Heuven et al., 2014), the frequency of each noun ranged from 5.98 to 514.00 per million words with an average of 109.77. Additionally, the majority of these nouns are known to children by 3 years of age.

Graphic Symbols

Thirty-one static and animated Autism Language Program (ALP) Graphic Symbols, corresponding to the 31 verbs and prepositions, were used in this study. ALP symbols were chosen for two reasons: (a) this symbol set was designed specifically for children with ASD and (b) the symbol set developers created the animated symbols first. From the animations, developers created the static symbols using a single frame of the corresponding animated symbol, which resulted in two symbol formats identical in every way with the exception of movement (Schlosser et al., 2012, 2014, 2019). Previous studies reached consensus regarding the single static frame that best encompassed the verb and preposition's movement. The ALP symbols in this study were 2 x 2 inches in size.

Additional Picture Communication Symbols (PCS; Tobii Dynavox, 2021) were required to construct the sentence stimuli because the ALP symbol developers only included verbs and prepositions in their set at the time of the study. Therefore, all other noun-based symbols, except for "Woody," "Buzz," "Bo-Peep," "Spongebob," and "Patrick," were PCS symbols. The character symbols were cartoon line drawings akin to the PCS set. The PCS and character symbols in this study were 2 x 2 inches in size.

Finally, a total of 84 scenes were constructed using toy figurines and props that matched the sentences used in the familiarization and experimental tasks. Using an Apple iPhone 6s Plus with a 12-megapixel camera, photographs were taken of the scenes which depicted the 84 canonical (e.g., subject-verb-object-preposition-prepositional complement;

"Woody rides the bike inside the house") sentences. The photographs were arranged in a four-choice array. The photographs in this study were 2.05 x 4 inches in size. However, due to the online administration of all tasks, we cannot ensure that the participants viewed the photographs at this size as they completed the tasks through whatever device was available to them, regardless of screen size.

Sentences

The research team created 84 canonical sentences, or simple declarative sentences that follow an English constituent order (e.g., SVO; "Woody rides the bike inside the house") for the identification task; however, only 21 sentences (see Appendix A) were the intended experimental target. The remaining 63 sentences were incorrect foils. These 63 foils followed a consistent format with specific words that were incorrect: (a) N1 V N2 P(incorrect) NP (e.g., "Woody rides the bike next to the house"), (b) N1 V(incorrect) N2 P NP (e.g., "Woody pushes the bike inside the house"), and (c) N1 V(incorrect) N2 P(incorrect) NP (e.g., "Woody pushes the bike next to the house"). Thus, the identification task had 21 trials total and each trial included the intended target sentence and three foils (see Figure 1). Next, the reading task used the same 21 sentences for a total of 21 trials. The participants were exposed to a single sentence at a time. Finally, in the animated conditions of the identification and reading tasks, only the verb and preposition were animated in the graphic symbol sequence, while the remaining symbols were static. For example, "Woody [static] blows [animated] the bubbles [static] behind [animated] the rock [static]." In the static condition, all symbols in the sequence were stationary.

Hardware and Software

A Lenovo Yoga 730 laptop computer with a 13-inch display, an Intel Core i7 processor, and a 2.0- GHz processor speed with 8 GB of memory was used to present the experimental task. The tasks were delivered using Microsoft PowerPoint® through a video conferencing tool. A Lenovo YOGA Mouse with wireless Bluetooth capabilities or the arrow key on the keyboard (when using video conferencing) was used to advance through the PowerPoint. All experimental sessions were recorded through the, video conferencing software and the caregivers' smartphones for inter-rater reliability, procedural integrity, and response latency purposes. Finally, video editing software was used to calculate response latency in seconds (see Dependent Variables and Measures for response latency calculation).

Procedures

All experimental procedures, from consent to completion of the study, were completed through video conferencing. Video conferencing was used secondary to COVID-19 regulations. For each experimental test or task, specific modifications were made to ensure reliable and valid data collection via video conference. For example, caregivers were instructed not to assist their children in any aspect of the study. Appendix B provides those modifications for the knowledge of words screener, standardized assessment tasks, and the experimental identification and reading tasks. This appendix was provided to parents as a research facilitation tool with specific information about recording, video conferencing use, and other procedures. General Zoom conferencing procedures are also discussed within the text below.

For each day, the caregiver was instructed to connect to the video conference meeting using a laptop/computer/tablet. The child interacted with the researcher on this device. Additionally, they were instructed to film their child's behaviors and responses to the experimental tasks using a smartphone device. This device was silenced and had "airplane mode" enabled to silence any push notifications, texts, and calls.

Knowledge of Words and Standardized Assessments

During session 1, participants were administered two, 30-minute receptive language tasks: knowledge of words screener and *Oral and Written Language Scales-2* (*OWLS-2*;

Carrow-Woolfolk, 2011). The tasks were administered through a video conferencing modality with a 5-minute break in between tasks. First, an informal expressive and receptive knowledge screener was administered to exclude participants without knowledge of the words used in this study. The experimenter tested participants' expressive knowledge of verbs and prepositions by asking them to label the action that they completed using a standard set of props. For example, the experimenter bounced the ball then asked, "What did I do?" or put the ball under the table and asked, "Where is the ball?" If the child responded with a synonym for the target verb (e.g., "dribble" for "bounce"), this response was counted as correct. A list of accepted synonyms for this task is found in Appendix C. If the child could not correctly label the verb or preposition, the experimenter then tested participants' receptive knowledge of that word by asking them to perform the action using a standard set of props. For example, "Show me BOUNCE the ball" and "Show me go BEHIND the couch." If the child did not respond to this within 10 seconds, the statement was repeated. If the child did not respond after another 10 seconds, an indirect verbal prompt and another 10 seconds was given to respond. For example, "I bet the ball can go high, bounce the ball." To confirm the knowledge of nouns, a single photograph of a noun was presented using PowerPoint, and the child was asked to label the object (17 nouns) in response to a directive, "What is this?" If the participant did not respond within 30 seconds, the directions were repeated and a verbal prompt provided (e.g., "People live in a house."). If the child could not label the noun, a four-choice array of photographs (e.g., ball, bat, cup, plate) was presented using PowerPoint with the directive "Show me HOUSE." All participants comprehended 100% of the stimuli, either through elicitation or caregiver report, within the study to ensure that a limited semantic repertoire was not a confounding variable.

The second 30-minute task included the receptive language subtest from the *OWLS-2* to obtain a baseline measure of language comprehension skills. For video conferencing administration, the stimuli for the receptive language subtest were scanned into a PDF document so the experimenter could present the stimuli. The assessment was given using the same methods as the standardized procedures of the *OWLS-2*.

Finally, it is important to note that all responses from the knowledge of words screener and the *OWLS-2* were recorded with the caregivers' smartphone that was in airplane mode. The recordings depicted a view of the child and the computer screen so that responses could be calculated and verified by the research team. Additionally, all caregivers were instructed to not assist their children during the experiment.

Identification Task

Familiarization Trials. During sessions two and three, which occurred no later than three weeks after the previous session, a 5-minute familiarization task was administered. The experimenter was seated at a table with the experimental laptop. For video conferencing, both the experimenter and the caregiver connected via a laptop, desktop, or tablet that the participant subsequently utilized to view the tasks. Next, a line drawing of a smiley face (5 X 5 inches, see Figure 2) was placed on the computer or desk to standardize the distance required for a child's hand to move to make a selection on the PowerPoint. The picture was placed anterior to the cursor pad on the laptop, directly in front of the tablet, or in front of the desktop computer's monitor for all participants. The distance between the smiley face and the display was approximately 8 inches, and the caregivers were sent an image portraying the setup (Figure 2). The participants were instructed to place their hand on the smiley face prior to the start of each trial. The experimenter verified hand placement with the caregiver as well as confirmed the placement via the caregiver recordings. This procedure ensured that distance to the screen did not impact response latency times.

Next, the experimenter and the caregiver began recording the session using their respective devices to ensure the reliability of the data collected. The caregiver's smartphone device was placed in "airplane mode" to disable any push notifications, texts, or calls. The caregivers were instructed to provide no assistance. The experimenter asked the participant, "Are you ready to play a guessing game?" to ensure assent to participate. The experimenter stated that screen sharing would begin, verified with the caregiver that the screen was shared and in full screen, then the caregiver was instructed to minimize the videos and move that box out of the way.

Participants engaged in a single practice trial and three familiarization trials prior to the experiment. The practice trial included an introduction to the task using the sentence "The girl jumps on the trampoline." These directions can be found in Appendix D. Next, three familiarization trials were administered and included the following symbol sequences: (a) Spongebob hugs Patrick between the cars, (b) Spongebob climbs the ladder in front of the dog, and (c) Spongebob draws the cat on the paper. These trials, which were not used in the experiment proper, conditioned participants to the task. The PowerPoint, which was automated to ensure consistency across participants, presented a 5-second green screen with a pre-recorded voice stating, "Look at the computer." and "Get ready." The next slide automatically presented a four-choice photograph array of scenes depicting a sentence. Only one photograph depicted the graphic symbol sequence while the three others were foils. After 3 seconds, a graphic symbol sequence began to appear with either static or animated symbols. The symbols appeared one at a time and in two-second intervals. This graphic symbol sequence appeared above the photographs as seen in Figure 1. After the last symbol was presented, the message, "Point to the picture that matches the symbols" was stated followed by an audible beep indicating the start of the trial. The directive was provided a second time after 15 seconds had elapsed. The participant had a total of 30 seconds to respond by touching a photograph. In the video conferencing format, the caregiver stated which photograph their child touched using a code 1 (top left), 2 (top right), 3 (bottom left), or 4 (bottom right). After a response, the experimenter clicked the right arrow key on the keyboard to advance the slide. Correct and incorrect responses were acknowledged by the experimenter, “Yes, this is ___” or “No, this is ___.” After 30 seconds or a response by the participant, a blank white screen appeared for 1 second. Then a red screen appeared for 5 seconds before proceeding to the next trial. If the participant did not respond to the trial before the red screen appeared, the experimenter stated “Remember to point to the picture before the screen turns red.” The three trials were repeated until the participant responded with 100% accuracy.

Figure 1

Identification Task Example

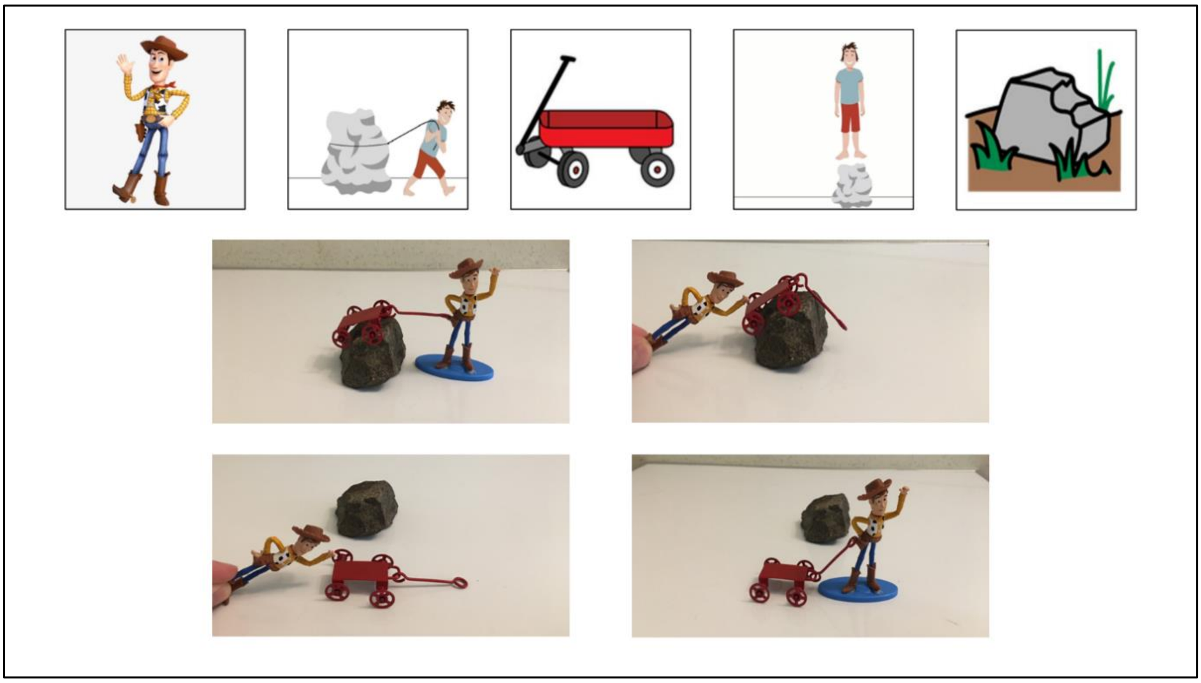
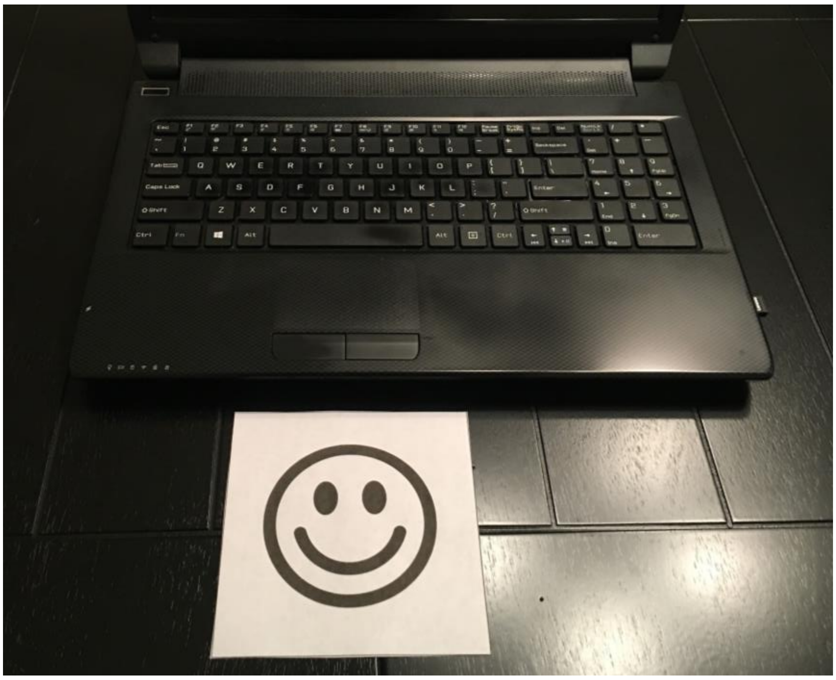


Figure 2

Smiley Face Placement



Experimental Trials. Immediately following the familiarization task, the experimental task was administered. The participants were engaged in the experimental tasks for approximately 15 minutes per experimental condition. The procedures for the experimental task matched the familiarization task; however, no demonstration, affirmation, or corrective feedback was given. Additionally, the experimenter's microphone was muted to reduce the background noise and distractions to the participant. The participants were provided with intermittent feedback to sustain their attention throughout the task (e.g., "You're working so hard."). This feedback was included in the PowerPoint, so it was presented automatically throughout each condition.

Reading Task

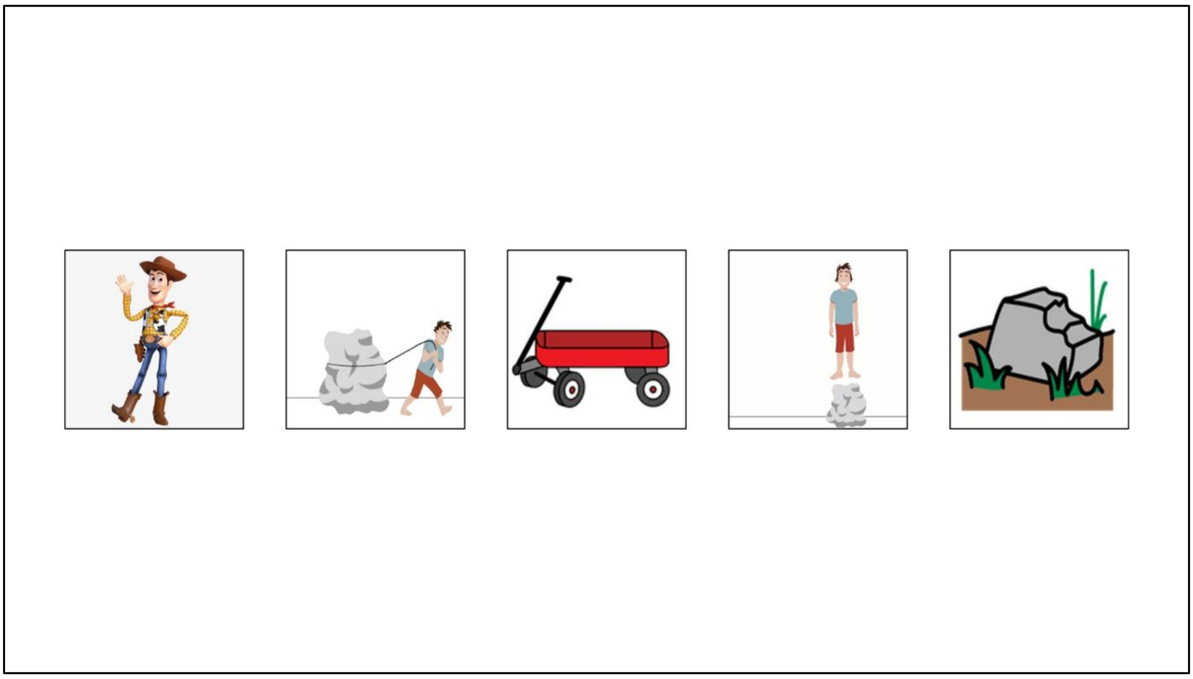
Familiarization Trials. The reading task included the same procedures as the identification task. Specifically, the experimenter provided the similar verbal directions as well the same single practice trial (see Appendix D) and three Spongebob symbol sequence trials. These trials were not part of the experiment proper.

Next, the PowerPoint presented a 5-second green screen with a pre-recorded voice stating, “Look at the computer.” and “Get ready.” The next slide automatically presented a graphic symbol sequence that appeared one symbol at a time and in two-second intervals. The layout of this task can be seen in Figure 3. After the last symbol was presented, the message, “Read the sentence out loud” was stated. The participant had a total of 30 seconds to respond by labeling or “reading” the symbol sequence. Correct and incorrect responses were acknowledged by the experimenter, “Yes, this is ___” or “No, this is ___.” After 30 seconds or a response by the participant, a blank white screen appeared for 1 second. Then a red screen appeared for 5 seconds before proceeding to the next trial. If the participant did not respond to the trial before the red screen appeared, the experimenter stated “Remember to say the sentence before the screen turns red.” The three trials were repeated until the participant responded correctly to each and confirmed comprehension of the game.

Experimental Trials. Immediately following the familiarization task, the experimental task was administered. The participants were engaged in the experimental tasks for approximately 10 minutes per experimental condition. The procedures for the experimental task matched the familiarization task; however, no demonstration, affirmation, or corrective feedback was given. Additionally, the experimenter’s microphone was muted to reduce the background noise and distractions to the participant. The participants were provided with intermittent feedback to sustain their attention throughout the task (e.g., “You’re working so hard.”). This feedback was included in the PowerPoint, so it was presented automatically throughout each condition.

Figure 3

Reading Task Example



Dependent Variables and Measures

The first dependent variable, identification accuracy, was expressed as a percentage (correct responses divided by 18 trials). A response was considered accurate when the participant touched the photograph that corresponded with the given symbol sequence prior to the red screen. Responses after the red screen were incorrect and marked as 'no response' to ensure that all participants had the same amount of time to engage in the task. If the participant touched more than one photograph, the first choice was selected as the response to maintain consistency in response scoring.

Second, response latency was measured during the identification task to assess the amount of time (seconds rounded to the hundredth) the participants took to make a selection between the animated and static conditions. This was measured by calculating the amount of time elapsed between the presentation of an audible beep on the PowerPoint slide and the participants' touch of a photograph. The response time was calculated from the session recordings using a video editing software called Camtasia. Response time was only calculated for correct responses.

The third dependent variable was reading accuracy. Two scores were given for each of the 18 trials; a score of 0 or 1 for the whole sentence (this will be referred to as ‘Reading by Whole Sentence’) and a score of 0-5 for each correct symbol spoken or “read” aloud (this will be referred to as ‘Reading Symbol-by-Symbol’). First, to earn a score of 1 for reading the entire sentence accurately, the child must have verbally labeled all symbols in order from left to right. Correct responses included complete, grammatical spoken sentences, such as “The girl jumps on the trampoline,” or labeling of each of the symbols, “Girl jump on trampoline.” Additionally, synonyms for target words were accepted as correct (see Appendix C for a list of synonyms). Verb conjugations such as infinitive forms (e.g., jump/to jump), third person present (e.g., jumps), present progressive (e.g., is jumping), and past tense (e.g., jumped) were all accepted as correct. Omission, substitution [other than a synonym], or addition of words were considered incorrect. If the child revised what they were saying as they were reading the sequence, the revision was scored as the final response (e.g., “Woody [revision] Bo Peep kicked the ball over- [revision] behind the rock” would be scored as “Bo Peep kicked the ball behind the rock.”). A reading accuracy score for the 18 trials was calculated by dividing the total number of correct responses by 18 and multiplying by 100.

Second, to determine how many words were accurately labeled in each condition (18 trials x 5 words = 90 words), every symbol labeled earned participants a single point for a maximum of 5 points per symbol sequence. Once again, synonyms, articles, and verb conjugations, were accepted as correct. Moreover, the addition of information was ignored in this analysis. The number of accurately labeled symbols was divided by the total number of words.

Reliability

Inter-Observer Agreement

Inter-observer reliability (IOA) data were collected for 20% of the participants. These observations occurred using a video recording of sessions. An independent, blind observer scored participants' responses (i.e., touching a symbol) using the video recordings. The investigator and independent observer's responses were compared. IOA was calculated by dividing the number of agreements by the number of agreements plus disagreements and multiplied by 100. This resulted in 97.89% IOA.

Procedural Integrity

Procedural integrity data were collected for 20% of the participants. A procedural integrity checklist was created that outlined the procedures of the experiment. While the checklist was included on both the identification and reading data sheets, the procedures were only completed once during each session prior to starting the first task, either the identification or reading task depending on the participant. Procedural integrity was calculated to determine if the procedures were followed by the experimenter adequately by calculating the percent of procedures followed during data collection. An independent, blind observer viewed the video recordings of sessions and followed the checklist to determine the percent of procedures followed by the experimenter during data collection. To calculate procedural integrity, the number of steps followed was divided by the total number of steps and multiplied by 100. This resulted in 100% of procedures followed during data collection.

Data Analysis

In addition to descriptive statistics, several paired samples *t*-tests were conducted to determine if there was a statistical difference between the static and animated conditions with respect to identification accuracy, response latency in seconds, reading accuracy by whole sentence, reading accuracy symbol-by-symbol, and reading accuracy by word class (e.g., subject, object, verb, preposition, prepositional complement).

On a post hoc basis, a symbol performance analysis was conducted for verbs and prepositions in the identification task and for the whole sentence in the reading task. This analysis will help aid in the development of more iconic symbols in the future. To do this, we used Schlosser et al.'s (2019) heuristic symbol performance criteria that was adapted from the American National Standards Institute which sets standards for traffic sign comprehensibility (Hancock et al., 2004). Specifically, Schlosser et al. (2019) stated that verb or preposition symbols that were identified with at least 85% accuracy were considered to be performing exceptionally in their identification task. Thus, in the current study, the same categories were used to show the range of identification performance of these symbol sequences: (a) exceptional (≥ 85%), (b) effective (≥ 75%), (c) adequate (≥ 50%), and (d) inadequate (< 50%). Additionally, these performance categories were used to analyze individual verb and preposition labeling in the reading task. Note that this individual symbol performance does not include how well participants "read" or labeled all symbols in a sentence, only the verbs and prepositions.

To calculate the how well participants "read" or labeled all symbols as a single message, we adapted Schlosser et al.'s (2011) criteria to reflect the increased difficulty associated with labeling a five-symbol sequence rather than a single symbol. Specifically, the following categories were used to show the range of reading by whole sentence (labeling) task performance: (a) exceptional (≥ 70%), (b) effective (≥ 55%), (c) adequate (≥ 40%), and (d) inadequate (< 40%).

In addition to the above analyses, several repeated measures ANOVAs and descriptive statistics analyses were completed to determine the effects that word frequency, imageability, and concreteness had on symbol-by-symbol reading accuracy between conditions. The target verbs and prepositions were divided into ‘low’ and ‘mid-to-high’ or ‘high’ groups for each linguistic factor (e.g., frequency, imageability, and concreteness). See Appendix E for ranges for each group and the target words that were placed into each group.

Chapter IV: Results

Identification Task

Two paired samples *t*-tests (two tailed) were conducted to determine the effects of symbol format on identification accuracy and response latency. The effect of symbol format was significant ($t(23) = 2.07$, $p = .05$, Cohen's $d = .42$), with participants using the animated sentences ($M = 64.12$, $SD = 15.45$, $SEM = 3.15$) to correctly identify the corresponding photograph with slightly better accuracy than the static sentence condition ($M = 57.65$, $SD = 16.93$, $SEM = 3.46$). A second paired samples *t*-test found no significant response latency difference ($t(20) = 0.90$, $p = .38$, Cohen's $d = .20$) between the two experimental conditions. Specifically, animated sentences ($N = 23$, $M = 7.19$, $SD = 3.62$, $SEM = 0.74$) were completed within a similar amount of time (seconds) as static sentences ($N = 17$, $M = 6.55$, $SD = 3.04$, $SEM = 0.66$).

Finally, a symbol sentence performance analysis was conducted for the identification task using Schlosser et al.'s (2019) heuristic symbol performance criteria. Specifically, Schlosser and colleagues indicated that a symbol identified with (a) ≥ 85% accuracy was performing exceptionally, (b) ≥ 75% accuracy was deemed effective, (c) ≥ 50% accuracy was adequate, and (d) < 50% was inadequate. This criterion was kept the same for the present study regardless of the increased difficulty of the task to allow for some consistency with past research. The results of heuristic symbol performance analyses indicated that there were only slight differences with respect to identification accuracy in terms of symbol format. Specifically, 14 out of 18 animated sentences achieved a status of 'adequate' or better (77.8%) compared to 12 out of 18 static sentences (66.7%). Only one animated sentence achieved 'exceptional' status, while zero static sentences achieved this status. Table 3 provides descriptive data and symbol performance data from the identification task for both symbol format conditions.

Table 3

Descriptive Statistics for the Identification Task across Conditions

Sentence	Symbol Format	Identification *M*% (*SD*) (*SEM*)	Identification Whole Sentence Performance*
Woody blows bubbles behind the rock.	Static	75.00 (44.23) (9.03)	Effective
	Animated	79.17 (41.49) (8.47)	Effective
Bo Peep bounces the ball behind the rock.	Static	75.00 (44.23) (9.03)	Effective
	Animated	75.00 (44.23) (9.03)	Effective
Buzz Lightyear catches the ball in the house.	Static	70.83 (46.43) (9.48)	Adequate
	Animated	75.00 (44.23) (9.03)	Effective
Bo Peep closes the box in the house.	Static	20.83 (41.49) (8.47)	Inadequate
	Animated	54.17 (50.90) (10.39)	Adequate
Woody covers the wagon next to the rock.	Static	83.33 (38.07) (7.77)	Effective
	Animated	83.33 (38.07) (7.77)	Effective
Buzz Lightyear cuts paper next to the tree.	Static	50.00 (51.08) (10.43)	Adequate
	Animated	87.50 (33.78) (6.90)	Exceptional
Woody drops the spoon under the chair.	Static	29.17 (46.43) (9.48)	Inadequate
	Animated	41.67 (50.36) (10.28)	Inadequate
Bo Peep eats the apple behind the chair.	Static	75.00 (44.23) (9.03)	Effective
	Animated	66.67 (48.15) (9.83)	Adequate
Woody gives the paper over the chair.	Static	62.50 (49.45) (10.09)	Adequate
	Animated	62.50 (49.45) (10.09)	Adequate
Buzz Lightyear hits the ball out of the house.	Static	12.50 (33.78) (6.90)	Inadequate
	Animated	45.83 (50.90) (10.39)	Inadequate
Bo Peep kicks the ball off the rock.	Static	41.67 (50.36) (10.28)	Inadequate
	Animated	54.17 (50.90) (10.39)	Adequate
	Static	62.50 (49.45) (10.09)	Adequate

Buzz Lightyear opens the box next to the rock.	Animated	70.83 (46.43) (9.48)	Adequate
Bo Peep picks up the apple in the house.	Static	75.00 (44.23) (9.03)	Effective
	Animated	66.67 (48.15) (9.83)	Adequate
Woody pulls the wagon over the rock.	Static	66.67 (48.15) (9.83)	Adequate
	Animated	79.17 (41.49) (8.47)	Effective
Buzz Lightyear pushes the bike out of the house.	Static	45.83 (50.90) (10.39)	Inadequate
	Animated	45.83 (50.90) (10.39)	Inadequate
Woody rides the bike in the house.	Static	83.33 (38.07) (7.77)	Effective
	Animated	62.50 (49.45) (10.09)	Adequate
Bo Peep takes the bubbles off the chair.	Static	29.17 (46.43) (9.48)	Inadequate
	Animated	33.33 (48.15) (9.83)	Inadequate
Buzz Lightyear throws the ball under the basketball hoop.	Static	79.17 (41.49) (8.47)	Effective
	Animated	70.83 (46.43) (9.48)	Adequate

Note. Performance groupings are as follows: exceptional (≥ 85%), effective (≥ 75%), adequate (≥ 50%), inadequate (< 50%).

Reading Task

Two paired samples *t*-tests (two tailed) were used to determine if there was a significant effect for symbol format on reading sentence accuracy (i.e., whole sentence read accurately and number of symbols read accurately). Results revealed a significant symbol format difference ($t(23) = 5.09$, $p < .001$, Cohen's $d = 1.04$) on whole sentence reading accuracy, with animated sentences ($M = 53.24$, $SD = 21.23$, $SEM = 4.33$) read more accurately than static sentences ($M = 33.10$, $SD = 19.55$, $SEM = 3.99$). A significant difference was also found ($t(23) = 6.38$, $p < .001$, Cohen's $d = 1.30$) for total number of symbols read correctly, with animated sentence symbols ($M = 88.24$, $SD = 7.62$, $SEM = 1.56$) being read more accurately than static sentence symbols ($M = 81.44$, $SD = 7.91$, $SEM = 1.61$).

Given that this is the first study investigating animation at the sentence level, additional paired samples *t*-test analyses were conducted to identify areas in which symbol format impacted correct "reading" of each word class in the sentence. Table 4 provides those analyses to better understand how symbol format impacted word class. Overall, in the animated sentence condition, verbs, direct objects, prepositions, and prepositional complements were significantly read with greater accuracy compared to those word classes in the static sentence condition. Finally, there were large effect sizes for the verbs and prepositions, while the direct objects and prepositional complements had medium effect sizes. While there were medium effect sizes for these word classes, it should be noted that there were only small differences in the means between the static and animated condition (e.g., 96.76% vs. 98.84% for the direct objects, and 95.37% vs. 98.61% for the prepositional complements).

Table 4

Word Class Descriptive Statistics and Paired Samples t-tests Across Conditions

Paired Samples	Symbol Format	*M*% (*SD*) (*SEM*)	Paired Samples *t*-test Sig. (2-tailed)
Subject	Static	94.91(9.82) (2.00)	$t(23) = -.89$, $p = .38$, Cohen's $d = -.18$
	Animated	93.29(13.00) (2.65)	
Verb	Static	55.56(16.46) (3.36)	$t(23) = 6.44$, $p = <.001$, Cohen's $d = 1.31$
	Animated	78.24(16.78) (3.43)	
Object	Static	96.76(5.41) (1.10)	$t(23) = 2.10$, $p = .05$, Cohen's $d = .43$
	Animated	98.84(2.83) (0.58)	
Preposition	Static	64.58(17.32) (3.54)	$t(23) = 3.14$, $p = .005$, Cohen's $d = .64$
	Animated	72.22(19.66) (4.01)	
Prepositional Complement	Static	95.37(6.89) (1.41)	$t(23) = 2.60$, $p = .02$, Cohen's $d = .53$
	Animated	98.61(2.95) (0.60)	

Next, Table 5 provides descriptive data for symbol-by-symbol reading accuracy expressed as a percentage for all prepositions used in this study. Each trial for the 7 prepositions used in the study were combined to show the overall accuracy with that target word. This also shows that the participants' overall accuracy did not increase significantly as they were exposed to the preposition again.

Table 5

Descriptive Statistics for Reading Accuracy Symbol-by-Symbol across Conditions

Preposition	Symbol Format	Trial 1 *M*% (*SD*)	Trial 2 *M*% (*SD*)	Trial 3 *M*% (*SD*)	Trial 4 *M*% (*SD*)	Aggregate *M*% (*SD*) (*SEM*)
Behind	Static	91.67 (28.23)	91.67 (28.23)	95.83 (20.41)	-	93.06 (21.93) (4.48)
	Animated	95.83 (20.41)	95.83 (20.41)	91.67 (28.23)	-	94.44 (21.23) (4.33)
In	Static	95.83 (20.41)	87.50 (33.78)	91.67 (28.23)	87.50 (33.78)	90.63 (25.34) (5.17)
	Animated	87.50 (33.78)	91.67 (28.23)	95.83 (20.41)	83.33 (38.07)	89.58 (23.22) (4.74)
Next to	Static	87.50 (33.78)	87.50 (33.78)	91.67 (28.23)	-	88.89 (25.38) (5.18)
	Animated	75.00 (44.23)	91.67 (28.23)	83.33 (38.07)	87.50 (33.78)	84.38 (29.32) (5.98)
Off	Static	4.17 (20.41)	4.17 (20.41)	-	-	4.17 (20.41) (4.17)
	Animated	16.67 (38.07)	8.33 (28.23)	-	-	12.50 (30.40) (6.20)
Out	Static	45.83 (50.90)	37.50 (49.45)	-	-	41.67 (45.84) (9.36)
	Animated	54.17 (50.90)	50.00 (51.08)	-	-	52.08 (47.73) (9.74)
Over	Static	29.17 (46.43)	25.00 (44.23)	-	-	27.08 (36.05) (7.36)
	Animated	16.67 (38.07)	-	-	-	16.67 (38.07) (7.77)
Under	Static	54.17 (50.90)	54.17 (50.90)	-	-	54.17 (48.72) (9.94)
	Animated	83.33 (38.07)	91.67 (28.23)	-	-	87.50 (30.40) (6.20)

Subsequently, we analyzed reading (labeling) symbol sequence performance at the whole sentence level (i.e., correctly read all five symbols or not) using an adapted performance criterion from Schlosser et al. (2011). Given the relative difficulty associated with labeling every symbol in the whole sentence in the reading task when compared to labeling a single symbol, the following performance categories were used: (a) exceptional (≥ 70%), (b) effective (≥ 55%), (c) adequate (≥ 40%), and (d) inadequate (< 40%). The results indicated that 10 out of 18 (55.6%) animated sentences achieved a performance category of “effective” or better while only two static sentences (11.11%) achieved status above the “adequate” level. See Table 6 for more specific performance data.

Table 6

Descriptive Statistics for the Reading Task by Whole Sentence across Conditions

Sentence	Symbol Format	Reading Whole Sentence *M%* (*SD*) (*SEM*)	Reading Whole Sentence Performance*
Woody blows bubbles behind the rock.	Static	50.00 (51.08) (10.43)	Adequate
	Animated	91.67 (28.23) (5.76)	Exceptional
Bo Peep bounces the ball behind the rock.	Static	33.33 (48.15) (9.83)	Inadequate
	Animated	58.33 (50.36) (10.28)	Effective
Buzz Lightyear catches the ball in the house.	Static	16.67 (38.07) (7.77)	Inadequate
	Animated	45.83 (50.90) (10.39)	Adequate
Bo Peep closes the box in the house.	Static	16.67 (38.07) (7.77)	Inadequate
	Animated	41.67 (50.36) (10.28)	Adequate
Woody covers the wagon next to the rock.	Static	45.83 (50.90) (10.39)	Adequate
	Animated	70.83 (46.43) (9.48)	Exceptional
Buzz Lightyear cuts paper next to the tree.	Static	37.50 (49.45) (10.09)	Inadequate
	Animated	50.00 (51.08) (10.43)	Adequate
Woody drops the spoon under the chair.	Static	45.83 (50.90) (10.39)	Adequate
	Animated	87.50 (33.78) (6.90)	Exceptional
	Static	70.83 (46.43) (9.48)	Exceptional

Bo Peep eats the apple behind the chair.	Animated	83.33 (38.07) (7.77)	Exceptional
Woody gives the paper over the chair.	Static	12.50 (33.78) (6.90)	Inadequate
	Animated	12.50 (33.78) (6.90)	Inadequate
Buzz Lightyear hits the ball out of the house.	Static	0.00 (0.00) (0.00)	Inadequate
	Animated	29.17 (46.43) (9.48)	Inadequate
Bo Peep kicks the ball off the rock.	Static	4.17 (20.41) (4.17)	Inadequate
	Animated	8.33 (28.23) (5.76)	Inadequate
Buzz Lightyear opens the box next to the rock.	Static	37.50 (49.45) (10.09)	Inadequate
	Animated	58.33 (50.36) (10.28)	Effective
Bo Peep picks up the apple in the house.	Static	41.67 (50.36) (10.28)	Adequate
	Animated	58.33 (50.36) (10.28)	Effective
Woody pulls the wagon over the rock.	Static	25.00 (44.23) (9.03)	Inadequate
	Animated	62.50 (49.45) (10.09)	Effective
Buzz Lightyear pushes the bike out of the house.	Static	45.83 (50.90) (10.39)	Adequate
	Animated	41.67 (50.36) (10.28)	Adequate
Woody rides the bike in the house.	Static	70.83 (46.43) (9.48)	Exceptional
	Animated	83.33 (38.07) (7.77)	Exceptional
Bo Peep takes the bubbles off the chair.	Static	0.00 (0.00) (0.00)	Inadequate
	Animated	4.17 (20.41) (4.17)	Inadequate
Buzz Lightyear throws the ball under the basketball hoop.	Static	41.67 (50.36) (10.28)	Adequate
	Animated	70.83 (46.43) (9.48)	Exceptional

Note. Performance groupings are as follows: exceptional (≥ 70%), effective (≥ 55%), adequate (≥ 40%), inadequate (< 40%).

Table 7 provides verb symbol reading (labeling) accuracy using Schlosser et al.'s (2019) heuristic criteria. The results for individual verb symbols across static and animated formats bolstered the results of the statistical group analyses in that 88.9% of animated verbs achieved “adequate” status or better compared to 61.1% of the static verbs. Likewise, 12 out of 18 (66.7%) static verbs were placed in the lower two categories (i.e., adequate or inadequate), whereas 11 out of 18 (61.1%) animated verbs were placed in the upper two categories (i.e., effective or exceptional). Interestingly, only 4 out of 18 (22.2%) of the static verbs attained the exceptional status, whereas ten (55.6%) animated verbs did. See Table 7 for more information on specific symbol performance across the symbol formats.

Table 7

Individual Static and Animated Verb Symbols Grouped into Mean Percentage Performance Categories for the Reading Task Symbol-by-Symbol

	Exceptional (>/=85%)		Effective (>/= 75%)		Adequate (>/= 50%)		Inadequate (< 50%)	
Verbs	Anime M/SD	Static M/SD	Anime M/SD	Static M/SD	Anime M/SD	Static M/SD	Anime M/SD	Static M/SD
Blow	100.00/0.00[a]					50.00/51.08		
Bounce					70.83/46.43[b]			41.67/50.36
Catch					58.33/50.36			16.67/38.07
Close					54.17/50.90			16.67/38.07
Cover	87.50/33.78					50.00/51.08		
Cut					58.33/50.36			41.67/50.36
Drop	87.50/33.78					66.67/48.15		
Eat	95.83/20.41			75.00/44.23				
Give					66.67/48.15[c]	50.00/51.08		
Hit							45.83/50.90	8.33/28.23
Kick	95.83/20.41	100.00/0.00						
Open			75.00/44.23					41.67/50.36

Pick up	87.50/33.78					54.17/50.90		
Pull	91.67/28.23			83.33/38.07				
Push	95.83/20.41	100.00/0.00						
Ride	95.83/20.41	87.50/33.78						
Take							41.67/50.36	20.83/41.49
Throw	100.00/0.00	95.83/20.41						
Total Anime.	10		1		5		2	
Total Static		4		2		5		7

Note. Anime. = animated.

a = green ovals indicate a two-category improvement from static to animated format; b = blue ovals indicate a one-category improvement from static to animated format; c = red ovals indicate no change in category.

Table 8 provides preposition reading (labeling) accuracy using the heuristic criteria from Schlosser et al. (2019). The data indicated that 5 out of 7 (71.4%) animated prepositions achieved a status of “adequate” or better compared to the 4 out of 7 (57.1%) static prepositions. For the preposition ‘under’, animation improved two performance categories over its static counterpart. For the preposition ‘out’, animation improved one performance category over its static counterpart. Only one static preposition improved one performance category over its animated counterpart (i.e., next to).

Table 8

Individual Static and Animated Preposition Symbols Grouped into Mean Percentage Performance Categories for the Reading Task Symbol-by-Symbol

	Exceptional (>/=85%)		Effective (>/= 75%)		Adequate (>/= 50%)		Inadequate (< 50%)	
Prepositions	Anime M/SD	Static M/SD	Anime M/SD	Static M/SD	Anime M/SD	Static M/SD	Anime M/SD	Static M/SD
Behind	94.44/21.23[c]	93.06/21.93						
In	89.58/23.22	90.63/25.34						
Next to		88.89/25.38[d]	84.38/29.32					
Off							12.50/30.40	4.17/20.41
Out					52.08/47.73[b]			41.67/45.84
Over							16.67/38.07	27.08/36.05
Under	87.50/30.40[a]					54.17/48.72		
Total Anime.	3		1		1		2	
Total Static		3		0		1		3

Note. Anime. = animated. a = green ovals indicate a two-category improvement from static to animated format; b = blue ovals indicate a one-category improvement from static to animated format; c = red ovals indicate no change in category; d = gray ovals indicate a one-category improvement from animated to static format.

Word Frequency, Imageability, and Concreteness across Symbol Format

Several repeated measures ANOVAs were conducted to compare the effects of verb and preposition frequency, imageability, and concreteness on reading symbol-by-symbol accuracy in static and animated conditions. There was a significant main effect for verb word frequency ($F(1,23) = 112.24$, $p < .001$, $\eta^2 = .83$) and preposition word frequency $F(1,23) = 124.65$, $p < .001$, $\eta^2 = .84$). The Bonferroni post-hoc analyses indicated that low frequency verbs and prepositions were labeled with significantly greater accuracy when compared to high frequency verbs and prepositions, regardless of symbol format (see Table 9). There were no significant interactions between symbol format and word frequency for verbs ($F(1,23) = 1.49$, $p = 0.23$, $\eta^2 = .00$) or prepositions ($F(1,23) = 0.02$, $p = 0.89$, $\eta^2 = .00$); however, the post-hoc analyses indicated significant differences between symbol format and frequency for each word class (see Table 10). Specifically, it appears that lower frequency verbs and prepositions in the animated and static conditions were labeled more accurately than high frequency verbs and prepositions in the same conditions.

There was a significant main effect for verb imageability ($F(1,23) = 42.75$, $p < .001$, $\eta^2 = .65$) and preposition imageability ($F(1,23) = 42.75$, $p < .001$, $\eta^2 = .65$). The Bonferroni post-hoc analyses indicated that highly imageable verbs and prepositions were labeled with significantly greater accuracy when compared to verbs and prepositions with low imageability (see Table 9). There was a significant interaction between symbol format and imageability for verbs ($F(1,23) = 15.27$, $p < .001$, $\eta^2 = .040$), but not for prepositions ($F(1,23) = 3.31$, $p = 0.08$, $\eta^2 = .13$). As observed in Table 10, highly imageable and animated verbs were labeled with greater accuracy in the reading task when compared to all other variables. Moreover, animation resulted in a 30% increase in accuracy for verbs with low imageability when compared to the static condition. Given that the interaction between symbol format and imageability was approaching significance for prepositions, the post-hoc analyses were reviewed. Similar to verbs, highly imageable and animated prepositions were labeled with greater accuracy when compared to all other variables (see Table 10). Additionally, animation appears to have a facilitative effect by increasing labeling accuracy for both low and highly imageable prepositions.

There was a significant main effect for verb concreteness ($F(1,23) = 20.67$, $p < .001$, $\eta^2 = .47$) and preposition imageability ($F(1,23) = 93.05$, $p < .001$, $\eta^2 = .80$). The Bonferroni post-hoc analyses indicated that highly concrete verbs and prepositions were labeled with significantly greater accuracy when compared to verbs and prepositions with low concreteness (see Table 9). Additionally, it appears that concreteness had more of a labeling accuracy impact on the prepositions than the verbs. Finally, there were no significant interactions between symbol format and concreteness for verbs ($F(1,23) = 2.02$, $p = .17$, $\eta^2 = .08$) or prepositions ($F(1,23) = .02$, $p = 0.90$, $\eta^2 = .00$).

Table 9

Word Frequency, Imageability, and Concreteness Descriptive Statistics Across Word Class and Symbol Format

Linguistic Factor	Condition	Grouping	*M* (*SD*) (*SEM*)	
			Verbs	Prepositions
Word Frequency	Static	Low	67.80(18.18) (3.71)	84.72(21.23) (4.33)
		Mid-to-High	36.31(20.63) (4.21)	24.31(21.97) (4.48)
	Animated	Low	88.26(16.19) (3.31)	88.78(22.57) (4.61)
		Mid-to-High	62.50(20.98) (4.28)	29.17(28.88) (5.90)
Imageability	Static	Low	43.98(22.81) (4.66)	62.88(16.29) (3.32)
		High	67.13(12.47) (2.54)	67.26(25.09) (5.12)
	Animated	Low	73.61(19.61) (4.00)	67.05(18.54) (3.78)
		High	82.87(16.38) (3.34)	80.36(24.86) (5.07)
Concreteness	Static	Low	44.44(21.80) (4.45)	45.83(17.74) (3.62)
		High	61.11(17.32) (3.54)	83.33(22.22) (4.54)
	Animated	Low	72.22(18.82) (3.84)	53.70(23.32) (4.76)
		High	81.25(18.92) (3.86)	90.74(21.40) (4.37)

Table 10

Word Frequency, Imageability, and Concreteness Bonferroni Corrected Post-hoc Analyses Across Symbol Format and Word Class

Linguistic Factor	Word Class	Comparison*		Mean Difference	Standard Error	Post-hoc Analyses
Frequency	Verbs	Animation high	Animation low	-25.76	3.58	$t(45.13) = -7.19$, $p <.001$
		Animation high	Static high	26.19	4.42	$t(38.70) = 5.93$, $p <.001$
		Animation high	Static low	-5.30	4.61	$t(41.87) = -1.15$, $p = 1.00$
		Animation low	Static high	51.95	4.61	$t(41.87) = 11.26$, $p <.001$
		Animation low	Static low	20.45	4.42	$t(38.70) = 4.63$, $p <.001$
		Static high	Static low	-31.49	3.58	$t(45.13) = -8.80$, $p <.001$
	Prepositions	Animation high	Animation low	-59.62	6.10	$t(35.27) = -9.77$, $p <.001$
		Animation high	Static high	4.86	3.93	$t(45.71) = 1.24$, $p = 1.00$
		Animation high	Static low	-55.56	6.00	$t(33.69) = -9.26$, $p <.001$
		Animation low	Static high	64.48	6.00	$t(33.69) = 10.74$, $p <.001$
		Animation low	Static low	4.06	3.93	$t(45.71) = 1.03$, $p = 1.00$
		Static high	Static low	-60.42	6.10	$t(35.27) = -9.90$, $p <.001$
Imageability	Verbs	Animation high	Animation low	9.26	3.05	$t(41.47) = 3.04$, $p = .025$
		Animation high	Static high	15.74	3.94	$t(34) = 3.99$, $p = .002$
		Animation high	Static low	38.89	4.31	$t(41.29) = 9.03$, $p < .001$
		Animation low	Static high	6.48	4.31	$t(41.29) = 1.51$, $p = .84$
		Animation low	Static low	29.63	3.94	$t(34) = 7.51$, $p < .001$
		Static high	Static low	23.15	3.05	$t(41.71) = 7.59$, $p <.001$
	Prepositions	Animation high	Animation low	6.75	2.71	$t(23) = -2.47$, $p = .129$
		Animation high	Static high	13.10	3.54	$t(23) = 3.70$, $p = .007$
		Animation high	Static low	17.48	4.00	$t(23) = 4.37$, $p < .001$
		Animation low	Static high	6.35	4.49	$t(23) = 1.41$, $p = 1.00$
		Animation low	Static low	10.73	3.62	$t(23) = 2.97$, $p = .041$
		Static high	Static low	4.38	4.33	$t(3) = -1.01$, $p = 1.00$

Concreteness	Verbs	Animation high	Animation low	9.03	3.90	$t(45.89) = 2.31$, $p = .151$
		Animation high	Static high	20.14	4.54	$t(42.26) = 4.44$, $p < .001$
		Animation high	Static low	36.81	4.62	$t(43.26) = 7.97$, $p < .001$
		Animation low	Static high	11.11	4.62	$t(43.26) = 2.41$, $p = .123$
		Animation low	Static low	27.78	4.54	$t(42.26) = 6.12$, $p < .001$
		Static high	Static low	16.67	3.90	$t(45.89) = 4.27$, $p < .001$
	Prepositions	Animation high	Animation low	37.04	4.37	$t(23) = 8.48$, $p < .001$
		Animation high	Static high	7.41	2.73	$t(23) = 2.71$, $p = .074$
		Animation high	Static low	44.91	3.87	$t(23) = 11.60$, $p < .001$
		Animation low	Static high	-29.63	5.17	$t(23) = -5.74$, $p < .001$
		Animation low	Static low	7.87	3.31	$t(23) = 2.38$, $p = .156$
		Static high	Static low	37.50	4.17	$t(23) = 9.00$, $p < .001$

Note. Comparison* refers to how each word class was grouped according to the linguistic factors. For example, in the frequency rows, some verbs were considered high frequency or low frequency.

Chapter V: Discussion

This study addressed three research questions. Specifically, what was the effect of symbol format on (a) sentence identification accuracy, (b) identification response time, and (c) reading accuracy for whole sentences and symbol-by-symbol. The main findings included the following: (a) animated symbols resulted in significant improvements in children's identification accuracy; (b) response times were not significantly different between the animated and static conditions; (c) children read significantly more whole sentences (i.e., contained all five symbols spoken) in the animated condition than in the static condition; and (d) children read a significantly greater number of individual symbols in the animated condition than in the static condition.

Effect of Symbol Format on Identification Accuracy

The children did relatively poorly on the identification task compared to previous studies (Schlosser et al. 2014; 2019) who used the same task. However, the current study incorporated a symbol sequence rather than single symbols. Animations did prove to be beneficial for improving identification accuracy, with approximately a 7% difference between conditions and a medium effect size. Although animations resulted in improved identification, for four trials, participants had a higher mean accuracy rate in the static condition. There was also a large standard deviation for this task, indicating a variability in performance on this task. The poor performance may reflect the participants' ability to interpret vs. comprehend the target symbol sentences. While the children often read the individual symbol accurately in the reading task, our data show that they may have had difficulty comprehending the message of the sentence as a whole and attaching that meaning to the corresponding photo. Alternatively, there were inherent difficulties associated with the identification task that may have contributed to the children's poorer performance.

First, the photographs used may have been difficult to interpret. Specifically, children's toys were used to depict actions that are difficult to replicate without movement (e.g., Bo Peep dropping a spoon under a chair). Perhaps photographs or videos of real people and their actions would improve the outcomes on this task. Second, the sentences including the verbs 'close,' 'drop,' 'hit,' 'push,' and 'take' had overall low identification accuracy across both conditions. As Schlosser et al. (2011) noted, many of those verbs (e.g., close, drop, and hit) are not readily guessable, hence their follow up study adding sound to the animated symbols to improve guessability (Harmon et al., 2014). Third, the verbs 'take' and 'give' as well as 'close' and 'open' were often incorrect in the animated condition because of a potential looping confound. That is, the animated symbols initiated immediately at the start of the trial; however, the child viewed the subject and object symbols prior to the animated verb symbol. Thus, 'open' had already looped and subsequently looked more like 'close.' The same occurred with the prepositions 'in' and 'out.' Overall, sentences that included both a difficult verb and preposition were identified less accurately (e.g., "Bo peep closes the box in the house"). This may also explain the participants' greater performance on some static sentences; the location represented by the preposition was clearer in the static condition and not confounded by the looping effect.

Sutton et al. (2010) completed a similar task to examine the identification accuracy of static photographs that corresponded to a SVO sentence in 3-year-old children with typical development. Despite the fact that most children this age have mastered SVO sentence structure, identification accuracy was low (52% identified correctly). Similarly, the 7- and 8-year-olds in the present study should have mastered the syntactic structures and words; however, identification accuracy was low in the animated (64%) and static conditions (57%). This is an interesting finding as one would expect children this age to perform well on such simple sentences both receptively and expressively (e.g., Binger et al., 2017). There are several explanations for our results as well as those from Sutton et al. (2010) to be discussed.

First, it is possible, although unlikely, that comprehension of symbol sequences is inherently difficult. However, that difficulty was mitigated to a small yet significant degree by inclusion of the animated symbols. The second and more likely explanation may be that the photograph stimuli in each study were inadequate. Specifically, it is difficult to convey a 3- or 5-symbol sequence as a static photograph because movement information associated with verbs and prepositions is “lost” within the photograph. For example, Figure 1 depicts Woody riding the bike in the house; however, the corresponding photograph does not show him riding the bike. Rather, it appears that Woody is on the bike in the house. Fixing this problem is relatively easy with the introduction of short videos instead of photographs, but it would make isolating the effects of symbol format impossible. Future research should include an identification task using short videos to determine how the children would perform without the constraint of the still photographs. Finally, children with typical development may lack the motivation necessary to utilize symbols when compared to actual children with complex communication needs (Binger et al., 2017). While studies including children with typical development offer proof of concept, research needs to include children who will utilize the AAC technology.

Effect of Symbol Format on Response Time

Response latency was not significantly different between the symbol format conditions. This has important implications for the use of animations. These data show that the animations were processed at nearly the same speed as the static symbols. Thus, animated symbols do not appear to require greater cognitive effort to process. Even with two animated symbols on the same screen, which adds extra sensory information to be processed, participants viewed and interpreted the animated symbols just as quickly as they did the static symbols. This is a positive finding, as previous research has suggested that animations may cause information overload or provide too complex of information to be beneficial to the learner (Berney & Bétrancourt, 2016; Jones & Scaife, 2000; Lowe, 1999; Mayer & Moreno, 2002). While only two animated symbols were present on the screen for each trial, it is not recommended to implement an entire grid of animations. This has the potential to overwhelm the learner and reduce the animations' effectiveness. Thus, the utility of animation is best thought of as a tool to teach children more complex word classes and syntactic structures.

Effect of Symbol Format on Reading Accuracy

Reading Symbol-by-Symbol

A significant effect was found, in favor of animation, on symbol-by-symbol reading accuracy. Participants had a relatively high accuracy level on this task indicating that animations helped with the comprehension of each individual symbol in the sentence. With the presence of animation, participants were more accurate in interpreting the action (e.g., verb) or location (e.g., preposition) represented by the symbol. It is possible that the animations provided a graphic representation of the action taking place, thereby circumventing the children's need to internally produce a mental representation of the movement. Höffler and Leutner (2007) suggested that creating mental representations utilizes cognitive resources; however, with the introduction of animation, the working memory resources can be distributed to interpreting opaque symbols. While there were positive effects seen for the animated symbols, it should be noted that for several verbs and prepositions, participants had slightly higher accuracy in the static condition (e.g., kick, push, inside, next to, over). There are two possible explanations for this occurrence. First, the looping confound may have impacted the participant's understanding of the prepositions; in the static condition, this was not a confound, thereby increasing their accuracy for these target words. Additionally, each of these verbs had high imageability ratings, which provided an adequate mental representation of the word. Therefore, the animations were not as important for their understanding due to the high imageability of the words.

To corroborate this interpretation, additional paired samples *t*-tests for each word class revealed significant differences, with children better able to read individual symbols in the animated condition than in the static condition. More specifically, in the animated condition, the static symbols (i.e., object and prepositional complement) were read more accurately resulting in medium effect sizes. However, the differences in mean accuracy between conditions were small. These data suggests that the animated verbs and prepositions may facilitate sentence interpretation and comprehension of the whole message by connecting word classes together. This is notable because Boyer et al. (2012) found that their participants had high levels of accuracy when reading symbol sequences (i.e., 95.1% passed this task) and could accurately label individual symbols; however, the children were unable to act-out (i.e., live demonstration) the same symbol sequences, which suggests they were not understanding the message of the entire symbol sequence. Finally, large effect sizes were observed in the present study for the animated verb and preposition word classes, suggesting that animation may have clinical utility. Not only may animations facilitate verb comprehension, the positive effects seen for the direct object in the animated condition suggests that this technology can also assist with teaching the verb phrase and therefore the nouns that connect to the verbs. This has important implications for teaching word connections as well as expanding syntax.

Reading by Whole Sentence

When compared to the symbol-by-symbol reading score, the whole sentence score is more reflective of the children’s ability to connect ideas between individual symbols to create a meaningful message. There was a significant difference between conditions showing that animations facilitated the children's ability to read the entire sentence accurately, resulting in large effect sizes. However, across participants, overall performance was still low.

While 5-symbol sequences have not been researched in the past, Boyer et al. (2012) and Trudeau et al. (2014) completed a similar reading task in 3- to 6-year-old children with typical development using static SVO sentences. Given that SVO structures are mastered by most 3-year-olds, it is not surprising that children performed at or near ceiling levels. Therefore, previous research incorporated an act-out task to determine if children accurately interpreted the meaning of the SVO symbol sequence. Boyer et al. (2012) and Trudeau et al. (2014) found a slightly lower accuracy with the act-out task indicating the children may have more difficulty understanding the meaning of the symbol sequence. While the current study did not have an act-out comparison task, it is interesting that children did not perform at or near ceiling levels because the syntactic structures should also have been mastered by 7- and 8-year-olds. Therefore, the low whole sentence reading accuracy may be related to the increased syntactical complexity of the target sentences, the participants' inability to connect the ideas within the sentence, and their decreased motivation to utilize these symbols.

Word Frequency, Imageability, and Concreteness

Finally, a discussion of word frequency, imageability, and concreteness is warranted. First, it should be noted that all participants had confirmed knowledge of each target word in the study which mitigated the effects of any linguistic differences. Interestingly, low frequency verbs and prepositions elicited higher accuracy rates than those with mid-to-high frequencies across conditions. This suggests that higher frequency words do not necessarily indicate ease of or better understanding because high frequency words are often difficult to portray graphically. For example, the graphic symbol for 'GO' is usually depicted by a green light or arrow pointing to the right. Thus, it is necessary to consider the iconicity or imageability (e.g., level of opaqueness or transparency) of the target words.

Highly imageable verbs and prepositions elicited higher labeling accuracy rates across both conditions. However, the imageability effect was also impacted by word class and symbol format. First, the imageability effect was more pronounced in the static condition. This likely occurred because static symbols require the participant to create a mental representation of the word; therefore, imageability had a strong effect on static outcomes and less of an effect on animated outcomes. This is because, as Höffler and Leutner (2007) noted, animation provides a mental representation of movement, with animated symbols more easily labeled. Second, the verbs and prepositions used in this study were associated with a motoric and locative meaning, respectively; however, the imageability effect was more pronounced for verbs. This confirms previous results in that movement appears to be more integral for verbs than prepositions, but this does not mean that animation is detrimental to labeling prepositions (Schlosser et al., 2014).

Overall, the imageability results may be best explained by two competing theories: (a) the context availability theory (Schwanenflugel & Shoben, 1983) and (b) the dual-coding theory (Paivio, 1986). In terms of the context availability theory, highly imageable words, which also tend to be more concrete, activate more associative information than words with low imageability that are also likely considered abstract. However, when provided context, as was the case in this study (i.e., additional words and graphic representation), even the most abstract/poorly imageable words will be recognized just as quickly as concrete/highly imageable words. With respect to the dual coding theory, graphic symbols are unique because they include a verbal representation (i.e., the actual word) and a nonverbal representation (i.e., graphic representation of the word). Therefore, in AAC, individual graphic symbols and symbol sequences are processed by both the verbal and nonverbal systems, resulting in better task performance. Moreover, with the addition of animation to a graphic symbol sequence, it is likely that additional regions of the brain are recruited to interpret and formulate the spoken message conveyed by the symbol sequence. For example, the superior temporal sulcus responds to biological motion representation while the left supplementary motor area responds to action verbs with movement (Berlingeri et al., 2008; Van Dam et al., 2010). The recruitment of these additional regions of the brain may facilitate the interpretation and spoken production of the symbol sequences.

When considering concreteness, the results mimicked the imageability results. Specifically, highly concrete verbs and prepositions were labeled with greater accuracy compared to abstract verbs and prepositions. More specifically, there was a greater mean difference in the static preposition condition, with concrete prepositions labeled with 40% more accuracy than more abstract prepositions. Similar results were found in the verb condition, but they were not as pronounced, with only a 20% difference between concrete and more abstract verbs. Animation mitigated the effects of concreteness for both verbs and prepositions. As previously discussed, the context availability theory (Schwanenflugel & Shoben, 1983) and the dual-coding theory (Paivio, 1986) may explain why these results occurred. Overall, it is clear that linguistic characteristics should be considered when choosing treatment targets (e.g., those that animations will provide the greatest facilitation for); however, regardless of linguistic differences, the animated verbs and prepositions were read with more accuracy than those in the static condition showing their clinical utility.

Limitations

There are some limitations of this study that warrant discussion. First, all assessment and experimental tasks were administered on an online platform due to COVID-19. There are some inherent difficulties with this method of administration. Notably, the examiner was not able to see the participant fully (e.g., where they pointed on the screen), and the standardized tests do not have psychometric data associated with an online administration modality. Additionally, we cannot be sure that the participants viewed the identification photographs at the standardized size of 2.05 x 4 inches or the graphic symbols due to the completion of the tasks on their personal device, in which the screen size was unknown. Second, some caregivers were consistently reminded to place their child's hand on the smiley face during the identification task to maintain consistent response time measurement. This may have impacted the overall response latency results; however, the average latency for each condition was not significantly different, at 7.19 for the animated condition and 6.55 for the static condition. It is unlikely that hand placement had any major impact on these data. Third, five videos from the parents were lost or not available due to caregiver technology issues. These issues will likely be mitigated in future research as people become more familiar with digital technology secondary to the pandemic. Fourth, this study cannot definitively conclude whether children comprehended the symbol sequence as an entire message or simply a collection of five symbols to read. An act-out task, with toy props, would have been beneficial for children to demonstrate comprehension of the symbol sequences used in this study.

Finally, two pairs of animations (e.g., open/close, in/out) may have been interpreted incorrectly when used in a five-symbol sequence due to the time at which they looped and the time at which the child viewed each symbol in the sequence. For example, when the animation for 'in' looped and subsequently reset, the symbol may have been interpreted as 'out.' Those participants who viewed the symbol after it looped may have lower overall accuracy scores and possibly response latencies in each task.

Clinical Implications

It is clear that animations have clinical utility in the field of speech-language pathology, and not just for children who require aided AAC systems. Specifically, animations could be used as a tool to teach children more complex word classes because animations turn opaque symbols into more transparent symbols (i.e., verbs and prepositions). This is because animations add information to these opaque symbols that otherwise may be difficult to understand due to the inherent movement that is critical for their interpretation. Additionally, verbs should be the focus of aided AAC intervention. This is because verbs have the added benefit of carrying additional syntactic and semantic information within the activated lemma (e.g., Bastiaanse et al., 2016). When a verb is activated, so are the thematic roles and argument structures associated with the verb; that is, additional words (e.g., nouns) are mapped onto verbs to create more complex sentences (Levelt, 1989). Thus, verbs are more difficult to generate than nouns because of the additional information associated with each verb. In contrast, nouns are more easily represented graphically and easier to retrieve (especially higher frequency nouns). Moreover, nouns do not offer the same level of mapping to expand an AAC user's communicative functions or syntax because they do not carry the additional semantic and syntactic information as verbs.

In terms of discourse, recent research has found that animated stories are associated with longer, more complex narrative retells in children with typical development when compared to standard book-based stories (Diehm et al., 2020). The animated stories likely reduce cognitive load by creating a mental representation of the movement for the individual, and those "spared" resources can be used for other tasks (Höffler & Leutner, 2007).

While it may not be possible for all individuals to use animated symbols on their AAC system or to animate every symbol on a device, the animations may hold value for teaching different word classes and syntactic structures. Once the child masters these skills, clinicians should move back to a static-based symbol to avoid multiple animations playing simultaneously in a grid. Overall, animation may reduce teaching time and improve generalization, allowing the professional to focus on more complex language skills.

Future Directions

More research is needed to determine the effectiveness of animation at the sentence level. A logical next direction would be to replicate this study with children who have developmental disabilities and require an AAC system to communicate. This replication would improve the generalizability of the present results. Additionally, this will help us better understand the clinical implications of animations in our field with this population.

With respect to methodology, an act-out and sentence generation task should be implemented using animations and 5-symbol sequences for two reasons. First, the act-out task would confirm whether or not children have difficulty interpreting a symbol sequence as an entire message. Second, previous research indicates that SVO symbol construction is either difficult for children with typical development or relatively easy for actual children utilizing AAC (Binger et al., 2017; Sutton et al., 2010. Therefore, an investigation into the effect of symbol format on sentence generation accuracy could assist in providing a resolution to this inter-study discrepancy. Additionally, future studies should include an identification task using an array of short videos rather than the static photographs. This task would eliminate the constraint of action-based situations being difficult to represent in still photographs.

Finally, previous studies have investigated symbol sequence interpretation outcomes using PCS symbols. This symbol type is more commonly found among AAC systems and may be more readily available to individuals who require symbols to communicate. It would be beneficial to replicate the present study with PCS and ALP symbols to determine which set has better outcomes.

Chapter VI: Conclusions

Animations made it easier for 7- and 8-year-old children to identify photographs that corresponded to a 5-symbol sequence. Additionally, the children had overall greater reading accuracy for both reading metrics (i.e., whole sentence read accurately and number of symbols read accurately) in the animated condition. This is an important finding as animations may be used as a clinical tool to reduce the time spent teaching individual symbol meaning, especially for verbs and prepositions, and improve our clients' understanding and use of more complex language structures.

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Appendix A

Target Sentences

1. Spongebob hugs Patrick between the cars.
2. Spongebob climbs the ladder in front of the dog.
3. Spongebob draws a cat on the paper.
4. Woody drops the spoon under the chair.
5. Woody pulls the wagon over the rock.
6. Woody rides the bike in the house.
7. Bo Peep kicks the ball off the rock.
8. Buzz Lightyear opens the box next to the rock.
9. Buzz Lightyear cuts paper next to the tree.
10. Buzz Lightyear pushes the bike out of the house.
11. Bo Peep picks up the apple in the house.
12. Woody gives the paper over the chair.
13. Buzz Lightyear catches the ball in the house.
14. Bo Peep bounces the ball behind the rock.
15. Buzz Lightyear throws the ball under the basketball hoop.
16. Woody blows bubbles behind the rock.
17. Woody covers the wagon next to the rock.
18. Bo Peep closes the box in the house.
19. Bo Peep takes the bubbles off the chair.
20. Bo Peep eats the apple behind the chair.
21. Buzz Lightyear hits the ball out of the house.

Appendix B

Zoom Procedures for Parents

First, below is information about how this research will be completed using Zoom Video Conferencing. It is important that you download the Zoom software and are familiar with it. There are basic tutorials at support.zoom.us/hc/en-us, and you can always ask me for assistance. Second, it is important that you refrain from helping your child respond to the questions/prompts they are given. This is vital to ensure that the results yielded from this experiment are valid.

You will need a computer/laptop/tablet that is Zoom capable as well as a smartphone device for recording your child's responses. The computer/laptop/tablet will be used for your child to view the researcher and tasks. Make sure that the Zoom device has the video enabled and audio enabled. When recording with your smartphone, please silence your smartphone and enable "Airplane Mode" to disable any push notifications, texts, or calls.

Day 1: Knowledge of Verbs and Standardized Assessment Tasks

This meeting will last between 60 and 90 minutes. Required Items include a Phone for recording and a Laptop, Desktop, or Tablet for the Zoom session. Additionally, the researcher will be screen recording today's session using Zoom. The recording will be shared with no one except for myself and Dr. Kris Brock (research mentor). **You will need a laptop, desktop, or tablet to connect to the Zoom meeting. Please use your phone to record your child during today's meeting. When recording please make sure we can see (1) part of your child's face and (2) the computer screen. Please ensure that your child's voice is able to be heard in the recording (i.e., be within 18 inches of your child with a view of**

the computer). Please gather the following materials and put them in a bag to which you control access:

Teddy bear

Piece of paper

Crayon

Ball

Book

Toy car

Napkin

Box

Task 1 will take 20 minutes

The researcher will complete an interview with you to determine your child's ASD severity rating. Your child does not need to be present during this interview.

Task 2 will take 20 minutes

You will begin filming your child using your smartphone. Ensure that we can see a whole body view of your child for this task. The researcher will demonstrate 25 verb-based actions (e.g., jump) and 10 locations (e.g., under) using toys/props. Your child will be asked to label the action. If your child is unable to label the action, the researcher will ask your child to perform that action using toys/props. She will tell you which of the above materials to make available for your child if needed. Once the action is completed, take away the toy/prop and put it away/out of reach of your child. Please ensure that your child and the materials are fully in the frame. **Please refrain from providing any prompts or support.**

Task 3 will take 5 minutes

The researcher will share her computer screen with you. Once the screen is successfully shared and your child is in front of the computer please start recording with your smartphone camera. Your child will see 1 picture and be asked to label that picture (e.g., tree). If your child is unable to label the picture, 4 pictures and one word will be presented. Your child will be asked to point to the picture that matches that word. After your child points you will need to tell the researcher to which picture your child pointed using 1, 2, 3, or 4 using the table below. If the researcher is unable to hear your response, she may ask you to repeat the number your child pointed to. **Please minimize our videos during the screen sharing process by hovering the mouse over our videos and CLICKING the " – " icon in the top left hand corner. Then click and drag that box out of view. Please refrain from providing any prompts or support. Finally, please ensure that you are accurately reporting your child's response.**

1	2
3	4

Task 4 will take 30 to 45 minutes

The researcher will share her computer screen with you. Once the screen is successfully shared and your child is in front of the computer please start recording with your smartphone camera. Your child will see 4 pictures and hear a question or prompt. Your child will be asked to point to the picture that answers the question or accurately matches the prompt. After your child points you will need to tell the researcher to which picture your child pointed using 1, 2, 3, or 4 using the same table as day 1. If the researcher is unable to hear your response, she may ask you to repeat the number your child pointed to. **Please minimize our**

videos during the screen sharing process by hovering the mouse over our videos and CLICKING the " – " icon in the top left-hand corner. Then click and drag that box out of view. Please refrain from providing any prompts or support. Finally, please ensure that you are accurately reporting your child's response.

UPLOAD VIDEO: After these tasks are completed, please upload your recordings to Box, which is a HIPPA and FERPA secure cloud-based storage service. I will send you a personal Box link for this upload. No one else will be able to access this Box link except for me and Dr. Kris Brock (my research mentor).

Day 2: Animated or Static Condition

This meeting will last about 25 minutes. Required Items include a Phone for recording and a Laptop, Desktop, or Tablet for the Zoom session. **You will need a laptop, desktop, or tablet to connect to the Zoom meeting. Please use your phone to record your child during today's meeting. When recording please make sure we can see (1) part of your child's face and (2) the computer screen. Please ensure that your child's voice is able to be heard in the recording (i.e., be within 18 inches of your child with a view of the computer).**

Task 1 will take 15 minutes

The researcher will share her screen with you. Once the screen is successfully shared and your child is in front of the computer please start recording with your smartphone camera. You will hear a recorded voice give most of the directions today. Your child will be shown three practice sentences and will be required to **TOUCH** to one of four pictures that matches the symbol sentence. During these, your child will be given feedback as to the accuracy of his/her answer. After those three sentences have been correctly identified, your child will only receive neutral feedback. After your child points you will need to tell the researcher to which picture your child pointed using 1, 2, 3, or 4 using the same table as day 1. If the researcher is unable to hear your response, she may ask you to repeat the number your child pointed to. **Please minimize our videos during the screen sharing process by hovering the mouse over our videos and CLICKING the " – " icon in the top left-hand corner. Then click and drag that box out of view. Please refrain from providing any prompts or support. Finally, please ensure that you are accurately reporting your child's response.**

Task 2 will take 10 minutes

The researcher will share her screen with you. Once the screen is successfully shared and your child is in front of the computer please start recording with your smartphone camera. You will hear a recorded voice give most of the directions today. Your child will be shown three practice sentences and will be required to read the sentence out loud. During these, your child will be given feedback as to the accuracy of his/her answer. After those three sentences have been correctly identified, your child will only receive neutral feedback. **Please minimize our videos during the screen sharing process by hovering the mouse over our videos and CLICKING the " – " icon in the top left-hand corner. Then click and drag that box out of view. Please refrain from providing any prompts or support.**

UPLOAD VIDEO: After the task is completed, please upload your recording to Box, which is a HIPPA and FERPA secure cloud-based storage service. I will send you a personal Box link for this upload. No one else will be able to access this Box link except for me and Dr. Kris Brock (my research mentor).

Day 3: Static or Animated Condition

This meeting will last about 25 minutes. Required Items include a Phone for recording and a Laptop, Desktop, or Tablet for the Zoom session. **You will need a laptop, desktop, or tablet to connect to the Zoom meeting. Please use your phone to record your child during today's meeting. When recording please make sure we can see (1) part of your child's face and (2) the computer screen. Please ensure that your child's voice is able to be heard in the recording.**

Task 1 will take 15 minutes

The researcher will share her screen with you. Once the screen is successfully shared and your child is in front of the computer please start recording with your smartphone camera. You will hear a recorded voice give most of the directions today. Your child will be shown three practice sentences and will be required to point to one of four pictures that matches the symbol sentence. During these, your child will be given feedback as to the accuracy of his/her answer. After those three sentences have been correctly identified, your child will only receive neutral feedback. After your child points you will need to tell the researcher to which picture your child pointed using 1, 2, 3, or 4 using the same table as day 1. If the researcher is unable to hear your response, she may ask you to repeat the number your child pointed to. **Please minimize our videos during the screen sharing process by hovering the mouse over our videos and CLICKING the " – " icon in the top left-hand corner. Then click and drag that box out of view. Please refrain from providing any prompts or support. Finally, please ensure that you are accurately reporting your child's response.**

Task 2 will take 10 minutes

The researcher will share her screen with you. Once the screen is successfully shared and your child is in front of the computer please start recording with your smartphone camera. You will hear a recorded voice give most of the directions today. Your child will be shown three practice sentences and will be required to read the sentence out loud. During these, your child will be given feedback as to the accuracy of his/her answer. After those three sentences have been correctly identified, your child will only receive neutral feedback. **Please minimize our videos during the screen sharing process by hovering the mouse over our videos and CLICKING the " – " icon in the top left-hand corner. Then click and drag that box out of view. Please refrain from providing any prompts or support.**

UPLOAD VIDEO: After the task is completed, please upload your recording to Box, which is a HIPPA and FERPA secure cloud-based storage service. I will send you a personal Box link for this upload. No one else will be able to access this Box link except for me and Dr. Kris Brock (my research mentor).

Appendix C

Accepted Synonyms for Reading Tasks

1. Hug: squeeze
2. Draw: color
3. Bounce: dribble
4. Cover: put the rug/rag/paper/blanket over/on, uncover, hide
5. Close: shut
6. Give: hand
7. Hit: karate chop, smack
8. Look at: stare
9. Pick up: grab, pick, lift
10. Pull: drag, tug, bring
11. Take: grab, get, snatch
12. Throw: toss
13. On: on top
14. Between: in between, in the middle
15. Behind: back, in the back of
16. In: inside
17. Next to: by, on the side, beside, near, nearby, close to
18. Out: outside
19. Over: above
20. Under: below, on the bottom, underneath
21. Ball: bouncy ball, soccer ball
22. Basketball hoop: basket, hoop, net
23. Bike: bicycle

24. Bubbles: bubble soap, bubble wand
25. Cat: kitten, kitty
26. Dog: puppy, doggy
27. Paper: piece of paper, page
28. Rock: stone
29. Wagon: cart, wheelbarrow
30. Spongebob: he
31. Patrick: he, starfish, friend
32. Woody: he, the cowboy, the boy
33. Bo Peep: she, the girl, Bo, little Bo Peep, the sheep girl, little Po P, little Po Peep, little P, little miss P, Bo Bell
34. Buzz Lightyear: he, the boy, Buzz, astronaut (Pete), Buzz Light, Buzz Lightning

Appendix D

Directions for Identification and Reading Tasks

“I am going to show you some cartoon symbols (Experimenter points to/hovers mouse over cartoons symbols). These cartoon symbols are actually a secret message. Your job is to think of what that message is. Once you know, point to the picture (Experimenter points to pictures) that goes with the sentence. Let me show you one. If you see these cartoon symbols, the message could say “The girl jumps on the trampoline” (Experimenter points to each symbol as they say the word). Then you look at the four pictures on the bottom. Child's name, find the picture of the girl jumping on the trampoline (Experimenter and/or child touches the correct picture). Now you try. Point to the picture that matches the cartoon symbols. (If they point to the correct picture say, “Yes this is, ‘the girl jumps on the trampoline’”) (If they do not point to the correct picture say, “No this is *sentence they pointed to” then circle the mouse around the correct picture and say “This is, ‘the girl jumps on the trampoline’”). (Proceed to familiarization trial 1).

Appendix E

Word Frequency, Imageability, and Concreteness Groupings

Word Frequency:

- Verbs Low (9.84 – 146.45): blow, bounce, catch, cover, drop, kick, pick up, pull, push, ride, throw
- Verbs Mid-to-High (219.43 – 1891.04): close, cut, eat, give, hit, open, take
- Prepositions Low (15.18 – 261.92): behind, inside, next to, under
- Prepositions High (1179.51 – 3865.31): off, out, over

Word Imageability:

- Verbs Low (3.65 – 4.85): blow, catch, close, cover, drop, give, open, pull, take
- Verbs High (4.86 – 6.13): bounce, cut, eat, hit, kick, pick up, push, ride, throw
- Prepositions Low (1.70 – 4.00): inside, next to, off, over
- Prepositions High (4.01 – 6.18): behind, out, under

Word Concreteness:

- Verbs Low (2.83 – 3.75): blow, close, give, open, ride, take
- Verbs High (3.76 – 4.55): bounce, catch, cover, cut, drop, eat, hit, kick, pick up, pull, push, throw
- Prepositions Low (2.46 – 3.10): next to, off, out, over
- Prepositions High (3.11 – 3.67): inside, under, behind