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# Effects of symbol type on naming and identification of graphic symbols by typically developing three, four, five and six-year olds children.

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# EFFECTS OF SYMBOL TYPE ON NAMING AND IDENTIFICATION OF GRAPHIC SYMBOLS BY TYPICALLY DEVELOPING THREE, FOUR, FIVE AND SIX-YEAR OLD CHILDREN

by

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## ABSTRACT

Speech-language pathologists and educators face unique challenges in assessing the language skills of children with complex communication needs due to the wide array of impairments with which these individuals present. For example, most receptive language assessment tools require that children either point to or label line drawings to determine whether or not they comprehend the depicted concepts; task demands such as these preclude administering such assessment tools with children who are unable to physically point to or verbally label presented stimuli. In light of these challenges, the use of eye tracking technologies has become particularly appealing since this alternate response mode reduces the behavioral demands associated with standardized assessment procedures. Another challenge clinicians and educators face as they strive to ensure accurate receptive language assessment results with children who have complex communication needs is the type of stimuli utilized in such assessments. When individuals with cognitive delays are presented with stimuli that may not be comprehensible to them, there is a risk of under-estimating language comprehension abilities (Emerson, 2003). Given the documented challenges that individuals with disabilities often have in identifying constructs depicted by the types of line drawings typically included in receptive language assessment tools (e.g., Mirenda & Locke, 1989; Mizuko, 1987), there is a critical need to include recognizable stimuli in assessment tools in order to determine this population's true receptive language capabilities. Beyond this potential to improve the validity of receptive language assessments, improvement in assessment practices such as these also have potential positive implications for effective AAC technology selection and AAC treatment planning.

The current investigation examined the effect of symbol type (color photograph symbols[1] vs. SymbolStix©[2] color line drawing symbols) on identification and naming of graphic symbols for nouns, verbs and adjectives in typically developing three, four, five and six-year old children. A quasi-experimental design was employed, with counterbalance for experimental stimuli (color photograph symbols[1] vs. SymbolStix©[2] symbols) and task (identification task vs. naming task). Eighty-nine participants completed the identification and naming tasks with both examined symbol types (color photograph symbols[1] vs. SymbolStix©[2] symbols) on two different days. Multivariate Analysis of Variance (MANOVA) was used to examine the effects of symbol type on both accuracy and rate of identification, and on accuracy of naming. Bivariate correlation was completed to determine the relationship between participants' touch and eye identification rates, and to determine the relationship between identification accuracy and eye rate. Mean scores revealed that all participants achieved higher accuracy for the identification and naming tasks with color photograph symbols[1], and that participants evidenced faster touch and eye identification rates for the color photograph symbol[1] condition.  These findings suggest that color photograph symbols[1] are more transparent and thus more easily identifiable. Therefore, potential future assessment modifications include the incorporation of color photograph symbols[1] as stimuli and eye gaze as a selection option within AAC assessment tools. Overall, results of this study have the potential to change the way speech-language pathologists and educators assess the receptive language skills of children with complex communication needs to yield more accurate assessment results.

This dissertation is dedicated to my husband Brian, son Jackson, and parents Sondra and Edward Alfonsin - without whom completion of this investigation would not have been possible.

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# CHAPTER ONE: INTRODUCTION

This investigation examined the effect of symbol type (color photograph symbols[1] vs. SymbolStix©[2] symbols) on identification and naming of graphic symbols for nouns, verbs and adjectives in typically developing three, four, five and six-year old children. The study determined the extent to which, symbol type (color photograph symbols[1] vs. SymbolStix©[2] symbols): (1) increased identification, as measured by percent correct and rate, (2) impacted the relationship between touch and eye rates on identification of graphic symbols, (3) increased naming, as measured by percent correct and (4) affected naming and identification across word class and age group.  This chapter presents the: (a) problem, (b) purpose of the study, (c) research questions, (d) hypotheses, (e) limitations, (f) delimitations, (g) assumptions, and (h) operational definitions.

## Statement of the Problem

The assessment of individuals with complex communication needs poses unique challenges due to the wide array of impairments these individuals face (Beukelman & Mirenda, 2013). Children with complex communication needs include those who may have motor, sensory and/or perceptual impairments in addition to significant speech impairments (Beukelman & Mirenda, 2013). These children often utilize augmentative and alternative communication (AAC) to meet daily communication and language needs in their homes, schools and throughout the community. The American Speech Language Hearing Association (ASHA) Special Interest Division 12: defines AAC as "an area of research, clinical and educational practice," involving "attempts to study and when necessary compensate for temporary or permanent impairments, activity limitations, and participation/restrictions of individuals with severe disorders of speech-language production and/or comprehension including spoken and written modes of communication" (2005, p.1).

Currently, there is no standardized battery of tests that comprise an AAC evaluation (ASHA, 2004). The lack of valid and reliable assessment options for individuals with complex communication needs can impede the speech-language pathologist's ability to obtain an accurate picture of an individual's language skills (Haaf, Duncan, Skarakis-Doyle, Carew & Kapitan, 1999). Many of the current forms of assessment utilize color line drawings to evaluate receptive language skills, and often require participants to possess motor skills within normal limits. If children with complex communication needs do not possess these capabilities, speech-language pathologists and educators may not be able to accurately assess the receptive language skills of these children. Therefore, there is a need to explore the construct of symbol format, more specifically the type of stimuli utilized in assessments, as it relates to measuring the receptive language skills of children with complex communication needs. Just as symbol type is important for assessment, so too are modifications to assessments and their relationship to device selection and intervention.

Modifications to assessments often are necessary to aid in the development of appropriate intervention goals and device selection (McDougall, Vessoyan, & Duncan, 2012); "assessment tools must be reasonably adapted to allow clients independent opportunities to communicate and to allow objective interpretation of clients' responses" (McDougall et al., 2012, p.127). Speech-language pathologists have been anecdotally noted to frequently modify assessment tools for individuals who use AAC (Proctor & Zangari, 2009). Empirically, there have been a number of studies conducted to investigate the effects of making modifications to AAC assessments that warrant further discussion.

Some work has been done to determine the validity and reliability of modified assessment approaches with a specific focus on computer-based assessment tools; to date, this research has focused on presenting line drawings in a computer-based format instead of paper-based format (e.g., Geytenbeek, Heim, Vermuelen, & Ostrom, 2010; Haaf et al.,1999; McDougall et al., 2012). Although this approach may be appropriate for use with some children, other children with severe cognitive delays have been noted to be at risk for experiencing more difficulty recognizing line drawings used as stimuli in tests compared to photograph-based symbols (Beukelman & Mirenda, 2013; Cauley, Michnick-Golinkhoff, Hirsh-Pasek & Gordon, 1989; Geytenbeek, et. al., 2010; Mirenda & Locke, 1989; Romski & Sevcik, 1996). Because these individuals may not be presented with comprehensible stimuli, there is a risk of under-estimating their language comprehension skills through standardized assessment (Emerson, 2003). Although some research has been conducted on the use of photograph-based symbols in assessment of individuals with disabilities (Buekelman & Mirenda, 2013; Mirenda & Locke, 1989), further research is needed to investigate the effects of task changes (e.g., symbol type, computer-based assessment tools) and to validate the usefulness of task modifications for individuals with complex communication needs (Fallon, Light, McNaughton, Drager & Hammer, 2004).

## Purpose of the Study

The purpose of this investigation was to determine the effect of symbol type on identification and naming of nouns, verbs and adjectives by typically developing three, four, five and six-year old children. Typically developing children were selected to participate in the current investigation since the use of children without disabilities is recommended as a first step in the investigation of new approaches to AAC assessment and intervention, in order to address underlying cognitive and language development issues (Drager et al., 2003; Mizuko, 1987; Musselwhite & Ruscello, 1984). Several constructs had to be examined in order to quantify children's ability to identify and use graphic symbols.

In determining how to quantify children's ability to identify and use graphic symbols, the constructs of transparency, iconicity, and symbol identification, as defined in the literature, were closely considered. Transparency refers to the ability of a participant to guess the meaning of a symbol when presented with one symbol at a time (Fuller & Lloyd, 1991). Iconicity refers to the degree to which a symbol looks like what it represents (Mirenda & Locke, 1989). In contrast, symbol identification refers to an individual's ability to see a relation between a spoken word and a graphic symbol (Schlosser et al., 2012). Previous studies conducted with individuals with cognitive impairments revealed that this population had strengths in matching objects to color photographs, and difficulty in matching objects to line drawings (Romski & Sevcik, 1996). These findings were consistent with the established symbol hierarchy which places color photographs at the easiest level for individuals to comprehend and line drawings at a more complex level for individuals to comprehend (Mirenda & Locke, 1989).

Studies also have been conducted to investigate transparency of word classes with typically developing children (Mizuko, 1987; Schlosser et al., 2012) and children with disabilities (Romski & Sevcik, 1996, 2005). Mizuko (1987), investigated transparency and ease of learning of symbols represented by Blissymbols, Picture Communication Symbols (PCS) and

Picsyms (i.e., a variety of line drawings) with typically developing 3-year-old children. Results revealed Picsyms and PCS symbols were more transparent and easier to learn than Blissymbols. Regardless of the word class (i.e., nouns, verbs, descriptors), fewer Blissymbols were correctly identified than either PCS or Picsyms (Mizuko, 1987). However, this study did not examine the transparency of color photograph symbols[1] or SymbolStix©[2] symbols and the impact on typically developing children's ability to identify or name graphic symbols.

Schlosser and colleagues (2012), explored the effects of symbol type, (static symbols vs. animation) on transparency and identification of graphic symbols, across word class, by typically developing three, four and five-year old children. Results revealed developmental trends for naming of graphic symbols, favoring animation for verbs. However, there was not an effect on children's ability to identify graphic symbols even with animation across word class. These findings, therefore, suggested that there is limited evidence to indicate that transparency ratings of different representational symbol systems are consistent across different word categories. Further, these findings lent support for iconicity, transparency and symbol identification, as important factors in children's ability to understand symbols and use them for communication.

Other investigations have been conducted to explore the differences in identification and naming of line drawings including: Blisssymbols, Picture Communication Symbols (PCS) and Picsyms (Mizuko, 1987); however, no known studies have examined the use of SymbolStix©[2] symbols, a different type of color line drawing on identification and naming of graphic symbols. Although there have been studies which examined the impact of color photograph symbols on nouns (Mirenda & Locke, 1989), to date researchers have not investigated the impact of color photograph symbols on verbs and adjectives in terms of identification and naming of graphic symbols, as measured by percent correct. Accuracy, as a measure of identification and naming of graphic symbols, in conjunction with rate as a correlating variable for identification should be considered and warrants further discussion and investigation.

Researchers have utilized rate, via eye-tracking technologies to examine the effects of pageset layouts (i.e., grid-based vs. visual scene displays) on dynamic AAC displays (Brown et al., 2015; Light, Drager, 2002). Brown and colleagues used eye-tracking technologies to determine the impact of three different pageset layouts (text only, icon only, icon with text) on the rate of identification of targets by neurological typical and neurologically impaired adults (Brown et al., 2015). Findings indicated that increased identification rate (faster selection of targets) - measured using eye tracking technologies - was found for the icon only AAC display for both neurological typical and neurologically impaired adults. However, this study did not examine the interaction effect and/or relationship between rate and identification accuracy for graphic symbols (color photograph symbol[1] vs. SymbolStix©[2] symbol), nor were the participants typically developing children. Therefore, further research is warranted relating to the effects of symbol type on identification, as measured by accuracy and rate by typically developing young children.

The literature indicates that color photographs are more transparent than line drawing symbols (Mirenda & Locke, 1989; Mizuko, 1987) and that individuals with cognitive-language disabilities more readily identify photograph-based symbols (Beukelman & Mirenda, 2013; Cauley et al., 1989; Geytenbeek et al., 2010; Mirenda & Locke, 1989; Romski & Sevcik, 1996). Although studies have been conducted to examine effects of symbol type on identification and naming of graphic symbols, to date, the transparency and iconicity of SymbolStix©[2] symbols a-widely used symbol set (Beukelman & Mirenda, 2013) - has not yet been investigated. Additionally, rate as a measure of identification as well as the relationship between rate and identification accuracy and touch and eye rates have not been explored. As previously stated, symbol type, iconicity and transparency of graphic symbols are important considerations for AAC displays for individuals with complex communication needs. Thus, the exploration of symbol type would serve as an attempt to ensure that researchers are not underestimating the receptive language abilities of preschoolers and children with complex communication needs. Given the evidence base for symbol type consideration (e.g., Beukelman & Mirenda, 2013; Cauley et al., 1989; Geytenbeek, et. al., 2010; Mirenda & Locke, 1989; Romski & Sevcik, 1996), and its impact on individuals' ability to identify and name graphic symbols, further research is needed to examine the effects of symbol type on identification and naming of graphic symbols by typically developing young children.

The study could have implications for speech-language pathologists in many ways including, clinical implications for: (a) the stimuli used for assessing comprehension of spoken language (receptive vocabulary), (b) efficiency (time) of conducting assessments, and (c) alternate response modes (eye gaze) that can be used for standardized test administration with individuals who have significant motor impairments. Finally, if young children do identify color photograph symbols at a faster rate than SymbolStix©[2] symbols, this could have implications regarding appropriate symbol type selection for AAC systems.

**Research Questions**

1. Are there statistically significant differences between symbol types (color photograph symbols[1] vs. SymbolStix©[2] symbols) on identification of graphic symbols for nouns,

verbs and adjectives as measured by percent correct and rate for three, four, five and six-year old children? If yes, what are the differences?

2. Is there a relationship between: accuracy and rate and touch and eye rate for identification of graphic symbols (color photograph symbols[1] vs. SymbolStix©[2] symbols)? If yes, are these relationships statistically significant?
3. Are there statistically significant differences between symbol types (color photograph symbols[1] vs. SymbolStix©[2] symbols) on naming of graphic symbols for nouns, verbs and adjectives as measured by percent correct for three, four, five and six-year old children? If yes, what are the differences?

## Null Hypotheses

1. There are not statistically significant differences between symbol types (color photograph symbols[1] vs. SymbolStix©[2] symbols) on identification of graphic symbols for nouns, verbs and adjectives as measured by percent correct and rate for three, four, five and six-year old children.
2. The relationships between accuracy and rate and touch and eye rate for identification of graphic symbols are not statistically significant.
3. There are not statistically significant differences between symbol types (color photograph symbols[1] vs. SymbolStix©[2] symbols) on naming of graphic symbols for nouns, verbs and adjectives as measured by percent correct and rate for three, four, five and six year-old children.

## Limitations of the Study

The study has the following limitations:

1. Preschoolers and children participating in the study were typically developing. Although the use of children without disabilities is recommended as a first step in the investigation of new approaches to AAC intervention in order to address underlying cognitive and language development issues (Drager, Light, Speltz, Fallon, & Jeffries, 2003; Mizuko, 1987; Musselwhite & Ruscello, 1984), results of the investigation are not generalizable to children with complex communication needs.
2. Participants whom took part in the study live in Central Florida exclusively, and, therefore, may not be representative of participants living in other areas.

## Delimitations

1. The study included four groups of participants: (a) a group consisting of 25 three-year old preschoolers; (b) a group consisting of 29, four-year old preschoolers; (c) a group consisting of 20, five-year old children; and (d) a group consisting of 21, six-year old children.
2. Participants were required to meet the following inclusionary criteria:
   (a) be of chronological age between 3.0 – 6.11 years, as per preschool/school records (Appendix A).
   (b) speak English as primary language at home, as per preschool/school records (Appendix A).
   (c) have no uncorrected visual or hearing difficulties, as per preschool/school

records (Appendix A).

(d) have no known cognitive impairments, as evidenced by educational placement and parent report (Appendix A).

(e) have age-appropriate: receptive language skills, expressive language skills, articulation skills, voice and fluency as determined by passing score on the *Preschool Language Scales, Fifth Edition Screening Test* ([PLS-5]; Zimmerman, Steiner, & Pond, 2011) See Appendices B-E.

(f) demonstrate receptive knowledge of all the nouns, verbs and adjectives to be used in the study (Appendix F), as exhibited by 100% accuracy score on the screening task and data collection sheet described in the methodology section (Appendix G, Appendix H).

3. Participants in each developmental age group (i.e., three, four, five and six-years of age) were randomly assigned to the following: color photograph symbol[1] or SymbolStix©[2] symbol condition, expressive or receptive task with counterbalance.
4. Participants were recruited from preschools and private schools, which are service locations of the University of Central Florida (UCF) Communication Disorders Clinic, located in Central Florida.
5. Study sessions were conducted at preschools and private schools in the Orlando area.
6. Three sessions were conducted for a total of approximately 45 minutes in length.

## Assumptions

This study made the following assumptions:

1. Symbol type is a key consideration in accurately assessing preschoolers' receptive language abilities.
2. The established transparency hierarchy (Mirenda & Locke, 1989) which only applies to one-word class (i.e., nouns), will generalize to verbs and adjectives.
3. The lack of valid and reliable assessment modifications for individuals with complex communication needs impedes the speech-language pathologist's ability to obtain an accurate picture of an individual's receptive language skills (Haaf, et al., 1999).
4. Children with severe cognitive delays may have more difficulty recognizing line drawings used as stimuli in tests compared to photograph-based symbols (Beukleman & Mirenda, 2013; Cauley et al., 1989; Geytenbeek et al., 2010; Mirenda & Locke, 1989; Romski & Sevcik, 1996).
5. The researcher, an ASHA certified and state licensed speech-language pathologist is qualified to conduct the proposed investigation.
6. The researcher, an ASHA certified and state licensed speech-language pathologist and graduate/undergraduate students and clinical fellow supervised by the researcher are qualified to administer and score all assessment tasks.

## Operational Definitions

The following terms were operationally defined for the purpose of the study:

1. *Individuals with Complex Communication Needs:* Persons who may present with motor and/or sensory/perceptual impairments in addition to significant speech impairments (Beukelman & Mirenda, 2013).

2. *Augmentative and Alternative Communication:* The use of a wide range of unaided and aided strategies and techniques to enhance communication (Light & McNaughton, 2014a).
3. *Symbol:* "Something that stands for or represents another thing or concept" (Alant, Bornman & Lloyd, 2006, p. 145).
4. *Referent:* The "something" that a symbol represents may include an object, attribute or action (Vanderheiden & Yoder, 1986, p.15)
5. *Graphic symbols:* Various types of symbols which intend to represent individual words or phrases (Sigafoos, Schlosser & Sutherland, 2010).
6. *Color photograph symbol[1]:* A transparent symbol in which the symbol meaning can be easily guessed without the presence of its referent; color photograph symbols[1] were retrieved from iStock (www.istock.com).
7. *SymbolStix©[2] symbol* (*Crick Software;http://www.cricksoft.com/us/products/symbols/symbolstix.aspx):* Color line drawing symbols that depict activities and people as lively stick figures (Beukelman & Mirenda, 2013).
8. *Tobii DynaVox Communicator 5 Software:* A software package, which converts text and symbols into voice output, featuring Symbolstix©[2] symbol set (www.tobiidynavox.com).
9. *Transparency/Transparent Symbols:* "The shape, motion or function of the referent is depicted to such an extent that meaning of the symbol can be readily guessed in the absence of the referent" (Fuller & Lloyd, 1991, p. 217); the ability of a participant to guess the meaning of a symbol when presented with one symbol at a time.

10. *Iconicity:* The degree to which a symbol looks like what it represents (Mirenda & Locke, 1989); any association that an individual forms between a symbol and its referent (Schlosser, 2003, p. 350).
11. *Pictorial Competence:* The ability to perceive, interpret, understand and use pictures communicatively (Deloache, Pierroustakos & Uttal, 2003).
12. *Identification:* An individual's ability to see a relation between a spoken word and a graphic symbol (Schlosser et al., 2012); a symbol was considered identified correctly if the child touched the quadrant with the symbol corresponding to the spoken name provided.
13. *Tobii DynaVox I15+ Eye Tracker:* The Tobii DynaVox I15+ is a speech-generating device that can be controlled by gaze interaction via a built in eye-tracker (www.tobiidynavox.com).
14. *Tobii DynaVox Gaze Viewer:* An assessment tool available for use with Tobii DynaVox eye tracking technology, which allows for real time, audio and visual recording of eye tracking data (http://www.tobiidynavox.com/gazeviewer/).
15. *Eye Tracking Rate:* Elapsed time in seconds from the end of the prompt, to the fixation immediately preceding participant's touch to target.
16. *Time to Touch Rate:* Elapsed time in seconds from the end of the prompt to the participant's touch to target.

**Summary**

This chapter provided an overview for the study including: the problem, purpose of the study, research questions, hypotheses, limitations, delimitations, assumptions, and operational definitions. The study examined the effects of symbol type (color photograph symbols[1] vs. SymbolStix©[2] symbols) on identification and naming of graphic symbols for nouns, verbs and adjectives in typically developing three, four, five and six- year old children.

## CHAPTER TWO: LITERATURE REVIEW

Although prevalence of significant communication disorders varies by age group (Beukelman & Mirenda, 2013), all individuals who require AAC share one unifying characteristic: the need for adaptive assistance to speak and/or write due to inadequate gestural, spoken, or written communication to meet all communication needs (Beukelman & Mirenda, 2013). Without access to relevant communication supports, individuals with complex communication needs are not able to functionally communicate in natural environments. Several recent studies have reported specific prevalence data for differing pediatric populations in the United States. Binger and Light (2006) surveyed speech-language pathologists (SLPs) from 11 agencies in rural and urban areas in Pennsylvania who serve preschool-aged children. These SLPs reported that 12% of students on their caseloads who received special education services required AAC for effective communication. Similarly, Kent-Walsh and colleagues (2008) surveyed school-based SLPs in a large Florida urban school district, and reported that 57.8% of respondents had students with identified AAC needs on their caseloads. It is noteworthy that beyond reporting a high percentage of children actually receiving AAC services, Kent-Walsh and colleagues also reported that participants indicated a higher percentage of individuals on their caseloads who "would achieve greater academic success if they had additional supports and services to facilitate consistent use of AAC in the classroom." These findings taken as a whole make a strong statement about the need for increased AAC service-delivery for pre-school and school-aged populations. Furthermore, given the growing prevalence of children with complex communication needs, there is a need to investigate modifications to current assessment practices in order to develop appropriate treatment plans for this population.

Children requiring AAC assessment and intervention have been noted to have a range of physical and cognitive disabilities which may yield the need to modify traditional assessment tools in order to gain more accurate representations of their' communication skills (Kent-Walsh et al., 2008). Examples of modifications include computerized administration of standardized assessments and providing alternate access methods (e.g., track ball, switch scanning, eye tracking) in order for children to participate in evaluations despite physical limitations. Another key consideration is the type of stimuli currently utilized in standardized assessment tools. To date, the literature indicates heavy reliance on line drawings to represent concepts being tested. Given that the literature suggests that individuals with cognitive impairments have significant difficulty in identifying constructs depicted by line drawings (e.g., Mirenda & Locke, 1989; Mizuko, 1987), there is a critical need to examine the effects of including more recognizable stimuli in AAC assessment procedures. The broader AAC assessment framework lays the foundation for such considerations.

## AAC Assessment

### Comprehensive AAC Assessment Framework

The goal of intervention for children with complex communication needs is to facilitate functional communication in the full spectrum of natural environments. Just as a range of natural environments are relevant to individuals using AAC, a broad range of AAC assessment options also should be considered for individuals with complex communication needs. Given the heterogeneity in AAC populations and that the goal of any AAC assessment process is to accurately describe the communication skills of the person being assessed, a clear argument can be articulated for customizing assessment procedures to be responsive to the specific needs of individual children. In other words, unless the individual being assessed can fully participate in all components of the investigation, the findings of the assessment will be invalid. Although necessary, this need for customization makes it difficult to develop and utilize a standardized AAC protocol (Dietz, Quach, Lund & McKelvey, 2012). Despite the fact that there is no standardized battery of tests that comprise an AAC evaluation, there are several models and approaches that guide the AAC assessment process (Beukelman & Mirenda, 2013; Calculator, 2009; Glennen & Decoste, 1997). Two of these approaches are as follows: (a) the Participation Model (Beukelman & Mirenda, 1988), and (b) the feature-matching (Beukelman & Mirenda, 2013).

**Participation model.** In a 2004 technical report, ASHA endorsed the Participation Model as a framework for conducting AAC assessment and intervention (ASHA, 2004). The Participation Model (Beukelman & Mirenda, 2013; 1988) provides a systematic process for conducting AAC assessments and intervention based on the functional participation requirements of peers without disabilities of the same chronological age (Beukelman & Mirenda, 2013). This model considers the interactions of the individual who relies on assistive technology, the activity to be completed, and the context in which the activity is performed (Cook & Polgar, 2008). Within this model, the assessment focuses on the identification of an individual's strengths in the following areas: communication needs and participation patterns, expressive language, receptive language, cognition, natural speech, sensory-perceptual skills, motor skills, symbol representation skills and AAC system trials (Beukelman & Mirenda, 1988). Although this framework exists for assessing individuals with complex communication needs, there is a widespread tendency to over-assess capabilities when implementing this framework; in other words, there is a tendency for professionals to administer an excessive number of tests which end up revealing little information and having limited bearing on future intervention or outcomes. Further, over-assessment is concerning since it is time consuming and places undue demands on individuals and their families (Beukelman & Mirenda, 2013).

**Feature matching approach.** As a supplement to the Participation Model (Beukelman & Mirenda, 1988), many AAC specialists utilize a feature-matching approach for AAC assessment (Costello, & Shane, 1994; Glennen, 1997; Yorkston & Karlan, 1986). This approach encompasses a number of the same principles as the Participation Model (Beukelman & Mirenda, 1988). For example, when following a feature matching approach, the team administers judiciously selected, criterion-referenced tasks that are designed to answer relevant question regarding an individual’s capabilities. The feature-matching approach is a recursive process that is used to identify relevant AAC system features or functionality that are consistent with an individual’s, cognitive, language, literacy, access and sensory skills at a given time (Beukelman & Mirenda, 2013). One area which is often at the forefront of the feature matching process is AAC system access. Identifying a reliable mode of accessing an AAC system is critical for individuals with a range of motor impairments. The team must identify the most reliable motor movement a client has during the assessment process and a technique that the individual can use for alternative AAC access in the long-term. In both the Participation Model (Beukeleman & Mirenda, 2013) and the feature matching approach (Costello, & Shane, 1994; Glennen, 1997; Yorkston & Karlan, 1986), the AAC team makes predictions based on the assessment of the above-described areas regarding an AAC system or technique to set up a trial of the selected AAC components for a designated period.

In addition to access, an important component of the AAC system assessment process relates to the manner in which tested concepts are represented within assessment stimuli. The types of symbols used to depict tested concepts can directly affect test outcomes. In other words, the way in which an individual understands the symbols impacts a person's ability to make appropriate symbol selections within an assessment process. If the person does not understand the symbols from which they must choose in response to an assessment question, they will not be able to make an accurate selection. There are several factors that influence symbol learning and understanding, including spoken language comprehension and developmental age.

**Language and Symbol Comprehension**

According to Smith (2015), receptive language skills may be a relative strength in comparison to other aspects of cognition for many aided communicators (Berninger & Gans, 1986; Ross & Cress, 2006). Therefore, many people consider receptive language skills a more reliable measure of overall cognitive ability in very young children with developmental disabilities. Given that a young child's physical or speech impairment may interfere with his or her performance on standardized expressive language and nonverbal cognitive tasks (DeVeney, Hoffman & Cress, 2012), receptive language assessment options can offer advantageous approaches to measuring children's true skill levels. Prior to delving into the literature regarding spoken language comprehension, one must define language comprehension and investigate its impact on aided symbol understanding and learning.

Language comprehension refers to a person's ability to understand the meaning of spoken words and may impact the rate and development of aided symbol learning (Brady, Anderson, Hahn, Obermeier & Kapa, 2014; Romski & Sevcik, 1993; Sevcik & Romski, 2002). Language comprehension has also been described as a driver of language development in speaking children and is considered an important indicator of young children's ability to engage with non-speech symbols (Brady et al., 2013; Ingram, 1989). Knowledge of spoken language use and language content are rarely referenced for children who use aided communication (Smith, 2015). Developing a better understanding of language comprehension for children with complex communication needs can shed light on how receptive language skills influence symbol understanding. Therefore, consideration of both spoken language use and language content is essential to understanding young children's symbol development.

Language content encompasses semantics, including vocabulary and knowledge of objects and events (Smith, 2015). Children with complex communication needs who have physical impairments have different experiences than same age typically developing peers, and may at times infer different meanings that are prominent and appropriate to their experiences (Smith, 2015). However, these children still have to learn how concepts map onto words. Not surprisingly, children with complex communication needs often present with severe expressive impairments, and for these children, "receptive communication may reflect more closely a young child's communicative and procedural competence…" (Ross & Cress, 2006; p. 101). Although receptive language skills may be a significant strength for individuals who use aided communication, where vocabulary scores from formal assessments are reported, they are often calculated to be unexpectedly low (Blockberger & Johnston, 2003; Bruno & Trembath, 2006; Kent-Walsh, Binger & Hasham, 2010; Lund & Light, 2006).

Children with complex communication needs often present with severe speech impairments and are therefore vulnerable to specific gaps in their understanding of spoken language -- "gaps that may not be readily identified using global measures of language comprehension" (Smith, 2015 p. 218). Blockberger and Johnson (2003) found that even when matched for vocabulary with peers with language delay, children with severe speech impairments made more errors across a range of receptive measures. It is logical that the speech and expressive language impairments often experienced by this population will have an influence on their ability to understand spoken language, and in turn to develop symbol comprehension. However, an additional factor that may contribute to the reported lower receptive language skills of some children with complex communication needs is the type of stimuli utilized in receptive language assessments. In other words, although this population is vulnerable to gaps in their understanding of spoken language generally, there are other factors that influence symbol understanding including iconicity and transparency, which may also negatively influence the estimation of receptive language ability.

**Factors influencing symbol learning and understanding.** According to Mirenda and Locke (1989), one of the most important considerations in designing a communication system for non-verbal individuals with intellectual disabilities is the selection of the symbol type used to represent various messages. A symbol is something that represents something else (Vanderheiden & Yoder, 1986). The "something else" represented by the symbol is known as its referent (Beukelman & Mirenda, 2013). Symbols can be described in terms of a variety of characteristics including: realism, iconicity, ambiguity, complexity, efficiency, color and size (Fuller, Lloyd & Stratton, 1997; Schlosser, 2003; Schlosser & Sigafoos, 2002; Wilkinson & Jagaroo, 2004). Iconicity has been defined in terms of a continuum - ranging from transparent to translucent to opaque depending on the symbol's "guessability" by naïve viewers (Bellugi & Klima, 1976; Mizuko, 1987). Simply put, iconicity refers to the degree to which a symbol looks like what it represents (Mirenda & Locke, 1989). The iconicity hypothesis suggests that symbols that closely resemble their referents are easier to recognize and to learn to use than more abstract symbols (Fuller & Lloyd, 1991; Lloyd & Fuller, 1990; Loncke, Campbell, England, & Haley, 2006; Schlosser, 2003). This hypothesis has been supported by findings from studies including both children and adults without disabilities (Mizuko, 1987; Musselwhite & Ruscello, 1984), and studies including individuals with intellectual disabilities (Mirenda & Locke, 1989; Mizuko & Reichle, 1989; Sevcik & Romski, 1986)

The meaning of any symbol is also determined by a variety of intrinsic factors, including an individual's motivation, neurological status, developmental age, sensory abilities, cognitive skills, communication/language abilities, and world experience (Mineo-Mollica, 2003). According to DeLoache and MarZolf (1992), experience responding to a certain entity as a representation of something other than itself increases an individual's readiness to respond to other entities in an abstract, rather than concrete, mode. Iconicity (i.e., perceptual similarity between a symbol and its referent) and symbol learning also appear to be "culture-bound, time-bound and in general experience-bound" (Brown, 1977, p. 29).

Romski and Sevcik (1996; 2005) have suggested that spoken language comprehension plays a critical role in the process of symbol learning. In their studies involving children who were diagnosed with severe cognitive disabilities (ages 2.0 – 3.8 years), those children who understood the meaning of particular referents learned to recognize the referents' abstract symbols more readily than those children without such skills. Developmental age is another factor which influences symbol understanding with regard to graphic/pictorial symbols (Beukelman & Mirenda, 2013).

***Developmental age.*** A fully developed understanding of the shared representational function of symbols takes time for children to acquire (Callaghan, 2008; Nelson, 2006, 2007; Rochat & Callaghan, 2005; Tomasello, 1999, 2008). Namy and colleagues (Namy, 2001; Namy, Campbell, & Tomasello, 2004) examined symbolic development of young typically developing children between the ages of 18 months and 4 years of age, and found that the degree of iconicity facilitates meaning in children at 26 months of age. Furthermore, findings from these studies also indicated that as children develop a more refined understanding of the rules that govern human communication at 24 months and beyond, they begin to employ iconicity as an indicator that non-verbal symbols are intended to refer to the target objects. This research suggests that as children get older, iconicity has a greater influence on their symbol understanding and acquisition. The results of these studies were consistent with other study findings of children without disabilities indicating that the development of "pictorial competence" (i.e., the ability to perceive, understand, interpret and use pictures communicatively) gradually evolves over the first few years of life (DeLoache et al., 2003, p. 114).

Research involving matching pictorial symbols to corresponding real objects suggests that important components of representational understanding develop somewhat later (Callaghan, Rochat & Corbit, 2012). Pictorial competence (i.e., the ability to understand and use symbols communicatively) does not emerge uniformly for all symbols and referents even after the age of three years, and the ability to comprehend and use a variety of symbol types continues to develop until at least five years of age (Rochat & Callaghan, 2005). Given the age ranges noted for symbol development and use (i.e., 3:0 - 5:0+), it is necessary to review the research that has been conducted in this area (e.g., Light, 2008; Romski & Sevcil, 1986; Visser, Alant & Harty, 2008) to gain a better understanding of the importance of symbol type.

In a study conducted by Visser, Alant and Harty (2008), one quarter of typically developing 4-year-olds struggled to recognize line-drawing symbols for the emotions *sad, angry, and scared/afraid*, but had little difficulty with *happy.* These findings are consistent with previous studies which indicated that nouns are relatively easier to represent in comparison to verbs, descriptors and wh-questions (Bloomberg, Karlan & Lloyd, 1990; Lund, Millar, Herman, Hinds, Light, 1998; Mizuko, 1987; Worah, 2008). The emerging knowledge base on how young children without disabilities learn to use objects and pictures as symbols may inform exploration and understanding of the development of the use of pictures as communication symbols by individuals with disabilities (Stephenson, 2009).

***Other factors.*** A child's ability to identify and understand the meaning of symbols depicting abstract linguistic concepts (e.g., verbs, adjectives) can be affected by additional factors beyond developmental age including: concreteness, familiarity, context, wholeness, color and focus (Light et al., 2008). Concrete symbols are those symbols that are more readily understood as they more clearly depict people and/or observable activities (Light et al., 2008; Lund et al., 1998). According to a study conducted by Romski and Sevcik (1986), individuals with severe intellectual disabilities and functional language skills were able to match objects to both line drawings and color photographs. In contrast, people with no functional language skills and limited comprehension of words could only match objects to photographs, and were not able to match objects to line drawings (Romski & Sevcik, 1986). The literature to date (e.g., Light, 2008; Romski & Sevcik, 1986; Visser, Alant & Harty, 2008) underscores the importance of symbol type as a key factor in a child's ability to understand and use symbols communicatively. As such, it is important to have a theoretical framework to explain how these factors interact with one another and influence symbol development (DeLoache, 1995).

***Model of symbol understanding and development***. One theoretical model for the development of symbol understanding was developed by DeLoache **(**1995). DeLoache's model incorporates several factors including: characteristics of the symbol itself (salience), the symbol referent relationship (iconicity), the symbol user (experience), and the social context (instruction) (DeLoache, 1995). DeLoache describes that these factors interact with one another, and she indicates that high levels of one factor can compensate for low levels of another. For example, although a young child may not have experience with an object, he or she can comprehend the symbol referent relationship when presented with a highly iconic representation (e.g., color photo of an object) and instruction. Furthermore, DeLoache describes that representational insight - the basic realization of the existence of a symbol-referent relation - is the pivotal element in this model (2005). According to DeLoache (1995), the end point of the model is the child's behavior of using the symbol as a source of information, which requires mapping (i.e., mental representation) between symbol and referent.

The central component of DeLoache's model (1995) is the construct of representational insight. The key to representational insight is that children must be able to represent the object or picture in its own right (i.e., mental representation) and as something that represents another object (DeLoache, 1995). This is referred to as dual representation, and is crucial to a child's ability to utilize pictures or objects as symbols. It may be easier for children to perceive the relationship between the symbol and the referent if there is some level of perceptual similarity or iconicity (Stephenson, 2009). Yet, more abstract representations of constructs (e.g., line drawings) are used as stimuli in assessment tools to determine receptive language skills of children.

DeLoache (1995) considers iconicity to be the perceptual similarity between a symbol and its referent and in order to use an object or picture as a symbol, an individual needs to be aware of the relationship between the object and its' referent (Stephenson, 2009). Furthermore, it is necessary to be able to map the correspondence between them and draw an inference from one to the other (DeLoache, 1995). Iconicity generally facilitates symbol understanding and use; meaning that the more a symbol resembles its referent the easier it is to perceive the similarity between the two (DeLoache, 1995). Many symbol–referent relationships are considered arbitrary with no physical resemblance at all (e.g., letters, numerals). While others are highly iconic -with significant resemblance to the object the symbol represents (e.g., color photograph symbols).

Another key concept covered in DeLoache's (1995) model is pictorial competence. Pictorial competence includes a range of abilities in perception, interpretation and comprehension of pictures (DeLoache & Burns, 1993,1994; DeLoache, Pierroutsakos & Uttal, 2003). Pictorial competence requires the ability to recognize the object depicted and knowledge of the relationship of the picture and its referent as well as the intent of the picture producer (Stephenson, 2009). For a child to use a picture symbolically, he or she must perceive the similarity between the picture and the referent and use this perceived relationship to see or interpret what the picture represents. To use graphic symbols to communicate, individuals who use AAC must not only recognize the relationship between the graphic representation and the linguistic concept, but they also must be able to use the symbol in different situations to communicate a variety of communicative intentions (Worah, McNaughton, Light & Benedek-Wood, 2015). It has been suggested that reflection on DeLoache's model can facilitate better understanding of how iconicity impacts graphic symbol understanding and use by people with severe disabilities (Stephenson, 2009).

Given that symbol type (e.g., line drawings, photograph-based symbols) has an impact on an individual's ability to match, identify and use symbols communicatively, there is a need to examine the use of symbols in the assessment of receptive language skills for children with complex communication needs. A more complete understanding of the characteristics of symbols may lead to a more refined AAC assessment protocol for children with complex communication needs, and a more refined receptive language profile will provide a strong foundation for interventions aimed at improving receptive language skills.

## Receptive Language Assessment

**Overview of available receptive language assessment tools and procedures.** One of the key components of an AAC assessment is the evaluation of receptive vocabulary skills. Receptive language assessments provide SLPs and educators with important information such as a child's receptive vocabulary and knowledge of nouns, verbs and adjectives. Several receptive vocabulary tests currently exist and are utilized as part of a comprehensive AAC assessment when evaluating children with complex communication needs. Such tests include: *The Receptive One Word Picture Vocabulary Test Fourth Edition* ([ROWPVT-4], Brownell, 2011), *The Peabody Picture Vocabulary Test Fourth Edition* ([PPVT-4], Dunn & Dunn, 2007) and the *Test for Auditory Comprehension of Language-Fourth Edition* (Carrow-Woolfolk, 2014a). However, several of these tests contain unequal proportions of word classes. An analysis consisting of percentage of word class for these receptive language assessments revealed the following: ROWPVT-4 (Brownell, 2000) nouns = 70%, verbs = 18% and adjectives = 15%, PPVT-4 (Dunn & Dunn, 2007) nouns = 80%, verbs = 15%, and adjectives = < 1%, TACL-4 (Carrow-Woolfolk, 2014a) nouns = 47%, verbs = 24%, and adjectives = 29%. It is not surprising that several studies conducted in the field of AAC have included participants with complex communication needs and utilized children's scores from the TACL-4 (Carrow-Woolfolk, 2014a) as part of subject selection criteria (e.g., Binger, Maguire-Marshall, & Kent-Walsh, 2011; Kent-Walsh, Binger, & Buchanan, 2015) since the TACL-4 (Carrow-Woolfolk, 2014a) affords a more even distribution of word classes and has been normed on populations with varying disabilities (e.g., intellectual disorders, deaf/hard of hearing, autism spectrum disorder).

However, all of the aforementioned assessments utilize color line drawings to depict objects, actions, spatial locations and attributes despite past research indicating that these representations can be challenging for children with disabilities to identify (Beukelman & Mirenda, 2013; Cauley et al., 1989; Geytenbeek et al., 2010; Mirenda & Locke, 1989; Mizuko, 1987; Romski & Sevcik, 1996). A review of shortcomings of standardized test use with children with disabilities provides a much-needed perspective on how the receptive language skills of many children are underestimated.

### Barriers in executing standardized receptive language assessment procedures.

Research has been conducted over the years on the shortcomings of standardized test use with children with disabilities generally (Utley, Haywood & Masters, 1992; Tzuriel, 2000). We know that when children are assessed with static assessments, the examiner records responses without trying to change, modify, or improve the examinee's performance (Tzuriel, 2000). Therefore, standardized test use with children with disabilities does not capture an examinee's: learning ability, specific deficient functions, change processes or mediation strategies that are responsible for cognitive modifiability (Haywood & Lidz, 2007; Haywood & Tzuriel, 1992; Lidz & Elliot, 2000; Tzuriel, 2000). Additionally, problems with standardized tests are magnified when applied to children with cognitive impairments or those from culturally and linguistically diverse backgrounds since these populations may experience difficulty understanding the directives of the evaluation tasks (Tzuriel, 2000). Furthermore, static, norm-referenced tests have been noted to lack sensitivity to the limited educational experiences of children with severe disabilities (Mirenda, 2014) given that these children often present with physical and/or cognitive impairments, unlike their typically developing peers.

Utley and colleagues (1992) criticized the limited value of standardized tests since they are used principally for classification purposes and are aimed at providing differential treatment for individuals differing in level or pattern of intelligence. Static tests have been noted to discount important factors including: specific strategies that facilitate learning and what a child might achieve with an adult's guidance or peer's help (Tzureil, 2000). Norm-referenced assessment is another static assessment option; and is often difficult to administer to children with disabilities for several reasons.

Norm-referenced assessments include administration of formal or standardized tests to compare an individual's abilities with those of same-age peers. According to Beukelman and Mirenda (2013), professionals are often frustrated given the difficulty in administering these tests in a standardized manner for individuals with complex communication needs. Further, standardized assessments often require verbal responses or physical manipulation of stimuli, which for individuals with complex communication needs may not always be possible, secondary to speech and motor limitations. Thus, many professionals utilize these assessments with modifications based on an individual's particular needs (Beukelman & Mirenda, 2013). Such modifications might include; alternate response modes, (e.g., eye tracking to indicate responses vs. pointing, yes-no response format) or computerized administration of paper-based standardized test materials (Geytenbeek, et al., 2010; Haaf, et al., 1999; & McDougall et al., 2012). When norm-referenced tests are administered with modifications, they can provide general information related to an individual's capabilities. However, it is inappropriate to use such tests, when modified, to compare individuals with complex communication needs to peers of the same chronological age without disabilities, or to determine eligibility for AAC services (Snell et al., 2003). Furthermore, execution of norm-referenced procedures must be implemented with considerable caution in light of the different physical, cognitive and educational experiences of children with disabilities (Beukelman & Mirenda, 2013). The American Educational Research Association [AERA], American Psychological Association [APA], and the National Council on Measurement in Education [NCME], 1999) indicate that a person with a disability may require adaptations to an assessment procedure and have established standards for doing so (i.e., standard 1.4 & 10.3).

One additional modification beyond response mode and administration variations relates to the type of stimuli utilized in standardized assessments for children with complex communication needs. Moreover, the American Speech Language Hearing Association [ASHA] supports an evaluator's need to modify assessment procedures even breaking standardization when appropriate in order to obtain a valid assessment of communication skills. If the goal of an AAC assessment is to identify a client's strengths and abilities, and to develop a strategy for building on those strengths (SAC, 2015), further research is needed to investigate the effects of modifications - - specifically, the type of symbols utilized in standardized assessments in order to meet current and future language and communication needs of children with complex communication needs.

There are many challenges facing individuals with complex communication needs in terms of standardized assessment practices. One of the barriers that merit consideration is the type of stimuli utilized in assessment tools. Given the limitations of standardized assessments as they relate to children with disabilities, and available evidence indicating that individuals with cognitive-language disabilities more readily identify photograph-based symbols in comparison to other symbol formats (Beukelman & Mirenda, 2013; Cauley et al., 1989; Geytenbeek et al., 2010; Mirenda & Locke, 1989; Romski & Sevcik, 1996), there is a need for the development of evaluation tools with comprehensible stimuli in order to facilitate accurate measurement of receptive language capabilities for children with complex communication needs. Considering the impact of both transparency and iconicity on children's ability to accurately identify and understand symbols, symbol type can be viewed as a barrier to children's accurate identification of constructs or concepts presented in receptive language assessments.

**Concept representation barriers within standardized assessment stimuli.** The importance of comprehension as it relates to symbol understanding and use has been well acknowledged in the AAC field (Trudeau, Sutton & Morford, 2014). Comprehension of the spoken language of the environment and understanding of the symbols in one's AAC system are both aspects of linguistic competence (Light, 1989; 2003). The way in which one interprets an individual symbol influences the use one will make of it. Comprehension of graphic symbols, therefore, is critical to an individual's ability to use graphic symbols for expression (Harris & Reichle, 2004).

According to Light (1989), linguistic competence refers to "an adequate level of mastery of the linguistic code, including phonological, morphological, syntactic and semantic aspects" (Light, 1989, p. 139). There are many barriers faced by individuals who use AAC systems in attaining linguistic competence, including learning their native language as spoken by the community and mastering the linguistic code required by the AAC system (Light, 1989). Individuals who use AAC systems must develop the receptive language skills necessary to function within their community and as many spoken expressive language skills as possible (Light, 1989).

An understanding of the phonological, morphological, syntactic and semantic aspects of language must be acquired despite developmental constraints experienced by most individuals who utilize AAC -especially those who are with physical disabilities, including limited physical and cognitive experiences (Light, 1989; Yoder & Kraat, 1983). Moreover, individuals who use AAC systems must also master the linguistic code of the AAC system by learning the symbols that comprise their system (e.g., PCS, SymbolStix©[2], Picsyms, traditional orthography). In order to facilitate the linguistic competence of children with complex communication needs, there is a need to have assessment tools with appropriate symbol types, which can afford accurate characterizations of receptive language skills. Because individuals with severe cognitive delays may not be presented with comprehensible stimuli during assessment procedures, there is a risk of under-estimating verbal comprehension abilities (Emerson, 2003). The establishment of valid and psychometrically sound measures will facilitate the interdisciplinary teams' assessment of linguistic competence for individuals using AAC systems (Light, 1989). In order to validate symbol change effects on identification of graphic symbols used in receptive language assessments, there is a critical need for research to be conducted in this area. Understanding the role of iconicity and transparency of stimuli utilized in receptive language assessment is crucial to obtaining an accurate representation of children's vocabulary knowledge and warrants further discussion.

***Iconicity.*** In reflecting on iconicity in the context of standardized assessment stimuli, we know that the primary use of line drawings (a less iconic representation) may be problematic for children with disabilities to perceive the similarities between the symbols and their referents. Given that line drawings are not highly iconic, the use of such stimuli in standardized assessments may result in an inaccurate representation of children's receptive language skills, as errors may be erroneously attributed to a lack of concept knowledge vs. the type of symbolic representation used. Iconicity clearly plays a role in one's ability to understand, identify and use symbols communicatively and therefore can be viewed as a barrier to accurate assessment of receptive language skills. Transparency is another factor, which can impact the accurate identification and use of symbols that also needs to be considered in the context of assessment.

***Transparency.*** Symbol transparency has also been identified as an important consideration when choosing a symbol system for individuals with complex communication needs (Daniloff, Lloyd, & Fristoe, 1983; Musselwhite & Ruscello, 1982). Transparency refers to the ease of identification of symbols when no additional cues such as printed labels or verbal hints are provided (Musselwhite & Ruscello, 1984). A symbol is said to be a transparent depiction when the symbol to referent relationship is clear and obvious (Patel, Schooley and Wilner, 2007). Musselwhite and Ruscello (1984) conducted a study with typically developing children and adults (ages 3:0 – 21:11) to investigate the transparency of three communication symbol systems: Blissymbols, Picsyms and Rebus in a forced-choice identification task. Significantly fewer symbols from the Bliss system were found to be transparent in comparison to Picsyms and Rebus. The researchers identified several reasons for the lower transparency of the Bliss system which related to their relative abstractness, graphic detail and discriminability; they concluded that transparency is an important consideration in symbol selection for individuals with complex communication needs. These conclusions build support for additional research to be conducted to examine transparency of other symbol systems (Musselwhite & Ruscello, 1984).

Mizuko (1987) also investigated transparency and ease of symbol learning with Blissymbols, Picture Communication Symbols (PCS) and Picsyms (i.e., a variety of line drawings) with typically developing 3-year-old children. Results revealed Picsyms and PCS symbols were more transparent and easier to learn than Blissymbols. Although Blissymbols were noted to be more difficult to learn, no specific word class error patterns were noted.

In a related investigation, Mirenda and Locke (1989) included 40 nonspeaking participants, who ranged in age from 3:11 to 20:10 and presented with varying degrees of intellectual disability (i.e., mild, moderate and severe intellectual disability, developmental delay, etc.,) and a range of primary medical diagnoses (e.g., cerebral palsy, autism). These investigators focused on the identification of 11 different symbol types representing objects and the word class of nouns. The following transparency hierarchy, in the order of easiest to hardest, was identified: objects, color photographs, black-and-white photographs, miniature objects, black-and-white line drawings, Blissymbols and written words. The established transparency hierarchy derived from work with individuals with intellectual disabilities revealed benefits for the use of highly transparent symbols for noun depiction.

It has also been argued that the use of iconic symbols (i.e., symbols that are most transparent) might be a better communication choice for people with severe intellectual disabilities because recognition of these symbols does not depend on the same level of symbolic ability as for arbitrary symbols (e.g., Blissymbols), and thus, cognitive demands may be lessened (Rowland & Schweigert, 1989, 2003; Siegel & Cress, 2002; Stephenson, 2009; Wilkinson & McIlvane, 2002). Photographs and line drawings of specific items, whose meaning and relationship to the referents can be easily identified, are considered highly transparent (Worah et. al., 2015). Contrastingly, highly symbolic representations that assume little resemblance to their referent (i.e., printed words) are considered to be low in transparency (Shane, Laubscher, Schlosser, Flynn, Sorce & Abramson, 2012).

Some researchers have suggested that there is a sequential development from the use of pictures to more abstract forms such as traditional orthography (Von Tetzchner & Grove, 2003). For those individuals with little or no comprehension of the spoken word, graphic symbols (e.g., various symbol types, line drawings, PCS) might be needed for both comprehension and expression (Von Tetzchner & Martinsen, 2000). Research has demonstrated generalized use of pictures and other graphic symbols (i.e., various symbol types, line drawings, PCS, etc.) by people with severe intellectual disabilities who have good comprehension of spoken language (Carr, Wilkinson, Blackman, & McIlvane, 2000; Mineo Mollica, 2003; Romski & Sevcik, 1996). However, the acquisition and generalized use of graphic symbols (i.e., various symbol types, line drawings, PCS, etc.) by people who have little or no comprehension of the spoken word has been studied less frequently to date (Romski & Sevcik, 1996; Snell et al., 2006; Von Tetzchner et al., 2004).

Although it may be easy to represent concrete vocabulary (e.g., nouns) by using iconic symbols, it is more difficult to represent abstract concepts, such as verbs and descriptors (e.g., Bloomberg, Karlan, & Lloyd, 1990; Mizuko, 1987; Worah et al., 2015). Just as vocabulary items can be coded on a continuum of abstraction (i.e., concrete to abstract), so too can vocabulary representation be coded on a continuum of transparency (Worah, et al., 2015). In reflecting on this continuum, it is not surprising that children with complex communication needs are often underestimated in terms of their receptive language skills on standardized assessments. In other words, if this population is not presented with recognizable stimuli (i.e., line drawings vs. color photograph symbols), it is difficult for SLPs and educators to acquire an accurate representation of their receptive vocabulary abilities and in turn develop appropriate treatment plans.

There has been a dearth of literature examining the effects of symbol type on transparency, iconicity and identification across word classes (nouns, verbs, adjectives); none of the studies conducted to date examined the effects of color photograph-based symbols and color line drawings on children's ability to identify and name graphic symbols.  Transparency, like iconicity, is an important factor in determining appropriate symbols sets for children with complex communication needs. The evidence base regarding the effects of iconicity, transparency and the way in which linguistic concepts are represented symbolically affects children's ability to identify and name graphic symbols, and therefore merits further review.

Current AAC systems frequently represent abstract linguistic concepts (e.g., questions, descriptors) using symbolic representations based on adult conceptual models for particular vocabulary items and often require notable metalinguistic skills for interpretation (Worah et al., 2015). As a result, current AAC system symbol representations may not be meaningful for young children who may have difficulty seeing the relationship between the graphic symbol representation and the linguistic concept (Light & Drager, 2012; Light et al., 2008). The use of symbols that are more readily understood by young children generally may also be learned more easily and more functionally used by children with AAC needs (Light et al., 2005). The limited knowledge about how children with severe intellectual disabilities - particularly those with little or no comprehension of spoken language -might acquire symbolic understanding and use of pictures impacts the types of symbols utilized for both assessment and intervention. Several studies have been conducted to examine graphic symbol representation use with young children (e.g., Light et al., 2008; Lund et al., 1998; Schlosser et al., 2012; Worah et al., 2015).

Light and colleagues (2008) examined typically developing children's drawings of 10 abstract and early emerging concepts (i.e., more, up, all done, come, big, who, what, eat, open, want) along with the children's verbal descriptions of these drawings. The researchers then compared the children's drawings to a commercially available symbol set, PCS, which is typically rated high on transparency in comparison with other symbol sets (e.g., Mizuko, 1987).

Key differences noted by the investigators between the children's drawings and the PCS symbols were as follows: the children's drawings were rooted in personal experiences, typically involved interactions, were highly detailed, and featured complete depictions of objects and persons. Contrastively, the PCS symbols intended to represent the same concepts often made use of partial objects and persons, which were represented without supporting context, included arrows to focus attention, and made use of linguistic markers, such as question marks to represent the concept *who* (Worah et al., 2015). Due to the need to provide representations for both concrete and abstract vocabulary and the resulting use of highly symbolic representations, symbol sets like PCS have repeatedly been identified to be difficult for young children to learn and use (Light & Drager, 2002, 2007).

Subsequent to this study, Worah and colleagues (2015) conducted a study to investigate the identification performance of 40 typically developing young children (2:5- 3:5 year of age) with symbols developed using a new approach to representing vocabulary items. Specifically, the investigation was employed to determine if Developmentally Appropriate Symbols (DAS) created using guidelines suggested by Light and colleagues (Light et al., 2008) would result in improved identification, better performance (i.e., higher percent correct), and higher preference in comparison with a commercially available symbol set (PCS). The target concepts included: *all gone, big, come, eat, more, open, up, want, what and who.* These targets were selected for the following reasons: (a) there was beginning research base to assist in developing representations of the selected concepts (Light et al., 2008; Lund, 1998), (b) they were all early emerging concepts (i.e., develop between 1 – 2 years of age), and (c) they were abstract and almost all difficult to represent pictorially (Worah et al., 2015). For each of the 10 concepts, the children were presented with a static card containing either the DAS or PCS symbols and asked to point/touch the symbol, which corresponded to the target. Worah and colleagues (2015) reported that children were 82% accurate for identification of symbols in the DAS condition in comparison to 58% accurate for identification of symbols in the PCS condition. Given evidence that a symbols set like DAS can enhance a young child's ability to identify early emerging and frequently used vocabulary in comparison to the commonly used symbol set of PCS, identifiability and utility of other commonly used AAC symbol sets may be called into question.

Schlosser and colleagues (2012) conducted a study to examine the effects of symbol format (animation) on transparency, name agreement, and identification of graphic symbols for verbs and prepositions in typically developing 3, 4 and 5-year old children ($n = 52$). A total of 24 verbs generated from a list of 40 verbs (Huttenlocher, Smiley, & Charney, 1983) were selected based upon availability of these verbs in the ALP Animated Graphics Set developed by the Center for Communication Enhancement at Children's Hospital Boston, MA. Additionally, eight spatial prepositions were included in the study. Schlosser and colleagues (2012) included a screening procedure, familiarization procedure, transparency procedure, name agreement procedure, and identification procedures. Findings indicated that animation enhanced transparency and name agreement especially for verbs; however, animation did not enhance identification accuracy. There was a developmental effect across the three dependent variables of symbol format (animated vs. static), age group (3, 4, and 5 year-olds) and word class (verbs vs. prepositions). Older children tended to perform better at guessing symbol meaning, naming the symbols exactly, and identifying the symbols from an array. Percentage name agreement for three-year olds ($M = 58.23$) was significantly ($p < .05$) lower than that of five-year olds (M =

71.91), and name agreement for four-year olds (M = 62.50) was significantly lower than that for five-year olds. However, there was no statistically significant difference in name agreement between three and four-year olds. Additionally, there was a significant interaction between symbol format (static vs. dynamic) and word class (verbs, prepositions). That is, that animation appeared to aid naming of verbs, but not prepositions.

Schlosser and colleagues (2012) reported significant main effects for word class and age, but not for symbol format (animated symbols vs. static symbols). Developmental effects were similar to those found for the naming agreement task (i.e., overall percent identification scores for 5-year-olds were higher than 4-year olds and 3-year olds, with no difference between 3-year-olds and 4-year-olds). Additionally, across age groups and symbol formats, a higher percentage of verbs were correctly identified in comparison to prepositions. Findings of this study (Schlosser et al., 2012) further support the construct that "when symbols are transparent, the symbol-referent relationship does not need to be taught explicitly" (p. 355). Therefore, symbols that are more guessable (highly transparent) help reduce the "cost of communicative competence" (Beukelman, 1991, p. 2). Suggestions for future research included: exploring the use of different symbol sets in order to assess the external validity of the results and increasing the complexity of the identification task (i.e., increasing number of symbols on the display).

In summary, the existing literature provides evidence that transparency and iconicity have an effect on symbol identification and learning by both typically developing individuals and those with complex communication needs (Fuller & Lloyd, 1987; Light et al., 2008; Mirenda & Locke, 1989; Mizuko, 1987; Musselwhite & Ruscello, 1984; Schlosser et al., 2012; Worah et al., 2015); recent finding also suggest the need to investigate other commercially available AAC symbol sets to determine relative iconicity and learnability (Beukelman & Mirenda, 2013). Just as concept representation barriers, including symbol type, present a challenge in the assessment of individuals with complex communication needs, so too do behavioral response modes that are required for individuals to physically participate in standardized assessments.

**Behavioral response mode barriers of standardized assessments.** Individuals with complex communication needs often present with physical impairments, which can prevent them from participating in standardized assessments (Light, 1989; Yoder & Kraat, 1983). For example, some individuals with complex communication needs have increased or decreased muscle tone, which can make voluntary movement difficult (Beukelman & Mirenda, 2013). There are other reflexive patterns including asymmetrical or symmetrical tonic neck reflex (ATNR, STNR), which impact an individual's motor control. The latter often impacts the individual's functional use of his or her arms, and consequently affects the individual's ability to access objects, point to pictures and/or access AAC systems. Improper positioning and inadequate physical support can affect a person's fatigue, comfort levels, emotional state and ability to move and attend to task (Beukelman & Mirenda, 2013). Therefore, behavioral response modes including pointing which is typically required within receptive language assessment administration procedures (e.g., PPVT-4, TACL-4), can present a significant challenge for individuals with complex communication needs. In order to gain a better understanding of the impact of modifications to receptive language assessments, a review of variable testing formats and response modes is provided.

### Potential modifications to receptive language tools and procedures.

**Variable testing formats.** Several researchers have conducted studies to investigate the effects of modifications to standardized assessments in the area of receptive vocabulary for children with complex communication needs (Geytenbeek, et al., 2010; Haaf, et al., 1999; & McDougall et al., 2012). Many of these studies included typically developing children as participants in order to verify construct validity - the verification as to whether or not examined modifications to an assessment tool change the construct of what the test purports to measure. Computerized test administration is one type of modification, which has been explored.

***Computerized administration.*** The effects of computerized versions of assessments have been investigated in order to validate test modifications for children with complex communication needs. For example, McDougall and colleagues (2012) investigated modification of the standard administration of subtest I (Symbol Size and Number) of the *Test of Aided-Communication Symbol Performance* [TASP] through a computerized adaptation (Bruno, 2006). Sixteen participants with complex communication needs, ranging in age from 6 to 21-years, were randomly assigned to either the standard or computerized condition; in other words, all sixteen participants took either the standard version or the computerized version of the TASP, and then took the other test two months later. All participants were non-speaking, had experience with computer access, had direct selection capabilities, comprehended English, demonstrated potential to use line drawings, such as Picture Communication Symbols ([PCS] Mayer-Johnson, 1986), and had the ability to self-correct. To determine whether this assessment modification impacted individuals' performance in terms of accuracy and efficiency (i.e., time, related to pace of administration), statistical analyses including Repeated Measure ANOVA, showed no statistical effect between standard and the computerized versions of the TASP ($r = .86$, $p = .05$) for thirteen participants. Three of the sixteen participants' scores were markedly different than the thirteen other participants (i.e., demonstrated a larger score difference between individual trials). The authors concluded that there was insufficient data to explain the differences; in other words, variations in participants' attention and/or health on given days may have yielded important variations and, therefore, these scores were not included in the ANOVA analyses (McDougall et al., 2012). Nevertheless, the results of the pilot study lend support for the validity of computerized test administration, especially when using a closed set of test items as in the TASP (McDougall et al., 2012). Benefits of computerized versions of tests were reported by the researchers to include: efficiency (i.e., time), improved clinical outcomes, determination of optimal starting points with communication systems, effectiveness of communication system design and development, efficiency related to pace of development and client satisfaction (McDougall et al., 2012). Although this modification may be viable for some children with complex communication needs, there are those who present with significant physical impairments (e.g., cerebral palsy) including limited mobility of their upper extremities, which prevent them from participating in a computerized version of a standardized assessment tool. Therefore, other studies (e.g., Haaf et al., 1999) have been conducted to examine computerized administration of receptive language tools with the inclusion of alternate/variable response modes (e.g., scanning, track ball use, eye-tracking technologies).

**Variable response modes.** In the context of the AAC assessment process, determining an appropriate access method is an important component to ensure accurate assessment findings. Variable response modes may include, the use of head tracking, infrared selection methods, indirect selection capabilities, and eye-tracking technologies. Studies conducted in the area of modifications to receptive language assessment procedures to date have primarily involved the use of switch scanning and eye tracking technologies. A review of these studies follows.

***Switch scanning.*** Some research has been done focusing on the inclusion of alternate response modes in the context of receptive language assessment. For example, Haaf and colleagues (1999) investigated modifications to the Peabody Picture Vocabulary Test Revised ([PPV-T]; Dunn & Dunn, 1981) involving alternate response modes via a computerized version of the test with typically developing children; this adaptation was speculated to be potentially highly relevant to children with complex communication needs given their significant motor impairments. Seventy-two typically developing children, ranging in age from 4.0 to 8:11 years were assigned to the following three alternate response conditions: manual pointing, response selection using a computer trackball, or response selection using computer switches in a scanning format. Results from this study revealed the same construct was measured (receptive vocabulary) and the computerized PPVT-R (Dunn & Dunn, 1981) formats including, scanning or trackball access did not compromise the validity of the original test (Haaf et al., 1999). These results suggest the potential utility of developing modifications for standardized assessments. However, although these modifications have proven to be appropriate for some children with complex communication needs, there are those that do not possess the necessary motor skills to participate in an assessment via switch scanning or track ball use. As such, researchers have investigated the utility of eye-tracking technologies to bypass motor limitations often required by standardized assessment practices.

***Eye tracking.*** Eye tracking is another technological tool that can assist in deciphering in the true meaning of receptive language test results. For example, in order to determine if an error made by an individual is reflective of the person's actual skill level or reflective of their difficulty understanding the testing directives, eye-tracking technologies can be used. Given that many individuals with complex communication needs, present with physical limitations, the use of eye-tracking technologies bypasses the need for behavioral responses (i.e., pointing to targets) often required for participation in standardized assessments. Therefore, eye tracking technologies have become particularly appealing because they place minimal demands on the individual given that there is no need for the individual to comply with directions or provide a motor response (Light & McNaughton, 2014b).

However, prior to conducting studies with children who present with complex communication needs, it is best practice to assess learning effects of typically developing children (e.g., Drager et al., 2003; Mizuko, 1987; Musselwhite & Ruscello, 1984; Wilkinson, Light, Drager, 2012; Wilkinson & Mitchell, 2014) without the confounding variables (e.g., motor, sensory perceptual, and other impairments) for the establishment of a control group for a basis of comparison for children with disabilities (Drager et al., 2003). Given the heterogeneous nature of individuals with complex communication needs, "there is a critical need for research that will allow researchers and clinicians to tailor assessment and intervention procedures to best fit the persons they serve" (Wilkinson & Mitchell, 2014, p. 106). Eye tracking research technology is one method for researchers to better understand some of the visual cognitive processes that underlie interaction via AAC (Light & McNaughton, 2014b) and how individuals with disabilities may respond to aided AAC systems (Wilkinson & Mitchell, 2014). Therefore, it is important to review the literature which investigates the relationship between behavioral responses and eye tracking in the context of receptive language assessment.

***Behavioral responses & eye tracking research***. Several studies have been conducted to examine the relationship between pointing and looking behaviors in the context of assessment utilizing eye-tracking technologies with both typically developing children (e.g., Clements & Perner, 1994; Lee & Kuhlmeier, 2013; Ruffman, Garnham, Import, & Connolly, 2001; Southgate, Senju, and Csibra, 2001; Wilkinson & Light, 2014; Wilkinson, O'Neil, & McIlvane, 2014) and children and adults with a variety of disabilities (Brady et al., 2014; Brown et al., 2015). For example, Lee and Kuhlmeier (2012) utilized eye tracking with typically developing two-year old children to examine participants' eye gaze and pointing behaviors, as it relates to accuracy of responses. The researchers implemented a tube task to examine the interplay between eye gaze behavior and pointing behavior. Results revealed that children who failed the tube task by pointing to an erroneous object nevertheless looked to the correct location. One theory as to why these dissociations occurred is that the elicited responses that some tasks depend on (i.e., verbally responding to researcher-posed questions) pose challenges beyond the actual formation of the representation, which could overwhelm young children's limited cognitive resources (Lee & Kuhlmeier, 2012). Spontaneous measures such as looking time, duration and eye gaze allow children's underlying representational abilities to be demonstrated through measurable behavior, while simultaneously reducing the physical and cognitive demands of assessment tasks. (Lee & Kuhlmeier, 2012).

According to researchers, children's verbal, pointing and reaching errors shed light on the early representational frameworks and have informed theory regarding the mechanisms underlying conceptual development (Carey, 2009; Karmiloff-Smith, 1992). In other words, research has suggested that eye gaze may be more reliable, as the behavioral demands are reduced. Two such studies explored the interplay between eye gaze direction and verbal/pointing responses in young children. Children 2.5 years of age (Southgate, Senju, & Csibra, 2001) and 3 years of age (Clements & Perner, 1994; Ruffman, Garnham, Import, & Connolly, 2001) often correctly gazed at target locations even though their pointing and verbal responses were erroneously directed towards other locations. These findings highlight the use of eye-tracking technologies with very young children and further support the use of these technologies for examining underlying conceptual development.

Eye tracking technologies have also been used to measure speech comprehension in typically developing children and those with complex communication needs. Brady and colleagues (2014) conducted a study using eye-tracking technologies with 14 boys with autism spectrum disorder and 14 developmentally matched typically developing boys (age range: 42-82 months) to measure speech comprehension. The purpose of the study was twofold; to document how behaviors recorded with eye-tracking technology map onto conventional behaviors (i.e., pointing to pictures) and to lay the foundation for using eye-tracking technology as a measurement of speech comprehension in children with ASD who are using AAC (Brady et al., 2014).

All participants were first tested via standard administration of the PPVT (Dunn & Dunn, 2007) and then received the experimental condition via a computer with eye tracking. Statistical analyses were completed and findings indicated that both typically developing participants and participants with ASD looked longer at target pictures than at non-target pictures within a known condition (i.e., words for which participants had demonstrated comprehension). However, for children with ASD, there was no significant difference for looking to targets vs. non-targets in the unknown condition (i.e., stimuli which they incorrectly identified during standard administration of PPVT).

These findings have important implications for addressing the problem of assessing language comprehension in children who cannot readily participate in other forms of standardized assessments, and lay the foundation for further investigation of how looking times for individual items reflect emergent word knowledge in children (Brady et al., 2014). Developing better language comprehension measures is important for individuals who use AAC (Brady et al., 2014). Furthermore, accurate information about children's comprehension could facilitate the development of communication programs that more accurately reflect children's underlying abilities and influence decisions about vocabulary selection for their AAC devices (Brady et al., 2014). Just as eye tracking technologies can provide insight into the true receptive language capabilities of children with complex communication needs, so too can the use of eye tracking technologies shed light on ways in which rate and accuracy of message generation can be improved.

Wilkinson and colleagues (2014) utilized eye-tracking technology to investigate 14 typically developing children's (ages 7-12 years of age) point-of-gaze across two AAC displays. One display contained symbols -sharing an internal color clustered together - and the other display contained symbols sharing an internal color and were distributed across the display. Findings indicated that participants were significantly slower to fixate on the target when like-color symbols were distributed. Additionally, there was a significant increase in the number of fixations to distracters that did not share color with the target (Wilkinson et al., 2014). Study findings further support that principles of color cueing and guided search do apply to meaningful AAC symbols. Additionally, results of this study add to existing evidence that even small changes to AAC displays can reliably affect speed of behavioral response for selecting a target (Wilkinson et al., 2014). This study, however, only investigated the effects of spatial location and color on efficiency of point-of-gaze for AAC displays containing Boardmaker symbols (one type of color line drawing) and one-word class (nouns).

In related work, Brown and colleagues (2015) investigated efficient target location (speed of locating target nouns) in adults with and without Traumatic Brain Injury (n = 18) across three different displays (icon only, text-only, and icon-plus word). Results revealed significantly more efficient target location for icon-only grids than for text-only or icon-plus-text grids for both participant groups. Both participant groups tended to locate target words most rapidly when viewing grids in which icons appeared (Brown et al., 2015). However, this study included only the one-word class of nouns; therefore, lingering questions remained about target location patterns for other parts of speech (verbs, adjectives) which are noted to be more abstract and difficult to represent with iconic symbols (e.g., Bloomberg, et al., 1990; Mizuko, 1987; Worah et al., 2015). The reviewed studies shed light on the advantages that eye tracking technologies can offer individuals with complex communication needs in the context of standardized assessments, but much work remains to be done in this area.

***Unique benefits of eye tracking technologies & traditional assessment practices.*** Eye tracking research technology offers two unique types of information that are highly challenging, or impossible, to obtain using traditional testing methods. First, eye tracking enables evaluation of skills which can be hard to measure in individuals with disabilities secondary to physical, language or cognitive barriers (Wilkinson & McIlvane, 2014). For example, an individual may possess the necessary cognitive skills to understand the directives and complete tasks associated with a cognitive test, but still be unable to demonstrate that capability due to physical impairment. Furthermore, detailed recording of the path of visual attention or visual-cognitive processes are difficult to detect using behavior response models. Secondly, eye-tracking technologies provide information about visual/auditory processing in real time as processing occurs. Measures that capture responses after processing has occurred (i.e., verbal responses, pointing, switch selection) do not offer this same advantage (Venker & Kover, 2015). Because eye-gaze methods require only passive engagement (i.e., sitting and looking at a screen), they have been reported to have more limited behavioral demands relative to assessment techniques that require a purposeful response (Abbeduto, Kover, & McDuffie, 2012; Falck-Ytter, Bölte, & Gredebäck, 2013; Karatekin, 2007).

Contrastingly, traditional assessment and data collection procedures that require behavioral responses, such as pointing, may underestimate the capabilities of many individuals with complex communication needs (Light and McNaughton, 2014b). These individuals include those with: (a) comprehension deficits which limit their understanding of instructions or task requirements, (b) motor impairments that limit their access to required behavioral responses, (c) attention deficits that limit their ability to complete tasks, and (d) challenging behaviors (Light & McNaughton, 2014b; Wilkinson et al., 2014). Traditionally, these individuals have been considered impossible to test via traditional assessment methods (Light & McNaughton, 2014b). Therefore, state-of-the-art eye tracking technologies can provide tremendous insight into visual cognitive processes and comprehension abilities of individuals with complex communication needs, who have previously been considered untestable. Furthermore, eye tracking research methods place minimal demands on the individual, which allow evaluators to bypass comprehension and motor limitations in order to obtain a reliable measure of capabilities and communicative needs for those individuals with complex communication needs (Light & McNaughton, 2014b).

## Summary

In summary, there is no standardized battery of tests comprising an AAC evaluation (ASHA, 2004). The lack of reliable and valid assessment modifications for individuals with complex communication needs can impede the ability of SLPs and educators to obtain an accurate picture of an individual's language skills (Haaf et al., 1999). Although frameworks currently exist for conducting AAC assessments, there is a widespread tendency to over-assess individuals. Over-assessment can interfere with AAC intervention because it is time-consuming and places undue demands on the family and the person who will rely on AAC (Beukelman & Mirenda, 2013), and often yields little in terms of helpful information to guide intervention.

The existing literature suggests that children with severe cognitive delays may have more difficulty recognizing line drawings used as stimuli in tests compared to photograph-based symbols (Beukelman & Mirenda, 2013; Cauley et al., 1989; Geytenbeek et al., 2010; Mirenda & Locke, 1989; Romski & Sevcik, 1996). Yet, the majority of standardized assessments utilize color line drawings to evaluate individuals' receptive language skills. Because these individuals are not necessarily being presented with stimuli that are readily comprehensible to them, there is a risk of under-estimating verbal comprehension abilities (Emerson, 2003). Work conducted to date to investigate the effects of modifications to standardized assessments (e.g., Geytenbeek et al., 2010; Haaf et al., 1999; & McDougall et al., 2012) has focused on examination of the utility of alternate response modes (e.g., track ball, switch scanning).

One area of a comprehensive AAC assessment which continues to be crucial to both AAC assessment and ultimately to selecting appropriate AAC systems for children with complex communication needs is symbol type. Several researchers have done promising work investigating the effects of symbol type on iconicity and transparency in both typically developing children and individuals with cognitive/intellectual disabilities (e.g., Fuller & Lloyd, 1991; Mirenda & Locke, 1987; Mizuko, 1987; Musselwhite & Ruscello, 1984; Sevcik & Romski, 1986; Schlosser et al., 2012; Worah et al., 2015). However, work has not yet been conducted to examine the effects of color photograph symbols[1] compared to line drawing symbols on participants' ability to: (1) identify graphic symbols as measured by accuracy and rate, or (2) name graphic symbols across word class (nouns vs verbs vs. adjectives). Furthermore, incorporation of eye gaze in investigations with the use of eye tracking technologies offers another way to gain insight into children's ability to understand various graphic symbol types and word classes without the behavioral demands associated with traditional standardized assessment procedures. Additional investigation into the effects of symbol type on identification and naming of graphic symbols for nouns, verbs and adjectives by young children is warranted in order to have a solid theoretical and practical foundation for AAC interventions.

# CHAPTER THREE: METHODS

This study investigated the effects of symbol type (color photograph symbols vs. color line drawing symbols[1], SymbolStix©[2] symbols) on identification and naming of graphic symbols for nouns, verbs and adjectives in typically developing three, four, five and six-year old children. This study was conducted in local preschools and private schools, which are service locations of the UCF Communication Disorders Clinic in the Central Florida area. The methods employed in the study are reported as follows: (a) research questions, (b) research design, (c) participants, (d) instrumentation and materials, (e) procedures, (f) data analysis, (g) fidelity, and (h) limitations.

## Research Questions

1. Are there statistically significant differences between symbol types (color photograph symbols[1] vs. SymbolStix©[2] symbols) on identification of graphic symbols for nouns, verbs and adjectives as measured by percent correct and rate for three, four, five and six-year old children? If yes, what are the differences?
2. Are there relationships between: identification accuracy and rate, touch rate and eye rate for identification of graphic symbols by three, four, five and six-year olds children? If yes, are these relationships statistically significant?
3. Are there statistically significant differences between symbol types (color photograph symbols[1] vs. SymbolStix©[2] symbols) on naming of graphic symbols for nouns, verbs and adjectives as measured by percent correct for three, four, five and six-year old children? If yes, what are the differences?

## Research Design

A quasi-experimental design was used in the current study to investigate the effect of symbol type (color photograph symbols[1], SymbolStix©[2] symbols), age, and word class on identification and naming of graphic symbols. For this study, the researcher utilized a counterbalanced research design. All participants received both expressive (naming) and receptive (identification) tasks under color photograph symbol or SymbolStix©[2] symbol conditions at different time points. Participants were randomly assigned into two groups for each age group and received two tasks under the two different conditions in the counter orders.

## Independent and Dependent Variables

The independent variables were symbol type, with two variations: color photograph symbols[1] and SymbolStix©[2] symbols, age group (three, four, five and six-year old children) and word class (nouns, verbs and adjectives). The dependent variables were: identification as measured by percent correct and rate, and naming of symbols as measured by percent correct. The measures of rate were defined as: eye tracking rate; elapsed time in seconds from the end of the prompt, to the fixation immediately preceding participant's touch to target, and time to touch; elapsed time in seconds from the end of the prompt to the participant's touch to target. For Time 1, participants in Group 1 received the expressive task (naming) followed by the receptive (identification) task under color photograph symbol[1] condition. While, participants in the Group 2, received the receptive task (identification), followed by the expressive task (naming) under the SymbolStix©[2] symbol condition. For Time two, participants in Group 1 received the expressive task (naming), followed by the identification task (identification) under the SymbolStix©[2]

symbol condition. While participants in Group 2 received the receptive task (identification), followed by the expressive task (naming) under the color photograph symbol[1] condition. The above-described research design is expressed by, Table 1. Counterbalanced design was employed for symbol conditions with identification and expressive tasks at counter orders for the experimental groups. Repeated measure design was utilized, as this statistical analysis has the advantage to increase statistical power with a reduced sample size, while parsing out between subject variance from confounding factors (Shadish, 2002). The counterbalanced design controlled for carryover effects.

| | Time 1 | Time 2 | Time3 | Time 4 |
|---|---|---|---|---|
| Group 1 | $X_1$A | $X_1$B | $X_2$A | $X_2$B |
| Group 2 | $X_2$B | $X_2$A | $X_1$B | $X_1$A |

Figure 1. Experimental sequence.
This figure depicts the experimental sequence for this investigation, where $X_1$ represents the Color Photograph symbol[1] condition, $X_2$ represents the SymbolStix©[2] symbol condition, *A* represents the Expressive Task (Naming) and B represents the Receptive Task (Identification).

## Participants

The use of children without disabilities is recommended as a first step in the investigation of new approaches to AAC assessment and intervention, in order to address underlying cognitive and language development issues (Drager et al., 2003; Mizuko, 1987; Musselwhite & Ruscello, 1984). Using typically developing children allows the researcher to determine the effects of the AAC organizations on learning without the confounding variables of motor, sensory perceptual, and other impairments. Thus, providing a control group for a basis of comparison for children with disabilities in the future (Drager et al., 2003). Therefore, typically developing children were recruited for this study via convenience sampling. As per Gall, et al., (2007), a sample can be convenient for a variety of reasons: including the sample is located at or near where the researcher works (p.175). Although, the researcher acknowledges the limitations when employing convenience sampling, “it is usually better to do a study with a convenience sample than to do no study at all” (Gall, Gall & Borg, 2007, p. 175).

Participants were recruited from preschools and private schools, which are service locations of the UCF Communication Disorders Clinic within the central Florida area, according to the below inclusion criteria. A child was classified as 3 years old if he or she had a chronological age of 3;0 (years; months) to 3;11. A child was classified as 4-years old if the child’s chronological age was between 4;0-4;11. A child was classified as 5-years old if the child’s chronological age was between 5;0-5;11. A child was classified as 6-years old if the child’s chronological age was between 6;0-6;11. In order to qualify for inclusion, the children met the following selection criteria:

a) chronological age of 3-6 years, as per preschool and private school records (Appendix A);
b) English spoken as primary language at home, as per preschool and private school records and parent report (Appendix A);
c) no uncorrected visual or hearing difficulties, as per preschool and private school records and parent report (Appendix A);
d) have no known cognitive impairments, as evidenced by educational placement and parent report (Appendix A);

e) have age-appropriate receptive language skills, expressive language skills, articulation skills, voice and fluency as determined by a passing score on the PLS-5 Screening Test (Zimmerman et al., 2011) See Appendices B-E.

f) 100% receptive knowledge of the nouns, verbs and adjectives used in the study (Appendix F) based on screening task described below (Appendix G) and corresponding data collection sheets (Appendix H).

A total of 25 three-year olds, 29 four-year olds, 21 five-year olds, and 20 six-year olds were recruited from the five service locations of the UCF Communication Disorders Clinic.

**Settings**

Procedures for this investigation were conducted in quiet rooms (e.g., libraries, resource rooms) at five preschools and private schools, which are service locations of the UCF Communication Disorders Clinic. Trained undergraduate and graduate students in speech-language pathology served as experimenters and/or reliability observers. Participants were recruited via email distribution of IRB approved informed consents and HIPAA forms by all site directors. Sessions were recorded using a small portable video camera focused on the participants. Sessions involving the Identification Task of the study were also recorded via Gaze Viewer (tobiidynavox.com). Children were seated at a small table in front of the laptop computer and/or the Tobii DynaVox I15+ with eye tracker.

One of the service locations is located in Maitland, Florida and provides educational services for children ages 2 – 5 years of age. Twenty-one children and their siblings were recruited and participated in the study. The second service location is a private school located in

Maitland, Florida and provides educational services for children ages 3 – 10 years of age. Twenty-four children and their siblings were recruited and participated in the study. The third service location is a preschool, which provides educational services for children ages 2 – 5 years of age, located in Winter Park, Florida. Twenty-seven children were recruited and twenty-five children participated in the study. The fourth service location is a preschool located in Orlando, Florida, which provides educational services for children ages 2 – 5 years of age. Seventeen children were recruited and sixteen of these children participated in the study. The final service location is a preschool located in Orlando, Florida, which provides educational services for children ages 2 – 5 years of age. Ten children were recruited and participated in the study. Table 2 provides an overview of the participant demographics. Table 3 provides demographic information by age group and service location.

Table 1

*Participant Demographics for Age Group by Service Location*

| Variable | Group 1<br>n = 44 | | Group 2<br>n = 51 | | Total Sample<br>n = 95 | |
|---|---|---|---|---|---|---|
| | n | % | n | % | n | % |
| **Gender** | | | | | | |
| Male | 17 | 41 | 30 | 73 | 48 | 50 |
| Female | 27 | 59 | 21 | 53 | 48 | 50 |
| **Age** | | | | | | |
| 3 | 10 | 24 | 15 | 38 | 26 | 27 |
| 4 | 14 | 30 | 15 | 38 | 29 | 30 |
| 5 | 10 | 24 | 10 | 23 | 20 | 21 |
| 6 | 10 | 22 | 11 | 28 | 21 | 22 |
| **Ethnicity** | | | | | | |
| Caucasian | 32 | 74 | 33 | 80 | 66 | 69 |
| African American | 10 | 22 | 8 | 20 | 18 | 19 |
| Asian | 0 | 0 | 2 | 5 | 2 | 2 |
| Hispanic | 1 | 2 | 6 | 15 | 7 | 7 |
| Middle Eastern | 1 | 2 | 2 | 5 | 3 | 3 |
| **Service Location** | | | | | | |
| 1 | 12 | 66 | 6 | 34 | 18 | 19% |
| 2 | 10 | 43 | 13 | 57 | 23 | 24% |
| 3 | 7 | 30 | 16 | 70 | 23 | 24% |
| 4 | 5 | 36 | 9 | 64 | 14 | 15% |
| 5 | 9 | 53 | 8 | 47 | 17 | 18% |

## Instrumentation

### Materials

The nouns, verbs and adjectives for this study were selected from the Vocabulary subtest of the Test for Auditory Comprehension of Language Fourth Edition (TACL-4; Carrow-Woolfolk, 2014a), see Appendix I. The TACL-4 (Carrow-Woolfolk, 2014a) was selected for use in this study as this receptive language test is often utilized with children who require AAC, as the normative sample includes those children with exceptionalities including: Autism Spectrum

Disorder, Deaf/Hearing Impairment, Articulation Disorders (Carrow-Woolfolk, 2014b). In order for children with complex communication needs to effectively communicate across a variety of linguistic contexts, AAC devices need to contain a variety of words (Light & Drager, 2002, 2007). Therefore, analyses consisting of percentage of word class were completed for three receptive language tests that are often used to evaluate receptive language skills during a comprehensive AAC assessment. These tests included: *The Receptive One Word Picture Vocabulary Test Fourth Edition* ([ROWPVT-4], Brownell, 2011), *The Peabody Picture Vocabulary Test Fourth Edition* ([PPVT-4], Dunn & Dunn, 2007) and the *Test for Auditory Comprehension of Language-Fourth Edition* (Carrow-Woolfolk, 2014a). Analyses by word class revealed the following: ROWPVT-4 (Brownell, 2000) nouns = 70%, verbs = 18% and adjectives = 15%, PPVT-4 (Dunn & Dunn, 2007) nouns = 80%, verbs = 15%, and adjectives = < 1%, TACL-4 (Carrow-Woolfolk, 2014a) nouns = 47%, verbs = 24%, and adjectives = 29%. As per the percentage by word class analyses, the TACL-4 (Carrow-Woolfolk, 2014a) provided a more even distribution of word classes in comparison to the other assessments of receptive language skills. Furthermore, several studies conducted in the field of AAC, have included participants with complex communication needs, and utilized children's scores from the TACL-4 (Carrow-Woolfolk, 2014a) as part of subject selection criteria (e.g., Binger, Maguire-Marshall, & Kent-Walsh, 2011; Kent-Walsh, Binger, & Buchanan, 2015).

To ensure the use of stimuli were well within range of expected receptive/expressive language for the participants, all vocabulary, (e.g., nouns, verbs, adjectives) were selected from the Vocabulary subtest of the TACL-4 (Carrow-Woolfolk, 2014a) which is intended for use with children ranging from 3 to 12 years of age. Additionally, all vocabulary targets from the TACL-4

(Appendix I) were cross referenced with *The MacArthur-Bates Communicative Development Inventories: Words and Sentences* ([CDI]; Fenson et al., 2007) (Appendix L) to ensure stimuli were well within the range of expected receptive/expressive vocabulary skills for participants (i.e., CDI is used with toddlers up until 30 months of age) and to isolate the effects of symbol type.

The researcher selected target items from the vocabulary subtest of the TACL-4 (Carrow-Woolfolk, 2014a), as verbal comprehension is known to play a pivotal role in early language development and comprehension of words can develop even if a child is not speaking (Romski & Sevcik, 1996; Sevcik, 2006). Moreover, verbal comprehension skills have important implications for the development of the child's AAC system and/or education program (Geytenbeek et al., 2010). Therefore, a total of seventeen target stimuli and 20% of the total stimuli (i.e., 3 stimuli) were randomly repeated during presentation to facilitate reliability and consistency of participants' responses. Thus, there were a total of twenty targets (Appendix F) for each of the screening (Appendix G, Appendix H), naming (Appendix P, Appendix, Q) and identification tasks (Appendix R, Appendix S). Nouns, verbs and adjectives were included in the study if items met the following criteria: (a) the word had to be represented in SymbolStix©[2] form (Crick Software;http://www.cricksoft.com/us/products/symbols/symbolstix.aspx) in the Communicator 5 software (www.tobiidynavox.com); and (b) the word was included in the MacArthur-Bates CDI Words and Sentences (Fenson, et al., 2007); and (c) the word was represented in the color photograph program, iStock by Getty Images, Essentials Collection (www.istock.com). Of the seventeen words selected from the Vocabulary subtest of the TACL-4 (Carrow-Woolfolk, 2014a), four words were eliminated based on the above inclusion criteria: wagon, cross, oval and sew. These four stimuli were randomly replaced with words in the same class (i.e., noun, adjective, verb) selected from the *MacArthur-Bates CDI Words and Sentences* (Fenson, et al., 2007) (Appendix I) in order to preserve the percentages of word classes featured in the TACL-4 (Carrow-Woolfolk, 2014a). Cross, was replaced by bowl, oval was replaced by noisy, wagon was replaced by stroller and sew was replaced by shake (Appendix F Stimuli). The availability of the new stimuli was verified in the Communicator5 software (www.tobiidynavox.com) and the color photograph symbol program; iStock by Getty Images, Essentials Collection (www.istock.com) according to the search selection procedures described below. Please see Appendix F for a complete list of targets and foils that were utilized for the identification task (Appendix J, Appendix K).

**TACL-4**. The TACL-4 (Carrow-Woolfolk, 2014a) is a norm-referenced, reliable test that yields valid results for receptive language for children ages 3 years 0 months (3-0) through 12 years 11 months (12-11). Norms for the TACL-4 (Carrow-Woolfolk, 2014a) are based on a nationally representative sample of 1,142 children in the United States (Carrow-Woolfolk, 2014b). The primary purpose of the TACL-4 (Carrow-Woolfolk, 2014b) is to evaluate the receptive language proficiency of children who are having difficulty communicating orally. Because the test utilizes a point-to-the-picture response format, it can be used with children with widely varying abilities, including those with intellectual disabilities as well as children who have a specific language impairments and articulation disorders (Carrow-Woolfolk, 2014b). As previously stated, children with complex communication needs often exhibit difficulty verbally communicating secondary to language impairments, motoric and/or significant speech impairments. Therefore, targets for the current study were selected from the Vocabulary subtest of the TACL-4. Additionally, the normative sample (N = 1,142) utilized in the development of the TACL-4, included children with the following diagnoses: Intellectual disability (4%), Deaf/hard of hearing (1%), Language impairment (4%), Learning disability (4%), Attention-deficit/hyperactivity disorder (3%), and Autism spectrum disorder (2%) (Carrow-Woolfolk, 2014b). Targets for this study (Appendix F) were selected from the Vocabulary subtest of the TACL-4 (Appendix I).

**PLS-5 Screening Test.** The PLS-5 Screening Test (Zimmerman et al., 2011) is an assessment tool used to: identify infants, toddlers and young children at risk for a language disorder and conduct infant, toddler and kindergarten screenings of emerging developmental communication skills. The PLS-5 Screening Test (Zimmerman et al., 2011) enables the evaluator to screen six speech-language areas including: language, articulation, connected speech, social/interpersonal communication skills, stuttering and voice. The PLS-5 Screening Test (Zimmerman et al., 2011) reports scores for infants, toddlers and children ages birth - 7:11. A passing score from the PLS-5 Screening Test (Zimmerman et al., 2011) was utilized as part of the inclusionary criteria for the current study. Appendix B-E.

**MacArthur-Bates Communicative Development Inventories.** *The MacArthur-Bates Communicative Development Inventories: Words and Sentences* ([CDI]; Fenson et al., 2007) was utilized in this investigation to verify the target words (Appendix F) selected for the screening, naming and identification tasks were well within the age range for expressive and receptive language skills of participants. The CDI is a parent self-report form designed for children, from 16-to-30 months old. According to Fenson and colleagues (2007), the CDI may be used for children with developmental delays outside of the recommended age range. The form provides information about parents' knowledge of their children's emerging language skills, understanding and use of words. Therefore, target words selected for the study have been verified in the CDI.

**SymbolStix©[2] Symbols**. Several representational symbol systems are used widely in North America and other countries. However, "their relative iconicity and learnability have not been studied" (Beukelman & Mirenda, 2013, p.56). One such representational symbol system is SymbolStix©[2] (Crick Software; http://www.cricksoft.com/us/products/symbols/symbolstix.aspx). The SymbolStix©[2] symbol library includes more than 12,000 color line drawing symbols that depict activities and people as lively stick figures. SymbolStix©[2] symbols are used in Proloquo2Go (AssistiveWare), which was the first large-scale communication app for i-platform devices and are also available on many designated speech generating devices, including: TobiiDynavox I-series and Saltillo NovaChat. SymbolStix©[2] symbols are also available by subscribing to SymbolStix© online at https://store.n2y.com/PartnerProducts/Home/. Given the paucity of research regarding iconicity and learnability for SymbolStix©[2] and the fact that these symbols are widely used on designated systems, the researcher has selected this symbol set for the color line drawing condition for the naming task (Appendix M) and the identification task (Appendix J) of the current study.

**Color Photograph Symbols[1].** Color photograph symbols[1] were selected and retrieved from iStock by Getty Images, Essentials Collection (www.istock.com) according to the search selection procedures described below for the identification task (Appendix K) and naming task (Appendix N). This program features over millions of royalty-free images. Availability of target stimuli (Appendix F) was verified in iStock by Getty Images, Essentials Collection (www.istock.com).

**Eye tracking Technology.** Based on the review of literature regarding AAC and eye tracking technologies (Brown et al., 2014; Light & McNaughton, 2014b; Wilkinson & Jagaroo, 2004; Wilkinson et al., 2014; Wilkinson & Mitchell, 2014), the researcher selected eye tracking technology to determine rate of selection, as an additional measure of identification for this study. Tobii DynaVox I15+ with eye tracker (www.tobiidynavox.com) was utilized to track eye gaze rate for identification of target symbols. Tobii DynaVox Communicator 5 speech-generating software was used to create templates for both symbol type conditions (Appendix J, Appendix K), as this software features SymbolStix©[2] and is featured on the Tobii I15+. Eye gaze rate was measured by determining the elapsed time in seconds from the end of the verbal prompt, to the fixation immediately preceding the single finger point to target via analysis of heat maps. Time to touch target was measured by determining the elapsed time in seconds from the end of the verbal prompt to participant's touch to target (signified by red outline). Given the abundance of information eye tracking technologies can provide, the researcher selected rate, as measured by eye tracking (seconds), for a second measure of identification of graphic symbols.

Data collection for eye tracking research consists of two phases: (a) calibration phase, in which, the technology obtains information about the size, curvature, and position of the eye, and (b) the research phase, which presents the task of interest for data attainment (Wilkinson & Mitchell, 2014). Several studies have been conducted in the field of AAC, utilizing eye tracking technologies (Brown et al., 2015; Wilkinson, O'Neil, & Mcllvane, 2014; Thiesen et al., 2015) from a variety of manufacturers (i.e., Tobii Technology, Inc., ISCAN, SMI, etc.). Although several research-based eye tracking technologies are available, the researcher selected the Tobii DynaVox I15 + with eye tracker (ww.tobiidynavox.com), as it features Gaze Viewer (http://www.tobiidynavox.com/gazeviewer/). Gaze Viewer allows for real time recording and provides gaze plots and heat maps in order to analyze an individual's eye tracking performance on a particular task (http://www.tobiidynavox.com/gazeviewer/). Thus, the Tobii Dynavox I15+ with eye tracker was utilized to determine eye identification rate of graphic symbols for the current study.

**Tobii DynaVox I15+ with Eye Tracker.** The Tobii Dynavox I15+ is a large screen, eye controlled speech-generating device (tobiidynavox.com). The Tobii Dynavox I15+ features: a 15.0" wide screen with Led backlight and screen resolution of 1024 x 768 pixels, a 10 point multi touch dynamic display encased with Gorilla R glass, 2 x 3 W closed box speakers, and an Intel Celeron Quad Core Processor J1900 (https://www.tobiidynavox.com/en-US/devices/eye-gaze-devices/i-15-with-communicator-5/#specifications).

The Tobii I15+ eye tracking component allows an individual to control the Tobii I15+ via their eyes. This eye tracking component allows for extensive Freedom of Head Movement, thus once the system is calibrated in front of the user, no further adjustments are needed. In accordance with recommendations from the Tobii I Series User Manual (2013), the Tobii I15+ with built in eye tracker was placed parallel to each participant's eyes at a distance of approximately 60 cm (23.5 inches). The eye tracking component of the Tobii I15+ also features the largest track box in the industry with the following approximate dimensions (width x height x depth): 30 centimeters x 20 centimeters / 11.8 inches' x 7.9 inches (Tobii I Series Manual, 2013).

Therefore, the Tobii I15+ with built in eye tracker was selected for use to determine the rate of identification (i.e., time to touch, eye gaze rate) for this study.

**Tobii DynaVox Gaze Viewer.** Tobii DynaVox Gaze Viewer is an assessment tool, which allows for real time recording of eye tracking data (http://www.tobiidynavox.com/gazeviewer/). The Tobii DynaVox Gaze Viewer allows for recording of both audio and video and provides gaze plots and heat maps in order to analyze an individual's eye tracking performance on a particular task (http://www.tobiidynavox.com/gazeviewer/). The Tobii DynaVox Gaze Viewer has many uses for assessment including: comprehension testing, reading/literacy assessments for non-verbal children, cognitive-processing delay assessments, and validating the potential use of an eye tracking AAC device for communication (http://www.tobiidynavox.com/gazeviewer/). For this study, the Tobii Dynavox Gaze Viewer was utilized with each participant, during the identification tasks for both color photograph and color line drawing symbol conditions to record both audio and video real time eye tracking data. Eye tracking data in the form of heat maps were then reviewed to determine rate to touch and eye gaze rate for the identification task. Please see data analysis section of this chapter for further details.

## Procedures

**Participant Recruitment and Screenings.** Prior to the initiation of the study, de-identified preschool and private school screening data (Appendix A, B, C, D) were reviewed at the UCF Communication Disorders Clinic in order to determine eligibility for potential participation in the current study. Screenings were conducted at local preschools and private schools, which are service locations of the UCF Communication Disorders Clinic in the greater Orlando area. These screenings assess children's hearing, speech and language skills via use of the PLS-5 Screening Test (Zimmerman, et al., 2011). Therefore, the scores from the de-identified completed preschool and private school screens, performance on the PLS-5 Screening Test (Appendix B, C, D, and E) and registration/participant demographic form (Appendix A) were utilized in the above described subject selection criteria for the current study. The researcher recruited participants according to the subject selection criteria from five preschools and private schools.

**SymbolStix©[2] Symbol Search and Selection Procedures.** SymbolStix©[2] symbols were chosen for the identification task (Appendix J) and the naming task (Appendix M) via the following search and selection procedures. When searching the Communicator 5 software, the first SymbolStix©[2] symbol that appeared for the target word from the generated list (Appendix F) was selected according to the following criteria: (a) search for exact label or keyword reserved for the symbol by the research team and/or a different form of the same label (e.g., cut for cutting), (b) in items where the target word has a homonym, the semantic equivalent will be selected (e.g., ball – a solid sphere that is kicked or thrown vs. a formal social gathering for dancing), (c) exact match for word class (e.g., bicycle – symbolic representation of a bicycle, vs. stick figure riding a bicycle), (d) a balanced number of persons representing various ethnic groups (e.g., Caucasian, Hispanic, African American), (e) include no irrelevant background or details (Carrow-Woolfolk, 2014), (f) do not contain written form of target (e.g., blue – symbolic representation is a blue crayon with word blue on it), (g) excludes characters from known franchises/pop culture (e.g., girl – "Boo" character from Monsters Inc., and (h) do not solely contain associated objects/accessories of the target (e.g., baby – symbol of diaper would be eliminated, as this is an associated object/accessory of the target).

**Color Photograph Symbol[1] Search and Selection Procedures.** Color photograph symbols[1] were retrieved via the following search and selection procedures for the identification task (Appendix K) and the naming task (Appendix N). When searching, iStock by Getty Images, Essentials Collection (www.istock.com) the first photograph-based symbol that appeared for the target word from the generated list (Appendix F) was selected according to the following criteria: (a) search for exact label or keyword reserved for the symbol by the research team and/or a different form of the same label (e.g., cut for cutting), (b) in items where the target word has a homonym, the semantic equivalent will be selected (e.g., ball – a solid sphere that is kicked or thrown vs. a formal social gathering for dancing), (c) exact match for word class (e.g., bicycle – symbolic representation of a bicycle, vs. stick figure riding a bicycle), (d) a balanced number of persons representing various ethnic groups (e.g., Caucasian, Hispanic, African American), (e) include no irrelevant background or details (Carrow-Woolfolk, 2014), (f) do not contain written form of target (e.g., blue – symbolic representation is a blue crayon with word blue on it), (g) excludes characters from known franchises/pop culture (e.g., girl – "Boo" character from Monsters Inc., and (h) do not solely contain associated objects/accessories of the target (e.g., baby – symbol of diaper would be eliminated, as this is an associated object/accessory of the target). The color photograph symbols[1] were retrieved and downloaded from iStock on August 21, 2016.

**Tasks**

**Familiarization Task.** Familiarization trials were conducted prior to the screening task and each experimental task (identification and naming tasks) with each word class and symbol type (color photograph symbols[1] and SymbolStix©[2] symbols). This provided a way for the participants to become acquainted with each task before the investigation began. All familiarization task stimuli were selected from the CDI (Fenson et al., 2007). Participants were seated at a table in front of materials for the screening task, laptop computer for the identification and tasks with the researcher or trained graduate student sitting next to them. The familiarization task procedure for the proposed study was adapted from Schlosser and colleagues (2012) and was implemented as follows. Three practice items were introduced for each task (screening, identification and naming tasks). For the screening task, the researcher and/or trained undergraduate/graduate student delivered the following prompt "_____ [participant's name], let's play a game. I am going to show you three objects and ask you to point to one of them (noun and adjective word classes)." For the word class of verbs, the researcher and/or trained research assistant delivered the following prompt, "_____ [participant's name], I am going to do three things, watch what I am doing. When you see me ____ hit the bell." Correct responses provided by participants were acknowledged ("Yes this is___") and incorrect responses were corrected ("No, this is ___"). The researcher and/or trained undergraduate/graduate student also inquired to verify that the participants understood the task ("Do you understand how to play the game?"). For the naming task, the researcher and/or trained graduate student delivered the following prompt "[participant's name], let's play a game on the computer. You will see a picture and I will ask you what it is." Then the researcher and/or trained graduate student delivered the following prompt, “First I am going to show you how to play the game” while pointing to the computer screen. Now I want you to listen carefully and I will tell you when to tell me what it is.” The researcher and/or trained undergraduate/graduate student delivered the following prompt, “What’s this?” or “Who’s this?” for nouns, “What is he/she doing?” for verbs and “Tell me about this picture…What do you see?” for adjectives.  The participant was expected to provide a label for the stimuli. Correct responses provided by participant were acknowledged (“Yes this is ____”) and incorrect responses were corrected (“No, this is ___”). The researcher and/or trained graduate student inquired to verify that the participants understood the task (“Do you understand how to play the game?”). In order to familiarize participants with the identification task, the same protocol was followed with the exception that, participants were directed to point/select target item (“Point to ____”) on the computer screen which displayed three symbol choices for both the color photograph symbol and color line drawing symbol conditions. Correct responses provided by participants were acknowledged (“Yes this is___”) and incorrect responses were corrected (the researcher and/or trained undergraduate/graduate student modeled the correct response by selecting the target on the computer screen).  Please see Appendix O for familiarization task procedures.

**Screening Task.** Each child’s knowledge of the seventeen lexical items selected for the experiment were tested through the following procedure, which was adapted from a recent study conducted by Schlosser and colleagues (2012). Prior to initiating the screening task, the researcher and/or trained undergraduate/graduate student obtained child’s assent for participation.  For each target, a choice of three objects or actions, were presented. First, the researcher and/or trained undergraduate/graduate student performed the action (verb) with a prop as deemed necessary or presented a real object (noun) and the child was asked to identify the action or item (Miller & Paul, 1995). For adjectives, the researcher presented an object with the target adjective (i.e., yellow, the researcher presented a yellow, brown and black block) and the child was asked to identify the attribute (e.g., show me yellow, etc.) by pointing to the object. No corrective or affirmative feedback was provided. The researcher intermittently offered non-specific feedback (e.g., nice job) to sustain participation. Participants, which demonstrated 100% receptive knowledge of all nouns, verbs and adjectives, were included in the study. A response was considered correct, if the participant pointed to the target object or action. A choice of three objects, were utilized for the nouns and adjectives. In the case of verbs, the researcher and/or trained research assistant performed three actions, and the participant was instructed to identify the target action (verb) by selecting a bell. See Appendix G for Screening Task Procedures. Please see Appendix H for a complete list of items/actions utilized for the screening task and data collection form.

**Identification Task**. For the identification task, the order of presentation was consistent with the way in which it appears in the TACL-4 (Carrow-Woolfolk, 2014a), with the exception of three randomly repeated stimuli for consistency of response measurements. The identification task procedure for the proposed study was adapted from Schlosser and colleagues (2012) and was implemented as follows. Prior to initiating the identification task, the researcher and/or trained research assistants obtained child's assent for participation. Participants were seated at a table in front of the laptop computer with Tobii I15+ and eye tracker with the researcher or trained graduate student sitting next to them. The researcher and/or trained graduate student reminded the participant that this task worked just like the familiarization task. In this task, the participants were presented with three graphic symbols at a time, one target symbol and two foils for both the color photograph symbol[1] and SymbolStix©[2] symbol conditions, see Appendix F for list of stimuli, Appendix J and Appendix K for sample identification task stimuli. As described in the research design section, the order of the receptive (identification) and expressive (naming) tasks and symbol conditions were counterbalanced. A play-based break for 10 minutes was provided in between the receptive (identification) and expressive (naming) tasks.

Prior to presenting the graphic symbol templates, participants were calibrated via the eye tracker on the Tobii I15+ (www.tobiidynavox.com). Researcher and/or trained undergraduate/graduate student completed a five-point calibration of participant via the eye tracker.  Researcher and/or trained undergraduate/graduate student delivered the following prompt, "Now we are going to play a game. You are going to use your eyes. I am going to show you a ball and it will move across the screen. Listen to me and I will tell you when to look at the ball. Look at the ball."

Once calibration was achieved, Gaze Viewer was set to record the first slide containing three graphic symbols was presented. The slides were created via use of *Communicator 5 software (*www.tobiidynavox.com). The researcher and/or trained undergraduate/graduate student said, "Listen to me.  Point to___." The researcher and/or trained graduate student did not provide corrective or affirmative feedback, only intermittent, non-specific feedback to sustain participants' attention (e.g., "Nice job"). A symbol was considered identified correctly if the child touched the quadrant with the symbol corresponding to the spoken name provided.  Please see Appendix R for Identification Task data collection form and Appendix S for Identification

Task procedure. Please see Appendix J and Appendix K for sample templates for the identification task.

**Naming Task.** The participants were presented with one graphic symbol at a time on the touch screen laptop for the color photograph symbol[1] and the SymbolStix©[2] symbol conditions via PowerPoint. The order of presentation was just as it appears in the TACL-4 (Carrow-Woolfolk, 2014a), with the exception of three randomly repeated stimuli for consistency of response measurement (Appendix F). Prior to initiating the naming task, the researcher and/or trained research assistants obtained child's assent for participation. The researcher and/or trained graduate student reminded the participant that this task was just like the familiarization task. Participants were seated at a table in front of the laptop computer with the researcher or trained undergraduate/graduate student sitting next to them. The naming task procedure for the proposed study was adapted from Schlosser and colleagues (2012) and was implemented as follows. Prior to the symbol appearing on the screen, the researcher and/or trained undergraduate/graduate student stated, "Listen to me; I will tell you when to tell me what you see… You may see the same picture more than once, and that is ok." The symbol then appeared on the screen for a total of 14 seconds and after a 1 second delay, the researcher and/or trained graduate student delivered the following prompts according to word class: *Noun* - "What's this?" or "Who's this?" *Verb* – "What is he or she doing?" and *Adjective* – "Tell me about this picture…What do you see?" The child was expected to label the picture within the 14-second time period. There was 5-second delay built into the presentation of symbols between each target. The researcher and/or trained graduate student did not provide corrective or affirmative feedback, only intermittent, non-specific feedback to sustain participants' attention (e.g., "Nice job"). A response was considered correct if the participant provided the exact label reserved for the symbol by the research team, a different form of the same label (e.g., cut for cutting) or a sentence or phrase containing the target noun, verb or adjective (Schlosser et al., 2012). Please see Appendix P for Naming Data Collection Form and Appendix Q for Naming Task Procedures. Please see Appendix M and Appendix N for sample naming task templates. As described in the research design section of this chapter, the order of the expressive (naming) and receptive (identification) tasks and symbol condition were counterbalanced. A play-based break for 10 minutes was provided in between the expressive (naming) and receptive (identification) tasks.

## Data Analysis

### Identification and Naming Tasks

**Identification Task.** Data were obtained for the dependent variable of individual participant's accuracy and rate, for the identification task across both conditions; color photograph symbol[1] and SymbolStix©[2] symbol. Individual participant's accuracy for the identification task across both conditions (e.g., color photograph symbol[1] and SymbolStix©[2] symbol) was calculated via the following method: the sum of participant's performance on each of the twenty stimuli, then dividing by twenty to obtain the percent correct for identification task performance across both conditions. Each participant's performance was hand coded for accuracy. Individual participant's rate of identification was determined for two measures, rate to touch (i.e., elapsed time in seconds from end of the prompt to participant's touch to target) and eye tracking rate (i.e., elapsed time in seconds from the end of the prompt to participant's gaze immediately preceding touch to target) via analysis of heat maps. Heat maps of all participants' eye tracking performance collected during the identification tasks were retrieved from Gaze Viewer (http://www.tobiidynavox.com/gazeviewer/). A total of 168 heat maps (i.e., two heat maps per condition, per participant) were obtained from the Tobii Dynavox I15+ (www.tobiidynavox.com) and transferred to the researcher's password protected desktop computer, which is located in the UCF Communication Disorders Clinic. In order to determine the rate of selection via touch and eye gaze, all heat maps were viewed by the researcher, undergraduate and/or graduate research assistants on Windows Moviemaker (videowinsoft.com).

Methods were employed to ensure the quality of ongoing eye gaze calibration in the form of informal and formal checks (Hornof & Haverson, 2002). According to Wilkinson and Mitchell (2014), ongoing calibration checks are recommended to reduce chance for instrument drift (i.e., maintenance of eye gaze calibration overtime). According to Wilkinson and Mitchell (2014), "the regular presentation of a target in a fixed location, created specifically to draw the eye, can provide ongoing checks as to whether the recorded fixations remain within the RFL throughout the session" (p. 13). Therefore, a template containing a red fixation cross was presented between each stimuli template to ensure the recorded fixations remained within the RFL throughout the entire identification task. Informal checks were also employed by intermittently accessing the track status to ensure that participant's eye gaze calibration was maintained throughout the identification task.

Heat maps provide a visualization, which reflects the fixations from an individual participant represented by circles, while lines represent rapid jumps or saccades between the fixations (Wilkinson & Mitchell, 2014). The order of fixation is represented by, the numbers within the circles.  Eye gaze rate was determined by coding the time stamp (minutes: seconds.

milliseconds) for the end of the prompt and coding the time stamp for the fixation to target (i.e., the numbered circle), immediately preceding the participant's touch to target, as indicated by a red outline. Time to touch (i.e., the elapsed time in seconds from the end of the prompt to participant's touch to target) was determined according to the above-described procedure with the following exception: coding the time stamp (minutes: seconds. milliseconds) for the end of the prompt and coding the time stamp participant's touch to target, represented by red outline.

Once all 168 heat maps were hand coded by the researcher, undergraduate and/or graduate assistants on the identification task data collection form (Appendix R), all data were transferred to a Microsoft excel workbook to calculate the following: average touch rate and eye gaze rate across word class (noun, verb, adjective) for each individual participant. The average touch rate for nouns was calculated via the following formula: sum of the prompt end time – touch time for each of the eight nouns, divided by eight. The average touch time for verbs was calculated via the following formula: the sum of the prompt end time – touch time for each of the four verbs, divided by four. The average touch time for adjectives was calculated via the following formula: the sum of the prompt end time – touch time for each of the five adjectives, divided by five. Average eye gaze rate across nouns, verbs, and adjectives was calculated via the same formula with the exception of utilizing the gaze time vs. touch time. Average eye gaze rate for nouns was calculated via the following formula: sum of the prompt end time – gaze time for each of the eight nouns, divided by eight. The average eye gaze rate for verbs was calculated via the following formula: the sum of the prompt end time – gaze time for each of the four verbs, divided by four. The average eye gaze rate for adjectives was calculated via the following formula: the sum of the prompt end time – eye gaze time for each of the five adjectives, divided by five. The overall accuracy for the identification task was calculated by adding participant's performance on each of the twenty stimuli, then dividing by twenty to obtain the percent correct for identification task performance across both conditions. Data for each participant were transferred to SPSS to complete the below statistical procedures.

**Naming Task.** Individual participant's accuracy for the naming task across both conditions (e.g., color photograph symbol[1] and SymbolStix©[2] symbol) was calculated via the following method: the sum of participant's performance on each of the twenty stimuli, then dividing by twenty to obtain the percent correct for naming task performance across both conditions. Each participant's performance was hand coded for accuracy. When an error response was noted, the researcher, trained undergraduate and/or graduate assistant notated the error response (i.e., noisy… "he has no arms or tummy"). Naming task percent correct data for each participant were then transferred to SPSS (version 23) to complete the below statistical procedures.

## Statistical Analyses

Data were analyzed, by the researcher and trained undergraduate/graduate students using the statistical software SPSS version 23.0 on a computer with a secured network in a secured location. To answer the research questions presented at the beginning of the methodology section, Repeated Measure Multivariate Analysis of Variance (MANOVA) was completed.

MANOVA is a statistical technique used for determining whether groups differ on more than one dependent variable (Gall et al., 2007). MANOVA is appropriate for data analysis for this study, as it provided the researcher a way to conceptualize and analyze the nature of interrelated characteristics and determine whether there are statistically significant differences on naming and identification of graphic symbols between age groupings (Gall et al., 2007). The independent variables included: symbol type (color photograph symbols[1] vs. SymbolStix©[2] symbols), age, and word class and the dependent variables included: percent correct scores for naming, percent correct scores and rate for identification of graphic symbols.

## Fidelity of Implementation

### Procedural Reliability

Video recordings of the researcher and trained undergraduate/graduate assistants implementing the screening (Appendix G, Appendix H), naming (Appendix Q) and identification tasks (Appendix S) were analyzed by two graduate students, who were blind to the purpose of the study, in order to verify procedural reliability. Specifically, 20% of total number of sessions (i.e., a total of sixteen videos) were reviewed. The researcher provided training to undergraduate and graduate students regarding all instructional procedures and methods. Training continued until the researcher and reviewers reached 95% compliance and reliability of coding on the fidelity checklist for all tasks (Appendix T). Interobserver agreement data on procedural reliability was verified via blinded graduate students' completion of the screening, naming and identification protocols (Appendix G, Appendix Q, and Appendix S). Calculations including percentage of agreement were completed accordingly (Appendix U).

## Fidelity of Implementation

Fidelity of implementation was monitored by fidelity checklists created by the researcher (Appendix T). A random sample of 20% of all experimental sessions, were selected for fidelity review across the course of the study (Gast, 2010). Trained graduate students reviewed recorded sessions in the UCF Communication Disorders Clinic and completed the corresponding checklist.

## Interobserver Agreement

The interobserver procedure for the proposed study was adapted from Schlosser and colleagues (2012) and was implemented as follows. Interobserver agreement data were collected for 20% of sessions (Brown et al., 2014) and recorded on the Interobserver form created by the researcher (Appendix U). Two independent observers, who were blinded to the purpose of the study, recorded the responses to the naming and identification tasks. These were compared to the responses recorded by the primary researcher.  For the naming task, an agreement for naming response was recorded if both observers marked the verbal response the same way (i.e., correct, incorrect).  For the identification task, an agreement was scored if both noted the same name of the symbol to which the participant pointed. Percent agreement was calculated by taking the number of agreements divided by the number of agreements plus disagreement multiplied by 100 (Schlosser et al., 2012). See Appendix U.

## Data Entry Reliability

All data were transferred from Excel spreadsheets to SPSS (version 23) by two graduate assistants. The researcher checked that all data was transferred correctly via having one of the graduate research assistants read all numbers aloud in order to verify that all data were 100% entered correctly.

**Repeat Stimuli Reliability**

Three items were randomly inserted into the stimuli for naming and identification tasks to determine consistency and reliability of responses for both experimental conditions. As previously mentioned, the following targets were randomly inserted into the presentation: father (noun), play (verb) and noisy (adjective). As per percent correct, consistency of responses is reported as follows. Color photograph symbol[1] condition: reliability and consistency of responses were 95% accuracy in comparison to 86% accuracy for SymbolStix[2] symbol condition. Appendix P presents the naming task stimuli and data collection sheet and Appendix R presents the identification task data collection sheets.

**IRB**

The researcher obtained Internal Review Board approval in accordance with the policies and procedures outlined by the Office of Research and Commercialization at the University of Central Florida IRB. Informed consent was obtained via IRB approved Informed Consent Form and the study approval letter is located in Appendix V. The study schedule can be located in Appendix W.

## Summary

This chapter discussed the methodology for this study. The investigation utilized a quasi-experimental, counterbalanced design to investigate the research questions. The setting, participants, instruments, and data analysis procedures were presented. Finally, a discussion of fidelity and interobserver agreement of implementation was included.

# CHAPTER FOUR: RESULTS

This chapter reports the results of the analyses used to answer the research questions. This study employed a quasi-experimental, counter-balanced research design for symbol conditions with identification and expressive tasks at counter orders for the experimental groups. The research questions were primarily answered with the use of Repeated Measures Multivariate Analysis of Variance (MANOVA). Results related to the research questions using these statistical procedures are reported.

## Results of Data Analysis

Repeated Measures MANOVA was used to answer research questions one and three to test if there were statistically significant differences between identification accuracy, rate and naming accuracy of graphic symbols by three, four, five and six-year old children. For research question two Bivariate Correlation was utilized to test the relationship between percent correct and rate and the relationship between touch rate and eye rate for the identification of graphic symbols by three, four five and six-year old children. SPSS (Version 23) was used to conduct the analyses for the current study

### Assumption Testing

As previously noted, Repeated Measures MANOVA was utilized to answer research questions one and three. All questions were examined with an alpha level of .05. Repeated Measures was selected, as this statistical procedure test both within and between subject under different conditions of an experiment (Field, 2005). Repeated Measures design has several advantages. Most importantly, it reduces the unsystematic variability in the design and thus provides greater power to detect within subject effects (Field, 2005). However, the relationship between scores in different treatment conditions means an additional assumption must be made; we assume that the relationship between pairs of experimental conditions is similar (i.e., the level of dependence between experimental conditions is roughly equal). However, the assumption of independence is sensitive to Type I and/or Type II errors that occur when the assumption is violated (Lomas, 2007). The use of Repeated Measures MANOVA required the testing of four assumptions (Gall et al., 2007). These assumptions include: (1) Assumption of sphericity tested by Mauchly's test, (2) Multivariate normality (3) Levene's Test of Equality of Error Variances, and (4) Box's Test of Equality of Covariance Matrices.

**Assumptions of Sphericity**

Sphericity is a more general condition of compound symmetry. Compound symmetry holds true when both the variables across conditions are equal and the covariance between pairs of conditions are equal. Thus, assuming that the variation within experimental conditions is fairly similar and that no two conditions are any more dependent than any other two (Fields, 2005). Sphericity refers to the equality of variances of the differences between treatment levels. This study employed a quasi-experimental design with independent measures and separate measures. Sphericity is reported for research questions one and three.

***Mauchly's Test.*** Mauchly's test assesses the hypothesis that the variances of the differences between conditions are equal. Therefore, if Mauchly's test statistic is significant ($p<.05$) it can be concluded that there are significant differences between the variances of differences, therefore the condition of sphericity is not met. If Mauchly's test is non-significant (p>.05) then it can be concluded that the variances of differences are not significantly different (i.e., they are roughly equal). Mauchly's test results are reported for research questions one and three.

**Levene's Test of Equality of Error Variances**

Levene's Test of Equality of Error Variances tests the hypothesis that the variances in the groups are equal (i.e. the difference between the variance is zero). Therefore, if Levene's test is significant ($p < .05$) then it can be concluded that the null hypothesis is incorrect and the variances are significantly different therefore, the assumption of homogeneity of variances has been violated.

**Box's Test of Equality of Covariance Matrices**

Box's Test assesses the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.  Box's test is highly sensitive to non-normality and cells with larger variance-covariance matrices (Olson, 1974). A large number of dependent variables can contribute to unequal variance-covariance matrices and may reduce power, therefore, there is less reason for concern of violation of this assumption if statistical significance is found (Lomax & Has-Vaughn, 2012). Homogeneity of variance is reported for each research question. In this case, the group sizes are unequal (i.e., 3 year olds $n = 25$, 4-year olds $n = 29$, 5-year olds $n = 20$ and 6-year olds $n= 21$) and the harmonic mean of the group sizes were used. Therefore, Pillae's Trace was used, as it is more robust in MANOVA designs where heterogeneity of variance-covariance is violated and less balanced (Has-Vaughn, 2012). Type 1error levels are not guaranteed. However, the Levene's test does not take account of the covariance and thus the variance-covariance matrices should be compared between groups using Box's Test of Equality of Covariance Matrices. Because Box's test is susceptible to deviations from multivariate normality and can be non-significant not because the matrices are similar, but because the assumption of multivariate normality is not tenable.

**Bivariate Correlation**

For research question two, Bivariate Correlation was conducted to examine the relationship between identification accuracy and rate (touch, eye) for graphic symbols (color photograph symbols[1], SymbolStix©[2] symbols) and the relationship between touch and eye rate for identification of graphic symbols. In correlational research, the usual assumption is that the prediction or relationship being studied is linear (Gall, et al., 2007). The form of the variables to be correlated and the nature of the relationship determines, which technique is used. The use of Bivariate Correlation, Product-moment correlation technique required the testing of following assumption: the two variables are continuous (Gall et al., 2007). The Product-moment correlation technique (*Pearson r)* is the most stable technique and is the most widely used bivariate correlational technique because most educational measures yield continuous scores and because (Pearson r) has the smallest standard error (Gall et. al., 2007). Furthermore, the Product-moment correlation was selected, as it is the appropriate correlational statistic for determining the magnitude of relationship between participants' scores on two measures (Gall et al., 2007).

Cohen (1988) proposed using $r$ as a measure of effect size, ignoring the sign of the correlation of: $r = .1$ as a weak effect, $r = .3$ as a moderate effect and $r = .5$ as a strong effect size. For this study, product-moment correlation was selected to test the magnitude of the relationship between participants' scores on two measures (rate and percent correct) for identification of graphic symbols (color line drawings SS symbols vs. color photograph symbols[1]). Bivariate correlation results are reported for research question two.

### Statistical Analyses & Results

Statistical analyses and results are reported in the following order for research questions one and three: (a) descriptive statistics, (b) assumption testing, (c) multivariate, within subject effects, between subject effects, (d) post-hoc pairwise comparison tests (e) estimated marginal means, and (e) profile plots. Research question two results are reported in the following order: (a) descriptive statistics and (b) Pearson's *r* correlations.

## Testing the Research Questions

### Research Question One

*Question 1: Are there statistically significant differences between symbol types (color photograph symbols[1] vs.* SymbolStix©[2] *symbols) on identification of graphic symbols for nouns, verbs and adjectives as measured by percent correct and rate for three, four, five and six-year olds children? If yes, what are the differences?*

### Identification Accuracy (Percent Correct) of Graphic Symbols for Nouns, Verbs and Adjectives

The following developmental trends were noted for overall identification accuracy (percent correct) of color photograph symbols[1] as follows: six-year olds achieved the highest mean score for identification accuracy of color photograph symbols[1], followed by five-year olds, then four-year olds and finally three-year olds. For identification accuracy of SymbolStix©[2] symbols, six-year olds achieved the highest mean score followed by four-year olds, then five-year olds and finally three-year olds. Table 2 presents the descriptive statistics for the identification of graphic symbols for nouns, verbs and adjectives (percent correct) including symbol type and age group.

Table 2

*Descriptive Statistics for Identification Accuracy of Graphic Symbols for Nouns, Verbs and Adjectives by Age Group*

| Descriptive Statistics | | | | |
|---|---|---|---|---|
| | Age Group | Mean | Std. Deviation | N |
| Photo ID Noun | 3.00 | .9375 | .07587 | 20 |
| | 4.00 | .9777 | .05945 | 28 |
| | 5.00 | .9843 | .03971 | 20 |
| | 6.00 | 1.0000 | .00000 | 21 |
| | Total | .9754 | .05620 | 89 |
| SS ID Noun | 3.00 | .8750 | .12167 | 20 |
| | 4.00 | .9187 | .09804 | 28 |
| | 5.00 | .9378 | .08585 | 20 |
| | 6.00 | .9452 | .19727 | 21 |
| | Total | .9194 | .13139 | 89 |
| Photo ID Verb | 3.00 | .9000 | .14956 | 20 |
| | 4.00 | .9330 | .12947 | 28 |
| | 5.00 | .9400 | .13436 | 20 |
| | 6.00 | .9702 | .11114 | 21 |
| | Total | .9360 | .13137 | 89 |
| SS ID Verb | 3.00 | .8250 | .20033 | 20 |
| | 4.00 | .8571 | .19754 | 28 |
| | 5.00 | .9000 | .20520 | 20 |
| | 6.00 | .9226 | .11508 | 21 |
| | Total | .8750 | .18464 | 89 |
| Photo ID Adj | 3.00 | .9138 | .11851 | 20 |

| | | | | |
|---|---|---|---|---|
| | 4.00 | .9271 | .13154 | 28 |
| | 5.00 | .9475 | .11410 | 20 |
| | 6.00 | .9750 | .09014 | 21 |
| | Total | .9400 | .11625 | 89 |
| SS ID Adj | 3.00 | .7800 | .15761 | 20 |
| | 4.00 | .9125 | .12883 | 28 |
| | 5.00 | .8975 | .16739 | 20 |
| | 6.00 | .9881 | .05455 | 21 |
| | Total | .8972 | .14950 | 89 |
| Photo Identification Accuracy | 3.00 | .9050 | .07931 | 20 |
| | 4.00 | .9143 | .17206 | 28 |
| | 5.00 | .9250 | .11180 | 20 |
| | 6.00 | .9819 | .04718 | 21 |
| | Total | .9306 | .12048 | 89 |
| SS ID Accuracy | 3.00 | .8125 | .13943 | 20 |
| | 4.00 | .9100 | .09955 | 28 |
| | 5.00 | .8750 | .14002 | 20 |
| | 6.00 | .9557 | .06947 | 21 |
| | Total | .8910 | .12305 | 89 |

*Note.* Photo = Color photograph symbol[1], SS =SymbolStix©[2], N = Noun, V = Verb, Adj = Adjective.

Box's M test revealed that the homoscedasticity assumption was not met with $p$ = <.001. Since an assumption was violated, Pillae's Trace was reported, as it is more robust in MANOVA designs where heterogeneity of variance-covariance is violated and imbalanced (Has-Vaughn, 2012).

There was not a significant interaction effect between symbol type and age group with $F_{(12, 252)} = 1.116$ ($p$ >.001; partial eta squared = .347). A Repeated Measures MANOVA revealed significant differences of identification accuracy (percent correct) for the combined variables of symbol type (color photograph symbols[1] vs. SymbolStix©[2] symbols) and word class (nouns, verbs and adjectives).

Multivariate tests revealed a significant difference in identification accuracy (percent correct) of symbol type with $F_{(4, 82)} = 6.372$ ($p$ <.001; partial eta squared = .237) and significant age group differences on the combined variables with $F_{(12, 252)} = 2.14$, ($p$ = .015, partial eta squared = .092). (See Table 3).

Table 3

*Multivariate Test Results for Identification Accuracy of Graphic Symbols for Symbol Type, Word Class and Age Group*

**Multivariate Tests[a]**

| Effect | | | Value | *F* | Hypothesis *df* | Error *df* | *p* | Partial Eta Squared |
|---|---|---|---|---|---|---|---|---|
| Between Subjects | Intercept | Pillai's Trace | .995 | 4366.899[b] | 4.000 | 82.000 | <.001 | .995 |
| | | Wilks' Lambda | .005 | 4366.899[b] | 4.000 | 82.000 | <.001 | .995 |
| | | Hotelling's Trace | 213.019 | 4366.899[b] | 4.000 | 82.000 | <.001 | .995 |
| | | Roy's Largest Root | 213.019 | 4366.899[b] | 4.000 | 82.000 | <.001 | .995 |
| | Age_Group | Pillai's Trace | .277 | 2.138 | 12.000 | 252.000 | .015 | .092 |
| | | Wilks' Lambda | .733 | 2.250 | 12.000 | 217.243 | .011 | .098 |
| | | Hotelling's Trace | .349 | 2.346 | 12.000 | 242.000 | .007 | .104 |
| | | Roy's Largest Root | .302 | 6.342[c] | 4.000 | 84.000 | <.001 | .232 |
| Within Subjects | Symbol Type | Pillai's Trace | .237 | 6.372[b] | 4.000 | 82.000 | <.001 | .237 |
| | | Wilks' Lambda | .763 | 6.372[b] | 4.000 | 82.000 | <.001 | .237 |
| | | Hotelling's Trace | .311 | 6.372[b] | 4.000 | 82.000 | <.001 | .237 |
| | | Roy's Largest Root | .311 | 6.372[b] | 4.000 | 82.000 | <.001 | .237 |
| | Symbol Type * Age Group | Pillai's Trace | .151 | 1.116 | 12.000 | 252.000 | .347 | .050 |
| | | Wilks' Lambda | .852 | 1.126 | 12.000 | 217.243 | .340 | .052 |
| | | Hotelling's Trace | .169 | 1.134 | 12.000 | 242.000 | .333 | .053 |
| | | Roy's Largest Root | .136 | 2.864[c] | 4.000 | 84.000 | .028 | .120 |

a. Design: Intercept + age_group
Within Subjects Design: factor1

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha = .05

Repeated MANOVA reveals within subject effects that there are significant differences of identification accuracy (percent correct) between symbol type (color photograph symbols[1] vs.

SymbolStix©[2] symbols) across all word classes namely nouns with $F_{(1, 85)} = 15.26$ ($p <.001$; partial eta squared = .152), verbs with $F_{(1, 85)} = 10.89$ ($p = .001$; partial eta squared = .114), adjectives with $F_{(1, 85)} = 6.907$ ($p = .010$; partial eta squared = .075), and for overall word class with $F_{(1, 85)} = 8.643$ ($p = .004$; partial eta squared = .092). There is a statistically significant interaction between symbol type and age group for the word class of adjectives $F_{(3, 85)} = 3.126$ ($p = .042$; partial eta squared = .030) (See Table 4).

Table 4

*Within Subject Effects for Identification Accuracy of Graphic Symbols for Symbol Type, Word Class and Age Group*

**Univariate Tests**

| Source | Measure | | Type III Sum of Squares | *df* | Mean Square | *F* | *p* | Partial Eta Squared |
|---|---|---|---|---|---|---|---|---|
| Symbol type | Noun | Sphericity Assumed | .135 | 1 | .135 | 15.261 | <.001 | .152 |
| | | Greenhouse-Geisser | .135 | 1.000 | .135 | 15.261 | <.001 | .152 |
| | | Huynh-Feldt | .135 | 1.000 | .135 | 15.261 | <.001 | .152 |
| | | Lower-bound | .135 | 1.000 | .135 | 15.261 | <.001 | .152 |
| | Verb | Sphericity Assumed | .155 | 1 | .155 | 10.894 | .001 | .114 |
| | | Greenhouse-Geisser | .155 | 1.000 | .155 | 10.894 | .001 | .114 |
| | | Huynh-Feldt | .155 | 1.000 | .155 | 10.894 | .001 | .114 |
| | | Lower-bound | .155 | 1.000 | .155 | 10.894 | .001 | .114 |
| | Adjective | Sphericity Assumed | .094 | 1 | .094 | 6.907 | .010 | .075 |
| | | Greenhouse-Geisser | .094 | 1.000 | .094 | 6.907 | .010 | .075 |
| | | Huynh-Feldt | .094 | 1.000 | .094 | 6.907 | .010 | .075 |
| | | Lower-bound | .094 | 1.000 | .094 | 6.907 | .010 | .075 |
| | Overall | Sphericity Assumed | .082 | 1 | .082 | 8.643 | .004 | .092 |
| | | Greenhouse-Geisser | .082 | 1.000 | .082 | 8.643 | .004 | .092 |
| | | Huynh-Feldt | .082 | 1.000 | .082 | 8.643 | .004 | .092 |
| | | Lower-bound | .082 | 1.000 | .082 | 8.643 | .004 | .092 |
| Symbol type * Age group | Noun | Sphericity Assumed | .001 | 3 | .000 | .055 | .983 | .002 |
| | | Greenhouse-Geisser | .001 | 3.000 | .000 | .055 | .983 | .002 |
| | | Huynh-Feldt | .001 | 3.000 | .000 | .055 | .983 | .002 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Lower-bound | .001 | 3.000 | .000 | .055 | .983 | .002 |
| | Verb | Sphericity Assumed | .011 | 3 | .004 | .266 | .850 | .009 |
| | | Greenhouse-Geisser | .011 | 3.000 | .004 | .266 | .850 | .009 |
| | | Huynh-Feldt | .011 | 3.000 | .004 | .266 | .850 | .009 |
| | | Lower-bound | .011 | 3.000 | .004 | .266 | .850 | .009 |
| | Adjective | Sphericity Assumed | .127 | 3 | .042 | 3.126 | .030 | .099 |
| | | Greenhouse-Geisser | .127 | 3.000 | .042 | 3.126 | .030 | .099 |
| | | Huynh-Feldt | .127 | 3.000 | .042 | 3.126 | .030 | .099 |
| | | Lower-bound | .127 | 3.000 | .042 | 3.126 | .030 | .099 |
| | Overall | Sphericity Assumed | .048 | 3 | .016 | 1.709 | .171 | .057 |
| | | Greenhouse-Geisser | .048 | 3.000 | .016 | 1.709 | .171 | .057 |
| | | Huynh-Feldt | .048 | 3.000 | .016 | 1.709 | .171 | .057 |
| | | Lower-bound | .048 | 3.000 | .016 | 1.709 | .171 | .057 |
| Error(factor1) | Noun | Sphericity Assumed | .753 | 85 | .009 | | | |
| | | Greenhouse-Geisser | .753 | 85.000 | .009 | | | |
| | | Huynh-Feldt | .753 | 85.000 | .009 | | | |
| | | Lower-bound | .753 | 85.000 | .009 | | | |
| | Verb | Sphericity Assumed | 1.210 | 85 | .014 | | | |
| | | Greenhouse-Geisser | 1.210 | 85.000 | .014 | | | |
| | | Huynh-Feldt | 1.210 | 85.000 | .014 | | | |
| | | Lower-bound | 1.210 | 85.000 | .014 | | | |
| | Adjective | Sphericity Assumed | 1.152 | 85 | .014 | | | |
| | | Greenhouse-Geisser | 1.152 | 85.000 | .014 | | | |
| | | Huynh-Feldt | 1.152 | 85.000 | .014 | | | |
| | | Lower-bound | 1.152 | 85.000 | .014 | | | |
| | Overall | Sphericity Assumed | .802 | 85 | .009 | | | |
| | | Greenhouse-Geisser | .802 | 85.000 | .009 | | | |
| | | Huynh-Feldt | .802 | 85.000 | .009 | | | |
| | | Lower-bound | .802 | 85.000 | .009 | | | |

*Note.* Significant at the $p < .05$ level.

Between-subject effects revealed a significant difference for identification accuracy (percent correct) of graphic symbols for age group across word class namely, nouns with $F_{(3, 85)} = 3.069$ ($p$ =.032; partial eta squared = .098), with adjectives $F_{(3, 85)} = 7.027$ ($p < .001$; partial eta squared = .199), and with overall word class with $F_{(3, 85)} = 4.793$ ($p$ =.004; partial eta squared = .145). There are not significant age group differences of identification accuracy in verbs. Table 5 presents the between subject effects average of combined variables for identification accuracy of graphic symbols.

Table 5

*Between Subject Effects Identification Accuracy of Graphic Symbols (Percent Correct)*

**Tests of Between-Subjects Effects**

Transformed Variable: Average

| Source | Measure | Type III Sum of Squares | *df* | Mean Square | *F* | *p* | Partial Eta Squared | Noncent. Parameter | Observed Power[a] |
|---|---|---|---|---|---|---|---|---|---|
| Intercept | Noun | 156.541 | 1 | 156.541 | 14146.922 | .<.001 | .994 | 14146.922 | 1.000 |
| | verb | 143.275 | 1 | 143.275 | 3880.861 | .<.001 | .979 | 3880.861 | 1.000 |
| | Adjective | 146.993 | 1 | 146.993 | 8309.762 | .<.001 | .990 | 8309.762 | 1.000 |
| | Overall | 144.517 | 1 | 144.517 | 8165.800 | .<.001 | .990 | 8165.800 | 1.000 |
| Age Group | Noun | .102 | 3 | .034 | 3.069 | .032 | .098 | 9.207 | .700 |
| | Verb | .159 | 3 | .053 | 1.434 | .239 | .048 | 4.301 | .368 |
| | Adjective | .373 | 3 | .124 | 7.027 | .<.001 | .199 | 21.080 | .976 |
| | Overall | .254 | 3 | .085 | 4.793 | .004 | .145 | 14.378 | .890 |
| Error | Noun | .941 | 85 | .011 | | | | | |
| | Verb | 3.138 | 85 | .037 | | | | | |
| | Adjective | 1.504 | 85 | .018 | | | | | |
| | Overall | 1.504 | 85 | .018 | | | | | |

*Note.* Significant at the $p < .05$ level.

Levene's Test revealed that three out of the eight variables met assumption. ANOVA test revealed that the following three variables met assumption: Photo ID Accuracy with $F_{(3, 85)} = 24.20$, ($p = .072$), SymbolStix©[2] ID noun with $F_{(3, 85)} = .140$, ($p = .936$) and SymbolStix©[2] ID verb with $F_{(3, 85)} = 2.115$, ($p = .104$).

Homogenous subtests for identification accuracy revealed that a total of eighty-nine participants completed both experimental conditions for the identification task. Table 6 presents the homogenous subtest results for identification accuracy of graphic symbols for the color photograph symbol[1] condition and Table 7 presents the homogenous subtest results for the identification accuracy of graphic symbols for the SymbolStix©[2] symbol condition

Table 6

*Homogenous Subtests Photo Identification Accuracy*

**Photo Identification Accuracy**

| | Age Group | N | Subset 1 |
|---|---|---|---|
| Tukey HSD[a,b,c] | 3 | 20 | .9050 |
| | 4 | 28 | .9143 |
| | 5 | 20 | .9250 |
| | 6 | 21 | .9819 |
| | *p* | | .158 |

*Note.* Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .014.

a. Uses Harmonic Mean Sample Size = 21.818.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Table 7

*Homogenous Subtests Symbol Identification Accuracy*

**Symbol Identification Accuracy**

| | Age Group | N | Subset | |
|---|---|---|---|---|
| | | | 1 | 2 |
| Tukey HSD[a,b,c] | 3 | 20 | .8125 | |
| | 4 | 28 | .8750 | .8750 |
| | 5 | 20 | | .9100 |
| | 6 | 21 | | .9557 |
| | *p* | | .276 | .098 |

*Note.* Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .013.

## Post-Hoc Test for Identification Accuracy

Post-Hoc Test, Tukey HSD was completed to examine statistically significant differences between word class, symbol type and age group. Post-Hoc Tukey HSD, confirmed statistically significant differences for: identification accuracy of color photograph symbols[1] nouns between 3 and 5-year olds ($p$ = .001) and 3 and 6-year olds ($p$ = .030), overall identification accuracy of SymbolStix©[2] symbols between 3 and 4 year olds ($p$ = .023) and 3 and 6 year olds ($p$ = .001), and identification accuracy of SymbolStix©[2] symbols, adjectives between 3 and 4-year olds ($p$ = .006), 3 and 5 year olds ($p$ =.033), and 3 and 6 year olds ($p$ = <.001). Post-Hoc analyses control for Type I errors. Table 8 presents the post-hoc test results for pairwise comparison for color photograph symbols[1], word class and age group. Table 9 presents the post-hoc test results for pairwise comparison for SymbolStix©[2] symbols, word class and age group.

Table 8
*Post-Hoc Test for Pairwise Comparison Identification Accuracy of Color Photograph Symbols[1] for Nouns, Verbs and Adjectives*

**Multiple Comparison**

| Dependent Variable | | (I) Age Group | (J) Age Group | Mean Difference (I-J) | Std. Error | *p* | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|---|---|
| Photo Identification Accuracy | Tukey HSD | 3.00 | 4.00 | -.0093 | .03520 | .994 | -.1016 | .0830 |
| | | | 5.00 | -.0200 | .03802 | .953 | -.1197 | .0797 |
| | | | 6.00 | -.0769 | .03756 | .179 | -.1754 | .0216 |
| | | 4.00 | 3.00 | .0093 | .03520 | .994 | -.0830 | .1016 |
| | | | 5.00 | -.0107 | .03520 | .990 | -.1030 | .0816 |
| | | | 6.00 | -.0676 | .03471 | .216 | -.1587 | .0234 |
| | | 5.00 | 3.00 | .0200 | .03802 | .953 | -.0797 | .1197 |
| | | | 4.00 | .0107 | .03520 | .990 | -.0816 | .1030 |
| | | | 6.00 | -.0569 | .03756 | .433 | -.1554 | .0416 |
| | | 6.00 | 3.00 | .0769 | .03756 | .179 | -.0216 | .1754 |
| | | | 4.00 | .0676 | .03471 | .216 | -.0234 | .1587 |
| | | | 5.00 | .0569 | .03756 | .433 | -.0416 | .1554 |
| Photo ID Noun | Tukey HSD | 3.00 | 4.00 | -.0402 | .01562 | .057 | -.0811 | .0008 |
| | | | 5.00 | -.0467* | .01687 | .034 | -.0910 | -.0025 |
| | | | 6.00 | -.0625* | .01667 | .002 | -.1062 | -.0188 |
| | | 4.00 | 3.00 | .0402 | .01562 | .057 | -.0008 | .0811 |
| | | | 5.00 | -.0066 | .01562 | .975 | -.0475 | .0344 |
| | | | 6.00 | -.0223 | .01540 | .473 | -.0627 | .0181 |
| | | 5.00 | 3.00 | .0467* | .01687 | .034 | .0025 | .0910 |
| | | | 4.00 | .0066 | .01562 | .975 | -.0344 | .0475 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 6.00 | -.0158 | .01667 | .781 | -.0595 | .0280 |
| | | 6.00 | 3.00 | .0625* | .01667 | .002 | .0188 | .1062 |
| | | | 4.00 | .0223 | .01540 | .473 | -.0181 | .0627 |
| | | | 5.00 | .0158 | .01667 | .781 | -.0280 | .0595 |
| Photo ID Verb | Tukey HSD | 3.00 | 4.00 | -.0330 | .03907 | .833 | -.1355 | .0695 |
| | | | 5.00 | -.0400 | .04220 | .779 | -.1507 | .0707 |
| | | | 6.00 | -.0702 | .04170 | .338 | -.1796 | .0391 |
| | | 4.00 | 3.00 | .0330 | .03907 | .833 | -.0695 | .1355 |
| | | | 5.00 | -.0070 | .03907 | .998 | -.1095 | .0955 |
| | | | 6.00 | -.0372 | .03852 | .769 | -.1383 | .0639 |
| | | 5.00 | 3.00 | .0400 | .04220 | .779 | -.0707 | .1507 |
| | | | 4.00 | .0070 | .03907 | .998 | -.0955 | .1095 |
| | | | 6.00 | -.0302 | .04170 | .887 | -.1396 | .0791 |
| | | 6.00 | 3.00 | .0702 | .04170 | .338 | -.0391 | .1796 |
| | | | 4.00 | .0372 | .03852 | .769 | -.0639 | .1383 |
| | | | 5.00 | .0302 | .04170 | .887 | -.0791 | .1396 |
| Photo ID Adj | Tukey HSD | 3.00 | 4.00 | -.0134 | .03332 | .978 | -.1008 | .0740 |
| | | | 5.00 | -.0337 | .03599 | .785 | -.1282 | .0607 |
| | | | 6.00 | -.0612 | .03556 | .319 | -.1545 | .0320 |
| | | 4.00 | 3.00 | .0134 | .03332 | .978 | -.0740 | .1008 |
| | | | 5.00 | -.0204 | .03332 | .928 | -.1078 | .0671 |
| | | | 6.00 | -.0479 | .03286 | .468 | -.1341 | .0383 |
| | | 5.00 | 3.00 | .0337 | .03599 | .785 | -.0607 | .1282 |
| | | | 4.00 | .0204 | .03332 | .928 | -.0671 | .1078 |
| | | | 6.00 | -.0275 | .03556 | .866 | -.1208 | .0658 |
| | | 6.00 | 3.00 | .0612 | .03556 | .319 | -.0320 | .1545 |
| | | | 4.00 | .0479 | .03286 | .468 | -.0383 | .1341 |
| | | | 5.00 | .0275 | .03556 | .866 | -.0658 | .1208 |

*Note.* Based on observed means.

The error term is Mean Square(Error) = .018.

*. The mean difference is significant at the $p$ = .05 level.

Table 9

*Post-Hoc Test for Pairwise Comparison Identification Accuracy of SymbolStix©2 Symbols for Nouns, Verbs and Adjectives*

| **Multiple Comparison** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dependent Variable | | (I) Age Group | (J) Age Group | Mean Difference (I-J) | Std. Error | *p* | 95% Confidence Interval | |
| | | | | | | | Lower Bound | Upper Bound |
| Symbol Identification Accuracy | Tukey HSD | 3.00 | 4.00 | -.0975* | .03337 | .023 | -.1850 | -.0100 |
| | | | 5.00 | -.0625 | .03604 | .313 | -.1570 | .0320 |
| | | | 6.00 | -.1432* | .03561 | .001 | -.2366 | -.0498 |
| | | 4.00 | 3.00 | .0975* | .03337 | .023 | .0100 | .1850 |
| | | | 5.00 | .0350 | .03337 | .721 | -.0525 | .1225 |
| | | | 6.00 | -.0457 | .03290 | .510 | -.1320 | .0406 |
| | | 5.00 | 3.00 | .0625 | .03604 | .313 | -.0320 | .1570 |
| | | | 4.00 | -.0350 | .03337 | .721 | -.1225 | .0525 |
| | | | 6.00 | -.0807 | .03561 | .115 | -.1741 | .0127 |
| | | 6.00 | 3.00 | .1432* | .03561 | .001 | .0498 | .2366 |
| | | | 4.00 | .0457 | .03290 | .510 | -.0406 | .1320 |
| | | | 5.00 | .0807 | .03561 | .115 | -.0127 | .1741 |
| SS ID Noun | Tukey HSD | 3.00 | 4.00 | -.0437 | .03828 | .664 | -.1442 | .0567 |
| | | | 5.00 | -.0628 | .04134 | .432 | -.1712 | .0457 |
| | | | 6.00 | -.0702 | .04085 | .320 | -.1774 | .0369 |
| | | 4.00 | 3.00 | .0437 | .03828 | .664 | -.0567 | .1442 |
| | | | 5.00 | -.0190 | .03828 | .960 | -.1194 | .0814 |
| | | | 6.00 | -.0265 | .03774 | .896 | -.1255 | .0725 |
| | | 5.00 | 3.00 | .0628 | .04134 | .432 | -.0457 | .1712 |
| | | | 4.00 | .0190 | .03828 | .960 | -.0814 | .1194 |
| | | | 6.00 | -.0075 | .04085 | .998 | -.1146 | .0997 |
| | | 6.00 | 3.00 | .0702 | .04085 | .320 | -.0369 | .1774 |
| | | | 4.00 | .0265 | .03774 | .896 | -.0725 | .1255 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 5.00 | .0075 | .04085 | .998 | -.0997 | .1146 |
| SS ID Verb | Tukey HSD | 3.00 | 4.00 | -.0321 | .05441 | .935 | -.1749 | .1106 |
| | | | 5.00 | -.0750 | .05877 | .581 | -.2292 | .0792 |
| | | | 6.00 | -.0976 | .05807 | .340 | -.2499 | .0547 |
| | | 4.00 | 3.00 | .0321 | .05441 | .935 | -.1106 | .1749 |
| | | | 5.00 | -.0429 | .05441 | .860 | -.1856 | .0999 |
| | | | 6.00 | -.0655 | .05365 | .616 | -.2062 | .0753 |
| | | 5.00 | 3.00 | .0750 | .05877 | .581 | -.0792 | .2292 |
| | | | 4.00 | .0429 | .05441 | .860 | -.0999 | .1856 |
| | | | 6.00 | -.0226 | .05807 | .980 | -.1749 | .1297 |
| | | 6.00 | 3.00 | .0976 | .05807 | .340 | -.0547 | .2499 |
| | | | 4.00 | .0655 | .05365 | .616 | -.0753 | .2062 |
| | | | 5.00 | .0226 | .05807 | .980 | -.1297 | .1749 |
| Symbol ID Adj | Tukey HSD | 3.00 | 4.00 | -.1325* | .03978 | .007 | -.2368 | -.0282 |
| | | | 5.00 | -.1175* | .04296 | .038 | -.2302 | -.0048 |
| | | | 6.00 | -.2081* | .04245 | .000 | -.3194 | -.0967 |
| | | 4.00 | 3.00 | .1325* | .03978 | .007 | .0282 | .2368 |
| | | | 5.00 | .0150 | .03978 | .982 | -.0893 | .1193 |
| | | | 6.00 | -.0756 | .03922 | .225 | -.1785 | .0273 |
| | | 5.00 | 3.00 | .1175* | .04296 | .038 | .0048 | .2302 |
| | | | 4.00 | -.0150 | .03978 | .982 | -.1193 | .0893 |
| | | | 6.00 | -.0906 | .04245 | .151 | -.2019 | .0208 |
| | | 6.00 | 3.00 | .2081* | .04245 | .000 | .0967 | .3194 |
| | | | 4.00 | .0756 | .03922 | .225 | -.0273 | .1785 |
| | | | 5.00 | .0906 | .04245 | .151 | -.0208 | .2019 |

*Note.* Based on observed mean. The error term is Mean Square(Error) = .018. *. The mean difference is significant at the *p* = .05 level.

## Estimated Means

Grand mean was generated for factor 1 (symbol type) by word class. Grand mean results revealed the highest mean score for identification accuracy of graphic symbols, nouns (*M*ean = .95, *SE* = .008), followed by adjectives, overall identification and verbs. Estimated grand mean results revealed participants achieved a higher mean score for identification accuracy of color photograph symbols[1], across word class, (*Mean* = .93, *SE* = .013) in comparison to SymbolStix©[2] symbols (*Mean* = .89, *SE* = .012*)*. Table 10 presents the grand mean for overall identification accuracy of graphic symbols, identification of graphic symbols for nouns, verbs and adjectives.

Table 10

*Estimated Grand Mean Symbol Type Identification Accuracy (Percent Correct) Results*

| Grand Mean | | | | |
|---|---|---|---|---|
| Dependent Variable | Mean | Std. Error | 95% Confidence Interval | |
| | | | Lower Bound | Upper Bound |
| Photo ID Accuracy | .932 | .013 | .906 | .957 |
| Photo ID Noun | .975 | .006 | .964 | .986 |
| Photo ID Verb | .936 | .014 | .908 | .964 |
| Photo ID Adj | .941 | .012 | .916 | .966 |
| SS ID Accuracy | .888 | .012 | .864 | .913 |
| SS ID Noun | .919 | .014 | .891 | .947 |
| SS ID Verb | .876 | .020 | .837 | .915 |
| SS ID Adj | .895 | .014 | .866 | .923 |

*Note.* Photo = Color Photograph Symbol[1], SS = SymbolStix©[2] symbols, ID = Identification, Adj = Adjective.

Estimated marginal mean for symbol type (color photograph symbols[1], SymbolStix©[2] symbols) by word class for identification accuracy of graphic symbols was completed. Three, four, five and six-year old children achieved higher mean scores for overall identification accuracy and identification accuracy of nouns, verbs and adjectives for color photograph symbols[1] in comparison to SymbolStix©[2]symbols. Developmental trends of six-year olds achieving the highest mean score, followed by five-year olds, four-year olds and three year olds was noted for overall identification accuracy of graphic symbols, verbs and adjectives. However, for identification accuracy of nouns, for both color photograph[1] and SymbolStix©[2] symbols, six-year olds achieved the highest mean score followed by five and four-year olds and lastly three-year olds (*Mean* = .81, *SE* = .026). Developmental trends for identification of graphic symbols by type and word class are reported.

Color photograph symbols[1] results for identification accuracy were as follows: six-year olds (*Mean* = .98, *SE = .026)* achieved the highest overall mean score, followed by five-year olds (*Mean* = .93, *SE = .027)*, four-year olds (*Mean* = .91, *SE = .022)*, and three-year olds (*Mean* = .91, *SE = .027)*, for nouns six-year olds achieved the highest mean score (*Mean* = 1.00, *SE*= .011), followed by followed by five year olds (*Mean* =.98, *SE* = .012) and four-year olds (*Mean* = .98, *SE* = .012), and finally three-year olds (*Mean* = .94, *SE = .012),* for verbs, six year olds achieved the highest mean score (*Mean* = 97, *SE* = .029) followed by five-year olds (M =.94 , se=.029), then four-year olds (*Mean* =.93 , *SE*=.025) and finally three-year olds (*Mean* = .90, *SE* = .029), for adjectives, six-year olds achieved the highest mean score (*Mean = .98, SE* = .025), five-year olds, (*Mean* = .95, *SE* = .026), four-year olds (*Mean* = .93, *SE* = .022) and finally three year olds (*Mean =.91, SE = .026*).

SymbolStix©[2] symbols test results were as follows: for nouns, six-year olds achieved the highest mean score (*Mean*=.95, *SE* =.029), followed by five-year olds (*Mean*=.94, *SE* =.029), four- year olds (*Mean* = 92 , *SE*=.025), then three year olds (*Mean* = .88, *SE*=.029), for verbs, six-year olds (*Mean* = .92, *SE* = .040), five-year olds (*Mean*= .90, *SE*= .041) four year olds (*Mean* = .86, *SE* = .035), then three-year olds (*Mean*=.83 , *SE* =.041), for adjectives, six-year olds achieved the highest mean score (*Mean*= .99, *SE*=.029), followed by five-year olds (*Mean* = .90, *SE*=.030), followed by four-year olds (*Mean* =.91, *SE*=.025) and finally three-year olds (*Mean* = .78, *SE*=.030). Marginal means for symbol type and word class by age group are presented in Table 11. Table 12 presents marginal means for symbol type by word class.

Table 11

*Marginal Means for Identification Accuracy of Symbol Type & Word Class by Age Group*

| Estimates | | | | | |
|---|---|---|---|---|---|
| Dependent Variable | Age Group | Mean | Std. Error | 95% Confidence Interval | |
| | | | | Lower Bound | Upper Bound |
| Photo ID Accuracy | 3 | .905 | .027 | .852 | .958 |
| | 4 | .914 | .022 | .870 | .959 |
| | 5 | .925 | .027 | .872 | .978 |
| | 6 | .982 | .026 | .930 | 1.033 |
| Photo ID Noun | 3 | .938 | .012 | .914 | .961 |
| | 4 | .978 | .010 | .958 | .997 |
| | 5 | .984 | .012 | .961 | 1.008 |
| | 6 | 1.000 | .011 | .977 | 1.023 |
| Photo ID Verb | 3 | .900 | .029 | .842 | .958 |

| | | | | | |
|---|---|---|---|---|---|
| | 4 | .933 | .025 | .884 | .982 |
| | 5 | .940 | .029 | .882 | .998 |
| | 6 | .970 | .029 | .913 | 1.027 |
| Photo ID Adj | 3 | .914 | .026 | .862 | .965 |
| | 4 | .927 | .022 | .884 | .971 |
| | 5 | .947 | .026 | .896 | .999 |
| | 6 | .975 | .025 | .925 | 1.025 |
| SS ID Accuracy | 3 | .813 | .026 | .762 | .863 |
| | 4 | .910 | .022 | .867 | .953 |
| | 5 | .875 | .026 | .824 | .926 |
| | 6 | .956 | .025 | .906 | 1.005 |
| SS ID Noun | 3 | .875 | .029 | .817 | .933 |
| | 4 | .919 | .025 | .870 | .968 |
| | 5 | .938 | .029 | .880 | .996 |
| | 6 | .945 | .029 | .888 | 1.002 |
| SS ID Verb | 3 | .825 | .041 | .743 | .907 |
| | 4 | .857 | .035 | .788 | .926 |
| | 5 | .900 | .041 | .818 | .982 |
| | 6 | .923 | .040 | .843 | 1.002 |
| SS ID Adj | 3 | .780 | .030 | .721 | .839 |
| | 4 | .913 | .025 | .862 | .963 |
| | 5 | .898 | .030 | .838 | .957 |
| | 6 | .988 | .029 | .930 | 1.046 |

*Note.* Photo = Color Photograph Symbol[1], SS = SymbolStix©[2] symbols, ID = Identification, Adj = Adjective.

Table 12

*Marginal Means for Identification Accuracy Symbol Type by Word Class*

| Estimates | | | | | |
|---|---|---|---|---|---|
| Measure | Symbol Type | Mean | Std. Error | 95% Confidence Interval | |
| | | | | Lower Bound | Upper Bound |
| Noun | Photo | .975 | .006 | .964 | .986 |
| | SS | .919 | .014 | .891 | .947 |
| Verb | Photo | .936 | .014 | .908 | .964 |
| | SS | .876 | .020 | .837 | .915 |
| Adjective | Photo | .941 | .012 | .916 | .966 |
| | SS | .895 | .014 | .866 | .923 |
| Overall | Photo | .932 | .013 | .906 | .957 |
| | SS | .888 | .012 | .864 | .913 |

*Note.* Photo = Color Photograph Symbol[1], SS = SymbolStix©[2] Symbols.

## Profile Plots

Profile plots were generated for estimated marginal means for identification of graphic symbols by age group. Three, four, five and six-year old participants achieved a higher mean score for overall identification of graphic symbols, identification of graphic symbols for nouns, verbs and adjectives, favoring the color photograph symbol condition. Figure 2 presents estimated marginal means for overall identification accuracy of graphic symbols and Figure 3 presents estimated marginal means for identification accuracy of graphic symbols by word class and age group.

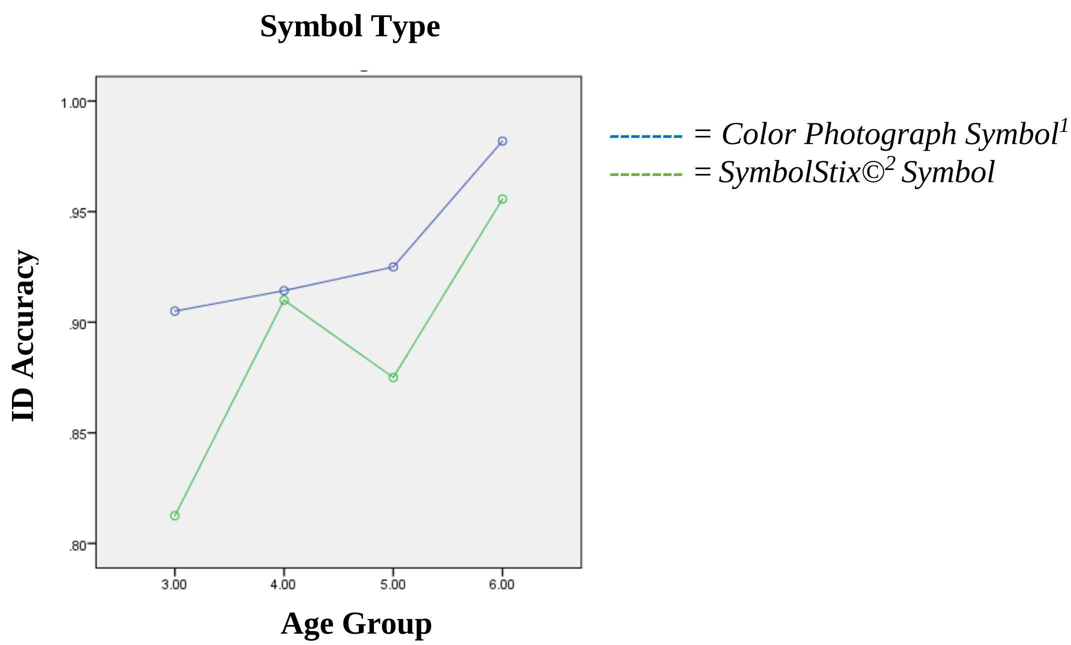



Figure 2. Estimated Marginal Means Overall Identification Accuracy of Graphic Symbols

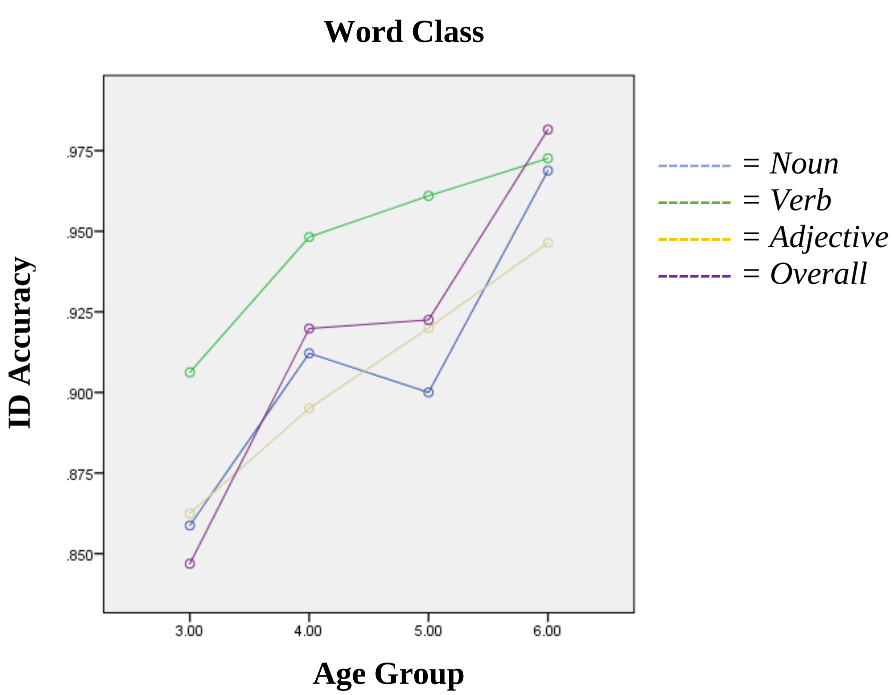



Figure 3. Estimated Marginal Means Identification Accuracy of Graphic Symbols, Word Class & Age Group

**Identification Touch Rate**

Three, four, five and six-year old participants achieved a higher mean score for overall touch rate of color photograph symbols[1] and for nouns, verbs and adjectives. Table 13 presents the descriptive statistics for the identification touch rate by symbol type, word class and age group.

Table 13

*Descriptive Statistics for Identification Touch Rate of Graphic Symbols by Symbol Type, Word Class & Age Group*

| Descriptive Statistics | | | | |
|---|---|---|---|---|
| | Age Group | Mean | Std. Deviation | N |
| Touch Photo Noun Avg | 3.00 | 1.8343 | .73459 | 21 |
| | 4.00 | 1.8793 | .80503 | 27 |
| | 5.00 | 1.5907 | .59950 | 20 |
| | 6.00 | 1.4525 | .43355 | 20 |
| | Total | 1.7060 | .68440 | 88 |
| Touch Photo Verb Avg | 3.00 | 2.1566 | .49015 | 21 |
| | 4.00 | 1.9037 | .56207 | 27 |
| | 5.00 | 2.0035 | .85099 | 20 |
| | 6.00 | 2.1066 | .76510 | 20 |
| | Total | 2.0328 | .66780 | 88 |
| Touch Photo Adj Avg | 3.00 | 2.0140 | .57623 | 21 |
| | 4.00 | 1.8842 | .56947 | 27 |
| | 5.00 | 1.8816 | .54984 | 20 |
| | 6.00 | 1.6793 | .61914 | 20 |
| | Total | 1.8680 | .58004 | 88 |
| Overall Touch Photo | 3.00 | 2.0017 | .47808 | 21 |
| | 4.00 | 1.8892 | .46026 | 27 |
| | 5.00 | 1.8274 | .44413 | 20 |
| | 6.00 | 1.7237 | .41324 | 20 |

| | | | | |
|---|---|---|---|---|
| | Total | 1.8644 | .45369 | 88 |
| SS Avg Touch Noun | 3.00 | 2.4271 | .99727 | 21 |
| | 4.00 | 1.9844 | 1.05436 | 27 |
| | 5.00 | 1.7547 | .92486 | 20 |
| | 6.00 | 1.4905 | .54409 | 20 |
| | Total | 1.9256 | .96142 | 88 |
| SS Avg Touch Verb | 3.00 | 2.7010 | 1.13511 | 21 |
| | 4.00 | 2.1317 | .94707 | 27 |
| | 5.00 | 2.3626 | .92797 | 20 |
| | 6.00 | 1.9334 | .68236 | 20 |
| | Total | 2.2750 | .96580 | 88 |
| SS Avg Touch Adj | 3.00 | 2.5180 | 1.29977 | 21 |
| | 4.00 | 1.9967 | .93112 | 27 |
| | 5.00 | 1.9905 | .77867 | 20 |
| | 6.00 | 1.5922 | .55912 | 20 |
| | Total | 2.0278 | .97488 | 88 |
| SS Overall Touch | 3.00 | 2.5486 | .97832 | 21 |
| | 4.00 | 2.0376 | .72950 | 27 |
| | 5.00 | 2.1083 | .67174 | 20 |
| | 6.00 | 1.7414 | .38840 | 20 |
| | Total | 2.1083 | .76802 | 88 |

*Note*. Photo = Color photograph symbols[1],SS= SymbolStix©[2], Touch = touch rate, Adj = adjective, Avg = average.

Box’s M test revealed that the homoscedasticity assumption was not met with $p$ = <.001. Since an assumption was violated, Pillae’s Trace was used, as it is more robust in MANOVA designs where heterogeneity of variance-covariance is violated and imbalanced (Has-Vaughn, 2012).

A Repeated Measures MANOVA revealed significant differences of identification touch rate for the combined variables of symbol type (color photograph symbols[1] vs. SymbolStix©[2] symbols) and word class (nouns, verbs and adjectives). Multivariate tests revealed a significant difference in identification touch rate of symbol type with $F_{(1, 84)} = 9.970$ ($p < .001$; partial eta squared = .106) and word class $F_{(3, 82)} = 7.468$, ($p$ = <.001, partial eta squared= .215). There is a statistically significant interaction effect between symbol type and age group $F_{(3, 84)} = 3.106$, ($p$ = <.001, partial eta squared= .100). There is not a statistically significant interaction between word class and age group with $F_{(9, 252)} = .875$, ($p$ = > .005, partial eta squared= .030). (See Table 14).

Table 14

*Multivariate Test Results for Identification Touch Rate of Graphic Symbols for Symbol Type, Word Class and Age Group*

**Multivariate Tests[a]**

| Variable | Pillai's Trace Value | *F* | Hypothesis *df* | Error *df* | *p* | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Symbol Type | .106 | 9.970[b] | 1.000 | 84.000 | .002 | .106 |
| Symbol Type* Age Group | .100 | 3.106[b] | 3.000 | 84.000 | .031 | .100 |
| Word Class | .215 | 7.468[b] | 3.000 | 82.000 | <.001 | .215 |
| Word Class * Age Group | .091 | .875 | 9.000 | 252.000 | .548 | .030 |
| Symbol Type * Word Class | .059 | 1.718[b] | 3.000 | 82.000 | .170 | .059 |
| Symbol Type * Word Class * Age Group | .075 | .717 | 9.000 | 252.000 | .693 | .025 |

*Note.* a. Design: Intercept + age_group
Within Subjects Design: factor1 + factor2 + factor1 * factor2

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Computed using alpha = .05

Within subject effects revealed a significant difference in touch identification rate of symbol type (color photograph symbols[1] vs. SymbolStix©[2] symbols) with $F_{(1, 84)} = 9.970$ ($p$ <.001; partial eta squared = .106) and word class $F_{(3, 84)} = 14.12$, error $df = 84$, ($p$ = <.001, partial eta squared = .144). There was a significant interaction effect between symbol type and age group with $F_{(3, 84)} = 3.106$ ($p < .001$; partial eta squared = .100). There was not a significant interaction between word class and age group with $F_{(9, 252)} = 1.426$ ($p > .005$; partial eta squared = .048). (See Table 15).

Table 15

*Within Subject Effects Identification Touch Rate of Graphic Symbols for Symbol Type, Word Class and Age Group*

Tests of Within Subjects Effects

| Variable | | Type III Sum of Squares | *df* | Mean Square | *F* | *p* | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Symbol Type | Sphericity Assumed | 8.248 | 1 | 8.248 | 9.970 | .002 | .106 |
| | Greenhouse-Geisser | 8.248 | 1.000 | 8.248 | 9.970 | .002 | .106 |
| | Huynh-Feldt | 8.248 | 1.000 | 8.248 | 9.970 | .002 | .106 |
| | Lower-bound | 8.248 | 1.000 | 8.248 | 9.970 | .002 | .106 |
| Symbol Type * Age group | Sphericity Assumed | 7.708 | 3 | 2.569 | 3.106 | .031 | .100 |
| | Greenhouse-Geisser | 7.708 | 3.000 | 2.569 | 3.106 | .031 | .100 |
| | Huynh-Feldt | 7.708 | 3.000 | 2.569 | 3.106 | .031 | .100 |
| | Lower-bound | 7.708 | 3.000 | 2.569 | 3.106 | .031 | .100 |
| Error(Symbol Type) | Sphericity Assumed | 69.491 | 84 | .827 | | | |
| | Greenhouse-Geisser | 69.491 | 84.000 | .827 | | | |
| | Huynh-Feldt | 69.491 | 84.000 | .827 | | | |
| | Lower-bound | 69.491 | 84.000 | .827 | | | |
| Word Class | Sphericity Assumed | 11.465 | 3 | 3.822 | 14.116 | <.001 | .144 |
| | Greenhouse-Geisser | 11.465 | 1.905 | 6.019 | 14.116 | <.001 | .144 |
| | Huynh-Feldt | 11.465 | 2.017 | 5.683 | 14.116 | <.001 | .144 |
| | Lower-bound | 11.465 | 1.000 | 11.465 | 14.116 | <.001 | .144 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Word Class* Age Group | Sphericity Assumed | 3.475 | 9 | .386 | 1.426 | .177 | .048 |
| | Greenhouse-Geisser | 3.475 | 5.714 | .608 | 1.426 | .210 | .048 |
| | Huynh-Feldt | 3.475 | 6.052 | .574 | 1.426 | .207 | .048 |
| | Lower-bound | 3.475 | 3.000 | 1.158 | 1.426 | .241 | .048 |
| Error(Word Class) | Sphericity Assumed | 68.227 | 252 | .271 | | | |
| | Greenhouse-Geisser | 68.227 | 160.005 | .426 | | | |
| | Huynh-Feldt | 68.227 | 169.468 | .403 | | | |
| | Lower-bound | 68.227 | 84.000 | .812 | | | |
| Symbol Type * Word Class | Sphericity Assumed | .211 | 3 | .070 | .279 | .841 | .003 |
| | Greenhouse-Geisser | .211 | 2.054 | .102 | .279 | .763 | .003 |
| | Huynh-Feldt | .211 | 2.182 | .097 | .279 | .776 | .003 |
| | Lower-bound | .211 | 1.000 | .211 | .279 | .599 | .003 |
| Symbol Type * Word Class * Age Group | Sphericity Assumed | .637 | 9 | .071 | .281 | .979 | .010 |
| | Greenhouse-Geisser | .637 | 6.163 | .103 | .281 | .948 | .010 |
| | Huynh-Feldt | .637 | 6.545 | .097 | .281 | .954 | .010 |
| | Lower-bound | .637 | 3.000 | .212 | .281 | .839 | .010 |
| Error(Symbol Type*Word Class) | Sphericity Assumed | 63.414 | 252 | .252 | | | |
| | Greenhouse-Geisser | 63.414 | 172.556 | .367 | | | |
| | Huynh-Feldt | 63.414 | 183.255 | .346 | | | |
| | Lower-bound | 63.414 | 84.000 | .755 | | | |

*Note.* Significant at the $p < .05$ level.

Between-subject effects revealed a significant difference for touch identification rate of graphic symbols for age group $F_{(3, 84)} = 4.003$ ($p$ =.010; partial eta squared = .125). Table 16 presents the between subject effects for the average of combined variables for identification touch rate of graphic symbols.

Table 16

*Between Subject Effects Identification Touch Rate of Graphic Symbols*

**Tests of Between-Subjects Effects**

Measure: Touch Rate

Transformed Variable: Average

| Source | Type III Sum of Squares | *df* | Mean Square | *F* | *p* | Partial Eta Squared | Noncent. Parameter | Observed Power[a] |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2699.302 | 1 | 2699.302 | 1237.950 | <.001 | .936 | 1237.950 | 1.000 |
| Age Group | 26.184 | 3 | 8.728 | 4.003 | .010 | .125 | 12.008 | .821 |
| Error | 183.159 | 84 | 2.180 | | | | | |

*Note.* Significant at the $p < .05$

hat seven of the eight variables met assumption. ANOVA test revealed that one variable, overall touch rate for SymbolStix©[2] symbols did not meet assumption with $F_{(3, 84)} = 5.298$ ($p$ =.002).

Homogenous subtests for identification touch rate revealed that a total of eighty-eight participants completed both experimental conditions for the identification task. Table 17 presents the homogenous subtest results for identification touch rate of graphic symbols.

Table 17

*Homogenous Subtest Identification Touch Rate*

| Touch Rate | | | |
|---|---|---|---|
| Age Group | N | Subset | |
| | | 1 | 2 |
| 3 | 20 | | 2.2752 |
| 4 | 27 | 1.9634 | 1.9634 |
| 5 | 20 | 1.9399 | 1.9399 |
| 6 | 21 | 1.7149 | |
| *p* | | .403 | .157 |

*Note.* Means for groups in homogenous subsets are displayed.

Based on observed means.
There error term is Mean Square (Error) = .273

a. Uses Harmonic Mean Sample Size = 21.662.
b. The group sizes are uneqal. The harmonic mean of the groups sizes is used. Type I error levels are not guaranteed.

Alpha = .05

## Post-Hoc Test for Touch Rate

Post-Hoc Test, Tukey HSD was generated to determine statistically significant differences between touch rate, word class and age group. Statistically significant differences were noted between 3 and 6-year olds for: overall touch rate of SymbolStix©[2] symbols ($p$ = .010) and touch rate for SymbolStix©[2] symbol adjectives ($p$ = 027). Table 18 presents the post-hoc test results for color photograph symbols[1] by word class and age group. Table 19 presents the post-hoc test results for SymbolStix©[2] symbols by word class and age group.

Table 18

*Post-Hoc Test for Pairwise Comparison Touch Rate of Color Photograph Symbols[1] for Nouns, Verbs and Adjectives*

**Multiple Comparisons**

Tukey HSD

| Dependent Variable | (I) Age_Group | (J) Age_Group | Mean Difference (I-J) | Std. Error | *p* | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|---|
| Touch Photo Noun Avg | 3.00 | 4.00 | -.0450 | .19580 | .996 | -.5582 | .4683 |
| | | 5.00 | .2437 | .21026 | .654 | -.3074 | .7948 |
| | | 6.00 | .3819 | .21026 | .273 | -.1692 | .9330 |
| | 4.00 | 3.00 | .0450 | .19580 | .996 | -.4683 | .5582 |
| | | 5.00 | .2887 | .19854 | .470 | -.2317 | .8091 |
| | | 6.00 | .4269 | .19854 | .146 | -.0935 | .9473 |
| | 5.00 | 3.00 | -.2437 | .21026 | .654 | -.7948 | .3074 |
| | | 4.00 | -.2887 | .19854 | .470 | -.8091 | .2317 |
| | | 6.00 | .1382 | .21281 | .915 | -.4196 | .6960 |
| | 6.00 | 3.00 | -.3819 | .21026 | .273 | -.9330 | .1692 |
| | | 4.00 | -.4269 | .19854 | .146 | -.9473 | .0935 |
| | | 5.00 | -.1382 | .21281 | .915 | -.6960 | .4196 |
| Touch Photo Verb Avg | 3.00 | 4.00 | .2530 | .19544 | .569 | -.2593 | .7652 |
| | | 5.00 | .1532 | .20987 | .885 | -.3969 | .7033 |
| | | 6.00 | .0501 | .20987 | .995 | -.5001 | .6002 |
| | 4.00 | 3.00 | -.2530 | .19544 | .569 | -.7652 | .2593 |
| | | 5.00 | -.0998 | .19817 | .958 | -.6192 | .4197 |
| | | 6.00 | -.2029 | .19817 | .736 | -.7223 | .3165 |
| | 5.00 | 3.00 | -.1532 | .20987 | .885 | -.7033 | .3969 |
| | | 4.00 | .0998 | .19817 | .958 | -.4197 | .6192 |
| | | 6.00 | -.1031 | .21241 | .962 | -.6599 | .4537 |
| | 6.00 | 3.00 | -.0501 | .20987 | .995 | -.6002 | .5001 |
| | | 4.00 | .2029 | .19817 | .736 | -.3165 | .7223 |
| | | 5.00 | .1031 | .21241 | .962 | -.4537 | .6599 |
| Touch Photo Adj Avg | 3.00 | 4.00 | .1298 | .16828 | .867 | -.3113 | .5709 |
| | | 5.00 | .1324 | .18071 | .884 | -.3413 | .6061 |
| | | 6.00 | .3347 | .18071 | .257 | -.1390 | .8084 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 4.00 | 3.00 | -.1298 | .16828 | .867 | -.5709 | .3113 |
| | | 5.00 | .0026 | .17063 | 1.000 | -.4447 | .4499 |
| | | 6.00 | .2049 | .17063 | .628 | -.2424 | .6521 |
| | 5.00 | 3.00 | -.1324 | .18071 | .884 | -.6061 | .3413 |
| | | 4.00 | -.0026 | .17063 | 1.000 | -.4499 | .4447 |
| | | 6.00 | .2023 | .18290 | .687 | -.2771 | .6817 |
| | 6.00 | 3.00 | -.3347 | .18071 | .257 | -.8084 | .1390 |
| | | 4.00 | -.2049 | .17063 | .628 | -.6521 | .2424 |
| | | 5.00 | -.2023 | .18290 | .687 | -.6817 | .2771 |
| Overall | 3.00 | 4.00 | .1125 | .13117 | .827 | -.2313 | .4563 |
| Touch Photo | | 5.00 | .1742 | .14085 | .605 | -.1950 | .5434 |
| | | 6.00 | .2780 | .14085 | .206 | -.0912 | .6472 |
| | 4.00 | 3.00 | -.1125 | .13117 | .827 | -.4563 | .2313 |
| | | 5.00 | .0617 | .13300 | .967 | -.2869 | .4104 |
| | | 6.00 | .1655 | .13300 | .601 | -.1831 | .5141 |
| | 5.00 | 3.00 | -.1742 | .14085 | .605 | -.5434 | .1950 |
| | | 4.00 | -.0617 | .13300 | .967 | -.4104 | .2869 |
| | | 6.00 | .1038 | .14256 | .886 | -.2699 | .4775 |
| | 6.00 | 3.00 | -.2780 | .14085 | .206 | -.6472 | .0912 |
| | | 4.00 | -.1655 | .13300 | .601 | -.5141 | .1831 |
| | | 5.00 | -.1038 | .14256 | .886 | -.4775 | .2699 |

*Note.* Based on observed means.

The error term is Mean Square(Error) = .529.

The mean difference is significant at the $p = .05$ level.

Table 19

*Post-Hoc Test for Pairwise Comparison Touch Rate of SymbolStix©[2] Symbols for Nouns, Verbs, and Adjectives*

**Multiple Comparisons**

Tukey HSD

| Dependent Variable | (I) Age_Group | (J) Age_Group | Mean Difference (I-J) | Std. Error | *p* | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| SS Avg Touch Noun | 3.00 | 4.00 | .4427 | .26688 | .352 | -.2569 | 1.1422 |
| | | 5.00 | .6724 | .28658 | .096 | -.0788 | 1.4236 |
| | | 6.00 | .9366* | .28658 | .008 | .1854 | 1.6878 |
| | 4.00 | 3.00 | -.4427 | .26688 | .352 | -1.1422 | .2569 |
| | | 5.00 | .2297 | .27060 | .831 | -.4796 | .9390 |
| | | 6.00 | .4939 | .27060 | .269 | -.2154 | 1.2032 |
| | 5.00 | 3.00 | -.6724 | .28658 | .096 | -1.4236 | .0788 |
| | | 4.00 | -.2297 | .27060 | .831 | -.9390 | .4796 |
| | | 6.00 | .2642 | .29006 | .799 | -.4961 | 1.0245 |
| | 6.00 | 3.00 | -.9366* | .28658 | .008 | -1.6878 | -.1854 |
| | | 4.00 | -.4939 | .27060 | .269 | -1.2032 | .2154 |
| | | 5.00 | -.2642 | .29006 | .799 | -1.0245 | .4961 |
| SS Avg Touch Verb | 3.00 | 4.00 | .5692 | .27364 | .168 | -.1480 | 1.2865 |
| | | 5.00 | .3384 | .29384 | .659 | -.4319 | 1.1086 |
| | | 6.00 | .7676 | .29384 | .051 | -.0026 | 1.5378 |
| | 4.00 | 3.00 | -.5692 | .27364 | .168 | -1.2865 | .1480 |
| | | 5.00 | -.2309 | .27746 | .839 | -.9581 | .4964 |
| | | 6.00 | .1984 | .27746 | .891 | -.5289 | .9256 |
| | 5.00 | 3.00 | -.3384 | .29384 | .659 | -1.1086 | .4319 |
| | | 4.00 | .2309 | .27746 | .839 | -.4964 | .9581 |
| | | 6.00 | .4292 | .29741 | .476 | -.3503 | 1.2088 |
| | 6.00 | 3.00 | -.7676 | .29384 | .051 | -1.5378 | .0026 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4.00 | -.1984 | .27746 | .891 | -.9256 | .5289 |
| | | 5.00 | -.4292 | .29741 | .476 | -1.2088 | .3503 |
| SS Avg Touch Adj | 3.00 | 4.00 | .5213 | .27270 | .231 | -.1935 | 1.2361 |
| | | 5.00 | .5276 | .29284 | .280 | -.2400 | 1.2951 |
| | | 6.00 | .9258* | .29284 | .012 | .1582 | 1.6934 |
| | 4.00 | 3.00 | -.5213 | .27270 | .231 | -1.2361 | .1935 |
| | | 5.00 | .0063 | .27651 | 1.000 | -.7185 | .7311 |
| | | 6.00 | .4045 | .27651 | .464 | -.3203 | 1.1293 |
| | 5.00 | 3.00 | -.5276 | .29284 | .280 | -1.2951 | .2400 |
| | | 4.00 | -.0063 | .27651 | 1.000 | -.7311 | .7185 |
| | | 6.00 | .3982 | .29639 | .538 | -.3786 | 1.1751 |
| | 6.00 | 3.00 | -.9258* | .29284 | .012 | -1.6934 | -.1582 |
| | | 4.00 | -.4045 | .27651 | .464 | -1.1293 | .3203 |
| | | 5.00 | -.3982 | .29639 | .538 | -1.1751 | .3786 |
| Overall Touch SS | 3.00 | 4.00 | .5110 | .21158 | .082 | -.0436 | 1.0656 |
| | | 5.00 | .4403 | .22720 | .220 | -.1552 | 1.0359 |
| | | 6.00 | .8072* | .22720 | .003 | .2117 | 1.4028 |
| | 4.00 | 3.00 | -.5110 | .21158 | .082 | -1.0656 | .0436 |
| | | 5.00 | -.0707 | .21453 | .988 | -.6330 | .4916 |
| | | 6.00 | .2962 | .21453 | .515 | -.2662 | .8585 |
| | 5.00 | 3.00 | -.4403 | .22720 | .220 | -1.0359 | .1552 |
| | | 4.00 | .0707 | .21453 | .988 | -.4916 | .6330 |
| | | 6.00 | .3669 | .22995 | .387 | -.2359 | .9696 |
| | 6.00 | 3.00 | -.8072* | .22720 | .003 | -1.4028 | -.2117 |
| | | 4.00 | -.2962 | .21453 | .515 | -.8585 | .2662 |
| | | 5.00 | -.3669 | .22995 | .387 | -.9696 | .2359 |

*Note.* Based on observed means.

The error term is Mean Square(Error) = .529.

*. The mean difference is significant at the .05 level.

**Estimated Means**

Grand mean was generated for touch rate for graphic symbols. Grand mean results revealed the overall mean touch rate for identification of color photograph symbols[1] (*Mean* = 1.9, *SE* = .048) was quicker than the overall mean touch rate for SymbolStix©[2] symbols (*Mean* = 2.1, *SE* = .078). Estimated marginal means were generated for age group and factor 1 (symbol type). Results revealed that 3, 4, 5 and 6-year olds achieved a quicker mean touch rate for color photograph symbols[1] in comparison to SymbolStix©[2] symbols. Developmental trends across word class were noted for quickest mean touch rate for nouns, followed by adjectives, then verbs for three, four, five and six-year olds children across symbol type (color photograph symbol[1] and SymbolStix©[2] symbols).

Estimated marginal mean for identification touch rate by symbol type (color photograph symbols[1], SymbolStix©[2] symbols) word class, and age group was generated. Three, four, five and six-year old children achieved quicker mean touch rates for identification of color photograph symbols[1] overall, nouns and verbs. Developmental trends for identification touch rate for color photograph symbols[1] and word class were as follows: for nouns, six-year olds achieved the quickest touch rate (*Mean* 1.5, = *SE* =.150 *)*, followed by five-year olds (*Mean* 1.6= *SE* =.150*)*, four- year olds (*Mean* 1.9= *SE* =.130*)*, and finally three-year olds (*Mean* = 1.8, *SE* =.147*)*, for verbs; four-year olds achieved the quickest touch rate (*Mean* = 1.9, *SE* =.129), followed by five-year olds (*Mean* = 2.0, *SE* =.150), then six-year olds, (*Mean* = 2.1, *SE* =.150), and finally three-year olds (*Mean* = 2.2, *SE* =.147), for adjectives; six-year olds achieved the quickest touch rate (*Mean* = 1.7, *SE* =.129 *)*, followed by five-year olds (*Mean* = 1.9, SE = .129) and four-year olds (*Mean* = 1.9, *SE* = .111 *)*, and finally three year olds. (*Mean* = 2.0, *SE*

=.126*)*, results for adjectives followed the same pattern, with the exception of 6-year olds achieving a slightly higher mean score for identification accuracy of SymbolStix©[2] symbols in comparison to color photograph symbols[1] (*Mean* = .99 vs. *Mean* = .98).

Developmental trends for identification touch rate for SymbolStix©[2] symbols and word class were as follows: for nouns, six-year olds achieved the quickest touch rate (*Mean* = 1.5, *SE* =.205*)*, followed by five-year olds (*Mean* = 1.8, *SE* =.205*)*, four- year olds (*Mean* = 2.0, *SE* =.177*)*, and finally three-year olds (*Mean* = 2.4, *SE* =.200*)*, for verbs; six-year olds achieved the quickest touch rate (*Mean* =1.9, *SE* =.210), followed by four-year olds (*Mean* = 2.1, *SE* =.181), then five-year olds, (*Mean* =2.4 , *SE* = .210), and finally three-year olds (*Mean* =2.7, *SE* =.205), for adjectives; six-year olds achieved the quickest touch rate (*Mean* = 1.6 , *SE* =.210), followed by five-year olds (*Mean* = 2.0, SE = .210) and four-year olds (*Mean* = 2.0, *SE* = .180 *)*, and finally three year olds (*Mean* = 2.5, *SE*= .205*)*. Table 20 presents grand means for identification touch rate and Table 21 presents estimated marginal means for identification touch rate symbol type, word class by age group.

Table 20

*Grand Mean Touch Rate Symbol Type by Word Class*

| Grand Mean | | | | |
|---|---|---|---|---|
| Dependent Variable | Mean | Std. Error | 95% Confidence Interval | |
| | | | Lower Bound | Upper Bound |
| Touch Photo Noun Avg | 1.689 | .072 | 1.545 | 1.833 |
| Touch Photo Verb Avg | 2.043 | .072 | 1.899 | 2.186 |
| Touch Photo Adj Avg | 1.865 | .062 | 1.741 | 1.988 |
| Overall Touch Photo | 1.860 | .048 | 1.764 | 1.957 |
| SS Avg Touch Noun | 1.914 | .099 | 1.718 | 2.110 |
| SS Avg Touch Verb | 2.282 | .101 | 2.081 | 2.483 |
| SS Avg Touch Adj | 2.024 | .101 | 1.824 | 2.225 |
| Overall touch SS | 2.109 | .078 | 1.954 | 2.264 |

*Note.* SS =SymbolStix©$^2$Symbols, AVG = average, Touch = Touch Rate, ADJ = Adjective.

Table 21

*Estimated Marginal Means for Touch Rate Symbol Type by Word Class*

| Estimates | | | | | |
|---|---|---|---|---|---|
| Dependent Variable | Age Group | Mean | Std. Error | 95% Confidence Interval | |
| | | | | Lower Bound | Upper Bound |
| Touch Photo Noun Avg | 3.00 | 1.834 | .147 | 1.542 | 2.126 |
| | 4.00 | 1.879 | .130 | 1.622 | 2.137 |
| | 5.00 | 1.591 | .150 | 1.291 | 1.890 |
| | 6.00 | 1.452 | .150 | 1.153 | 1.752 |
| Touch Photo Verb Avg | 3.00 | 2.157 | .147 | 1.865 | 2.448 |
| | 4.00 | 1.904 | .129 | 1.647 | 2.161 |
| | 5.00 | 2.003 | .150 | 1.705 | 2.302 |
| | 6.00 | 2.107 | .150 | 1.808 | 2.405 |
| Touch Photo Adj Avg | 3.00 | 2.014 | .126 | 1.763 | 2.265 |
| | 4.00 | 1.884 | .111 | 1.663 | 2.106 |
| | 5.00 | 1.882 | .129 | 1.624 | 2.139 |
| | 6.00 | 1.679 | .129 | 1.422 | 1.937 |
| Overall Touch Photo | 3.00 | 2.002 | .098 | 1.806 | 2.197 |
| | 4.00 | 1.889 | .087 | 1.717 | 2.062 |
| | 5.00 | 1.827 | .101 | 1.627 | 2.028 |
| | 6.00 | 1.724 | .101 | 1.523 | 1.924 |
| SS Avg Touch Noun | 3.00 | 2.427 | .200 | 2.029 | 2.825 |
| | 4.00 | 1.984 | .177 | 1.633 | 2.335 |
| | 5.00 | 1.755 | .205 | 1.347 | 2.163 |

| | | | | | |
|---|---|---|---|---|---|
| | 6.00 | 1.491 | .205 | 1.083 | 1.898 |
| SS Avg Touch Verb | 3.00 | 2.701 | .205 | 2.293 | 3.109 |
| | 4.00 | 2.132 | .181 | 1.772 | 2.492 |
| | 5.00 | 2.363 | .210 | 1.944 | 2.781 |
| | 6.00 | 1.933 | .210 | 1.515 | 2.352 |
| SS Avg Touch Adj | 3.00 | 2.518 | .205 | 2.111 | 2.925 |
| | 4.00 | 1.997 | .180 | 1.638 | 2.355 |
| | 5.00 | 1.990 | .210 | 1.574 | 2.407 |
| | 6.00 | 1.592 | .210 | 1.175 | 2.009 |
| Overall Touch SS | 3.00 | 2.549 | .159 | 2.233 | 2.864 |
| | 4.00 | 2.038 | .140 | 1.759 | 2.316 |
| | 5.00 | 2.108 | .163 | 1.785 | 2.432 |
| | 6.00 | 1.741 | .163 | 1.418 | 2.065 |

*Note*. SS =SymbolStix©[2] Symbols, AVG = Average, Touch = Touch Rate, ADJ = Adjective.

**Profile Plots**

Profile plots were generated for estimated marginal means for touch rate of graphic symbols by age group. Three, four, five and six-year old participants achieved a higher mean score for overall touch rate of graphic symbols, touch rate of graphic symbols for nouns, verbs and adjectives, favoring the color photograph symbol[1] condition. Figure 4 presents estimated marginal means for overall touch rate of graphic symbols, Figure 5 presents estimated marginal means for touch rate of graphic symbols by age and word class.

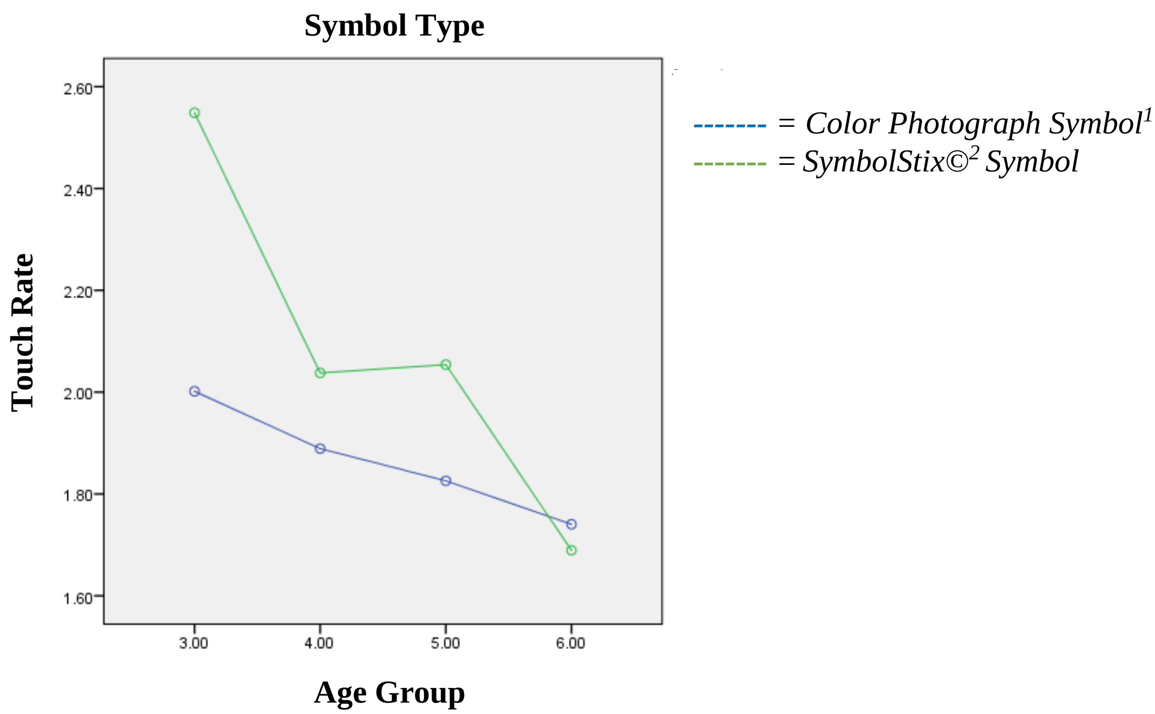



Figure 4. Estimated Marginal Means Identification Accuracy of Graphic Symbols, Word Class & Age Group

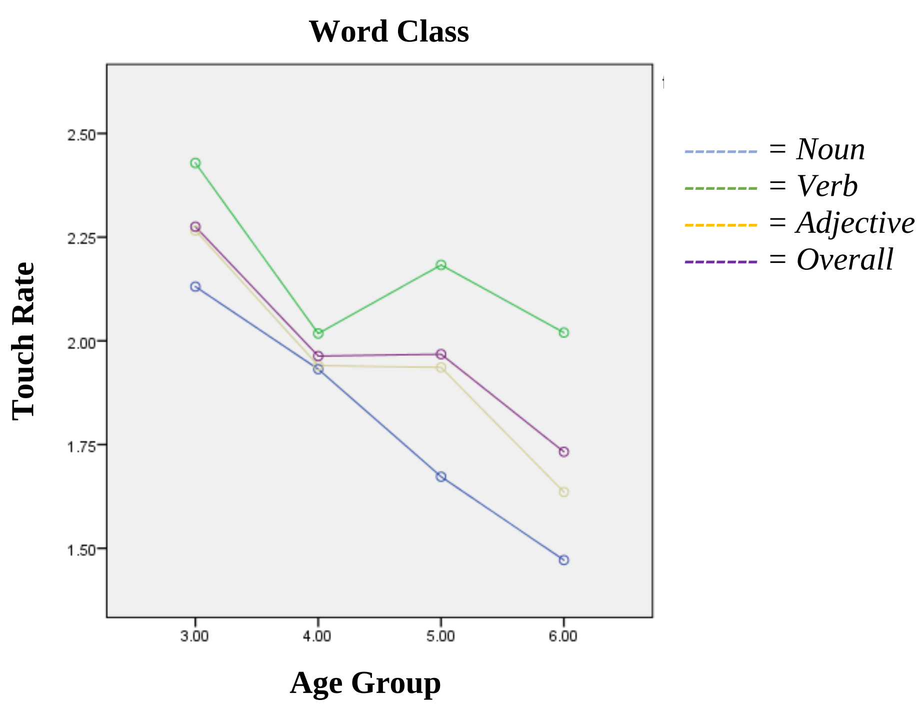



Figure 5. Estimated Marginal Means Identification Touch Rate Word Class by Age Group.

## Eye Rate

## Identification Eye Rate

Three, four, five and six-year old participants achieved a higher mean score for overall identification eye rate of color photograph symbols[1] and identification eye rate of nouns, verbs and adjectives. Table 22 presents the descriptive statistics for identification eye rate by symbol type, word class and age group.

Table 22

*Descriptive Statistics for Identification Eye Rate of Graphic Symbols, Word Class by Age Group*

| Descriptive Statistics | | | | |
|---|---|---|---|---|
| | Age Group | Mean | Std. Deviation | N |
| Photo Eye Noun Avg | 3.00 | 1.0632 | .78777 | 19 |
| | 4.00 | 1.0599 | .71664 | 26 |
| | 5.00 | .8944 | .43675 | 20 |
| | 6.00 | .8072 | .38520 | 19 |
| | Total | .9641 | .61404 | 84 |
| Photo Eye Verb Avg | 3.00 | 1.3934 | .83003 | 19 |
| | 4.00 | 1.1311 | .57796 | 26 |
| | 5.00 | 1.3487 | .82452 | 20 |
| | 6.00 | 1.3070 | .75430 | 19 |
| | Total | 1.2820 | .73500 | 84 |
| Photo Eye Adj Avg | 3.00 | 1.1550 | .82749 | 19 |
| | 4.00 | 1.0999 | .57946 | 26 |
| | 5.00 | 1.0026 | .36151 | 20 |
| | 6.00 | .9774 | .70643 | 19 |
| | Total | 1.0615 | .62665 | 84 |
| Overall Eye Photo | 3.00 | 1.2039 | .64703 | 19 |
| | 4.00 | 1.0934 | .46765 | 26 |
| | 5.00 | 1.0778 | .36140 | 20 |
| | 6.00 | .9874 | .48280 | 19 |
| | Total | 1.0907 | .49248 | 84 |

| | | | | |
|---|---|---|---|---|
| SS Eye Avg Noun | 3.00 | 1.3626 | .73769 | 19 |
| | 4.00 | 1.3044 | 1.20422 | 26 |
| | 5.00 | 1.1572 | .71816 | 20 |
| | 6.00 | .9719 | .48808 | 19 |
| | Total | 1.2073 | .86389 | 84 |
| SS Eye Avg Verb | 3.00 | 1.8903 | 1.19029 | 19 |
| | 4.00 | 1.3101 | .65042 | 26 |
| | 5.00 | 1.6301 | .82992 | 20 |
| | 6.00 | 1.3240 | .71399 | 19 |
| | Total | 1.5207 | .87167 | 84 |
| SS Eye Avg Adj | 3.00 | 1.5030 | 1.12338 | 19 |
| | 4.00 | 1.2160 | .97037 | 26 |
| | 5.00 | 1.1451 | .61060 | 20 |
| | 6.00 | .8544 | .43811 | 19 |
| | Total | 1.1822 | .85622 | 84 |
| Overall Eye SS | 3.00 | 1.5853 | .85128 | 19 |
| | 4.00 | 1.3915 | .85422 | 26 |
| | 5.00 | 1.3084 | .51020 | 20 |
| | 6.00 | 1.2186 | .64130 | 19 |
| | Total | 1.3765 | .73661 | 84 |

*Note.* Photo = Color Photograph Symbol[1], SS = SymbolStix©[2] Symbol

Box's M test revealed that the homoscedasticity assumption was not met with $p$ = <.001. Since an assumption was violated, Pillae's Trace was used, as it is more robust in MANOVA designs where heterogeneity of variance-covariance is violated and imbalanced (Has-Vaughn, 2012).

A Repeated Measures MANOVA revealed significant differences of identification eye rate for the combined variables of symbol type (color photograph symbols[1] vs. SymbolStix©[2] symbols) and word class (nouns, verbs and adjectives). Multivariate tests revealed a significant difference in identification eye rate of symbol type with $F_{(1, 80)} = 11.95$ ($p = .001$; partial eta squared = .130) and word class $F_{(3, 78)} = 9.316$, ($p = <.001$, partial eta squared= .264). There is not a statistically significant interaction effect between symbol type and age group $F_{(3, 80)} = .884$, ($p = >.001$, partial eta squared= .032) or word class and age group $F_{(9, 240)} = .993$, ($p = >.001$, partial eta squared= .036). (See Table 23).

Table 23

*Multivariate Test Results for Eye Identification Rate of Graphic Symbols for Symbol Type, Word Class and Age Group*

**Multivariate Tests[a]**

| Variable | Pillai's Trace Value | *F* | Hypothesis *df* | Error *df* | *p* | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Symbol Type | .130 | 11.953[b] | 1.000 | 80.000 | .001 | .130 |
| Symbol Type* Age Group | .032 | .884[b] | 3.000 | 80.000 | .453 | .032 |
| Word Class | .264 | 9.316[b] | 3.000 | 78.000 | <.001 | .264 |
| Word Class * Age Group | .108 | .993 | 9.000 | 240.000 | .446 | .036 |
| Symbol Type *Word Class | .052 | 1.415[b] | 3.000 | 78.000 | .245 | .052 |
| Symbol Type * Word Class * Age Group | .048 | .429 | 9.000 | 240.000 | .919 | .016 |

*Note.* a. Design: Intercept + age_group
Within Subjects Design: factor1 + factor2 + factor1 * factor2
b. Exact statistic
c. The statistic is an upper bound on F that yields a lower bound on the significance level.
d. Computed using alpha = .05

Within subject effects revealed a significant difference in eye identification rate of symbol type (color photograph symbols[1] vs. SymbolStix©[2] symbols[)] with $F_{(1, 80)} = 11.953$ ($p =$

.001; partial eta squared = .130) and word class with $F_{(3, 80)}$ = 12.826, ($p$ = <.001, partial eta squared = .138). There was not a significant interaction effect between symbol type and age group $F_{(3, 80)}$ = .884 ($p$ >.001; partial eta squared = .032) or word class and age group $F_{(9, 80)}$ = .1.296 ($p$ >.001; partial eta squared = .046). (See Table 24).

Table 24

*Within Subject Effects Eye Identification Rate of Graphic Symbols for Symbol Type, Word Class and Age Group*

**Tests of Within-Subjects Effects**

Measure: Eye Rate

| Variable | | Type III Sum of Squares | *df* | Mean Square | *F* | *p* | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Symbol Type | Sphericity Assumed | 8.227 | 1 | 8.227 | 11.953 | .001 | .130 |
| | Greenhouse-Geisser | 8.227 | 1.000 | 8.227 | 11.953 | .001 | .130 |
| | Huynh-Feldt | 8.227 | 1.000 | 8.227 | 11.953 | .001 | .130 |
| | Lower-bound | 8.227 | 1.000 | 8.227 | 11.953 | .001 | .130 |
| Symbol Type* Age Group | Sphericity Assumed | 1.825 | 3 | .608 | .884 | .453 | .032 |
| | Greenhouse-Geisser | 1.825 | 3.000 | .608 | .884 | .453 | .032 |
| | Huynh-Feldt | 1.825 | 3.000 | .608 | .884 | .453 | .032 |
| | Lower-bound | 1.825 | 3.000 | .608 | .884 | .453 | .032 |
| Error(Symbol Type) | Sphericity Assumed | 55.067 | 80 | .688 | | | |
| | Greenhouse-Geisser | 55.067 | 80.000 | .688 | | | |
| | Huynh-Feldt | 55.067 | 80.000 | .688 | | | |
| | Lower-bound | 55.067 | 80.000 | .688 | | | |
| Word Class | Sphericity Assumed | 11.413 | 3 | 3.804 | 12.826 | <.001 | .138<br>.138 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Greenhouse-Geisser | 11.413 | 2.362 | 4.832 | 12.826 | <.001 | |
| | Huynh-Feldt | 11.413 | 2.530 | 4.512 | 12.826 | <.001 | .138 |
| | Lower-bound | 11.413 | 1.000 | 11.413 | 12.826 | .001 | .138 |
| Word Class* Age Group | Sphericity Assumed | 3.461 | 9 | .385 | 1.296 | .239 | .046 |
| | Greenhouse-Geisser | 3.461 | 7.085 | .488 | 1.296 | .254 | .046 |
| | Huynh-Feldt | 3.461 | 7.589 | .456 | 1.296 | .250 | .046 |
| | Lower-bound | 3.461 | 3.000 | 1.154 | 1.296 | .281 | .046 |
| Error(Word Class) | Sphericity Assumed | 71.191 | 240 | .297 | | | |
| | Greenhouse-Geisser | 71.191 | 188.943 | .377 | | | |
| | Huynh-Feldt | 71.191 | 202.364 | .352 | | | |
| | Lower-bound | 71.191 | 80.000 | .890 | | | |
| Symbol Type * Word Class | Sphericity Assumed | .625 | 3 | .208 | .846 | .470 | .010 |
| | Greenhouse-Geisser | .625 | 2.466 | .253 | .846 | .451 | .010 |
| | Huynh-Feldt | .625 | 2.646 | .236 | .846 | .458 | .010 |
| | Lower-bound | .625 | 1.000 | .625 | .846 | .361 | .010 |
| Symbol Type * Word Class * Age Group | Sphericity Assumed | .639 | 9 | .071 | .288 | .978 | .011 |
| | Greenhouse-Geisser | .639 | 7.399 | .086 | .288 | .963 | .011 |
| | Huynh-Feldt | .639 | 7.938 | .081 | .288 | .969 | .011 |
| | Lower-bound | .639 | 3.000 | .213 | .288 | .834 | .011 |
| Error(Symbol Type*Word Class) | Sphericity Assumed | 59.132 | 240 | .246 | | | |
| | Greenhouse-Geisser | 59.132 | 197.298 | .300 | | | |
| | Huynh-Feldt | 59.132 | 211.689 | .279 | | | |
| | Lower-bound | 59.132 | 80.000 | .739 | | | |

*Note.* Significant at the $p < .05$ level.

Between-subject effects revealed that there is no significant difference for eye identification rate of graphic symbols between age group $F_{(3, 80)} = 1.476$ ($p$ =.227; partial eta squared = .052). Table 25 presents the between subject effects for the average of combined variables for eye identification rate of graphic symbols.

Table 25

*Between Subject Effects for Eye Identification Rate of Graphic Symbols*

**Tests of Between-Subjects Effects**

Measure: MEASURE_1

Transformed Variable: Average

| Variable | Type III Sum of Squares | *df* | Mean Square | *F* | *p* | Partial Eta Squared | Noncent. Parameter | Observed Power[a] |
|---|---|---|---|---|---|---|---|---|
| Intercept | 970.125 | 1 | 970.125 | 486.286 | <.001 | .859 | 486.286 | 1.000 |
| Age Group | 8.835 | 3 | 2.945 | 1.476 | .227 | .052 | 4.429 | .377 |
| Error | 159.598 | 80 | 1.995 | | | | | |

*Note.* Significant at the $p < .05$ level.

Levene's Test revealed that four out of the eight variables met assumption. ANOVA test revealed that the following four variables met assumption: Photo eye rate noun with $F_{(3, 80)} = 1.174$, ($p$ = .325), Photo eye rate verb with $F_{(3, 80)} = .505$, ($p$ = .680), Photo eye rate overall with $F_{(3, 80)} = 1.455$, ($p$ = .233), and SS eye rate adjective with $F_{(3, 80)} = 2.150$, ($p$ = .100).

Homogenous subtests for identification touch rate revealed that a total of eighty-four participants completed both experimental conditions for the identification task. Table 26 presents the homogenous subtest results for eye identification rate of graphic symbols.

Table 26

*Homogenous Subtests for Eye Identification Rate*

**Eye Rate**

| | Age Group | N | Subset 1 |
|---|---|---|---|
| Tukey HSD[a,b,c] | 3 | 19 | 1.3946 |
| | 4 | 26 | 1.2008 |
| | 5 | 20 | 1.1955 |
| | 6 | 19 | 1.0560 |
| | *p* | | .138 |

*Note.* Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .249.

a. Uses Harmonic Mean Sample Size = 20.648
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

## Post-Hoc Test for Eye Rate

Post-Hoc Test, Tukey HSD was completed to determine statistically significant differences between eye rate, for identification of graphic symbols by word class and age group. Tukey

HSD revealed no statistically significant differences between age groups or symbol types for eye rate for identification of graphic symbols. (Table 27).

Table 27

*Post-Hoc Test for Pairwise Comparison Eye Identification Rate of Graphic Symbols for Nouns, Verbs, Adjectives and Symbol Type*

**Multiple Comparisons**

Measure: Eye Rate

| | (I) Age Group | (J) Age Group | Mean Difference (I-J) | Std. Error | *p* | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| Tukey HSD | 3.00 | 4.00 | .1938 | .15072 | .575 | -.2017 | .5893 |
| | | 5.00 | .1991 | .15998 | .601 | -.2207 | .6188 |
| | | 6.00 | .3386 | .16202 | .165 | -.0865 | .7637 |
| | 4.00 | 3.00 | -.1938 | .15072 | .575 | -.5893 | .2017 |
| | | 5.00 | .0053 | .14853 | 1.000 | -.3844 | .3950 |
| | | 6.00 | .1448 | .15072 | .772 | -.2507 | .5403 |
| | 5.00 | 3.00 | -.1991 | .15998 | .601 | -.6188 | .2207 |
| | | 4.00 | -.0053 | .14853 | 1.000 | -.3950 | .3844 |
| | | 6.00 | .1395 | .15998 | .819 | -.2802 | .5593 |
| | 6.00 | 3.00 | -.3386 | .16202 | .165 | -.7637 | .0865 |
| | | 4.00 | -.1448 | .15072 | .772 | -.5403 | .2507 |
| | | 5.00 | -.1395 | .15998 | .819 | -.5593 | .2802 |

*Note.* Significant at the $p < .05$ level. Based on observed means.

The error term is Mean Square(Error) = .249.

## Estimated Means

Estimated marginal mean results revealed the mean eye rate for identification of graphic symbols was quicker for color photograph symbols[1] in comparison to overall mean eye rate for SymbolStix©[2] symbols for three, four, five and six-year olds. Estimated marginal means were generated for measure 1 (eye rate), age group and factor 1 (symbol type). Results revealed that three, four, five and six-year olds achieved a faster eye identification rate favoring the color photograph symbols[1] in comparison to SymbolStix©[2] symbols. Table 28 presents estimated marginal means for eye rate of identification of graphic symbols by age group.

Table 28

*Estimated Marginal Means Eye Identification Rate, Symbol Type by Age Group*

Measure: Eye Rate

| Age Group | Symbol Type | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| 3.00 | Photo | 1.204 | .114 | .978 | 1.430 |
| | SS | 1.585 | .150 | 1.287 | 1.883 |
| 4.00 | Photo | 1.096 | .097 | .903 | 1.289 |
| | SS | 1.306 | .128 | 1.051 | 1.560 |
| 5.00 | Photo | 1.081 | .111 | .860 | 1.301 |
| | SS | 1.310 | .146 | 1.020 | 1.600 |
| 6.00 | Photo | 1.020 | .114 | .794 | 1.246 |
| | SS | 1.092 | .150 | .794 | 1.390 |

*Note.* Photo = Color photograph symbols[1], SS = SymbolStix[2] Symbols.

Six-year old participants achieved the quickest mean eye rate for overall identification of color photograph symbols[1]. Developmental trends for eye rate identification for color photograph symbols[1] and word class were as follows: for nouns, six-year olds achieved the quickest eye rate (*Mean* = *.8 SE* =.141*)*, followed by five-year olds (*Mean* =*.9, SE* =.138*)*, four-year olds (*Mean* .1.1= *SE* =.126*)*, and finally three-year olds (*Mean* = 1.1, *SE* =.161*)*, for verbs;

five-year olds (*Mean* = 1.3, *SE* =.166), and six-year olds (*Mean* = 1.3, *SE* =.170), achieved the quickest eye rate followed by four-year olds (*Mean* = 1.1, *SE* = .145), and finally three-year olds (*Mean = 1.4*, *SE* =.170), for adjectives; six-year olds (*Mean* = 1.0, *SE* =.193 *)* and five-year olds (*Mean* = 1.0, SE = .142) achieved the quickest eye rate followed by four year-olds (*Mean* = 1.1, *SE* = .124), and finally three year olds. (*Mean* = 1.2, *SE* =.146*)*,

Developmental trends for identification eye rate for SymbolStix©[2] symbols and word class were as follows: for nouns, six-year olds achieved the quickest eye rate (*Mean* = 1.0, *SE* =.199*)*, followed by five-year olds (*Mean* =1.2, *SE* =.194*)*, four- year olds (*Mean* = 1.3, *SE* =.170*)*, and finally three-year olds (*Mean =1.4*, *SE* = .199*)*, for verbs; six-year olds achieved the quickest eye rate (*Mean* = 1.3, *SE* = .196 *)* followed by four-year olds (*Mean* = 1.3, *SE* =.167), then five-year olds (Mean = 1.6 , SE = .191) and finally three-year olds (*Mean* = 1.9, *SE* =.196), for adjectives; six-year olds achieved the quickest touch rate (*Mean* = .9 , *SE* =.193), followed by five-year olds (*Mean* =1.1, SE = .188) and four-year olds (*Mean* =1.2, *SE* = . 165*)*, and finally three year olds (*Mean* =1.5, *SE*= .193*)*. three, four, five and six-year olds achieved the quickest mean eye rate for identification of color photograph symbols[1], regardless of word class in comparison to SymbolStix©[2] symbols. Table 29 presents estimated marginal means for symbol type, word class by age group.

Table 29

*Estimated Marginal Mean Eye Identification Rate, Symbol Type, Word Class, Age Group*

| Measure: Eye Rate | | | | | | |
|---|---|---|---|---|---|---|
| Age Group | Symbol Type | Word Class | Mean | Std. Error | 95% Confidence Interval | |
| | | | | | Lower Bound | Upper Bound |
| 3.00 | Photo | Overall | 1.204 | .114 | .977 | 1.430 |
| | | Noun | 1.063 | .141 | .782 | 1.344 |
| | | Verb | 1.393 | .170 | 1.055 | 1.732 |
| | | Adjective | 1.155 | .146 | .865 | 1.445 |
| | SS | Overall | 1.585 | .169 | 1.248 | 1.922 |
| | | Noun | 1.363 | .199 | .967 | 1.758 |
| | | Verb | 1.890 | .196 | 1.500 | 2.280 |
| | | Adjective | 1.503 | .193 | 1.118 | 1.888 |
| 4.00 | Photo | Overall | 1.093 | .097 | .900 | 1.287 |
| | | Noun | 1.060 | .121 | .820 | 1.300 |
| | | Verb | 1.131 | .145 | .842 | 1.420 |
| | | Adjective | 1.100 | .124 | .852 | 1.347 |
| | SS | Overall | 1.392 | .145 | 1.103 | 1.680 |
| | | Noun | 1.304 | .170 | .966 | 1.643 |
| | | Verb | 1.310 | .167 | .977 | 1.643 |
| | | Adjective | 1.216 | .165 | .887 | 1.545 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5.00 | Photo | Overall | 1.078 | .111 | .857 | 1.298 |
| | | Noun | .894 | .138 | .621 | 1.168 |
| | | Verb | 1.349 | .166 | 1.019 | 1.678 |
| | | Adjective | 1.003 | .142 | .720 | 1.285 |
| | SS | Overall | 1.308 | .165 | .980 | 1.637 |
| | | Noun | 1.157 | .194 | .771 | 1.543 |
| | | Verb | 1.630 | .191 | 1.250 | 2.010 |
| | | Adjective | 1.145 | .188 | .770 | 1.520 |
| 6.00 | Photo | Overall | .987 | .114 | .761 | 1.214 |
| | | Noun | .807 | .141 | .526 | 1.088 |
| | | Verb | 1.307 | .170 | .969 | 1.645 |
| | | Adjective | .977 | .146 | .688 | 1.267 |
| | SS | Overall | 1.219 | .169 | .881 | 1.556 |
| | | Noun | .972 | .199 | .576 | 1.368 |
| | | Verb | 1.324 | .196 | .934 | 1.714 |
| | | Adjective | .854 | .193 | .470 | 1.239 |

*Note.* Photo = Color Photograph Symbol[1], SS =SymbolStix©[2] Symbols.

## Profile Plots

Profile plots were generated for estimated marginal means for eye rate of graphic symbols by age group. Three, four, five and six-year old participants achieved a higher mean for overall eye rate for identification of graphic symbols, favoring the color photograph symbol[1] condition. Three, four, five and six-year olds identified graphic symbols at a quicker eye rate for nouns, followed by adjectives, then verbs, for identification of graphic symbols, with the quickest mean eye rate noted for color photograph symbol[1] condition. Figure 6 presents estimated marginal means for eye rate, age group and symbol type.  Figure 7 presents estimated marginal means for eye rate, word class by symbol type. Figure 8 presents estimated marginal means identification eye rate, graphic symbols by word class and age group.

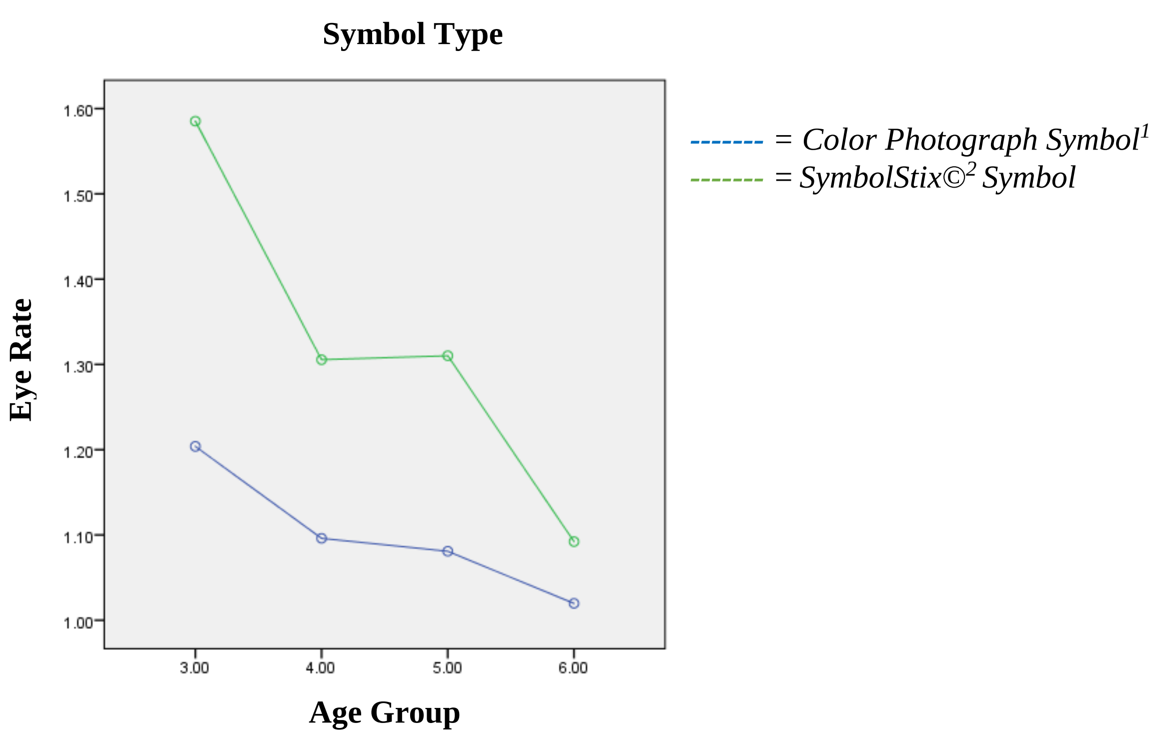



Figure 6. Estimated Marginal Means for Identification Eye Rate, Symbol Type, Age Group

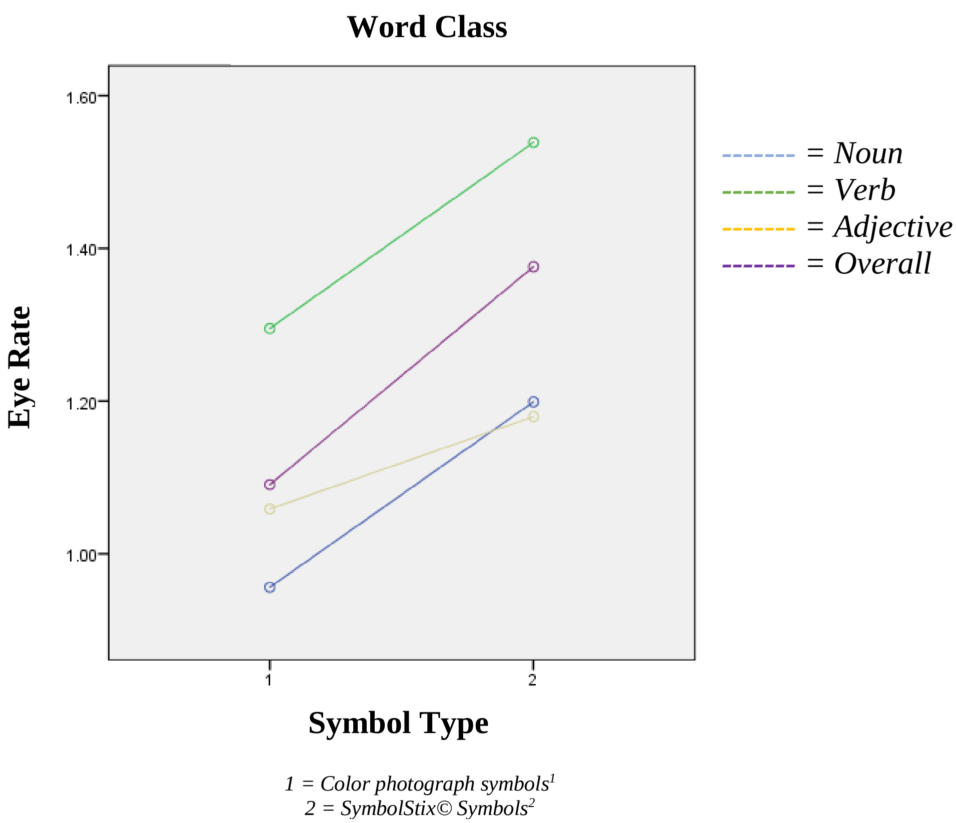



Figure 7. Estimated Marginal Means Identification Eye Rate, Word Class by Symbol Type

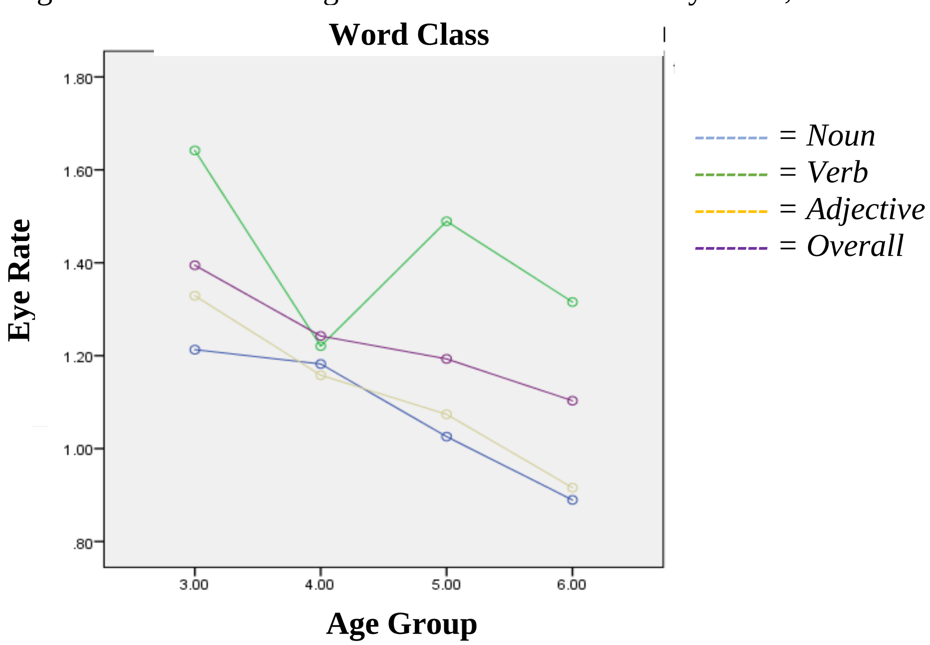



Figure 8. Estimated Marginal Means Identification Eye Rate, Graphic Symbols by Word Class & Age Group

## Research Question 2

*Is there a relationship between accuracy and rate and touch and eye rate for identification of graphic symbols? If yes, what are the differences and are these differences statistically significant?*

## Bivariate Correlations

Bivariate Correlation was generated to test if there is a relationship between accuracy and rate for identification of graphic symbols, and touch and eye rates for identification of graphic symbols. Correlational variables included: overall identification accuracy color photograph symbols[1], overall touch rate for color photograph symbols[1] and overall eye rate for color photograph symbols[1], overall identification accuracy SymbolStix©[2] symbols, overall touch rate for SymbolStix©[2] symbols and overall eye rate for SymbolStix©[2] symbols, overall touch and overall eye rates for color photograph symbols[1], and overall touch and overall eye rates for SymbolStix©[2] symbols. Bivariate Correlation testing revealed a statistically significant moderate to strong correlation, with a strong effect size for the following correlation pairs: overall touch rate for color photograph symbols[1] and overall eye rate for color photograph symbols[1] ($r$ = .567, $p$ < .001), and overall touch rate SymbolStix©[2] symbols and overall eye rate for SymbolStix©[2] symbols ($r$= .757, $p$ < .001). A statistically significant weak correlation, weak effect size was revealed for overall identification accuracy color photograph symbols[1] and overall eye rate for color photograph symbols[1] ($r$ = -.228, $p$ = .030). Table 30 presents the Pearson Correlation $r$ and statistical significance. Figures 9 and 10 present the scatterplots for the statistically significant bivariate correlations.

Table 30

*Pearson Correlations, Statistical Significance, Effect Size: Accuracy & Rate*

| Correlation Pairs | Pearson's *r* | Evidence | Direction | Strength | Significant? | Effect Size |
|---|---|---|---|---|---|---|
| Photo ID Accuracy & Photo Overall Eye Rate | *r* = -.228* | *p* = .030 | Negative | Weak | Yes | Weak |
| Photo Overall Touch Rate & Photo Eye Rate | *r* = .567** | *p* = <.001 | Positive | Moderate | Yes | Strong |
| SS Overall Touch Rate & SS Overall Eye Rate | *r* = .757** | *p* = <.001 | Positive | Moderate | Yes | Strong |

*Note*. *Correlation is significant at the <.05 level (2-tailed).
**Correlation is significant at the .001 level (2-tailed).
.1 = Weak effect size
.3 = Moderate effect size
.5 = Strong effect size
(Cohen, 1988)

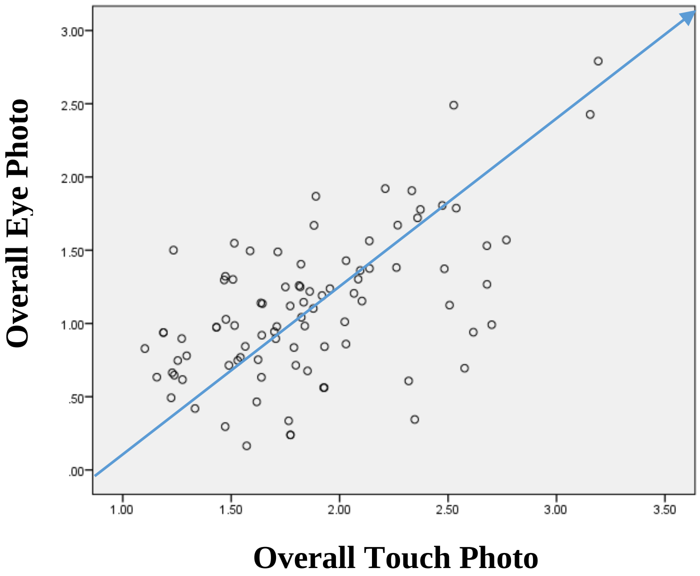



Figure 9. Scatterplot Overall Eye Rate and Overall Touch Rate Color Photograph Symbols[1]

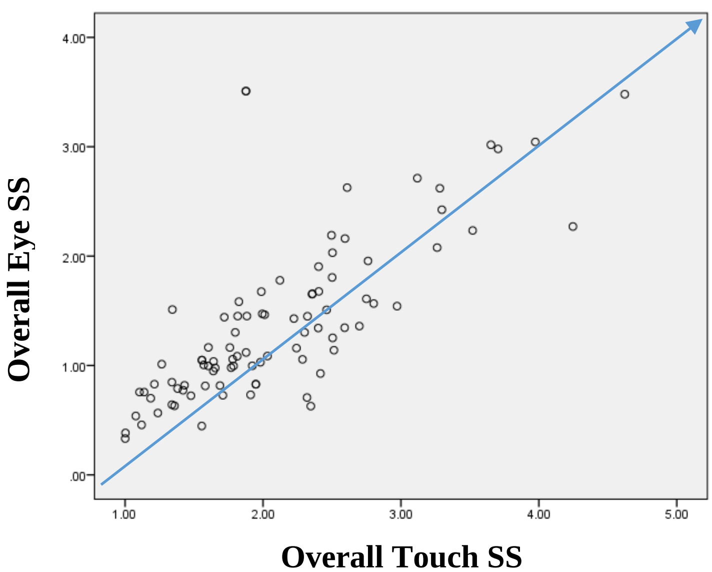



Figure 10. Scatterplot Overall Eye Rate and Overall Touch Rate SymbolStix©[2] Symbols

## Research Question 3

*Question 3: Are there statistically significant differences between symbol types (color photograph symbols[1] vs.* SymbolStix©[2] *symbols) on naming of graphic symbols for nouns, verbs and adjectives as measured by percent correct for three, four, five and six-year olds children? If yes, what are the differences?*

### Naming Accuracy (Percent Correct) of Graphic Symbols for Nouns, Verbs and Adjectives

The following developmental trends were noted for overall naming of color photograph symbols[1] as follows: six-year olds achieved the highest mean score for naming of color photograph symbols[1], followed by three and four year olds, and finally 5-year olds. For naming of SymbolStix©[2] symbols, six-year olds achieved the highest mean score followed by three year olds, four year olds and finally 5-year olds. Table 31 presents the descriptive statistics for the naming task including variables and age group.

Table 31

*Descriptive Statistics for Naming Accuracy of Graphic Symbols for Nouns, Verbs and Adjectives by Age Group*

| | Age Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Photo Naming | 3.00 | .8280 | .12590 | 25 |
| | 4.00 | .8293 | .12501 | 29 |
| | 5.00 | .8025 | .16098 | 20 |
| | 6.00 | .8548 | .12135 | 21 |
| | Total | .8289 | .13180 | 95 |
| Photo N naming | 3.00 | .8591 | .11122 | 25 |
| | 4.00 | .8536 | .11119 | 29 |
| | 5.00 | .8688 | .11806 | 20 |
| | 6.00 | .8681 | .08375 | 21 |
| | Total | .8614 | .10579 | 95 |
| Photo V Naming | 3.00 | .9300 | .11456 | 25 |
| | 4.00 | .9414 | .12179 | 29 |
| | 5.00 | .8625 | .15120 | 20 |
| | 6.00 | .9286 | .14015 | 21 |
| | Total | .9189 | .13212 | 95 |
| Photo Adj Naming | 3.00 | .7120 | .26508 | 25 |
| | 4.00 | .7310 | .26336 | 29 |
| | 5.00 | .7475 | .24142 | 20 |
| | 6.00 | .7929 | .22599 | 21 |
| | Total | .7432 | .24921 | 95 |

| | | | | |
|---|---|---|---|---|
| SS Naming | 3.00 | .6280 | .16143 | 25 |
| | 4.00 | .6103 | .17997 | 29 |
| | 5.00 | .5700 | .19628 | 20 |
| | 6.00 | .7490 | .15401 | 21 |
| | Total | .6372 | .18203 | 95 |
| SS N Naming | 3.00 | .7160 | .13048 | 25 |
| | 4.00 | .7241 | .18108 | 29 |
| | 5.00 | .6912 | .19182 | 20 |
| | 6.00 | .7738 | .14042 | 21 |
| | Total | .7261 | .16292 | 95 |
| SS V Naming | 3.00 | .7880 | .13562 | 25 |
| | 4.00 | .7586 | .19460 | 29 |
| | 5.00 | .5875 | .27236 | 20 |
| | 6.00 | .8333 | .18257 | 21 |
| | Total | .7468 | .21361 | 95 |
| SS Adj Naming | 3.00 | .4880 | .26508 | 25 |
| | 4.00 | .4138 | .29243 | 29 |
| | 5.00 | .5025 | .34961 | 20 |
| | 6.00 | .7143 | .29374 | 21 |
| | Total | .5184 | .31421 | 95 |

*Note.* Photo = Color Photograph Symbol[1], SS = SymbolStix©[2] Symbol.

Box's M test revealed that the homoscedasticity assumption was not met with $p$ = <.001. Since an assumption was violated, Pillae's Trace was used, as it is more robust in MANOVA designs where heterogeneity of variance-covariance is violated and imbalanced (Has-Vaughn, 2012).

A Repeated Measures MANOVA revealed significant differences of naming accuracy (percent correct) for the combined variables of symbol type (color photograph symbols[1] vs. SymbolStix©[2] symbols) and word class (nouns, verbs and adjectives). Multivariate tests revealed a significant difference in naming accuracy (percent correct) of symbol type with $F_{(1, 91)} = 115.304$ ($p < .001$; partial eta squared = .559) and word class $F_{(3, 89)} = 33.040$, ($p < .001$, partial eta squared= .527). There is a statistically significant interaction between age groups on symbol type, with $F_{(3, 91)} = 3.134$ ($p = .029$; partial eta squared = .094), on word class with $F_{(9, 273)} = 2.623$, ($p = .006$, partial eta squared= .080) and symbol type and word class $F_{(3, 89)} = 3.783$, ($p = .013$, partial eta squared = .113). (See Table 32).

Table 32

*Multivariate Test Results for Naming Accuracy of Graphic Symbols for Symbol Type, Word Class and Age Group*

**Multivariate Tests[a]**

| Variables | Pillai's Trace Value | *F* | Hypothesis *df* | Error *df* | *p* | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Symbol Type | .55 | 115.304[b] | 1.000 | 91.000 | .<.001 | .559 |
| Symbol Type* Age Group | .094 | 3.134[b] | 3.000 | 91.000 | .029 | .094 |
| Word Class | .527 | 33.040[b] | 3.000 | 89.000 | <.001 | .527 |
| Word Class * Age Group | .239 | 2.623 | 9.000 | 273.000 | .006 | .080 |
| Symbol Type * Word Class | .113 | 3.783[b] | 3.000 | 89.000 | .013 | .113 |
| Symbol Type * Word Class * Age Group | .100 | 1.046 | 9.000 | 273.000 | .404 | .033 |

*Note.* a. Design: Intercept + age_group
Within Subjects Design: factor1 + factor2 + factor1 * factor2
b. Exact statistic
c. The statistic is an upper bound on F that yields a lower bound on the significance level.
d. Computed using alpha = .05

Within subject effects revealed a significant difference in naming accuracy (percent correct) scores of symbol type (color photograph symbols[1] vs. SymbolStix©[2] symbols) with $F_{(1, 91)} = 115.304$ ($p < .001$; partial eta squared = .559) and word class $F_{(3, 91)} = 55.643$ ($p = <.001$, partial eta squared = .379). (See Table 33).

Table 33

*Within Subject Effects Naming Accuracy of Graphic Symbols for Symbol Type, Word Class and Age Group*

**Tests of Within-Subjects Effects**

Measure: MEASURE_1

| Source | | Type III Sum of Squares | *df* | Mean Square | *F* | *p* | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Symbol Type | Sphericity Assumed | 5.947 | 1 | 5.947 | 115.304 | <.001 | .559 |
| | Greenhouse-Geisser | 5.947 | 1.000 | 5.947 | 115.304 | <.001 | .559 |
| | Huynh-Feldt | 5.947 | 1.000 | 5.947 | 115.304 | <.001 | .559 |
| | Lower-bound | 5.947 | 1.000 | 5.947 | 115.304 | <.001 | .559 |
| Symbol type* Age Group | Sphericity Assumed | .485 | 3 | .162 | 3.134 | .029 | .094 |
| | Greenhouse-Geisser | .485 | 3.000 | .162 | 3.134 | .029 | .094 |
| | Huynh-Feldt | .485 | 3.000 | .162 | 3.134 | .029 | .094 |
| | Lower-bound | .485 | 3.000 | .162 | 3.134 | .029 | .094 |
| Error(symbol type) | Sphericity Assumed | 4.693 | 91 | .052 | | | |
| | Greenhouse-Geisser | 4.693 | 91.000 | .052 | | | |
| | Huynh-Feldt | 4.693 | 91.000 | .052 | | | |
| | Lower-bound | 4.693 | 91.000 | .052 | | | |
| Word Class | Sphericity Assumed | 3.908 | 3 | 1.303 | 55.643 | <.001 | .379 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Greenhouse-Geisser | 3.908 | 1.871 | 2.089 | 55.643 | <.001 | .379 |
| | Huynh-Feldt | 3.908 | 1.971 | 1.982 | 55.643 | <.001 | .379 |
| | Lower-bound | 3.908 | 1.000 | 3.908 | 55.643 | <.001 | .379 |
| Word Class * Age Group | Sphericity Assumed | .728 | 9 | .081 | 3.453 | <.001 | .102 |
| | Greenhouse-Geisser | .728 | 5.612 | .130 | 3.453 | .004 | .102 |
| | Huynh-Feldt | .728 | 5.914 | .123 | 3.453 | .003 | .102 |
| | Lower-bound | .728 | 3.000 | .243 | 3.453 | .020 | .102 |
| Error(Word Class) | Sphericity Assumed | 6.391 | 273 | .023 | | | |
| | Greenhouse-Geisser | 6.391 | 170.222 | .038 | | | |
| | Huynh-Feldt | 6.391 | 179.391 | .036 | | | |
| | Lower-bound | 6.391 | 91.000 | .070 | | | |
| Symbol Type * Word Class | Sphericity Assumed | .156 | 3 | .052 | 3.210 | .024 | .034 |
| | Greenhouse-Geisser | .156 | 1.954 | .080 | 3.210 | .044 | .034 |
| | Huynh-Feldt | .156 | 2.062 | .076 | 3.210 | .041 | .034 |
| | Lower-bound | .156 | 1.000 | .156 | 3.210 | .077 | .034 |
| Symbol Type * Word Class * Age Group | Sphericity Assumed | .191 | 9 | .021 | 1.310 | .231 | .041 |
| | Greenhouse-Geisser | .191 | 5.861 | .033 | 1.310 | .256 | .041 |
| | Huynh-Feldt | .191 | 6.186 | .031 | 1.310 | .253 | .041 |
| | Lower-bound | .191 | 3.000 | .064 | 1.310 | .276 | .041 |
| Error(Symbol Type*Word Class) | Sphericity Assumed | 4.427 | 273 | .016 | | | |
| | Greenhouse-Geisser | 4.427 | 177.790 | .025 | | | |
| | Huynh-Feldt | 4.427 | 187.634 | .024 | | | |
| | Lower-bound | 4.427 | 91.000 | .049 | | | |

*Note.* Significant at the $p < .05$ level.

Between-subject effects revealed a significant difference for naming accuracy (percent correct) of graphic symbols for age group $F_{(1, 91)} = 2.962$ ($p$ =.036; partial eta squared = .089). Table 34 presents the between subject effects for the average of combined variables for naming accuracy (percent correct) of graphic symbols.

Table 34

*Between Subject Effects Naming Accuracy of Graphic Symbols (Percent Correct)*

**Tests of Between-Subjects Effects**

Measure: MEASURE_1

Transformed Variable: Average

| Source | Type III Sum of Squares | *df* | Mean Square | *F* | *p* | Partial Eta Squared | Noncent. Parameter | Observed Power[a] |
|---|---|---|---|---|---|---|---|---|
| Intercept | 416.914 | 1 | 416.914 | 3350.645 | .000 | .974 | 3350.645 | 1.000 |
| age_group | 1.106 | 3 | .369 | 2.962 | .036 | .089 | 8.887 | .684 |
| Error | 11.323 | 91 | .124 | | | | | |

*Note.* Significant at the $p < .05$ level.

Levene's Test revealed that seven out of the eight variables met assumption. ANOVA test revealed that the following variable did not meet assumption: SymbolStix©[2]symbol verbs with $F_{(3, 91)} = 3.570$, ($p = .017$).

Homogenous subtests for naming accuracy (percent correct) of graphic symbols revealed that a total of ninety-five participants completed both experimental conditions for the naming task. Table 35 presents the homogenous subtest results for naming accuracy (percent correct) of graphic symbols.

Table 35

*Homogenous Test Naming Accuracy*

Tukey HSD[a,b,c]

| | | Subset | |
|---|---|---|---|
| Age Group | N | 1 | 2 |
| 3 | 25 | .7436 | .7436 |
| 4 | 29 | .7328 | .7328 |
| 5 | 20 | .7041 | |
| 6 | 21 | | .8143 |
| *p* | | .702 | .123 |

*Note.* Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = .016.
a. Uses Harmonic Mean Sample Size = 23.242.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

**Post-Hoc Test for Naming Accuracy**

Multiple comparisons, Tukey HSD was completed to determine if there were statistically significant differences for naming of graphic symbols across word class for three, four, five and six-year old participants. Statistically significant differences were noted for overall naming of SymbolStix©[2] symbols between: 4 & 6-year olds ($p$ =.032) and 5 and 6-year olds ($p$ = .007), for naming of SymbolStix©[2] symbol verbs between: 3 and 5 ($p$ = .006), 4 and 5-year olds ($p$ = .020) and 5 and 6-year olds ($p$ = .001) and for naming of SymbolStix©[2] symbol adjectives between 4 and 6-year olds ($p$ = .004). Tables 36 and 37 present the post-hoc Tukey HSD test results for the color photograph symbol and SymbolStix© symbol conditions. (See Table 36 and Table 37).

Table 36

*Post-Hoc Test for Pairwise Comparison Naming Accuracy of Color Photograph Symbols[1] for Nouns, Verbs, and Adjectives*

**Multiple Comparisons**

| Dependent Variable | | (I) Age Group | (J) Age Group | Mean Difference (I-J) | Std. Error | $p$ | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|---|---|
| Photo Naming | Tukey HSD | 3.00 | 4.00 | -.0013 | .03624 | 1.000 | -.0962 | .0935 |
| | | | 5.00 | .0255 | .03984 | .919 | -.0788 | .1298 |
| | | | 6.00 | -.0268 | .03931 | .904 | -.1296 | .0761 |
| | | 4.00 | 3.00 | .0013 | .03624 | 1.000 | -.0935 | .0962 |
| | | | 5.00 | .0268 | .03860 | .899 | -.0742 | .1278 |
| | | | 6.00 | -.0255 | .03805 | .909 | -.1250 | .0741 |
| | | 5.00 | 3.00 | -.0255 | .03984 | .919 | -.1298 | .0788 |
| | | | 4.00 | -.0268 | .03860 | .899 | -.1278 | .0742 |
| | | | 6.00 | -.0523 | .04149 | .591 | -.1609 | .0563 |
| | | 6.00 | 3.00 | .0268 | .03931 | .904 | -.0761 | .1296 |
| | | | 4.00 | .0255 | .03805 | .909 | -.0741 | .1250 |
| | | | 5.00 | .0523 | .04149 | .591 | -.0563 | .1609 |
| Photo N Naming | Tukey HSD | 3.00 | 4.00 | .0055 | .02929 | .998 | -.0712 | .0821 |
| | | | 5.00 | -.0097 | .03220 | .991 | -.0939 | .0746 |
| | | | 6.00 | -.0090 | .03177 | .992 | -.0922 | .0741 |
| | | 4.00 | 3.00 | -.0055 | .02929 | .998 | -.0821 | .0712 |
| | | | 5.00 | -.0151 | .03119 | .962 | -.0968 | .0665 |
| | | | 6.00 | -.0145 | .03075 | .965 | -.0950 | .0660 |
| | | 5.00 | 3.00 | .0097 | .03220 | .991 | -.0746 | .0939 |
| | | | 4.00 | .0151 | .03119 | .962 | -.0665 | .0968 |
| | | | 6.00 | .0007 | .03353 | 1.000 | -.0871 | .0884 |
| | | 6.00 | 3.00 | .0090 | .03177 | .992 | -.0741 | .0922 |
| | | | 4.00 | .0145 | .03075 | .965 | -.0660 | .0950 |
| | | | 5.00 | -.0007 | .03353 | 1.000 | -.0884 | .0871 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Photo V Naming | Tukey HSD | 3.00 | 4.00 | -.0114 | .03571 | .989 | -.1048 | .0821 |
| | | | 5.00 | .0675 | .03925 | .319 | -.0352 | .1702 |
| | | | 6.00 | .0014 | .03873 | 1.000 | -.0999 | .1028 |
| | | 4.00 | 3.00 | .0114 | .03571 | .989 | -.0821 | .1048 |
| | | | 5.00 | .0789 | .03803 | .169 | -.0206 | .1784 |
| | | | 6.00 | .0128 | .03749 | .986 | -.0853 | .1109 |
| | | 5.00 | 3.00 | -.0675 | .03925 | .319 | -.1702 | .0352 |
| | | | 4.00 | -.0789 | .03803 | .169 | -.1784 | .0206 |
| | | | 6.00 | -.0661 | .04088 | .375 | -.1731 | .0409 |
| | | 6.00 | 3.00 | -.0014 | .03873 | 1.000 | -.1028 | .0999 |
| | | | 4.00 | -.0128 | .03749 | .986 | -.1109 | .0853 |
| | | | 5.00 | .0661 | .04088 | .375 | -.0409 | .1731 |
| Photo Adj Naming | Tukey HSD | 3.00 | 4.00 | -.0190 | .06865 | .993 | -.1987 | .1606 |
| | | | 5.00 | -.0355 | .07546 | .965 | -.2330 | .1620 |
| | | | 6.00 | -.0809 | .07445 | .699 | -.2757 | .1140 |
| | | 4.00 | 3.00 | .0190 | .06865 | .993 | -.1606 | .1987 |
| | | | 5.00 | -.0165 | .07311 | .996 | -.2078 | .1749 |
| | | | 6.00 | -.0618 | .07207 | .826 | -.2504 | .1268 |
| | | 5.00 | 3.00 | .0355 | .07546 | .965 | -.1620 | .2330 |
| | | | 4.00 | .0165 | .07311 | .996 | -.1749 | .2078 |
| | | | 6.00 | -.0454 | .07859 | .939 | -.2510 | .1603 |
| | | 6.00 | 3.00 | .0809 | .07445 | .699 | -.1140 | .2757 |
| | | | 4.00 | .0618 | .07207 | .826 | -.1268 | .2504 |
| | | | 5.00 | .0454 | .07859 | .939 | -.1603 | .2510 |

*Note.* Significant mean difference is significant at the $p < .05$ level. Based on observed means. The error term is Mean Square(Error) = .089.

Table 37

*Post-Hoc Test for Pairwise Comparison Naming Accuracy of SymbolStix©² Symbols for Nouns, Verbs, and Adjectives*

**Multiple Comparisons**

| Dependent Variable | | (I) Age Group | (J) Age Group | Mean Difference (I-J) | Std. Error | *p* | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|---|---|
| Symbol Naming | Tukey HSD | 3.00 | 4.00 | .0177 | .04735 | .982 | -.1063 | .1416 |
| | | | 5.00 | .0580 | .05204 | .682 | -.0782 | .1942 |
| | | | 6.00 | -.1210 | .05135 | .093 | -.2554 | .0133 |
| | | 4.00 | 3.00 | -.0177 | .04735 | .982 | -.1416 | .1063 |
| | | | 5.00 | .0403 | .05042 | .854 | -.0916 | .1723 |
| | | | 6.00 | -.1387* | .04971 | .032 | -.2688 | -.0086 |
| | | 5.00 | 3.00 | -.0580 | .05204 | .682 | -.1942 | .0782 |
| | | | 4.00 | -.0403 | .05042 | .854 | -.1723 | .0916 |
| | | | 6.00 | -.1790* | .05420 | .007 | -.3209 | -.0372 |
| | | 6.00 | 3.00 | .1210 | .05135 | .093 | -.0133 | .2554 |
| | | | 4.00 | .1387* | .04971 | .032 | .0086 | .2688 |
| | | | 5.00 | .1790* | .05420 | .007 | .0372 | .3209 |
| SS N Naming | Tukey HSD | 3.00 | 4.00 | -.0081 | .04451 | .998 | -.1246 | .1083 |
| | | | 5.00 | .0248 | .04892 | .957 | -.1033 | .1528 |
| | | | 6.00 | -.0578 | .04827 | .630 | -.1841 | .0685 |
| | | 4.00 | 3.00 | .0081 | .04451 | .998 | -.1083 | .1246 |
| | | | 5.00 | .0329 | .04740 | .899 | -.0912 | .1569 |
| | | | 6.00 | -.0497 | .04673 | .713 | -.1720 | .0726 |
| | | 5.00 | 3.00 | -.0248 | .04892 | .957 | -.1528 | .1033 |
| | | | 4.00 | -.0329 | .04740 | .899 | -.1569 | .0912 |
| | | | 6.00 | -.0826 | .05095 | .372 | -.2159 | .0508 |
| | | 6.00 | 3.00 | .0578 | .04827 | .630 | -.0685 | .1841 |
| | | | 4.00 | .0497 | .04673 | .713 | -.0726 | .1720 |
| | | | 5.00 | .0826 | .05095 | .372 | -.0508 | .2159 |
| SS V Naming | Tukey HSD | 3.00 | 4.00 | .0294 | .05411 | .948 | -.1122 | .1710 |
| | | | 5.00 | .2005* | .05949 | .006 | .0448 | .3562 |
| | | | 6.00 | -.0453 | .05869 | .867 | -.1989 | .1083 |
| | | 4.00 | 3.00 | -.0294 | .05411 | .948 | -.1710 | .1122 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 5.00 | .1711* | .05763 | .020 | .0203 | .3220 |
| | | | 6.00 | -.0747 | .05681 | .556 | -.2234 | .0740 |
| | | 5.00 | 3.00 | -.2005* | .05949 | .006 | -.3562 | -.0448 |
| | | | 4.00 | -.1711* | .05763 | .020 | -.3220 | -.0203 |
| | | | 6.00 | -.2458* | .06195 | .001 | -.4080 | -.0837 |
| | | 6.00 | 3.00 | .0453 | .05869 | .867 | -.1083 | .1989 |
| | | | 4.00 | .0747 | .05681 | .556 | -.0740 | .2234 |
| | | | 5.00 | .2458* | .06195 | .001 | .0837 | .4080 |
| SS Adj Naming | Tukey HSD | 3.00 | 4.00 | .0742 | .08157 | .800 | -.1393 | .2877 |
| | | | 5.00 | -.0145 | .08966 | .998 | -.2492 | .2202 |
| | | | 6.00 | -.2263 | .08847 | .058 | -.4578 | .0053 |
| | | 4.00 | 3.00 | -.0742 | .08157 | .800 | -.2877 | .1393 |
| | | | 5.00 | -.0887 | .08687 | .738 | -.3161 | .1387 |
| | | | 6.00 | -.3005* | .08564 | .004 | -.5246 | -.0764 |
| | | 5.00 | 3.00 | .0145 | .08966 | .998 | -.2202 | .2492 |
| | | | 4.00 | .0887 | .08687 | .738 | -.1387 | .3161 |
| | | | 6.00 | -.2118 | .09338 | .113 | -.4562 | .0326 |
| | | 6.00 | 3.00 | .2263 | .08847 | .058 | -.0053 | .4578 |
| | | | 4.00 | .3005* | .08564 | | .0764 | .5246 |
| | | | 5.00 | .2118 | .09338 | .113 | -.0326 | .4562 |

*Note.* Significant mean difference is significant at the $p < .05$ level. Based on observed means. The error term is Mean Square(Error) = .089.

**Estimated Means**

Grand mean was generated for factor 1 (symbol type) by word class. Grand mean results revealed the highest mean percent correct for overall naming of color photograph symbols[1] (*Mean* = .83, *SE* = .011) vs. overall naming of SymbolStix©[2] symbols (*Mean* = .64, *SE* = .018). Across word class and symbol type, higher mean scores were noted for nouns, verbs and adjectives for naming of color photograph symbols[1] in comparison to SymbolStix©[2] symbols. Table 38 presents the estimated grand mean for overall naming of graphic symbols.

Table 38

*Grand Mean for Naming Accuracy of Graphic Symbols*

| Dependent Variable | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| Photo Naming | .829 | .014 | .801 | .856 |
| Photo N Naming | .862 | .011 | .840 | .884 |
| Photo V Naming | .916 | .014 | .889 | .943 |
| Photo Adj Naming | .746 | .026 | .694 | .798 |
| SS Naming | .639 | .018 | .604 | .675 |
| SS N Naming | .726 | .017 | .693 | .760 |
| SS V Naming | .742 | .021 | .701 | .783 |
| SS Adj Naming | .530 | .031 | .468 | .591 |

*Note.* Photo = Color Photograph Symbol[1], SS = SymbolStix©[2] symbols, N = Noun, V = Verb, Adj = Adjective.

Estimated marginal mean for symbol type (color photograph symbols[1], SymbolStix©[2]) by word class and age group for naming of graphic symbols were generated. Three, four, five and six-year old children achieved higher mean scores for overall naming of color photograph symbols[1], nouns, verbs and adjectives in comparison to SymbolStix©[2] symbols. Developmental trends for naming of color photograph symbols[1] by type and word class were as follows: for nouns, five and six-year olds (*Mean* = .87, *SE*= .023) achieved the highest mean score, followed by three year olds (*Mean* =.86, *SE* = .021) then four-year olds (*Mean* =.85, *SE* = .020), for verbs, three and six year olds with the highest mean score (*Mean* = .93, *SE* =.029) followed by four-year olds (*Mean* =.94 , *SE*=.024), then five-year olds (*Mean* =.86 , *SE*=.024), for adjectives six-year olds achieved the highest mean score (*Mean*=.79, se= .075), followed by five-year olds (*Mean*=.75, *SE* =.056), four-year olds (*Mean*=.73, se =.047), then three-year olds (*Mean*=71, *SE* =.050).

Developmental trends for naming of SymbolStix©[2] symbols and word class were as follows: for nouns, six-year olds achieved the highest mean score (*Mean*=.77, *SE* =.036), followed by three and four-year olds (*Mean* = .73 , SE =.033), then five year olds (*Mean* = .69, *SE*=.036), for verbs, six-year olds achieved the highest mean score (*Mean* = .83, *SE* = .043), followed by three year olds (*Mean*= .79, *SE*= .040) then four year olds (M = .76, se = .037), and finally five-year olds (*Mean*=.5 , se =.044), for adjectives, six-year olds achieved the highest mean score (*Mean*= .71, *SE*=.065), followed by five-year olds (M = .50, se=.065), followed by three-year olds (*Mean* =.49, *SE*=.060) and finally four-year olds (*Mean* = .41, *SE*=.056). Marginal means for symbol type by age group are presented in Table 39.

Table 39

*Marginal Means for Naming Accuracy for Symbol Type by Age Group*

| Dependent Variable | Age Group | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| Photo Naming | 3.00 | .828 | .027 | .775 | .881 |
| | 4.00 | .829 | .025 | .780 | .878 |
| | 5.00 | .802 | .030 | .744 | .861 |
| | 6.00 | .855 | .029 | .797 | .912 |
| Photo N naming | 3.00 | .859 | .021 | .816 | .902 |
| | 4.00 | .854 | .020 | .814 | .893 |
| | 5.00 | .869 | .024 | .821 | .916 |
| | 6.00 | .868 | .023 | .822 | .915 |
| Photo V Naming | 3.00 | .930 | .026 | .878 | .982 |
| | 4.00 | .941 | .024 | .893 | .990 |
| | 5.00 | .863 | .029 | .804 | .921 |
| | 6.00 | .929 | .029 | .872 | .985 |
| Photo Adj Naming | 3.00 | .712 | .050 | .612 | .812 |
| | 4.00 | .731 | .047 | .638 | .824 |
| | 5.00 | .748 | .056 | .636 | .859 |
| | 6.00 | .793 | .055 | .684 | .902 |
| SS Naming | 3.00 | .628 | .035 | .559 | .697 |
| | 4.00 | .610 | .032 | .546 | .674 |
| | 5.00 | .570 | .039 | .493 | .647 |
| | 6.00 | .749 | .038 | .674 | .824 |

| | | | | | |
|---|---|---|---|---|---|
| SS N naming | 3.00 | .716 | .033 | .651 | .781 |
| | 4.00 | .724 | .030 | .664 | .784 |
| | 5.00 | .691 | .036 | .619 | .764 |
| | 6.00 | .774 | .036 | .703 | .844 |
| SS V naming | 3.00 | .788 | .040 | .709 | .867 |
| | 4.00 | .759 | .037 | .685 | .832 |
| | 5.00 | .588 | .044 | .499 | .676 |
| | 6.00 | .833 | .043 | .747 | .919 |
| SS Adj naming | 3.00 | .488 | .060 | .369 | .607 |
| | 4.00 | .414 | .056 | .304 | .524 |
| | 5.00 | .503 | .067 | .370 | .635 |
| | 6.00 | .714 | .065 | .585 | .844 |

*Note.* Photo = Color Photograph Symbol[1], SS = SymbolStix©2, V = verb, N = noun, Adj = Adjective.

**Profile Plots**

Profile plots were generated for estimated marginal means for naming of graphic symbols by age group. The plots indicate that three, four, five and six-year old participants achieved a higher mean score for overall naming of graphic symbols, naming of graphic symbols for nouns, verbs and adjectives, favoring the color photograph symbol[1] condition. Figure 11 presents estimated marginal means for overall naming of graphic symbols by symbol type and age group. Figure 12 presents estimated marginal means for naming of graphic symbols by word class and symbol type.

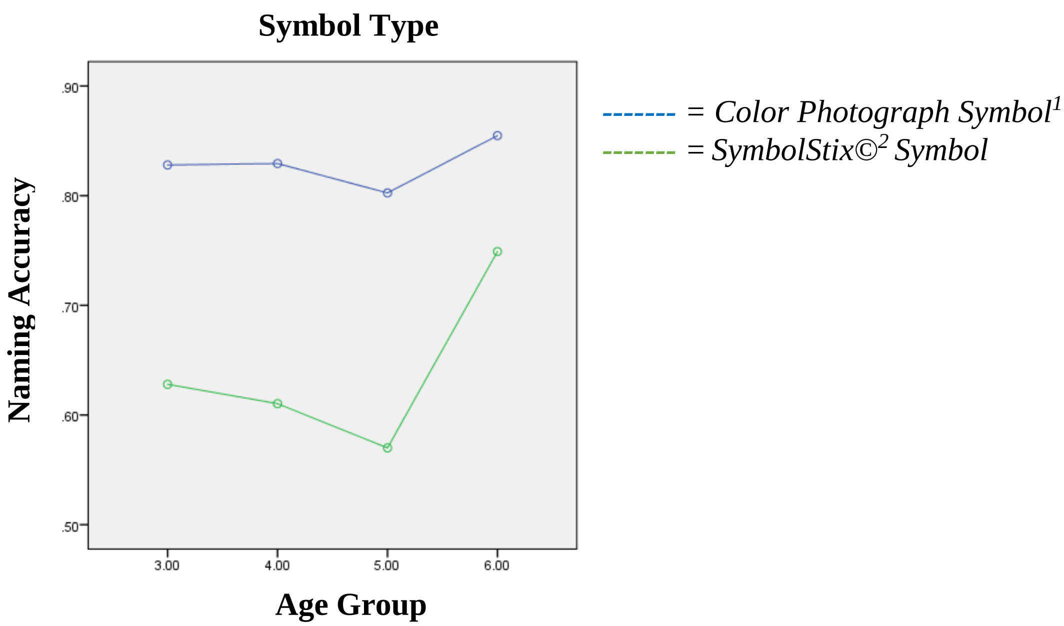



Figure 11. Estimated Marginal Means Overall Naming Accuracy of Graphic Symbols

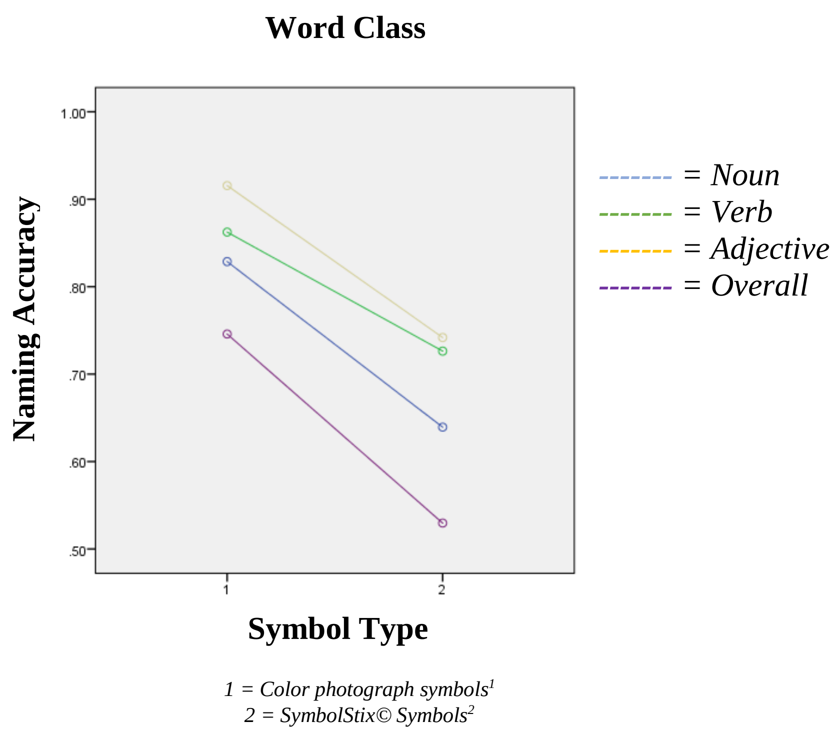



Figure 12. Estimated Marginal Means Naming Accuracy of Graphic Symbols, Symbol Type by Word Class

## Summary

This chapter presented the statistical analyses and results completed to answer the three research questions. Repeated measures MANOVA was utilized to answer questions one and three. Bivariate correlation was utilized to answer question two. Statistically significant differences were noted in overall identification accuracy of SymbolStix©[2] symbols, SymbolStix©[2] symbols adjectives and color photograph symbol[1] nouns with higher estimated marginal mean accuracy scores noted for the color photograph symbol[1] condition. Statistically significant differences were noted for overall touch rate for identification of SymbolStix©[2] symbols, with faster estimated marginal mean touch rates noted for the color photograph symbol[1] condition. Statistically significant differences were noted between age groups for overall naming accuracy of SymbolStix©[2] symbols, verbs and adjectives, with higher estimated marginal mean scores noted for the color photograph symbol[1] condition across word class. Bivariate correlation revealed moderate-strong statistically significant relationships with strong effect sizes between touch and eye rates for identification of color photograph symbols[1] and SymbolStix©[2] symbols. The findings from research questions one, two and three have important implications for clinical practice, which is comprehensively discussed in Chapter Five.

# CHAPTER FIVE DISCUSSION

Results of the current investigation provide evidence that typically developing three, four, five and six-year old children achieved: (a) higher accuracy for identification of color photograph symbols[1], (b) faster touch and eye rates for identification of color photograph symbols[1] and (c) higher mean scores for naming color photograph symbols[1]. A moderate positive correlation between touch and eye rates for identification of graphic symbols was also identified, along with a weak negative relationship between identification accuracy of graphic symbols and touch rate. Details of these results are discussed in this chapter, along with clinical implications of the findings, study limitations, and future research directions.

## Comparison of Results to Past Research

### Comparison of Identification Accuracy Results to Past Research

**Graphic symbol transparency.** It is difficult to draw direct comparisons between the findings of the current investigation and previous studies conducted in the area of symbol transparency. Studies conducted in this area to date differ from the current investigation in that they either: (a) only included the word class of nouns (Mirenda & Locke, 1989), (b) included individuals with intellectual disabilities (Mirenda & Locke, 1989; Mizuko & Reichle, 1989; Sevcik & Romksi, 1986), (c) explored effects of symbol type with the inclusion of animation (Schlosser et al., 2012), (d) did not include SymbolStix©[2], (e) did not include color photograph symbols[1], (g) did not include six-year olds, or (f) did not include nouns, verbs and adjectives from a standardized assessment of receptive language skills. Despite this variability across the specific elements examined in symbol transparency studies to date, the present investigation does add to the existing literature in three ways: firstly, by including transparency ratings for nouns, verbs and adjectives, secondly inclusion of SymbolStix©[2] symbols provides new transparency ratings for a widely used symbol set of which iconicity and learnability have not yet been studied (Beukelman & Mirenda, 2013) and thirdly the inclusion of typically developing 3 – 6 year old children provides a much needed baseline for which to compare the effects of symbol type across word classes.

In the current study, all participants achieved lower mean identification accuracy scores for SymbolStix©[2] in comparison to color photograph symbol representations[1] of nouns. This indicates that SymbolStix©[2] symbols - like other color line drawings - are lower in transparency than color photograph symbols. However, post-hoc analyses also revealed statistically significant differences for symbol type and age group for color photograph symbol[1] nouns when comparing performance of 3 and 5-year olds, and performance of 3 and 6-year olds. These developmental differences are consistent with the postulation that iconicity is experience bound (Brown, 1977). Despite higher mean identification accuracy scores for all typically developing participants favoring the color photograph symbol[1] condition, the statistical significance for the word class of nouns is a curious finding. Given that the established transparency hierarchy (Mirenda & Locke, 1989) did not include SymbolStix©[2] symbols or typically developing individuals, it is difficult to draw direct conclusions on this from the literature.

In addition to examining symbol transparency in nouns, varying aspects of additional word classes have been examined in the literature, including verbs and prepositions. Schlosser and colleagues (2012) reported that adding animation to line drawing symbols did not result in a statistically significant effect on children's ability to identify verbs or prepositions in comparison to static line drawing symbols. Similarly, findings from the present investigation did not reveal statistically significant differences across age groups for identification of verbs when comparing color photograph symbols[1] and SymbolStix©[2] symbols. Thus, further research may be needed to explore other variations to symbol type that may enhance transparency and increase identification accuracy for the word class of verbs.

However, the present investigation's analyses did reveal a statistically significant interaction effect between symbol type and age group for the word class of adjectives. Post-hoc analyses confirmed there were statistically significant differences in identification accuracy of SymbolStix©[2] adjectives when comparing performance of 3 and 5 year olds ($p$ =.033), and performance of 3 and 6 year olds ($p$ = <.001). This was not the case for adjectives represented by color photograph symbols[1]. In other words, the use of less transparent representations for an abstract word class, such as adjectives negatively impacts identification accuracy. Contrastingly, the higher mean identification accuracy scores for three, four, five and six-year old children found for the color photograph symbol[1] condition suggest the inclusion of highly transparent symbols (color photograph symbols[1]) facilitated identification accuracy of adjectives a word class known to depict more abstract concepts (e.g., Bloomber, Karlan & Lloyd, 1990; Mizuko, 1987; Worah et. al., 2015). Given that the present investigation's results indicate statistically significant differences for symbol type favoring the color photograph symbol[1] condition in comparison to SymbolStix©[2] symbols, it can be concluded that the inclusion of highly transparent symbols used to depict nouns, verbs and adjectives may result in a more accurate assessment of children's receptive language skills. Since the nouns, verbs and adjectives were selected from a frequently administered receptive language assessment (TACL-4), it can be inferred that modifying symbol type could be one viable option for improving current standardized assessment practices for evaluating the language skills of children with disabilities.

**Examination of SymbolStix©[2] Symbol Error Identification Patterns**

Typically developing children exhibited difficulty identifying SymbolStix©[2] symbols, as evidenced by an increased number of error responses for nouns, verbs and adjectives. Error analyses revealed the following thematic areas of difficulty in identifying SymbolStix©[2] symbols across word class: (a) Noun Errors – For nouns that participants did not identify accurately, children tended to select symbols semantically and visually similar to targets; (e.g., selected mother vs. father), (b) Verb Errors – For verbs that participants did not identify accurately, children selected symbols depicting similar actions which contained additional lines drawn in to indicate movement (e.g., running vs. jumping) and (c) Adjective Errors – For adjectives that participants did not identify accurately, children often selected symbols representing opposites of the targets (e.g., slow for fast, tired vs. noisy). Typically developing participants for the present study, achieved higher identification accuracy mean scores for the color photograph symbol[1] condition for overall identification and for nouns, verbs and adjectives; these findings again confirm that color photograph symbols[1] are more transparent than SymbolStix©[2] symbols.

The error analyses for SymbolStix©[2] symbols suggest that typically developing children exhibited a greater level of difficulty accurately identifying nouns, verbs and adjectives depicted by SymbolStix©[2] symbols. This is not surprising given that the current evidence base recognizes that color line drawings are less transparent than other symbolic representations, mainly color photograph symbols (Mirenda & Locke, 1989). However, receptive language assessments continue to utilize color line drawings to depict various constructs in order to determine children's receptive vocabulary knowledge. Taken as a whole, the findings of the present investigation provide evidence that symbol type may be contributing to the underestimation of receptive language skills in children with disabilities. In other words, in some cases, error responses noted during receptive language assessment tasks may not be an artifact of impaired vocabulary knowledge, but rather a result of incomprehensible stimuli used to represent concepts on receptive language skills.

**Comparison of Rate Results to Past Research**

***Message generation rates.*** The communication rate of individuals who use AAC ranges from 15-25 times slower than the conversational speaking rate of individuals who do not have disabilities which varies from 150-250 words per minute (Goldman-Eisler, 1986). The findings of the present investigation may have implications on options to increase the communication rates for individuals who use AAC. Specifically, three, four, five and six-year old children achieved faster mean touch rates for identification of color photograph symbols[1] in comparison to SymbolStix©[2] symbols in the present investigation. In other words, the use of highly transparent symbols as stimuli in standardized assessments of receptive language and AAC displays may result in more efficient assessment of receptive language skills as well as an increased rate of message generation for individuals with complex communication needs. When considering the noted challenges that children with complex communication needs experience when identifying line drawings (e.g., Beukelman & Mirenda, 2013; Cauley et al., 1989; Geytenbeek et al., 2010; Mirenda & Locke, 1989) the present outcomes (faster touch rates) indicate the use of color photograph symbols[1] could facilitate the accurate and efficient assessment of this population's receptive language skills.

***Eye rate & transparency of graphic symbols.*** The faster eye identification rates noted in the present investigation for color photograph symbols[1] in comparison to SymbolStix©[2] symbols lend support for the use of eye tracking as an additional measure of transparency and identification of graphic symbols. There are no known studies to date that have been conducted to examine the effects of symbol type on transparency and identification of graphic symbols as measured by eye rate. The current evidence base regarding transparency of graphic symbols (e.g., Mirenda & Locke, 1989) compared children's identification accuracy to determine transparency of different symbol types. The present investigation introduced a co-variable in terms of measuring accuracy: eye rate in seconds. Given the overall findings that all participants identified color photograph symbols[1] faster than SymbolStix©[2] symbols, it appears that there is a connection between eye rate of identification and transparency. These new findings contribute to the current evidence base in indicating potential utility of eye identification rate measurements to accurately measure children's symbol identification skills. Given that children with complex communication needs often present with motor impairment preventing them from participating via traditional response modes during standardized assessments, the faster eye identification rates noted for color photograph symbols[1] provide further support for: (a) the use of highly transparent symbols in order to efficiently obtain an accurate representation of children's receptive language skills, (b) the use of alternate response modes (eye tracking) for accurate assessment of receptive language skills and (c) eye identification rate as an additional measure of transparency and identification of graphic symbols.

## Comparison of Correlation Results to Past Research

**Interplay between eye gaze & pointing responses.** Prior studies have been conducted to examine the relationship between eye gaze and pointing responses as it relates to identification of target symbols with both typically developing children and children with autism spectrum disorder (ASD) who use AAC (Brady et al., 2014; Southgate et al., 2001; Clements et al., 2001). Building on these investigations, the present investigation's outcomes indicate a statistically significant positive relationship between touch and eye rates for identification of graphic symbols by typically developing children - further supporting a need for the validation of alternate response modes (eye gaze) for accurate and efficient assessment of receptive language skills across participants with a range of profiles, including ASD. Given the challenges associated with accurately assessing receptive language skills for children with complex communication needs who may face additional barriers such as significant motor impairment, the use of eye tracking technologies has potential to assist in reducing the underestimation of receptive language skills for this population. The present investigation's findings, including statistically significant moderate correlations between touch rate and eye rate with strong effect sizes for color photograph symbol[1] and SymbolStix©[2] symbol conditions indicate that behaviors recorded with eye tracking technology map onto conventional response behaviors (e.g., pointing/touch) and provide further support for validation of eye gaze as an alternate response mode for administering standardized assessment of receptive language skills.

**Examination of Children's Eye Rate, Touch Rate & Identification Accuracy**

The findings of the present investigation indicate that the relationship between eye rate and identification accuracy of graphic symbols merits further exploration. Although, bivariate correlations revealed a statistically significant weak, negative correlation and effect size for both eye rate and identification accuracy of color photograph symbols[1] – thus confirming that there was a relationship between these two variables. Results indicated that increased identification accuracy resulted in faster times (i.e., quicker eye rate) to correctly select a more transparent graphic symbols (color photograph symbols[1]). Contrastingly, there was no statistically significant correlation between identification accuracy and eye rate for SymbolStix©[2] symbols. Therefore, no relationship between accuracy and eye rate for the identification of less transparent symbols (SymbolStix©[2] symbols) could be inferred. This finding was perhaps not surprising given the current evidence base related to transparency of line drawings (i.e., less transparent than color photograph symbols). These findings further support the importance of symbol set selection for those individuals whom use AAC and for the use of color photograph symbols[1] as stimuli in the assessment of receptive language skills for children with complex communication needs.

**Comparison of Naming Results to Past Research**

Previous studies examined the effects of symbol type on naming of graphic symbols including: children's perception of graphic symbols; PCS vs. children's own drawings (Worah et al., 2015) and the effect of animation on typically developing children's ability to name verbs and prepositions (Schlosser et al., 2012). Building on these investigations, the present investigation was the first to examine typically developing children's ability to label graphic symbols; specifically color photograph symbols[1] and SymbolStix©[2] symbols -a widely used symbol set with no known research detailing its iconicity and learnability (Beukelman & Mirenda, 2013). In a related study, Schlosser and colleagues (2012) examined the effects of symbol type (animation) on the transparency, identification, and name agreement for verbs and adjectives. Results revealed animation enhanced three, four and five-year olds children's ability to name verbs to a greater extent than adjectives. Similarly, the present investigation found that three, four, five and six-year old children achieved higher mean scores for naming of nouns, verbs and adjectives depicted by color photograph symbols[1]. As per the literature, abstract concepts including verbs and adjectives are more difficult to depict symbolically than nouns (Bloomberg et al., 1990, Mizuko, 1987; Worah et al., 2015). The present investigation's findings, specifically the difficulty noted for naming of nouns, verbs and adjectives depicted by SymbolStix©[2] symbols provide further support for the incorporation of more transparent symbols on AAC system displays which in turn will facilitate increased accuracy of message generation.

Typically developing three, four, five and six-year old participants in the present investigation also demonstrated difficulty naming SymbolStix©[2] symbols. Specifically, the differences between five-year old (mean age 5.2) and six-year old (mean age 6.7) performance for word class, support the fact that pictorial competence does not emerge uniformly for all symbols and referents even after the age of three (DeLoache, Pierroustakos & Uttal, 2003). More importantly, these findings provide evidence that children's ability to understand and use graphic symbols continues to develop past five years of age. When these findings with typically developing children are contextualized in the literature indicating that children with varying cognitive impairments have difficulty identifying line drawings in general (Geytenbeeek et al., 2010; Cauley et al., 1989; Beukelman & Mirenda, 2013; Mirenda & Locke, 1989; Romski & Sevcik, 1996), it would be reasonable to conclude that children with cognitive impairments – who most often need to use these types of symbols for AAC purposes – also may experience significant difficulty identifying SymbolStix©[2] symbols and using these symbols expressively. Further, given that the present investigation found that color photograph symbols[1] are more readily identifiable for typically developing three, four, five and six-year old children, it also would be reasonable to conclude that an investigation using color photograph symbols[1] with children with cognitive impairments would be valuable to undertake. Therefore, the present investigation's naming findings may have the potential to impact the symbol sets utilized on AAC displays for children with complex communication needs in the future. More specific clinical implications of these findings are addressed later in this chapter.

**Examination of SymbolStix©[2] Symbol Error Naming Patterns**

Photographs and line drawings of specific items are considered highly transparent when the meaning and relationship to the referent can be easily identified (Worah, et al., 2015). Verbs and descriptors are more difficult to represent since these are considered abstract concepts (Bloomberg et al., 1990, Mizuko, 1987; Worah et al., 2015). Results of the present study indicate that color photograph symbols[1] were more transparent for overall naming of graphic symbols, nouns, verbs and adjectives by three, four, five and six-year old children in comparison to the examined line drawing symbols, SymbolStix©[2]symbols.

Error analyses revealed the following thematic areas of difficulty in naming SymbolStix©[2] symbols across word class: (a) Noun Errors – For nouns that participants did not name accurately, they often made statements indicating that they were confused by the absence of people depicted as a whole in the symbols (e.g., “He has no eyes” in response to a symbol that is intended to depict father through a drawing of a man, woman and children without any facial features, no eyes, no mouth) (b) Verb Errors – For verbs that participants did not name accurately, they asked questions about the arrows/lines featured in SymbolStix©[2] symbols to indicate movement (e.g., the dotted lines below a stick figure jumping), and (c) Adjective Errors - For adjectives that children did not name correctly, they often named an associated noun in error; (e.g., “it’s an egg” for an oval colored blue that is intended to represent the color “blue”).

Contrastingly, the same constructs depicted by color photograph symbols[1], proved to be more transparent (easily guessable) to the participating children in the present investigation, as evidenced by higher mean scores for overall naming of color photograph symbols[1] and across word class. It appears that the color photograph symbols[1] provided a more transparent and iconic depiction, thus representing a more-clear symbol to referent relationship for the participants. These findings provide further support for the iconicity hypothesis which suggests that symbols that closely resemble their referent are easier to recognize and to learn to use than more abstract symbols (Fuller & Lloyd, 1991; Lloyd & Fuller, 1990; Loncke et al., 2006; Schlosser et al., 2012).

## Clinical Implications of Findings

### Identification Accuracy Implications

The present investigation's findings have several clinical implications relating to assessment of receptive language skills and symbol set selection for those children with complex communication needs. According to the established transparency hierarchy for graphic symbols (Mirenda & Locke, 1987), which was developed from investigation(s) involving participants with intellectual disabilities, it appears that the outcomes of the present investigation would indicate that children with complex communication needs and/or intellectual disability would exhibit the same level of identification difficulty for SymbolStix©[2] symbols. Although the present investigation involved typically developing children, the statistically significant differences found for overall identification accuracy of SymbolStix©[2] symbols and adjectives (line drawings) by typically developing children may imply that significant differences would also be noted for children with complex communication needs (Beukelman & Mirenda, 2013; Cauley et al., 1989; Geytenbeek et al., 2010). Hence, the findings from the present investigation add to the emerging knowledge base of how typically developing young children identify color photograph symbols (Stephenson, 2009).

### Touch & Eye Identification Rate Implications

Although this investigation was preliminary in nature, there are some considerations for clinical practice which can be derived from the present investigation's outcomes relating to accuracy and rate for identification of graphic symbols. For example, given that study results revealed faster touch and eye rates for overall identification of color photograph symbols[1] across word class, the inclusion of highly transparent symbols within AAC displays may result in faster and more accurate message generation. Furthermore, the statistically significant differences noted across participants for overall touch rate for SymbolStix©[2] symbols (combined nouns, verbs and adjectives) and touch rate for SymbolStix©[2] adjectives, implies that SymbolStix©[2] symbols are less transparent and could be more difficult to identify for children. Findings including increased eye identification rates (longer time in seconds) for SymbolStix©[2] symbols provide further evidence of the impact of transparency on identification accuracy.

Eye tracking technologies offer unique benefits relating to modifications of standardized assessments for children with complex communication needs. For one, eye tracking technologies provide insight into the interplay between eye gaze and pointing responses that are often required for participation in standardized assessments (Brady et al; 2014, Southgate et al., 2001; Clements & Perner, 1994; Ruffman et al., 2001). Secondly, the finding in the present investigation that typically developing children achieved faster eye identification rates of color photograph symbols[1]overall fornouns, verbs and adjectives (vs. SymbolStix©[2] symbols), informs clinicians that color photograph symbols[1] may be more transparent, and therefore, appear to better represent nouns, verbs and adjectives. Furthermore, the current eye identification rate findings appear to introduce a potential new mechanism for determining transparency of graphic symbols (color photograph symbols[1] vs. SymbolStix©[2] symbols) - especially for those children who have significant motor impairments (i.e., children with complex communication needs) which prevent them from identifying graphic symbols via conventional response behaviors (i.e., pointing to symbols).

## Correlational Implications

The correlation findings from this investigation suggest three primary areas of clinical implication, including strengthened need for inclusion of: (1) alternate response mode options for participation in standardized AAC assessment procedures, (2) transparent stimuli for assessment of receptive language skills for children with complex communication needs, and (3) transparent symbol sets for AAC systems to enhance rate and accuracy of message generation. In the assessment literature, the Participation Model (Beukelman & Mirenda, 1988) focuses on identifying the strengths of individuals with complex communication needs, but does not include a standard protocol for the assessment of children with complex communication needs (Dietz et. al., 2012). Further, current methods of assessment for children with complex communication needs have been noted to often result in underestimation of these children's receptive language skills (Emerson, 2003).

Given the findings of the present investigation indicating that color photograph symbols[1] are more transparent - and thus faster and more accurately identified via touch and eye gaze than SymbolStix©[2] symbols - these results provide additional support for assessment modification for the evaluation of receptive language skills of children with complex communication needs. The present study's findings in light of the documented challenges with standardized assessment use for children with disabilities (Mirenda, 2014; Tzuriel, 2006; Utley et al.,1992) impacts assessment practices in two ways.

First, color photograph symbols[1] should be examined as potential stimuli to yield increased accuracy in assessing children's receptive language skills, and secondly, eye gaze should be considered for further investigation as a valid alternate response mode for assessment of receptive language skills. Children with complex communication needs often present with motor impairment, and, therefore, using eye gaze as an alternate response mode could afford this population with an alternate to standard behavioral responses (pointing to pictures). With the inclusion of eye gaze, SLPs and educators may be able to more accurately identify the needs, capabilities, and strengths of children with complex communication needs as required within the Participation Model (Beukelman & Mirenda, 1988) endorsed by ASHA (2004). These assessment modifications could result in SLPs and educators obtaining a more valid, efficient, and reliable determination of receptive language skills for children with complex communication needs.

**Naming Implications**

Past research indicates that pictorial competence (i.e., the ability to perceive, understand, interpret and use pictures communicatively) does not emerge uniformly for all symbols and referents even after the age of three (DeLoache et al., 2003), and the ability to comprehend and use symbol types continues to develop until around five years of age (Rochat & Callaghan, 2005). The present investigation's findings including statistically significant differences in naming accuracy between 5 and 6-year old children across word class (favoring color photograph symbols[1]) provides evidence that children continue to develop the ability to use symbols past five years of age. More specifically, findings from the current study have clinical implications in the following three areas: (1) the developmental trends for typically developing children's use of graphic symbols, (2) pictorial competence and (3) symbol set selection for AAC displays.

First, the inclusion of the six-year old age group in the present investigation allowed some new conclusions to be drawn about development of graphic symbol comprehension and labeling. Since the six-year old participants in the current investigation did make errors in naming graphic symbols (SymbolStix©[2] symbols), we have an indication that the ability to name graphic symbols may still be continuing to develop past five years of age. Findings from the current investigation also suggested that color photograph symbols[1] are more transparent, and therefore, may be more easily identifiable than SymbolStix©[2] symbols for typically developing three, four, five and six-year old children. This is a significant finding and has the potential to impact the symbol sets utilized within AAC displays as well as the length and accuracy of messages generated by children with complex communication needs.

**Symbol set for AAC displays.** One of the most important considerations in designing a communication system for individuals with complex communication needs who have intellectual disabilities is the selection of the symbol set used to represent various messages (Mirenda & Locke, 1989). Past research suggests that contemporary AAC systems do not always include symbols that are meaningful for young children; children have been reported to have difficulty seeing the relationship between the graphic symbol representations and referent linguistic concepts (Light & Drager, 2012; Light et al., 2008). Given the present investigation's findings, it may behoove us to further examine the types of utterances produced by children when using color photograph symbols[1]. If it is indeed true that children can more readily comprehend these symbols, it is possible that they may more readily use such symbols in message construction when provided with access to appropriate vocabulary.

**Documented strategies for expansion of message generation for children who use AAC.** Previous research has indicated that there are a number of aided language strategies (e.g., aided AAC modeling, increased pause time, open-ended question answering) that can be implemented to facilitate the length and appropriate use of syntax in messages generated by children with complex communication needs (e.g., Binger et al., 2008; Binger & Light; 2008; Bruno & Tremblath, 2006; Kent-Walsh et al., 2015; Whitmore et al., 2014). Given the present study's findings regarding typically developing children's ability to accurately identify and name graphic symbols depicted by color photograph symbols[1], it seems reasonable to assume that the inclusion of highly transparent, iconic symbols on children's AAC displays may also support children's productions of longer, more accurate and varied messages. Combining use of photograph symbols on AAC displays with evidence-based aided language strategies may represent viable future extensions of this investigation and previous aided language intervention research (e.g., Kent-Walsh et al., 2015; 2017).

## Limitations

Although this investigation contributes to the AAC assessment literature in several ways, the following four primary limitations should be considered when interpreting the results. First, there is a limitation in terms of generalizability of the present study's findings to: (1) typically developing three, four five and six-year old children living outside the sample area of Central Florida area, (2) children with complex communication needs, (3) other symbol sets; hence, the results that were yielded are valid only for color photograph symbols[1] and SymbolStix©[2] symbols. A fourth limitation of the present investigation relates to counterbalancing. Although counterbalancing was employed for order of experimental tasks and conditions an order effect cannot be ruled out.

First although the participants in the present investigation were only from the Central Florida area, the sample was quite diverse and included participants with the following ethnicities: (a) Caucasian (n = 66), (b) African American (n = 18), (c) Hispanic (n = 7), (d) Middle Eastern (n = 3), and (e) Asian (n = 2). Orlando is considered to be a diverse, metropolitan area. According to the Orlando Census Bureau (2016) profile from the 2010 census, the demographic breakdown includes: Caucasian (57.6%), African American (28%), Hispanic (25.4%) and Asian (3.8%). The current investigation's sample is similar in terms of the number of participants per each of the ethnic categories listed. Therefore, it is likely that the findings from the current study may be generalizable to typically developing three, four, five and six-year olds living in other metropolitan areas in the United States.

Secondly, given that the current study involved typically developing three, four, five and six-year olds, results cannot be generalized to children with complex communication needs. However, given the well documented challenges experienced by children with disabilities in identifying line drawings (e.g., Mirenda & Locke, 1989), it is likely that findings would be relevant to the population of children with complex communication needs.

Third, two symbols sets were used in this study to examine the effect of symbol type - color photograph symbols[1] and SymbolStix©[2] symbols. Thus, results yielded from the current study are only generalizable to these two symbol sets. However, given the established transparency hierarchy (Mirenda & Locke, 1989), in which color line drawings are deemed lower in terms of transparency, it appears that SymbolStix©[2] a type of color line drawing may indeed be considered lower on the transparency hierarchy as well.

An additional limitation of the present study's findings relates to counterbalancing. Although counterbalance and randomization were employed for order of experimental tasks (naming and identification tasks) and conditions (color photograph symbols[1] and SymbolStix©[2]), an order effect cannot be ruled out. Given that participants assigned to Time 2 received the receptive task (identification) prior to the naming task (expressive), it is a possibility that exposure to the targets in identification task, may have influenced their performance on the expressive task (naming).

## Future Research Directions

Results from this investigation lay the groundwork for several promising directions in future research, including replication of the current investigation with: (a) children across a broadened age range, (b) children who have complex communication needs, and (c) adults who have acquired neurogenic communication disorders. Further extensions of the present investigation also will be important in order to yield additional standardized assessment options for individuals with complex communication needs.

### Expanding Participant Populations in Future Study Replications

**Typically developing children.** Results of the present investigation indicate the potential utility of employing more transparent stimuli when assessing children's receptive language skills. However, only 3 - 6 -year olds were included in the present investigation. Given the present investigation's findings - specifically that children as old as six-years of age exhibited difficulty identifying and naming constructs depicted by SymbolStix©[2] symbols - including older children would provide a broader developmental baseline to determine the effects of symbol type. Thus, it will be important to expand the age range to include older children in future investigations. Casting a wider net in terms of age range will provide a greater understanding of the effects of symbol type (color photograph symbols, SymbolStix©[2]) across older typically developing children.

**Children with complex communication needs.** Another population with whom the current investigation should be replicated is individuals with complex communication needs. Given the documented challenges for standardized test use with individuals with disabilities, it is critical to determine the effects of symbol type on the comprehension of nouns, verbs and adjectives with transparent stimuli in order to gain an accurate representation of this population's receptive language abilities. Since the typically developing children who participated in the current investigation exhibited difficulty identifying and naming nouns, verbs and adjectives in SymbolStix©[2] symbol format, it is likely that at least a similar level of difficulty would be noted for children with complex communication needs – if not an increased level of difficulty. This investigation was the first of its kind to explore the transparency of one widely used symbol set (SymbolStix©[2] symbols) with unknown iconicity and learnability characteristics (Beukelman & Mirenda, 2013). It, therefore, would be clinically-useful to know if the findings of the current study are found to hold true in children with complex communication needs. If so, then a re-examination of current assessment procedures would certainly be warranted, with a goal of identifying ways to more accurately assess this population's receptive language skills. Replicating the current investigation with individuals with complex communication needs could potentially validate the generalizability of these transparency findings to this population. In addition to symbol type, another known barrier to the assessment of children with complex communication needs is their physical limitations which prevent this population from participating in standardized assessments.

The current study's findings support and identify a need to further validate the use of eye tracking as an alternate response mode for those children who present with significant motor limitations, as is the case with many children with complex communication needs. Eye tracking technologies have been used to examine the effects of alternate response modes on children's performance via traditional behavioral responses (pointing) to validate modified administration of receptive language assessments, such as the PPVT-4 (Brady et al., 2014). The present investigation's findings of significant positive correlations between touch and eye rates for identification of graphic symbols provide further support for the use of eye tracking as an alternate response mode for valid receptive language assessments of children with complex communication needs. Presenting individuals with comprehensible stimuli in conjunction with a manner in which to identify these symbolic representations of nouns, verbs and adjectives will provide SLPs and other specialists clinically-useful insight into this population's true receptive language capabilities.

**Adults with acquired communication disorders.** Just as the learnability of different symbol types has been examined with typically developing children and children with complex communication needs, so too has identification and learnability of symbol types been explored in neurological typical adults and persons with aphasia (Beck & Fritz, 1998). In one study, it was reported that both people with aphasia and adults without acquired language challenges learned concrete icons more proficiently than abstract icons (Beck & Fritz, 1998). An initial study in a line of research in this area involving adult populations could focus on examining the effects of symbol type (color photograph symbols[1] vs. SymbolStix©[2]) on the receptive language skills of neurologically typical adults and those with acquired communication disorders that may require AAC systems.

### Related Future Expansions of the Current Investigation

An expansion of the current investigation to include other widely-used AAC symbol sets (e.g., PCS symbols) could provide further insight into the effects of symbol type in the context of receptive language assessment for children with complex communication needs. The present study's inclusion of SymbolStix©[2] symbols in comparison to color photograph symbols[1] is a contribution to the current evidence base, as evidenced by lower identification and accuracy scores noted for nouns, verbs and adjectives represented by SymbolStix© symbols. Clearly, symbols that are less transparent negatively impact accurate identification and naming of symbols across word class. Just as SymbolStix©[2] symbols are a widely used symbol set, so too are PCS symbols. Although, some work has been done to investigate children's perception of PCS symbols (e.g., Worah, 2015), there has not been a study to dateexploring the effects of this symbol type on the identification and naming accuracy of PCS symbols across word class. Including an additional symbol set could help to expand the generalizability of the present investigation's findings.

The findings from the present investigation have the potential to change current assessment practices for individuals with complex communication needs across the lifespan.

When an individual is presented with comprehensible stimuli, his/her receptive language capabilities can be more accurately assessed. Accurate assessment, in turn, will yield the most appropriate treatment plans for effective AAC use.

## Conclusions

The outcomes from the present investigation further support the need to modify current receptive language assessment practices for children with complex communication needs. Given the speech, cognitive and motoric compromise commonly found in this population, current assessment practices often do not afford children with complex communication needs comprehensible stimuli and/or physical options to participate in standardized assessments. Findings indicating that typically developing participants had higher mean scores for identification and naming accuracy of highly transparent graphic symbols, highlights the importance of symbol type as a key consideration in the assessment of receptive language skills. Furthermore, overall results of the investigation provide evidence and support for the use of color photograph symbols[1] as stimuli for: (a) receptive language assessments to yield more reliable assessment results for children and (b) incorporation into AAC system displays for faster and more accurate message generation.

Findings from typically developing participants' rate and identification accuracy of graphic symbols from the current study contribute to the evidence base for the use and validation of: (1) eye gaze rates as a new measure for assessing transparency of graphic symbols, and (2) eye gaze as an alternate response mode for accurate evaluation of children's receptive language skills. By incorporating highly transparent symbols (color photograph symbols[1]) and eye tracking technologies into receptive language assessment practices, AAC service delivery could be enhanced and risks of underestimating the receptive language skills of children with complex communication needs could be reduced. Such adjustments in turn could lead to overall improved educational and social outcomes for children with complex communication needs.

# APPENDIX A: PARTICIPANT DEMOGRAPHIC FORM

## Registration Form (Please Print)/Formulario de Registro (Letra Imprenta)

**Child's Last Name**________________ **FirstName**________________ **MI**______
Apellido del niño/a — Nombre del niño/a — Inicial del segundo nombre

**School's Name**________________ **Class**__________ **Teacher**__________
Nombre de la escuela — Clase — Maestra

**Age**______ **DOB**__________ **Gender:** **Male**______ **Female**______
Edad — Fecha de nacimiento — Sexo: Masculino — Femenino

**Child's Country of Birth:**________________ **Parents' Country of Birth:**________________
Pais de nacimiento del niño/a: — Pais de nacimiento de los padres:

**Mother's Name**________________ **Father's Name**________________
Nombre de la madre — Nombre del padre

**Home Ph. #**________________ **Cell Ph.#**________________
Tel. de la casa — Tel. Celular

**Address**________________ **City**__________ **State**______ **Zip Code**__________
Dirección — Ciudad — Estado — Código postal

## Developmental Information:(Información sobre el desarrollo)

**1. Is your child's speech difficult to understand?** ............ ☐ YES ☐ NO ☐ N/A
¿Es difícil entender el habla de su niño/a?

**2. Does your child mispronounce sounds?** ............ ☐ YES ☐ NO ☐ N/A
¿Su niño/a tiene dificultades pronunciando sonidos?
**If yes, describe**________________________
¿Cuáles? Describa

**3. Does your child have difficulty forming sentences?** ............ ☐ YES ☐ NO ☐ N/A
¿Su niño/a tiene dificultades formulando oraciones?

**4. Does your child have difficulty following directions?** ............ ☐ YES ☐ NO ☐ N/A
¿Su niño/a tiene dificultades ejecutando órdenes?

**5. At what age did your child:** **sit alone?**______ **crawl?**______ **walk?**______
¿A qué edad su hijo se: sentó solo? gateó? caminó?

**6. Does your child stutter ( my- my- my name) and/or (n- n- name.)?** ............ ☐ YES ☐ NO ☐ N/A
¿Su niño/a tartamudea (mi mi mi nombre) y/o (n- n- nombre)?
**If yes, describe**________________________
¿Cuáles? Describa

**7. Does your child have a chronic hoarse voice?** ............ ☐ YES ☐ NO ☐ N/A
¿Su niño/a presenta una ronquera crónica?

**8. Is your child's speech like others of his/her age?** ............ ☐ YES ☐ NO ☐ N/A
¿El habla y el lenguaje de su niño/a es cómo el de otros niños/as de su edad?

**9. Has your child had previous speech therapy?** ............ ☐ YES ☐ NO ☐ N/A
¿Su niño ha recibido terapia del habla?
**If yes, describe**________________________
Por favor describa

**10. Is there a foreign language spoken at home?** ............ ☐ YES ☐ NO
¿Se habla un segundo idioma en la casa?
**Language?**______ **1st Language**______ **2nd Language**______
¿Cuál? — Primer idioma — Segundo idioma

**11. How long has your child been exposed to English?** ________________
¿Desde cuándo su niño/a ha sido expuesto al inglés?

---

**12. Has your child had frequent ear infections?** ............ ☐ YES ☐ NO ☐ N/A
¿Su niño/a ha tenido frecuentes infecciones de oído?
**How many?** ________________
¿Cuántas?

**13. Has your child had PE tubes?** ............ ☐ YES ☐ NO
¿Tiene su niño/a tubos de ventilación en sus oídos?
**When?**________
¿Desde cuándo?

**14. Does your child have a history of hearing loss?** ............ ☐ YES ☐ NO ☐ N/A
¿Su niño/a tiene perdida auditiva?

**15. Does your child wear glasses?** ............ ☐ YES ☐ NO ☐ N/A
¿Su niño/a usa lentes/espejuelos? (Los niños que usan lentes/espejuelos serán evaluados usándolos)

**16. Has your child ever been referred for an evaluation for Developmental Delay?** ............ ☐ YES ☐ NO ☐ N/A
¿Su niño/ a side referido para una evaluacion de retraso de desar?

**17. Additional comments and/or concerns:** Comentarios adicionales:

## APPENDIX B: PLS-5 SCREENING TEST PROTOCOL AGE 3

Zimmerman, I. L., Steiner, V. G., & Pond, R. E. (2011). *Preschool Language Scale Fifth Edition*. Upper Saddle River, NJ: Pearson.

**https://www.pearsonclinical.com/**

## APPENDIX C: PLS-5 SCREENING TEST PROTOCOL AGE 4

Zimmerman, I. L., Steiner, V. G., & Pond, R. E. (2011). *Preschool Language Scale Fifth Edition*. Upper Saddle River, NJ: Pearson.

**https://www.pearsonclinical.com/**

# APPENDIX D: PLS-5 SCREENING TEST PROTOCOL AGE 5

Zimmerman, I. L., Steiner, V. G., & Pond, R. E. (2011). *Preschool Language Scale Fifth Edition*. Upper Saddle River, NJ: Pearson.

**https://www.pearsonclinical.com/**

## APPENDIX: E PLS-5 SCREENING TEST PROTOCOL AGE 6

Zimmerman, I. L., Steiner, V. G., & Pond, R. E. (2011). *Preschool Language Scale Fifth Edition*. Upper Saddle River, NJ: Pearson.

**https://www.pearsonclinical.com/**

# APPENDIX F: STIMULI

| TACL-4 Vocabulary Subtest Stimuli | | | | Word Class | Percentage | MB | SS |
|---|---|---|---|---|---|---|---|
| **1** | Ball | Bike | **Baby** | Noun | 47% Noun<br>24% Verb<br>29% Adjective | Yes | Yes |
| **2** | Bunny | **Boy** | Car | Noun | | Yes | Yes |
| **3** | Hand | Foot | **Shoe** | Noun | | Yes | Yes |
| **4** | Bike | **Home** | Car | Noun | | Yes | Yes |
| **5** | **Box** | Boat | Bird | Noun | | Yes | Yes |
| **6** | **Girl** | Boy | Chair | Noun | | Yes | Yes |
| **7** | Eat | **Drink** | Make/Cook | Verb | | Yes | Yes |
| **8** | Catching/Playing | Hitting | **Cutting** | Verb | | Yes | Yes |
| **9** | Blue | **Yellow** | Red | Adjective | | Yes | Yes |
| **10** | Grandma | Mother | **Father**** | Noun | | Yes | Yes |
| **11** | **Jumping** | Standing | Running | Verb | | Yes | Yes |
| **12** | *Stroller | **Fast** | Slow | Adjective | | Yes | Yes |
| **13** | **Blue** | Red | Yellow | Adjective | | Yes | Yes |
| **14** | ***** Cup | *Fork | * **Bowl** | Noun | | Yes | Yes |
| **15** | **Up** | Down | *Right | Adjective | | Yes | Yes |
| **16** | *Little | ****Noisy** | *Soft | Adjective | | Yes | Yes |
| **17** | ****Play** | Paint | *Shake | Verb | | Yes | Yes |
| **18** | **Repeat | | | | | | |
| **19** | **Repeat | | | | | | |
| **20** | **Repeat | | | | | | |

# APPENDIX G: SCREENING TASK PROCEDURE

***Directions: Administer the screening task according to the procedures below.***

- Researcher obtains assent for child's participation.
    - Researcher and/or trained graduate student will perform the action (verb) with a prop as deemed necessary or present a real object (noun, adjective) and the child will be asked to identify the action or item (Miller & Paul, 1995).
    - The order of presentation will be just as it appears in the TACL-4 (Carrow-Woolfolk, 2014a), with the exception of three randomly repeated stimuli for consistency of response measurement.
    - Objects, props, prompts (Appendix H).
- Researcher and/or trained graduate student will provide prompts, as outlined in Appendix H.
- Researcher and/or trained graduate student **will not** provide corrective or affirmative feedback.
- Researcher and/or trained graduate student **will** provide only intermittent, non-specific feedback to sustain participants' attention (e.g., "Nice job").
- A response will be considered correct, if the participant points to the target object or action presented or performed by the researcher and/or trained graduate student. Responses will be recorded on the Screening Data Collection form (Appendix H).
- Participants demonstrated 100% receptive or expressive knowledge of the nouns, verbs and adjectives.

*Adapted from Schlosser et al. (2012)*

# APPENDIX H: SCREENING PROTOCOL DATA COLLECTION FORM

**Participant #: ___________** **Session #: ________**

**Location: _________________**

**Legend:**

**(+) = Correct** = *Noun/Adjective:* Pointed to target object. *Verb:* Rang bell for target action.

**(-) = Incorrect** **Researcher Notes:**

| Target | Actions/Items | Directive |
|---|---|---|
| **Practice Item #1 Noun** | • **Airplane**<br>• Bus<br>• Truck | Point to the **airplane.** |
| **Practice Item #2 Verb** | • Read<br>• **Build**<br>• Tear | Researcher and/or research assistant will:<br>Read with a book<br>Build a tower with blocks<br>Tear a piece of paper<br>*Participant will be directed to hit the bell when he/she sees* ***build.*** |
| **Practice Item #3 Adjective** | • Green block<br>• Red block<br>• **Orange block** | Point to **orange.** |
| **1. Baby** | • **Baby doll**<br>• Bear<br>• Cup | Point to the **baby** |
| **2. Boy** | • Girl doll,<br>• **Boy doll**<br>• Book | Point to the **boy** |

| Target | Actions/Items | Directive |
|---|---|---|
| **3. Shoe** | • **Children's sneaker**<br>• Bubbles<br>• Crayon | Point to the **shoe** |
| **4. Home** | • Ball<br>• Puzzle<br>• **Doll house** | Point to the **home** |
| **5. Box** | • **Cardboard box**<br>• Car<br>• Dog | Point to the **box** |
| **6. Girl** | • Boy doll<br>• Book<br>• **Girl doll** | Point to the **girl** |
| **7. Drink** | • **Cup**<br>• | Researcher or trained research assistant will:<br>**Drink** (with cup)<br>Run<br>Jump<br>*Participant will be directed to hit the bell when he/she sees **drink.*** |
| **8. Cutting** | • **Scissors**<br>• | Researcher or trained research assistant will:<br>Cry<br>Clap with hands<br>**Cut** paper with scissors<br>*Participant will be directed to hit the bell when he/she sees **cut**.* |
| **9. Blue** | • **Blue block**<br>• Green block<br>• Orange block<br>• | Point to **blue.** |
| **10. Father** | **Dolls**<br>• **Man with baby**<br>• Woman with baby<br>• Baby | Point to **father.** |

| Target | Actions/Items | Directive |
|---|---|---|
| **11. Jumping** | Jump rope | Researcher or trained research assistant will:<br>Open a container<br>**Jump with jump rope**<br>Blow with bubbles<br>*Participant will be directed to hit the bell when they see **jump.*** |
| **12. Fast** | Motorcycle | Researcher or trained research assistant will:<br>**Push motorcycle fast**<br>Push motorcycle slow<br>Motorcycle still<br>*Participant will be directed to hit the bell when they see **fast.*** |
| **13. Yellow** | • **Yellow block**<br>• Green block<br>• Orange block | Point to **yellow** |
| **14. Bowl** | • **Bowl**<br>• Fork<br>• Keys | Point to the **bowl.** |
| **15. Up** | Dolls<br>• One with hands down<br>• **One with hands up**<br>• One sitting in a chair | Point to **up.** |
| **16. Big** | Toys<br>• Miniature dog<br>• Miniature cat<br>• **Big teddy bear** | Point to **big.** |
| **17. Play** | • Food<br>• **Cards**<br>• Car | Researcher or trained research assistant will:<br>Sleep<br>**Play cards**<br>Drop a toy car |

| Target | Actions/Items | Directive |
| --- | --- | --- |
| | | *Participant will be directed to hit the bell when they see* ***play.*** |
| **TOTAL** | | |

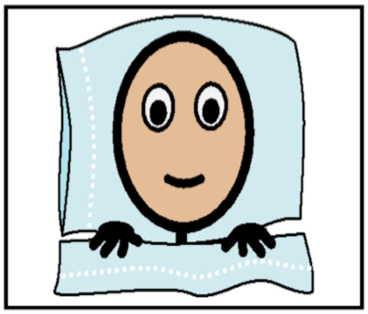
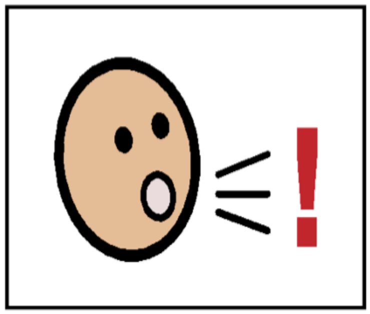
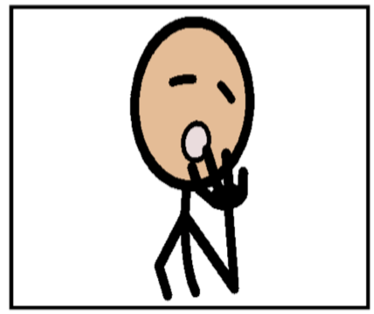
## APPENDIX I: TACL-4 PROTOCOL
## (Carrow-Woolfolk, 2014a)

Carrow-Woolfolk, E. (2014a). *Test for Auditory Comprehension of Language- Fourth Edition*. Austin, TX: Pro-Ed Inc.

**http://www.proedinc.com/**

## APPENDIX J: SAMPLE IDENTIFICATION TASK SYMBOLSTIX©[2] CONDITION

*Target: Noisy*

## APPENDIX K: SAMPLE IDENTIFICATION TASK COLOR PHORTOGRAPH SYMBOL[1] CONDITION

*Target: Noisy*

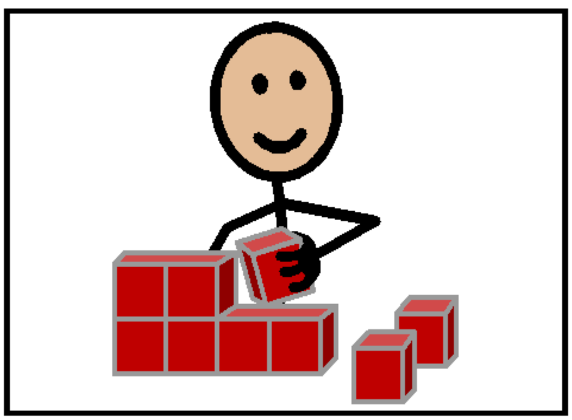
# APPENDIX L: MACARTHUR BATES CDI PROTOCOL

Fenson, L., Marchman, V. A., Thal, D. J., Dale, P. S., Reznick, J. S., & Bates, E. (2007). *MacArthur-Bates Communicative Development Inventories Words and Sentences.* Baltimore, MD: Brooks Publishing Company.

**http://www.brookespublishing.com/**

# APPENDIX M: SAMPLE NAMING TASK STIMULI SYMBOLSTIX©[2] CONDITION

*Target: Play*



# APPENDIX N: SAMPLE NAMING TASK STIMULI COLOR PHOTROGRAPH[1] SYMBOL CONDITION

*Target: Play*

## APPENDIX O: FAMILIARIZATION TASK PROCEDURE

***Directions: Administer the familiarization task according to the procedures below.***

- ☐ Researcher obtains assent for child's participation.

  - ☐ **Screening Task**

  - ☐ Three practice items consisting of objects and/or actions, which represent each word class (noun, verb, adjective) will be presented prior to the initiation of the screening task.

  - ☐ For the **screening task,** the researcher and/or trained research assistant will give the prompt, "____[participant's name], let's play a game. I am going to show you some things and do some things.

  - ☐ For Nouns and Adjectives, there will be a choice of three real objects placed on a table and the researcher and/or trained research assistant will give the prompt, " ____ [participant's name], point to the _____."

  - ☐ For Verbs, the researcher and/or research assistant will act out a set of three actions and the researcher and/or research assistant will give the prompt, "I'm going to do some things and I want you to watch me carefully. Hit the bell when you see me____."

- ☐ Correct and incorrect responses provided by participant will be acknowledged, researcher or trained research assistant will give the prompt "Yes this is ____" and incorrect responses will be corrected by researcher or trained research assistant will give the prompt, "No, this is ___".

- ☐ The researcher and/or trained graduate student will also inquire to verify that the participants understand the task by providing the following prompt: “Do you understand how to play the game?”

- ☐ Naming Task ☐ Identification Task

- ☐ Color Photograph Symbol[1] ☐ SymbolStix©[2] symbol

- ☐ Three practice items consisting of graphic symbols, which represent each word class (noun, verb, adjective) will be presented prior to the initiation of the experimental tasks.

- ☐ Touch Screen laptop with PowerPoint ☐ Tobii I15+ with eye tracker

- ☐ For the **naming task,** the researcher and/or trained graduate student will give the prompt, “____[participant’s name], let’s play a game on the computer. You will see a picture and I will ask you what it is.”
- ☐ Then the researcher and/or trained graduate student will give the prompt, “First I am going to show you how to play the game” while pointing to the computer screen. Now I want you to listen carefully and I will ask you what it is.”
- ☐ The researcher and/or trained graduate student will give the prompt “What’s this?” the participant will be expected to make a guess.
- ☐ Correct and incorrect responses provided by participant will be acknowledged, researcher or trained graduate student will give the prompt “Yes this is ____” and

incorrect responses will be corrected by researcher or trained graduate student will give the prompt, “No, this is ___”.

- The researcher and/or trained graduate student will also inquire to verify that the participants understand the task by providing the following prompt: “Do you understand how to play the game?”
- Researcher and/or trained graduate student **may** provide intermittent, non-specific feedback to sustain participants’ attention (e.g., “Nice job!”).
- A response will be considered correct, if the participant provides the exact label reserved for the symbol by the research team, a different form of the same label (e.g., cut for cutting) or a sentence or phrase containing the target noun, verb or adjective.
- For the **identification task,** the same protocol will be followed with the exception that participants will be directed to point/select target item. Researcher and/or trained graduate students will give the following prompt, “Point to ____” on the computer screen which will display three symbol choices for the color photograph symbol and color line drawing symbol conditions.
- Correct responses provided by participants will be acknowledged by researcher and/or trained graduate student providing the following prompt, “Yes this is.”
- Incorrect responses will be corrected by the researcher and/or trained graduate students by modeling the correct response by selecting the target on the computer screen.

*Adapted from Schlosser et al. (2012)*

## APPENDIX P: NAMING TASK COLLECTION & RELIABILITY FORM

**Participant #:** ___________ **Session #:** ________ **Video #:** _____________

**Location:** _________________ **Condition:** ___________

**Legend:** **Researcher Notes:**

**(+)** = Correct

**(-)** = Incorrect

**Different Form of Same Label** = jump for **jumping**

**Target Used in Phrase or Sentence =** Girl is **jumping**

| **Target** | **Number** | **Naming Responses** | | | |
|---|---|---|---|---|---|
| | | **Correct (+) or Incorrect (-)** | **Exact Match** | **Different Form of Same Label** | **Target Used in Phrase or Sentence** |
| **Practice 1** ***Noun*** **Balloon** | | | | | |
| **Practice 2** ***Verb*** **Throw** | | | | | |
| **Practice 3** ***Adjective*** **Hot** | | | | | |
| **Baby** | (1) | | | (1) | (1) |
| **Boy** | (2) | | | (2) | (2) |
| **Father** | (3) | | | (3) | (3) |
| **Shoe** | (4) | | | (4) | (4) |
| **Home** | (5) | | | (5) | (5) |
| **Box** | (6) | | | (6) | (6) |
| **Play** | (7) | | | (7) | (7) |
| **Girl** | (8) | | | (8) | (8) |
| **Drink** | (9) | | | (9) | (9) |
| **Noisy** | (10) | | | (10) | (10) |
| **Cutting** | (11) | | | (11) | (11) |
| **Yellow** | (12) | | | (12) | (12) |
| **Father**** | (13) | | | (13) | (13) |
| **Jumping** | (14) | | | (14) | (14) |
| **Fast** | (15) | | | (15) | (15) |
| **Blue** | (16) | | | (16) | (16) |

| | | | | | |
|---|---|---|---|---|---|
| **Bowl** | (17) | | | (17) | (17) |
| **Up** | (18) | | | (18) | (18) |
| **Noisy**** | (19) | | | (19) | (19) |
| **Play**** | (20) | | | (20) | (20) |
| **Total Percent Correct:** | | | | | |

# APPENDIX Q: NAMING TASK PROCEDURE

***Directions: Administer the naming task according to the procedures below.***

- ☐ Researcher obtains assent for child's participation.

  - ☐ The participants will be presented with one graphic symbol at a time on the touch screen laptop for the color photograph symbol and the color line drawing conditions via PowerPoint.

  - ☐ The order of presentation will be just as it appears in the TACL-4 (Carrow-Woolfolk, 2014a), with the exception of three randomly repeated stimuli for consistency of response measurement.

  - ☐ Touch screen laptop with PowerPoint

  - ☐ Color Photograph Symbol[1] ☐ SymbolStix©[2] Symbol

- ☐ Once the symbol appears, researcher and/or trained graduate student give the prompt: "Listen to me; I will tell you when to tell me what you see." The symbol will appear on the screen for a total of 14 seconds and after a 1 second delay, the researcher and/or trained graduate student will give the prompt, "What's this?"

- ☐ Researcher and/or trained graduate student **will not** provide corrective or affirmative feedback.

- ☐ Researcher and/or trained graduate student **will** provide only intermittent, non-specific feedback to sustain participants' attention (e.g., "Nice job").

- ☐ A response will be considered correct, if the participant provides the exact label reserved for the symbol by the research team, a different form of the same label (e.g., cut for cutting) or a sentence or phrase containing the target noun, verb or adjective.

- Responses will be recorded on Naming Data Collection Sheet (Appendix P).

*Adapted from Schlosser et al. (2012)*

# APPENDIX R: IDENTIFICATION TASK DATA COLLECITON & RELIABILITY FORM

| **Target** | **Number** | **Identification Responses** | | | | |
|---|---|---|---|---|---|---|
| | | **Correct (+) or Incorrect (-)** | **Calibration (+) (-)** | **Touch Screen Selection** | **Eye-Tracker Selection** | **Rate** |
| **Practice 1** ***Noun*** **Balloon** | | | | | | |
| **Practice 2** ***Verb*** **Sweep** | | | | | | |
| **Practice 3** ***Adjective*** **Orange** | | | | | | |
| **Baby** | (1) | | | | | |
| **Boy** | (2) | | | | | |
| **Father** | (3) | | | | | |
| **Shoe** | (4) | | | | | |
| **Home** | (5) | | | | | |
| **Box** | (6) | | | | | |
| **Play** | (7) | | | | | |
| **Girl** | (8) | | | | | |
| **Drink** | (9) | | | | | |
| **Noisy** | (10) | | | | | |
| **Cutting** | (11) | | | | | |
| **Yellow** | (12) | | | | | |
| **Father**** | (13) | | | | | |
| **Jumping** | (14) | | | | | |
| **Fast** | (15) | | | | | |
| **Blue** | (16) | | | | | |
| **Bowl** | (17) | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Up** | (18) | | | | | |
| **Noisy**** | (19) | | | | | |
| **Play**** | (20) | | | | | |
| **Total Percent Correct:** | | | | | | |

**Participant #:** ___________ **Session #:** ___ _____ **Video #:** _____________

**Location:** _________________ **Condition:** ___________

**Legend:** **Researcher Notes:**

**(+)** = Correct

**(-)** = Incorrect

**Touch Screen Selection**: Target selected by participant's hand **Rate:** ms

**Eye-Tracker Selection:** Target selected by participant's eyes

# APPENDIX S: IDENTIFICATION TASK PROCEDURE

***Directions: Administer the identification task according to the procedures below.***

- ☐ Researcher obtains assent for child's participation.

  - ☐ The participants will be presented with three graphic symbols at a time, one target symbol and two foils for both the color photograph symbol and color line drawing conditions, as described in the Materials section of this prospectus. The order of presentation will be just as it appears in the TACL-4 (Carrow-Woolfolk, 2014a), with the exception of three randomly repeated stimuli for consistency of response measurement.

  - ☐ Tobii I15+ eye tracker

  - ☐ Color photograph symbol[1] ☐ Symbolstix©[2] symbol

- ☐ Researcher and/or trained graduate student will complete a six-point calibration of participant via Tobii I15+ eye tracker. Researcher and/or trained research assistant will give the following prompt, "Now we are going to play a game. You are going to use your eyes. I am going to show you a ball and it will move across the screen. Listen to me and I will tell you when to look at the ball. Look at the ball."

- ☐ Once the first slide containing three graphic symbols is presented, the researcher and/or trained graduate student will give the prompt, "Listen to me, Point to ____."

- ☐ Fixation cross will be displayed for a 2 second duration in between each identification task slide.

- ☐ Researcher and/or trained graduate student **will not** provide corrective or affirmative feedback.

- Researcher and/or trained graduate student **will** provide only intermittent, non-specific feedback to sustain participants' attention (e.g., "Nice job").
- A symbol will be considered identified correctly if the child touches the quadrant with the symbol corresponding to the spoken name provided on the laptop computer.
- Responses will be recorded on Identification Task Data Collection Form (Appendix R).

*Adapted from Schlosser et al. (2012)*

# APPENDIX T: FIDELITY OF IMPLEMENTATION CHECKLIST SCREENING, NAMING & IDENTIFICAITON TASKS

| | |
|---|---|
| **Participant #: ________________________** | **Session #:______________________________** |
| **Video #:_______________________________** | **Reviewer:______________________** |

***Directions: Check the box next to each indicator if observed during the session.***

**Screening Task:**

- ☐ Researcher obtains assent for child's participation.
- ☐ Child is seated at table with researcher and/or graduate student.
- ☐ Researcher and/or graduate student completed familiarization task prior to administration of the transparency task.
- ☐ Researcher or trained graduate student either presents child with an object and/or are seen conducting a particular action (e.g., jumping).
- ☐ Researcher and/or trained graduate student follow all procedures outlined in screening protocol (Appendix G, Appendix H).
- ☐ Researcher and/or trained graduate student did not provide corrective or affirmative feedback.
- ☐ The researcher and/or graduate student may have intermittently offered non-specific feedback (e.g., keep up the good work) to sustain participation.
- ☐ No instruction occurs during administration.

**Naming Task:**

- ☐ Researcher obtains assent for child's participation.
- ☐ Child is seated at table in front of touch screen laptop with researcher and/or graduate student.
- ☐ Researcher and/or graduate student completed familiarization task prior to administration of the transparency task.
- ☐ Researcher and/or trained graduate student follow all procedures outlined in naming task protocol (Appendix P, Appendix Q).

- ☐ Researcher and/or trained graduate student did not provide corrective or affirmative feedback.
- ☐ The researcher and/or graduate student may have intermittently offered non-specific feedback (e.g., keep up the good work) to sustain participation.
- ☐ No instruction occurs during administration.

**Identification Task:**

- ☐ Researcher obtains assent for child's participation.
- ☐ Child is seated at table in front of touch screen laptop with Tobii I15+ with eye tracker (affixed to bottom of laptop) with researcher and/or graduate student.
- ☐ Child is calibrated with his or her eyes to laptop by researcher and/or trained graduate student.
- ☐ Researcher and/or graduate student completed familiarization task prior to administration of the identification task.
- ☐ Researcher and/or trained graduate student follow all procedures outlined in identification task protocol (Appendix R, Appendix S).
- ☐ Researcher and/or trained graduate student did not provide corrective or affirmative feedback.
- ☐ The researcher and/or graduate student may have intermittently offered non-specific feedback (e.g., keep up the good work) to sustain participation.
- ☐ No instruction occurs during administration.

**Calculations:** # Components implemented: ______________________________________ (A)

$\frac{(\square)}{18} =$ ____________________________% Components Implemented

*Adapted from Schlosser et al. (2012)*

# APPENDIX U: INTEROBSERVER AGREEMENT FORM

**Participant #: ___________ Session #: ________ Video #: _____________**

**Location: _________________** **Condition: ___________**

**Legend:**

**(+)Naming Task Agreement =** both observers mark the verbal response the same way (i.e., correct, incorrect).

(+) **Identification Task Agreement** = both observers note the same name of the symbol to which the participant points

**Calculations:** $\frac{\text{\# of agreements}}{\text{\# of agreements + \# of disagreements}}$ *X 100*

$\frac{(\square)}{} \square\ 100 =$ __________________________% Agreement

Percent agreement will be calculated by taking the number of agreements divided by the number of agreements plus disagreement multiplied by 100 (Schlosser et al., 2012).

*Adapted from Schlosser et al. (2012)*

## APPENDIX V: INSTITIIUTIONAL REVIEW BOARD APPROVAL LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

# Approval of Human Research

From: **UCF Institutional Review Board #1**
**FWA00000351, IRB00001138**

To: **Pamela J. Resnick**

Date: **March 09, 2017**

Dear Researcher:

On 03/09/2017 the IRB approved the following minor modifications to human participant research until 08/02/2017 inclusive:

| | |
|---|---|
| Type of Review: | IRB Addendum and Modification Request Form<br>Expedited Review |
| Modification Type: | Addition of new location. Revised Protocol was uploaded and revised consent was approved for use. |
| Project Title: | Effects of Symbol Type on Naming and Identification of Symbols for Three, Four, Five and Six-Year Old Children. |

| | |
|---|---|
| Investigator: | Pamela J. Resnick |
| IRB Number: | SBE-16-12412 |
| Funding Agency: | |
| Grant Title: | |
| Research ID | N/A |

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu. If continuing review approval is not granted before the expiration

date of 08/02/2017,
approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in IRIS so that IRB records will be accurate.
Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a signed and dated copy of the consent form(s).
All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Kamille Chaparro on 03/09/2017 01:58:01 PM EST
IRB Coordinator

## APPENDIX W: STUDY SCHEDULE

*Schedule*

| | |
|---|---|
| Week 1 | Conduct Screening Task |
| Week 2 | Conduct Experimental Tasks Across Symbol Conditions |
| Week 3 | Conduct Experimental Tasks Across Symbol Conditions in Counter Order |

***Contact Information***

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  - Main Clinic Fax: 407-882-0485

## ENDNOTES

1. Color Photograph Symbols retrieved from iStock by Getty Images, Essentials Collection (www.istock.com)
2. SymbolStix© https://store.n2y.com/PartnerProducts/Home/.

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