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Characterizing receptive vocabulary knowledge in minimally verbal children with autism spectrum disorder

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**CHARACTEIZING RECEPTIVE VOCABULARY
KNOWLEDGE IN MINIMALLY VERBAL CHILDREN WITH
AUTISM SPECTRUM DISORDER**

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
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Master of Arts

in

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by
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ABSTRACT

Background: Delayed or impaired language skills are common characteristics of children with autism spectrum disorder (ASD). Currently, there is little research examining the receptive language profile in children with ASD, and even less is known about children with ASD who are minimally verbal. The current study aimed to characterize the receptive vocabulary profile of minimally verbal children with ASD and to examine whether this profile differs from their typically developing peers. **Methods:** Participants included 31 minimally verbal children with ASD, aged 60-118 months, who were reported to produce between 0-10 words, 124 typical developing toddlers, aged 9-14 months, who were matched on expressive vocabulary, and 124 typical developing toddlers, aged 8-18 months, who were matched on receptive vocabulary. Semantic and syntactic features of words that the children understood was examined using word-level responses from the MacArthur-Bates Communicative Development Inventory (Fenson et al. 2007). **Results:** Minimally verbal children with ASD understood a greater proportion of verbs compared to both typically developing groups. In terms of semantic categories, multiple differences were found between the minimally verbal ASD group and the typically developing expressive vocabulary-matched group. Interestingly, when compared to the receptive vocabulary-matched group, only one difference was found. **Conclusions:** Minimally verbal children with ASD displayed a similar receptive vocabulary profile to typically developing toddlers who were matched on receptive vocabulary abilities despite large differences in expressive vocabulary knowledge, chronological age, and mental age. These findings suggest new insight for future research using receptive-vocabulary matched groups as a point of

comparison. Additionally, future studies should examine early verb learning and processing in minimally verbal children with ASD.

CHAPTER 1. INTRODUCTION

Current research has discussed early language and communication skills as predictors of later developmental outcomes in children with autism spectrum disorder (ASD; Tager-Flusberg, 2016). While previous studies have discussed the large variability in children with ASD's lexical profile and characterized early lexical development in young children with ASD (e.g., Charman, Drew, Baird, & Baird, 2003; Luyster et al. 2007), very little work has been done to characterize early lexical development in a particular subgroup of children, minimally verbal children with ASD. Furthermore, although minimally verbal children with ASD by definition produce very few words, we still have a limited understanding of their receptive language knowledge and the possible variability in the receptive knowledge that minimally verbal children with ASD possess. Within the few studies that have focused on this specific subgroup, results have shown large variability in receptive language abilities across multi-modal assessments (Bal et al., 2016; Plesa-Skewer, Jordan, Brukilacchio, & Tager-Flusberg, 2016). This variability provides additional motivation for further investigation of receptive language abilities in minimally verbal children with ASD. An enhanced understanding of receptive language in minimally verbal children with ASD will better guide assessment procedures and will offer valuable insight into early language and communication goals. Further, such knowledge may enhance our understanding of potential differences in how these children process language compared to typically developing peers. The aims of the current study are to characterize the early receptive vocabulary of minimally verbal children with ASD and to examine whether this receptive vocabulary profile differs from typically developing toddlers.

Variations in Minimally Verbal Definitions

Minimally verbal children are those who produce little to no spoken language. The criteria for how we define minimally verbal varies greatly though depending on different instruments and researchers' definitions of minimally verbal (Koegel et al., 2020). Currently, there is no clear agreed-upon approach to define a child as minimally verbal. As a result, there is substantial variation within the literature.

In one extensive study examining minimally verbal children with ASD, Bal, Katz, Bishop, and Krasileva (2016) address three research aims to provide a more comprehensive understanding of minimally verbal children with ASD. First, they examined the extent to which using different instruments to define minimally verbal cohorts affects sample composition. Second, they examined the overlap between minimally verbal groups defined by measures commonly used in ASD research. The final research question asked whether different definitions (within instruments and combining across instruments) affect resultant sample characteristics. This study included 1,470 children with ASD between the ages of 6-17 years. Children below 6 years were excluded to control for the possibility of them having a language delay. Bal et al. (2016) focused on the following tools to answer the research questions: Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 1999; Lord et al., 2012), Autism Diagnostic Interview-Revised (ADI-R; Rutter, Le Couteur, & Lord, 2003), Vineland Adaptive Behavior Scales, 2nd Edition (Vineland-II; Sparrow et al., 2005), Social Communication Questionnaire (Rutter, Bailey, & Lord, 2003), parent estimate of child language, cognitive level, and cognitive profile. The results showed that there was large variability between each instrument on what classified a child as minimally verbal. The ADOS yielded the greatest number of minimally verbal children ($n = 238$), and the Vineland Adaptive Behavior Scales

yielded the least ($n = 68$). There was considerable overlap between the ADOS and parent-report. Table 1 outlines the different descriptions, criteria, and subclassifications used to classify a child as minimally verbal using each of the four assessments. As shown in Table 1, the criteria for defining minimally verbal children for the ADOS and Vineland-II differ greatly. The criteria for the ADOS was identified as the child receiving the Module 1 of the ADOS, which would be appropriate for children who use single words or rote phrases only. Furthermore, Bal et al. (2016) used the ADOS scoring procedures to then classify the children into one of two subgroups. Children were either classified as having Few-to-No-Words, producing less than 5 words or approximations, or Some Words, producing 5 or more unique words during the administration of the ADOS. Bal and colleagues classified children as being minimally verbal using the Vineland-II if a child scored below 18 months. This corresponds to skills that are limited to the ability to complete items on the Vineland-II that assess nonverbal communication and single-word use. These criteria vary greatly in specificity and therefore yield largely different numbers of minimally verbal children. This study helps demonstrate that the number of children identified as minimally verbal depends greatly on the definitions and instrument used to classify verbal status. This also demonstrates the importance of taking into consideration the implications of choosing a given instrument or classification procedure.

Table 1. Bal et al. (2016) Assessment Characterizations of Minimally Verbal Children

Assessment	Description	Criteria	Subclassifications
ADOS	Observation assessment divided into modules by age and language level	Administered Module 1; use of single words or rote phrases	Few-to-No-Words: <5 words or approximations Some Words: 5+ words
ADI-R	Parent interview assessing symptoms in the areas of social interaction, communication, and restricted repetitive behaviors	Children not using functional 3-word phrases on a daily basis (Overall Level of Language, Item 30=0)	Some Words: Item 30=1, daily use of at least 5 words but no functional 3-word phrases Few-to-No-Words: Item 30=2, fewer than 5 words and/or speech not used daily
Vineland-II (Vineland:Exp)	Parent interview assessing communication, daily living skills and socialization	Below 18 months, raw score of 28 or less which reflects nonverbal communication and single-word use	none
Parent Estimate	Parents are given a questionnaire with 5 options to estimate their child's vocabulary	Parent reported child using no words, 1-5 words, or 5-25 words	Few-to-No-Words: no words or 1-5 words Some Words: 5-25 words

Across the literature it is apparent that, in addition to variations in the instruments used, researchers have also selected different criteria and cut-off scores to classify a child as minimally verbal. For instance, Kasari, Brady, Lord, and Tager-Flusberg (2013) reported a summary of a year-long series of meetings held by the National Institutes of Health discussing this specific subgroup of children with ASD. They defined minimally verbal as having a small number of spoken words or fixed phrases, with the exact number varying from no spoken words to 20 or 30. The authors did not specify a maximum number of spoken words because there are so many

factors that can influence a child's expressive language such as intervention history, access to alternative and augmentative communication (AAC) systems, and context or adult familiarity. This definition fails to encompass a child's receptive language skills. Adding to our lack of consistency in criteria used to classify children as minimally verbal, there is also variation in the specific labels that have been used for minimally verbal children.

Koegel, Bryan, Su, Vaidya, and Camarata (2020) conducted a systematic review of the way in which researchers have defined and classified children with ASD as “nonverbal” and “minimally verbal”. They found the literature consists of relatively few studies focusing on non/minimally verbal children with ASD - 31 research articles across 58 years (1960-2018) with 650 unique participants. They also found a lack of consistency in measures, definitions, and ages targeted. Ages across the studies ranged from 1 year 4 months to 23 years old. Across these studies, 293 participants were under 4 years 11 months and 250 participants were ages 5-11 years. In terms of measures, four studies assessed the participants during natural language interactions, eight studies included nonstandard behavioral observations, four studies included informal parent rereports, eight studies included a standardized target measure, and two studies included teacher reports. The remaining nine studies used a measure not used by any other study including the Autism Diagnostic Interview (ADI) assessment, picture-based assessments, phoneme repetition tests, language tests (e.g., CSBS), and other types of assessments (e.g., Mullen Scales of Early Learning, Leiter International Performance Scale – Revised). In terms of definitions, they found many authors to be vague and imprecise regarding a participant's communication level, with no clear way to define minimally verbal. Koegel and colleagues (2020) reported that some studies used production level (e.g., no more than 10, 20, or 25 words),

while other studies used descriptive terminology (e.g., severely language delayed) to classify children.

Like Koegel and colleagues (2020), we surveyed the literature to characterize how researchers classified children with ASD as minimally verbal. We also found that there was wide variation across studies. Examples are provided in Table 2, which displays different definitions and terminology used across 6 studies.

Table 2. Researcher characterization of minimally verbal definitions

Researcher	Age	Terms Used	Criteria
Yoder, Watson, and Lambert (2015)	20-48 months	Initially nonverbal/minimally verbal Nonverbal/minimally verbal	Produce no more than 5 different words in a 15 minute language sample Understand no more than 20 different root words according to MCDI
McDaniel, Yoder, Woyanarski, and Watson (2018)	20-48 months	Preverbal	Produce no more than 5 different words in a 15 minute language sample Understand no more than 20 different root words according to MCDI
Woyanarski, Watson, Gardner, Newsom, Keysili, and Yoder (2016)	20-48 months	Preverbal	Produce no more than 5 different words in a 15 minute language sample Understand no more than 20 different root words according to MCDI
Saul and Norbury (2020)	48-60 months	Minimally verbal	Fewer than 24 spoken words reported by parents

(table cont'd)

Researcher	Age	Terms Used	Criteria
Plesa Skwerer, Brukilacchio, Chu, Eggleston, Meyer, and Tager-Flusberg (2019)	8.6-20.2 years	Minimally verbal	Lack of spontaneous functional speech or inconsistent simple phrase speech of no more than three units
Plesa Skwerer, Jordan, Brukilacchio, and Tager-Flusberg (2016)	> 60 months	Minimally verbal	Produced fewer than 30 words/phrases reported by caregivers

When reviewing Table 2, it is important to be aware that Yoder et al. (2015), McDaniel et al. (2018), and Woyanarski et al. (2016) used an overlapping sample of children with ASD. Across the studies, Yoder and colleagues use the same age range of 20 to 48 months and criteria of a) understanding no more than 20 different root words according to the MacArthur Bates Communication Development Inventory-Words and Gestures Form (CDI-WG; Fenson et al. 2007) and b) producing no more than 5 different root words in a 15 minute language sample. Even though these three studies have the same criteria, different terminology has been used to define the subgroup of children. Yoder et al. (2015) refer to this group as initially nonverbal and minimally verbal. Both terms were used because Yoder and colleagues were analyzing a longitudinal study, which provided evidence of some children initially classified as minimally verbal or nonverbal but no longer meeting these criteria later in development. Yoder and colleagues reassessed the children across five different time points (the fifth visit occurred 16 months after entry of the study). Forty-five percent of participants remained nonverbal/minimally verbal. Therefore, the label of ‘initially nonverbal/minimal verbal’, refers to the children’s initial classification that was identified at the beginning of the study. In contrast to defining this subgroup as nonverbal/minimally verbal, McDaniel et al. (2018) and Woyanarski et al. (2016) both refer to the group as preverbal, even though they use the same criteria as Yoder et al.

(2015). This difference in terminology serves as a cautionary example that readers must carefully examine each study's classification procedures rather than relying solely on the classification terminology that the authors used. Table 2 also shows different criteria for characterizing older children as minimally verbal. Plesa Skwerer, Jordan, Brukilacchio, and Tager-Flusberg (2016) defined minimally verbal as having a diagnosis of ASD, being older than 60 months, and producing fewer than 30 words or phrases as reported by caregivers. This study only included children who were 5 years of age or older because they defined minimally verbal as the failure to develop fluent spoken language by school age (Plesa Skwerer, Jordan, Brukilacchio, & Tager-Flusberg, 2016). This definition and specification about age aligns with the definition discussed in Kasari et al. (2013). It also emphasizes the distinction between preverbal and minimally verbal, as some researchers differentiate preverbal and minimally verbal solely by age, as preverbal being characterized by preschool age (< 60 months) and minimally verbal as school age (> 60 months) with both groups having similar language abilities.

Nonverbal IQ

Previous studies have found that cognitive skills are associated with concurrent and later language skills in children with ASD (Ellis Weismer & Kover, 2015; Bal et al., 2016). But what does the nonverbal cognitive profile of minimally verbal children with ASD look like? Bal, Katz, Bishop, and Krasileva (2016) found that minimally verbal children varied by nonverbal IQ (NVIQ) level, with the highest proportion of minimally verbal children in the severe-to-profound range of cognitive impairment. While a minority, some minimally verbal children with ASD (16%) had nonverbal cognitive skills that were estimated to be in the borderline-to-average range. Even though the majority of the participants fell under the severe-to-profound range, it is important to look at cognitive and language dimensions separately, as minimally verbal is not

synonymous with cognitive impairment, indicated by the 16% that fell in the borderline-to-average range.

In their examination of nonverbal cognitive skills, Bal and colleagues identified two subgroups of minimally verbal children -- minimally verbal children with verbal abilities similar with their nonverbal cognitive abilities and minimally verbal children with language abilities that fell below their nonverbal skills. They found these two groups differed on nonverbal cognitive ability, but not verbal abilities or language skills reported by parents. This could lead to different explanations of what contributes to a child being minimally verbal. If a child has a cognitive profile similar to their verbal abilities, their language delay may be explained by general intellectual disability. If a child has a cognitive profile greater than their language abilities, their language deficits may be due to something other than intellectual ability, such as ASD-related deficits (i.e. joint attention, imitation skills). Plesa-Skwerer, Jordan, Brukilacchio, and Tager-Flusberg (2016) also assessed broader child characteristics using the Vineland II, ADOS, and Raven matrices (Ravens; Raven et al., 1998) and found that that nonverbal IQ scores ranged from very low to above-age expectations, further demonstrating there is variability in the relation between nonverbal IQ and verbal expression. These findings suggest that the link between nonverbal cognition and language outcomes may be more complex in the minimally verbal subgroup, relative to more verbally fluent individuals with ASD

Expressive Language

Previous studies have examined language patterns in children with ASD (e.g., Charman et al., 2003; Luyster et al., 2007; Ellis Weismer et al., 2010), with very few focusing on language patterns in minimally verbal children with ASD. Findings from current literature consistently

indicate that overall, children with ASD display delays in both receptive and expressive language. Although many children with ASD pick up speed in their language development, there is significant variability and a substantial number of children experience persistent language limitations (Pickles et al., 2014). Notably, the extant language literature in children with ASD has primarily focused on expressive language.

Chaman et al. (2003) broke down the proportion of words produced by children with ASD in each vocabulary category by the total number of words produced. They reported that the distribution of words across syntactic class did not differ between children with ASD and typically developing toddlers. However, this comparison by Charman and colleagues was descriptive only and did not statistically test for differences. Haebig et al. (2020) examined the characteristics of the early expressive lexicon specifically in minimally verbal children with ASD. They found that preverbal and minimally verbal children with ASD were reported to produce a higher proportion of verbs relative to typically developing toddlers. Both typically developing toddlers and minimally verbal children with ASD displayed a noun bias. In terms of semantic category, Haebig and colleagues found that minimally verbal and preverbal children with ASD produced a smaller proportion of people words and sound effects and animal sounds compared to the typically developing group. They also found that the ASD group produced a higher proportion of food and drink words compared to the typically developing group (Haebig, Jimenez, Cox, & Hills, 2020).

Receptive Language

As stated above, most of the current research has focused on expressive language in minimally verbal children with ASD. When conducting our literature search, results only yielded

three articles that carefully examined receptive language in minimally verbal children with ASD. This limited number of studies further motivates the current student.

While little is known about receptive language in minimally verbal children with ASD, it is known that receptive language can vary greatly. Some children may have relatively good comprehension compared to their production, while others may have worse comprehension than expected compared to their production (Plesa Skwerer et al., 2016). In the few studies that have been done, Plesa Skwerer, Jordan, Brukilacchio, and Tager-Flusberg (2016) examined the challenges of assessing receptive language in minimally verbal children by comparing several adapted measurement tools. They assessed each participant using the Peabody Picture Vocabulary Test (PPVT; Dunn and Dunn, 2007), a caregiver vocabulary checklist modified from the MCDI, and the caregiver-completed Vineland-II. They chose these three assessments based on previous use and recommendations from the literature. Kasari et al. (2013) recommends using the PPVT to assess receptive language in minimally verbal children with ASD due to its psychometric properties and wide age range. Currently, the most common caregiver report of measuring receptive vocabulary is the MCDI. The Vineland Adaptive Behavior Scales is another caregiver report that has the advantage of covering the full life span and going beyond just vocabulary knowledge. Plesa Skwerer and colleagues (2016) also used a subset of words that were included in the MCDI and incorporated them into an eye-tracking test of word comprehension. They also tested word comprehension using a computerized touch-screen task.

Results from Plesa Skewer et al. (2016) showed that 11 of 18 participants displayed the highest accuracy on the touch-screen task, 2 on the eye-tracking task, and 5 participants showed the highest proportion of known words on the vocabulary checklist according to caregivers'

report. These results emphasize the need to find individualized approaches for assessing receptive language in minimally verbal children with ASD. This also emphasizes the need for more research focusing on the characteristics of receptive language specifically in minimally verbal children with ASD, so that assessments can be more tailored to this population (Plesa Skwerer et al., 2016).

Brady, Anderson, Hahn, Obermeier, and Kapap (2014) examined the feasibility of eye tracking as a measure of receptive vocabulary in minimally verbal children with ASD. Eye tracking has been used to measure preferential looking and can give information about how long one looks at a specific target as well as lag-time until fixation on a target. Eye tracking has recently been used to examine preferential looking behaviors in children with ASD. Studies have found that young children with ASD (24-60 months) have similar scanning times to socially relevant stimuli compared to typical developing peers (e.g., Anderson et al., 2006; Speer, Cook, McMahon, & Clark, 2007). Brady and colleagues applied this assessment method to receptive language. They first tested all the participants with the PPVT-4. They used the results from the PPVT-4 to create individualized stimulus sets for each participant that consisted of the four PPVT-4 practice words, followed by twelve randomized PPVT-4 words that the child correctly identified in session 1. They found that all children looked longer at pictures they previously indicated understanding on the PPVT-4 (known condition). For the unknown condition, they found no significant differences in looking at target vs. non-target pictures for the minimally verbal children with ASD group and significant differences for children in the typical development group. This study focused on the feasibility of using eye tracking as a way of assessing receptive language in minimally verbal children with ASD and found it to be feasible

with their small sample size of 14 children with ASD. More research is needed to ensure eye tracking is plausible with various levels of cognition and behaviors (Brady et al., 2014).

Yoder, Watson, and Lambert (2015) examined 87 initially nonverbal and minimally verbal preschoolers with ASD at 5 time points over 16 months to assess value-added predictors of both expressive and receptive language growth. They observed responding to joint attention, parent reported receptive vocabulary, intentional communication, autism symptomology, and parent linguistic responses to determine which predict receptive growth. Results from this study indicate that early receptive vocabulary and autism severity were value-added predictors of receptive growth. Therefore, initially nonverbal children with ASD who had lower autism severity tended to have greater growth in receptive language skills and children who had more advanced receptive vocabulary knowledge were more likely to demonstrate larger receptive language growth over time. This study highlights the need for more comprehensive research in early receptive vocabulary as it may predict receptive language growth (Yoder et al., 2015). While the above studies examined one or more aspects of receptive language knowledge in minimally verbal children with ASD, the literature is lacking characterizing information about the specific receptive language profile of minimally verbal children with ASD.

Atypical Receptive/Expressive Gap

In typical development, children exhibit a larger receptive vocabulary than expressive vocabulary. While one might expect children with ASD to follow this pattern, a significant proportion of children with ASD demonstrate an atypical pattern of receptive and expressive vocabulary knowledge. Previous studies have discussed the atypical expressive/receptive gap in children with ASD (e.g., Charman et al., 2003; Davidson & Ellis Weismer, 2017; Haebig &

Sterling, 2017; Kwok, Brown, Smyth, & Oram Cardy, 2015). The degree and magnitude of these discrepancies vary across studies; however, overall, children with ASD tend to have expressive vocabulary levels that are higher than expected given their receptive vocabulary (Woyanarski, Yoder, & Watson, 2015). This atypical profile highlights a reduced receptive advantage.

Woyanarski, Yoder, and Watson (2015) examined 87 preverbal children with ASD, between the ages of 24 and 48 months, who produced no more than 20 different words according to the CDI, and no more than 5 different words during a 15-minute language sample. Results showed that age equivalency scores for expressive vocabulary knowledge exceeded age equivalency scores associated with receptive vocabulary knowledge; thus, an atypical receptive-expressive vocabulary profile has been documented in initially preverbal children with ASD, in addition to this profile being present in the broader ASD population. More research is needed to determine why some children with ASD show disproportionate deficits in receptive vocabulary levels. For instance, Woyanarski and colleagues argued that the reduced receptive advantage could possibly “result from such children deriving less benefit from the broad range of adult linguistic input that supports receptive vocabulary learning in typically developing children” (Woyanarski, Yoder, & Watson, 2015, p. 307).

McDaniel, Yoder, Woyanarski, and Watson (2018) evaluated two theoretical predictors of the atypical receptive-expressive vocabulary gaps in initially preverbal children with ASD – the speech attunement framework and the oral motor theory. They investigated the variation in the degree of typicality of receptive-expressive vocabulary size discrepancies by examining the child’s attention to a speaker and oral motor skills. The speech attunement framework suggests that children with ASD tend to attend to the speaker less, therefore having an input-processing deficit. This framework suggests that when children with ASD pay less attention to the speaker,

they will have an atypically small receptive-expressive vocabulary size discrepancy. The oral motor theory suggests that poor oral motor performance influences the gap between receptive and expressive vocabulary. McDaniel et al. found that overall participants with ASD exhibited smaller receptive-expressive vocabulary size discrepancies than typically developing peers at the same vocabulary level. Their analyses also indicated that attention towards a speaker predicted the typicality of the gap; in contrast, oral motor performance did not predict the vocabulary size discrepancy. This is consistent with the speech attunement framework which suggests that an input-processing deficit may explain an atypically small receptive-expressive vocabulary size discrepancy (McDaniel et al, 2018).

The above studies by McDaniel and colleagues and Woyanarski and colleagues examine the receptive-expressive vocabulary profile of children with ASD and emphasize a reduced receptive advantage. Both studies highlight the need to better understand receptive vocabulary knowledge in minimally verbal children with ASD.

Current Study

The current study aims to characterize the early receptive vocabulary profile of minimally verbal children with ASD, and to examine whether it differs from typically developing toddlers. We will do this by examining parent reports of child vocabulary comprehension that were collected using the CDI Words and Gestures form. Therefore, our specific research questions are:

1. Are there differences in the semantic categories of receptive vocabulary knowledge between minimally verbal children with ASD and typically developing toddlers who are matched on expressive vocabulary knowledge or on receptive vocabulary knowledge?

2. Are there differences in the syntactic classifications of receptive vocabulary knowledge between minimally verbal children with ASD and typically developing toddlers who are matched on expressive vocabulary knowledge or on receptive vocabulary knowledge?
3. Is there a relationship between nonverbal cognitive abilities and receptive knowledge in minimally verbal children with ASD and does this association differ from that of TD?

Given the very limited knowledge in this domain, we do not have strong predictions; however, comprehension skills may mirror previously reported expressive vocabulary patterns displayed by minimally verbal children with ASD or may demonstrate similar patterns that have been reported for verbally fluent children with ASD. Therefore, if comprehension mirrors production skills documented in minimally verbal children with ASD, the current sample of minimally verbal children with ASD may understand a greater proportion of verbs than typical developing toddlers, as well as a smaller proportion of people words and sound effects and animal sounds and higher proportion of food and drink words compared to the typically developing group (Haebig et al., 2020). If comprehension follows patterns of verbally fluent children with ASD, we may see no group differences in syntactic class (Charman et al., 2003; Luyster, Lopez, & Lord, 2007).

For our last research question, previous studies have reported a relationship between IQ and language for verbally fluent children with ASD (e.g., Ellis-Weismer et al., 2015). If NVIQ and language abilities in minimally verbal children with ASD follows this same pattern, we would expect there to be a relationship between nonverbal cognitive abilities and receptive knowledge. However, studies have shown that many minimally verbal kids with ASD have a NVIQ higher than their spoken communication (Bal et al., 2016). If receptive knowledge follows this same

pattern, we would predict that there is either no relationship or a weak relationship between nonverbal cognitive abilities and receptive knowledge.

CHAPTER 2. METHODS

Participants

We examined the receptive vocabulary profiles of 31 minimally verbal children with ASD (MV-ASD), and then compared this receptive profile to 124 toddlers with typical language development who were matched on expressive vocabulary and 124 typically developing toddlers who were matched on receptive vocabulary, using word-level data collected from the CDI-WG.

The sample of children with ASD was obtained from the National Database for Autism Research (NDAR; National Institute of Mental Health, n.d., Tifford & Ungar 2016). All participants had a diagnosis of ASD from the ADOS; ADI-R data were also collected for 29 of the 31 minimally verbal children with ASD. The typically developing (TD) group was obtained from Wordbank (Frank, Baginsky, Yurovsky, and Marchman, 2017), a public repository. WordBank is a publicly available database comprised of data from various studies. These children may have been screened for developmental delays, but there is no reporting of developmental testing to confirm typical development. Our expressive-matched sample was matched on expressive vocabulary size, measured using the CDI-WG ($M_{ASD} = 2.84$, $M_{TD} = 2.82$; $t(153) = -0.03$, $p = .979$; Cohen's $d = 0.007$; variance ratio = 1.01). Our receptive-matched sample was matched on receptive vocabulary size, measured using the CDI-WG ($M_{ASD} = 141.23$, $M_{TD} = 137.03$; $t(153) = -0.28$, $p = 0.781$; Cohen's $d = 0.055$; variance ratio = 1.29).

All participants in the MV-ASD group and expressive vocabulary-matched TD group were reported to produce between 0-10 words on the CDI-WG. Participants in the receptive vocabulary-matched TD group were reported to produce between 0-164 words and understand between 24-278 words. Because other developmental data are not available to confirm that the TD toddlers did not have developmental delays, we only included toddlers who scored between

the 45th and 55th percentile according to the CDI-WG normative data; percentiles were applied for the matching domain (e.g., word production percentiles for the expressive vocabulary-matched TD group, word comprehension normative percentiles for the receptive vocabulary-matched group). This is a much more stringent criteria than including children who scored within one standard deviation of the mean. Studies have shown that children scoring at or below the 10th percentile demonstrate significant language delay (D’Odorico, Assaneelli, Franco, and Jacob, 2007; Ellis-Weismer et al., 2011; Heilman, Ellis Weismer, Evans, Hollar, 2005). We followed a stringent definition of minimally verbal. To be included in the minimally verbal ASD group, each participant needed to have a complete CDI-WG with word-level information, a documented ASD diagnosis, be 60 months of age or older, and produce between 0-10 words. To be included in the TD group, each participant had to have a complete CDI with word-level information, and score between the 45th and 55th percentile according to the CDI-WG.

Receptive Vocabulary Assessment

We used the CDI-WG form that assessed production and comprehension of American English words. This form contains 396 words and was normed on children between 8 and 18 months. The CDI-WG is a parent checklist of early language competence that has the most complete standardization data and has been the most widely used in the literature. The CDI-WG form contains two parts. Part 1 asks the respondent to mark how many of 28 short statements, questions, or phrases the child understands, asks two questions about the frequency of the child’s labelling and imitation of words, and has a 396-item vocabulary checklist. Caregivers can indicate that the child either understands or understands and says each of the 396 words listed. The words are organized in 19 categories such as sound effects and animal sounds, animal

names, food and drink, and action words. We will examine syntactic class in terms of nouns and verbs. The nouns categorized by the CDI will be comprised in the following categories: Animals, Vehicles, Toys, Food and Drink, Clothing, Body Parts, Furniture and Drink, and Small Household Items, following (Bates et al., 1994). Verbs will consist of the words that are classified as Action Words on the CDI (55 words), Adjectives will consist of Descriptive words and Closed Class words will consist of Pronouns, Question words, Prepositions, and Quantifier words. Part 2 asks about the child's production of gestures.

Cognition

The Mullen Scales of Early Learning (MSEL; Mullen, 1995) was used to obtain estimates of nonverbal mental age for children in the ASD group. The MSEL is a developmental test intended for children between the ages of 1 and 68 months. Similar to Ellis Weismer and colleagues (2010) and Yoder and colleagues (2015), we will use the Fine Motor and Visual Reception subtests to give us NVIQ age equivalence values. Other subtests of the MSEL include Gross Motor, Expressive Language, and Receptive Language. While age equivalence is not always ideal due to this group's low development level, this allows us a general estimation and gives us important context of the child's development (Koegel et al., 2020). Table 3 provides information about the ASD and TD groups.

Table 3. Group Participant Characteristics

	Minimally Verbal Children with ASD (<i>n</i> = 31; 8 females)			Expressive Vocabulary-Matched Toddlers (<i>n</i> = 124; 32 females)			Receptive Vocabulary-Matched Toddlers (<i>n</i> = 124; 67 females)		
	<i>M</i>	<i>SD</i>	Range	<i>M</i>	<i>SD</i>	Range	<i>M</i>	<i>SD</i>	Range
Chronological Age (months)	75.71	13.37	60-118	10.77	2.29	9-14	13.78	2.56	8-18
Words Produced	2.84	3.001	0-10	2.82	2.98	0-10	25.97	35.66	0-164
AE – WP ¹	10.84	1.49	9-13	10.75	1.75	9-13	13.21	2.29	9-17
Words Understood	141.26	91.81	18-382	60.15	53.89	1-232	137.03	71.25	24-278
AE – WU ²	13.36	2.42	8-18	11.46	2.28	8-17	13.05	2.49	8-17
Nonverbal Mental Age	24.79	5.45	8.5-35						
ADOS Severity Score ³	7.55	1.26	6-10						

Note¹ There was missing data for age equivalency of words produced for 3 children in the Minimally Verbal ASD group and for 8 children in the receptive-matched group. If we used one month below or above the nearest age equivalency as an estimate, the averages would then be 13.52 and 13.65 respectively.

Note² There was missing data for age equivalency of words understood for 10 children in the receptive-matched group and 40 children in the expressive matched group. If we used one month below or above the nearest age equivalency as an estimate, the averages would be 13.53 and 10.02 respectively.

Note³ ADOS severity scores range from 1 to 10, with higher scores indicating more severe ASD characteristics.

Analysis Plan

For our first two research aims, we classified words according to semantic and syntactic categories and calculate the proportion of words that the child understands within that category out of each individual child's receptive vocabulary size. We assessed semantic categories only when at least 5% of children in at least one group were reported to understand at least one word in the category. We planned to assess the syntactic categories of nouns, verbs, adjectives, and closed classes by also comparing the proportion each child understands, relative to each individual child's receptive vocabulary size. Before conducting statistical analyses, we checked for parametric assumptions, such as normal distributions of data, and use a parametric test when appropriate. All of our models failed to meet at least one criterion for nonparametric test use (e.g. skewness, heteroscedasticity, and kurtosis). For our third research question, we planned to conduct a bivariate correlation to examine the association between mental age (age equivalent scores derived from the MSEL) and the number of words understood for the ASD group. We did not have information on nonverbal cognitive skills for the typically developing group; therefore, we primarily focused on the ASD group when addressing the third research question. However, because we strictly restricted the range of percentile scores for expressive vocabulary knowledge, we can assume that nonverbal mental age scores may be similar to chronological

age. Therefore, we also planned to conduct an exploratory analysis to examine the correlation between chronological age and the number of words understood in the typically developing group with the goal of descriptively comparing it to the correlation derived for the minimally verbal ASD group.

CHAPTER 3. RESULTS

Our first two research questions asked if there are differences in semantic and syntactic categories of receptive knowledge between minimally verbal children with ASD and typically developing toddlers matched on expressive and receptive vocabulary. We assessed the two comparison groups separately to better understand the composition of minimally verbal children with ASD's receptive vocabularies. In both comparison groups, we assessed the proportion of words understood in terms of syntactic class and semantic categories relative to each child's unique receptive vocabulary size.

Semantic Categories

Semantic Comparisons: MV-ASD vs. TD Expressive Vocabulary-Matched Groups. We examined whether the proportion of words understood across the semantic categories differed by group. The proportion of words produced across the nineteen semantic categories that were identified to contain sufficient data (see Analysis plan section) were compared between the groups using separate Wilcoxon rank-sum tests, with Bonferroni-corrected p values. All semantic categories met our criteria, with at least 14% of children in either group understanding at least one word in each category. In the production matched group, there were no significant group differences for eight categories including animals, household items, and food and drink. There were group differences for nine categories. Most notably, differences were found for action words, games and routines, people words, and sound effects and animal sounds. Other categories with group differences included outside words, furniture, body parts, and quantifiers. The full summary of Wilcoxon rank sum results for the expressive vocabulary-matched group is shown in Table 4. Figure 1 displays a bar plot comparing each semantic category in the MV-

ASD group and TD expressive vocabulary matched group. MV children with ASD understood a greater proportion of action words, body parts, clothing, furniture, quantifiers, prepositions and location words, quantifiers, vehicles, and outside words relative to TD toddlers. MV children with ASD understood a smaller proportion of games and routine words, people words, and sound effects and animal sounds compared to the TD group. Because the proportion values are influenced by the number of words understood within each category relative to the full receptive vocabulary size, we also took into account the raw counts of each category in both groups. The full list of raw number of words is noted in Table 5.

Table 4. Semantic Comparisons: MV-ASD vs. TD Expressive Vocabulary-Matched Groups Wilcoxon rank sum results (full list)

Category	<i>W</i>	<i>p</i>	Difference	Category	<i>W</i>	<i>p</i>
Action Words	2950.5	< .001*	ASD > TD	Food and Drink	2348.5	.054
Body Parts	2588	.002*	ASD > TD	Household Items	2142	.325
Prepositions	2610.5	.001*	ASD > TD	Time Words	2325	.008
Quantifiers	2692	< .001*	ASD > TD	Toys	1808	.609
Outside Words	2828	< .001*		Animals	2044.5	.581
Furniture and Rooms	2752	< .001*	ASD > TD	Descriptive Words	2299.5	.088

(table cont'd)

Category	<i>W</i>	<i>p</i>	Difference	Category	<i>W</i>	<i>p</i>
Sound Effects and Animal Sounds	1125	< .001*	TD > ASD	Clothing	2584.5	.0027
Games and Routine	947.5	< .001*	TD > ASD	Vehicles	2560	.0029
People Words	523	< .001*	TD > ASD	Pronouns	2340.5	.018
				Question Words	1948	.879

Note. *Significance set to *p*-values below *p* = 0.0026

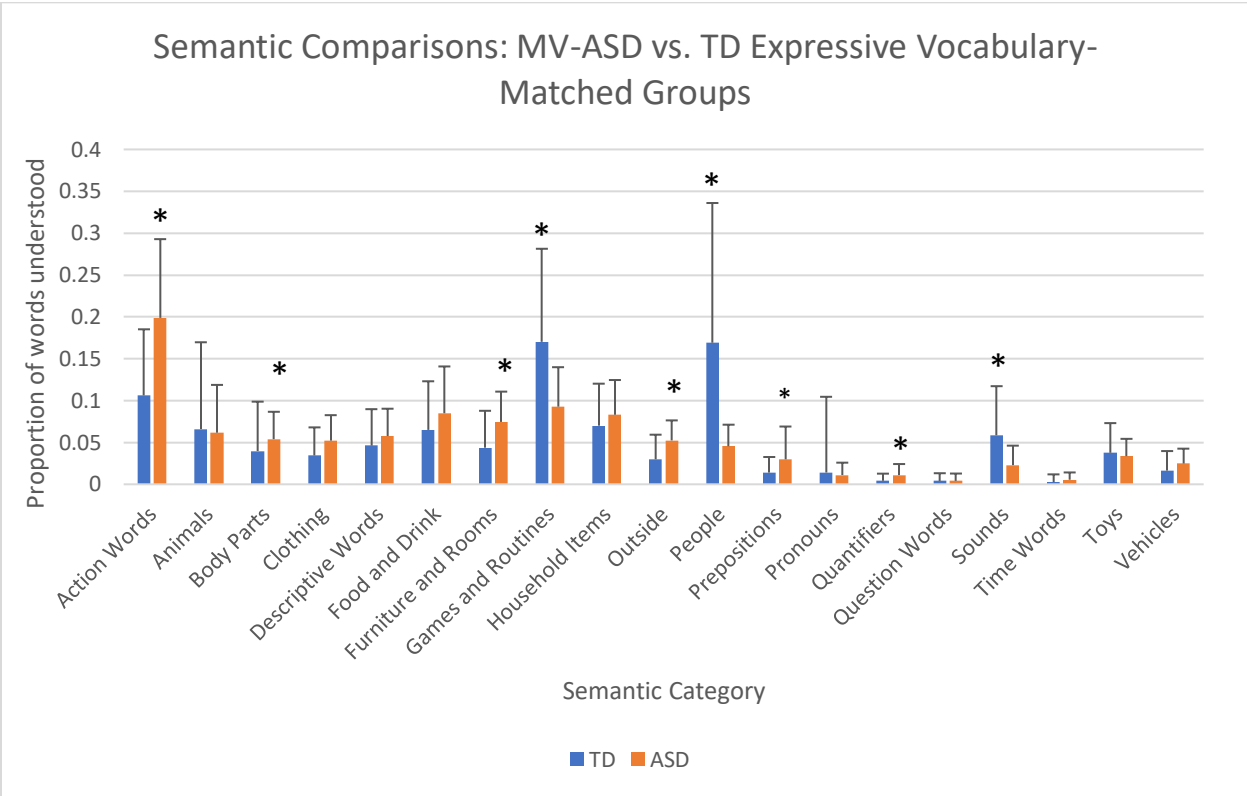


Figure 1. Semantic Comparisons: MV-ASD vs. TD Expressive Vocabulary-Matched Groups Bar Plot

Table 5. Semantic Comparisons: MV-ASD vs. TD Expressive Vocabulary-Matched Groups Raw Count Averages

Semantic Category	MV-ASD group	TD Expressive-Vocabulary Matched group
Action Words	25.13	10.28
Animals	13.67	5.43
Body Parts	10.56	5.27
Clothing	7.41	4.19
Descriptive Words	10.07	5.76
Food and Drink	13.67	6.88
Furniture and Rooms	10.1	6.03
Games and Routine	11.37	7.86
Household Items	12.53	6.48
Outside Words	9.07	4.25
People Words	6.93	5.34
Prepositions and Locations	4.38	2.88
Pronouns	4.86	2.66
Quantifiers	2.09	1.47
Question Words	3.38	1.37
Sound Effects and Animal Sounds	4.82	3.72
Time Words	2.91	1.72
Toys	4.89	3.21
Vehicles	4.42	2.55

Semantic Comparisons: MV-ASD vs. TD Receptive Vocabulary-Matched Groups. In the comprehension matched group, there were no group differences in eighteen categories including action word, body parts, food and drink, games and routines, and people words. There were group differences in sound effects and animal sounds. MV children with ASD understood a smaller proportion of sound effects and animal sounds compared to the TD group. Table 6 displays the full Wilcoxon rank sum results for the receptive vocabulary-matched group and figure 2 displays the bar plots comparing each group.

Table 6. Semantic Comparisons: MV-ASD vs. TD Receptive Vocabulary-Matched Groups
Wilcoxon rank sum results (full list)

Category	<i>W</i>	<i>p</i>	Difference	Category	<i>W</i>	<i>p</i>
Sound Effects and Animal Sounds	834.5	< .001*	TD > ASD	Toys	1434	.029
Action Words	2390	.037		Games and Routine	1645.5	.217
Animals	1799	.583		Household Items	1624.5	.184
Body Parts	1894	.904		Outside Words	2591.5	.003
Descriptive Words	1590	.138		People Words	1506.5	.063
Food and Drink	2056.5	.548		Prepositions	1800.5	.567
Clothing	2128.5	.357		Pronouns	1727	.367
Furniture and Rooms	2205.5	.206		Question Words	1509	.427
Vehicles	2074	.487		Quantifiers	2079.5	.474
				Time Words	2175	.159

Note. *Significance set to *p*-values < 0.0026

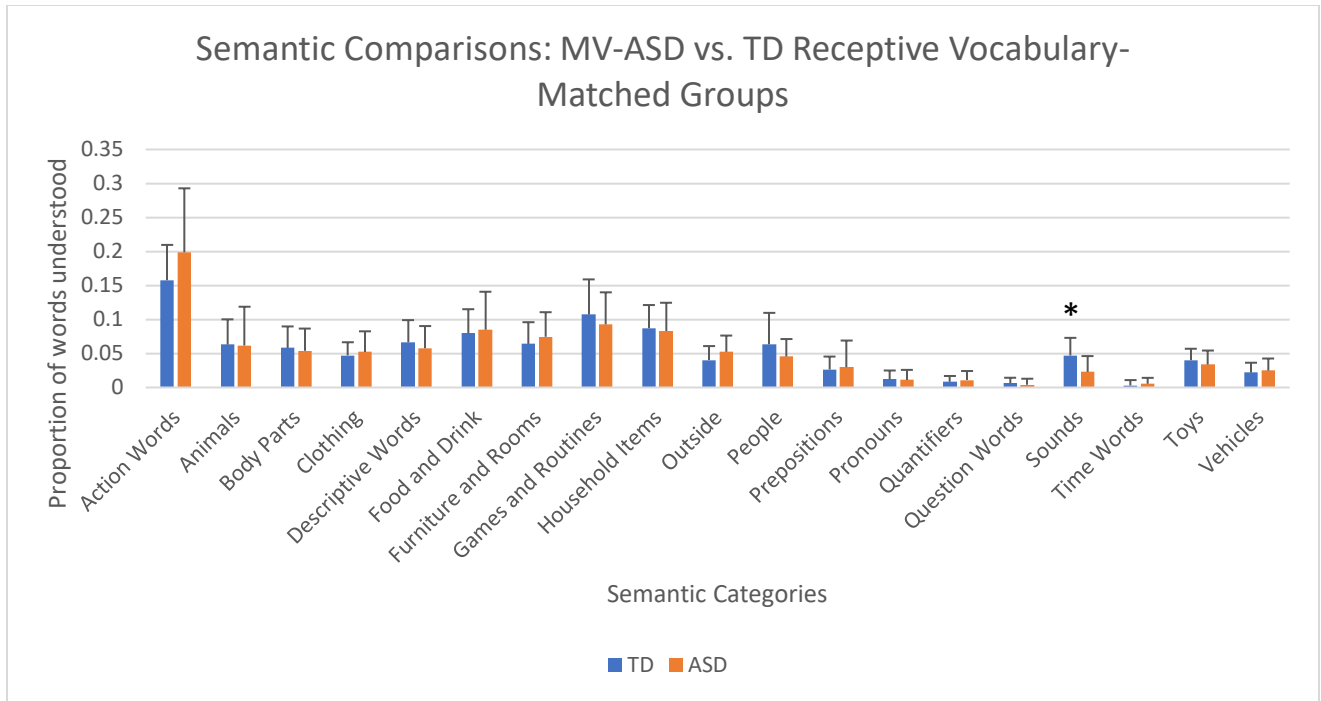


Figure 2. Semantic Comparisons: MV-ASD vs. TD Receptive Vocabulary-Matched Groups Bar Plot of Proportions

Syntactic Class

Syntactic Comparisons: MV-ASD vs. TD Expressive Vocabulary-Matched Groups We conducted Wilcoxon rank-sum tests to analyze group differences between the productions of nouns, verbs, adjectives, and closed classes. In the production matched group, there were significant group differences in the proportion of verbs and nouns understood. Children with ASD understood a higher proportion nouns and verbs relative to the TD group. There were no group differences in the proportion of words understood for adjectives or closed class words. Table 7 displays the full Wilcoxon rank sum results for the expressive vocabulary-matched group and Figure 3 displays bar plot comparisons of the MV ASD and TD expressive vocabulary-matched group.

Table 7. Syntactic Comparisons: MV-ASD vs. TD Expressive Vocabulary-Matched Groups Wilcoxon rank sum results (full list)

Syntactic Class	<i>W</i>	<i>p</i>	Difference
Verbs	2995.5	<.001*	ASD > TD
Nouns	2499.5	.009*	ASD > TD
Adjective	2299.5	.088	
Closed Class	2299.5	.088	

Note. *Significance set to *p*-values below $p = 0.0125$

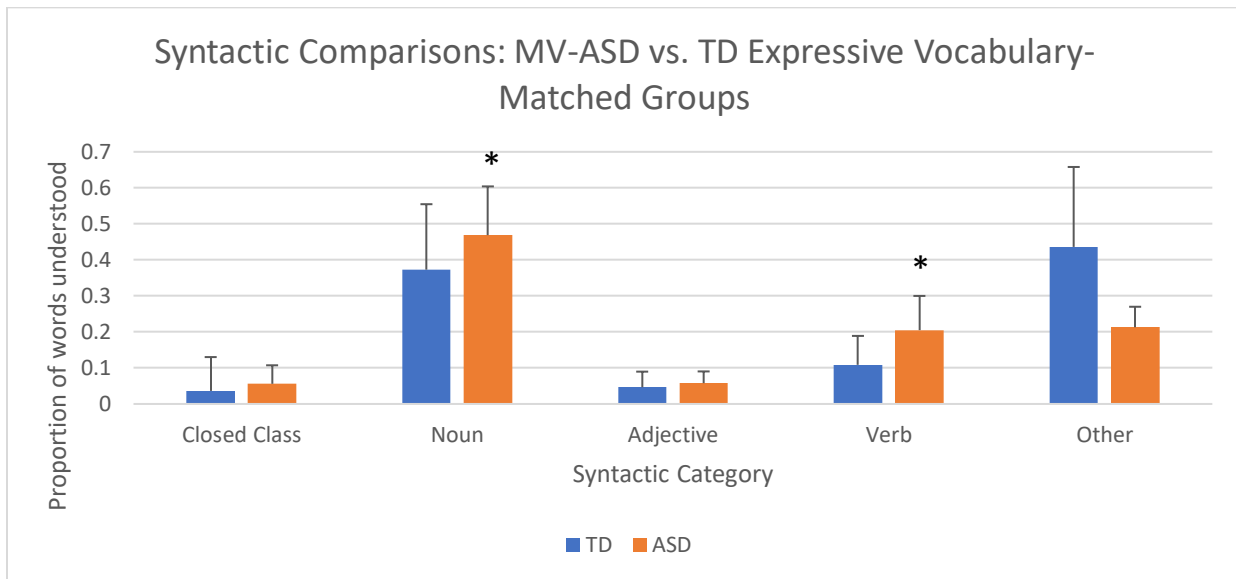


Figure 3. Syntactic Comparisons: MV-ASD vs. TD Expressive Vocabulary-Matched Groups Bar Plot of Proportions

Syntactic Comparisons: MV-ASD vs. TD Receptive Vocabulary-Matched Groups. In the comprehension matched group, there were significant group differences in the proportion of verbs ($W = 2455, p < .001$) understood; children with ASD understood a higher proportion of verbs compared to the TD group. There were no group differences in the proportion of nouns, adjectives, or closed class words understood. Table 8 displays the full Wilcoxon rank sum results for the receptive vocabulary-matched group.

Table 8. Syntactic Comparisons: MV-ASD vs. TD Receptive Vocabulary-Matched Groups
Wilcoxon rank sum results (full list)

Syntactic Class	<i>W</i>	<i>p</i>	Difference
Verbs	2455	< .001*	ASD > TD
Nouns	1945	.919	
Adjective	1590	.132	
Closed Class	1845	.733	

Note. *Significance set to *p*-values below $p = 0.0125$

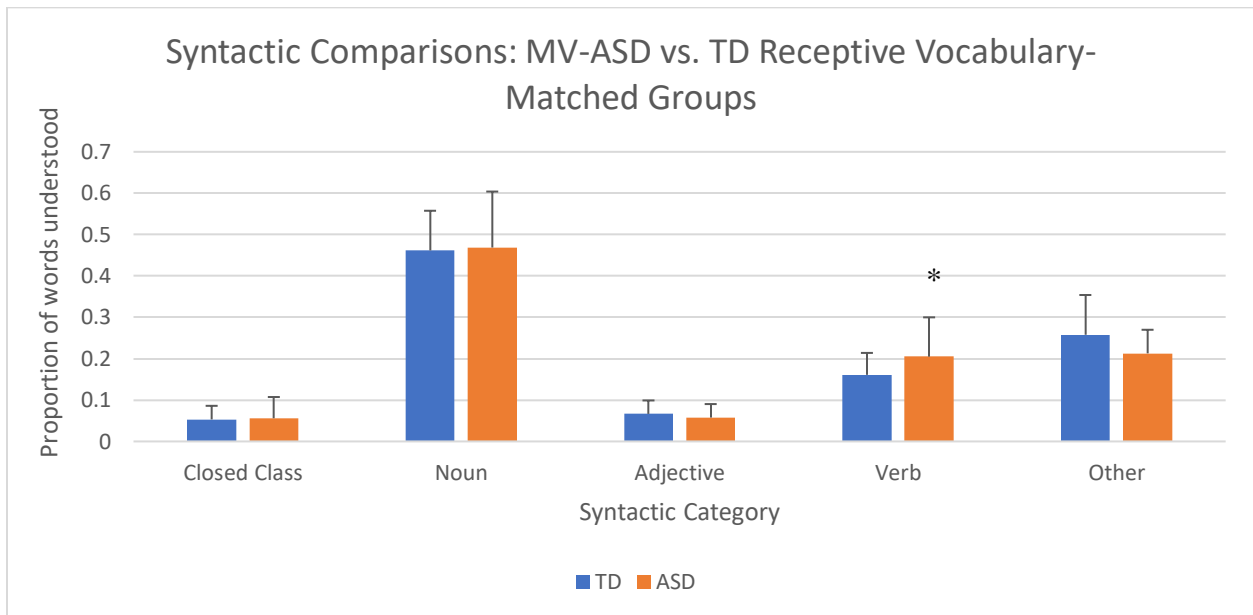


Figure 4. Syntactic Comparisons: MV-ASD vs. TD Receptive Vocabulary-Matched Groups Bar Plot of Proportions

Nonverbal IQ

Our third research question asked if there was a relationship between nonverbal cognitive abilities and receptive knowledge in minimally verbal children with ASD and whether this association differs from that of the TD group. There was not a significant correlation between mental age and words understood in the MV ASD group ($r = 0.286, p = .119$). Figure 5 displays

a scatterplot of nonverbal age equivalent scores and receptive vocabulary size. As shown in the scatterplot, there is no association between mental age and receptive vocabulary size for the MV-ASD group.

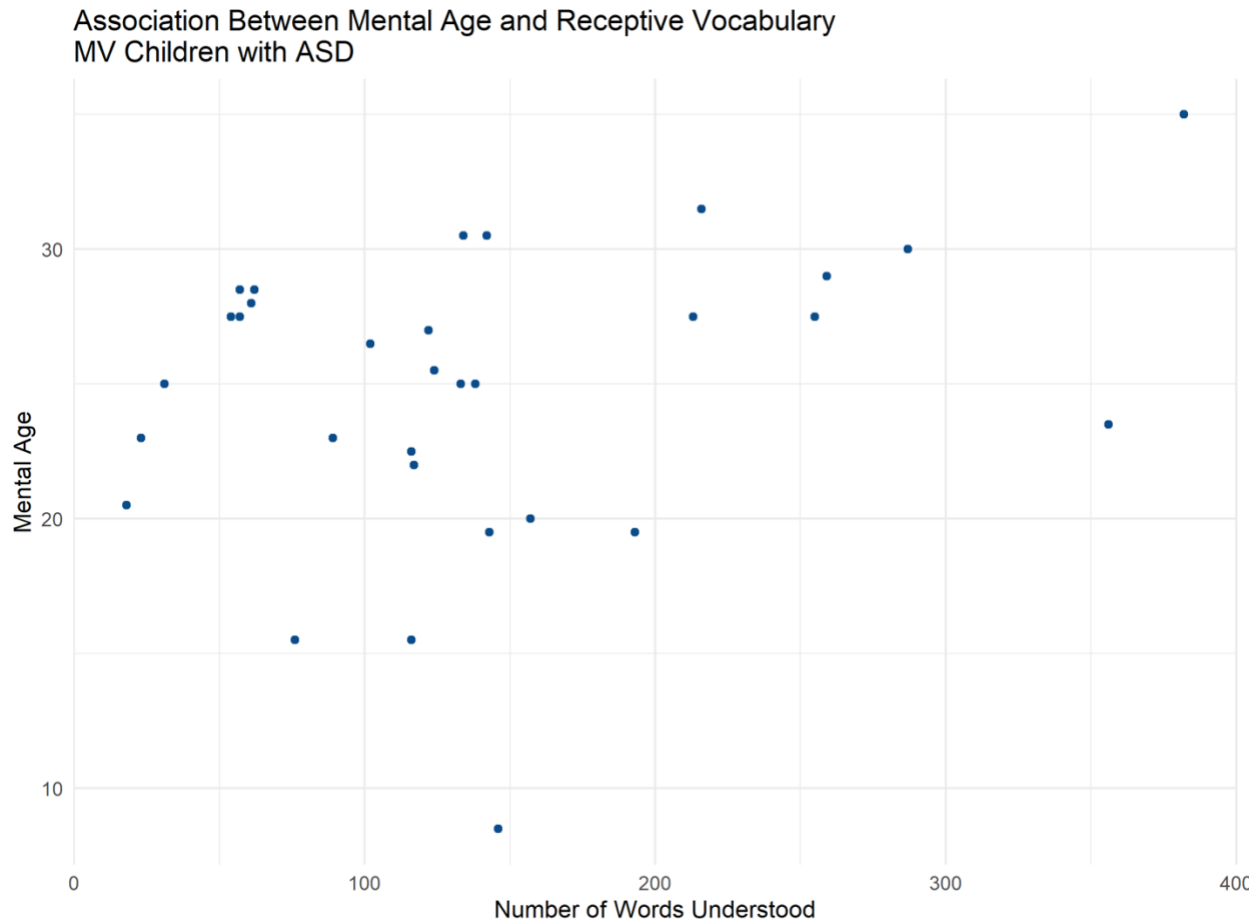


Figure 5. MV ASD group: Association between mental age and receptive vocabulary Scatterplot

We do not have information on nonverbal cognitive skills for the typical developing group, but because they were between 45th and 55th percentile we will the assumption that their mental age matchers chronological age. In order to explore the association between their developmental state and receptive vocabulary, we ran a bivariate correlation between chronological age and receptive vocabulary for each TD comparison group. For the production matched group, there is a moderate positive correlation ($r = 0.517, p < .001$) between age and

receptive vocabulary size. As these children are getting older, their receptive vocabulary size is increasing. For the comprehension matched group, we found a strong correlation ($r = 0.975, p < .001$), indicating a positive relationship between age and words understood. See figures 6 and 7 for scatterplots displaying the association between age and receptive vocabulary for both the expressive and receptive matched groups.

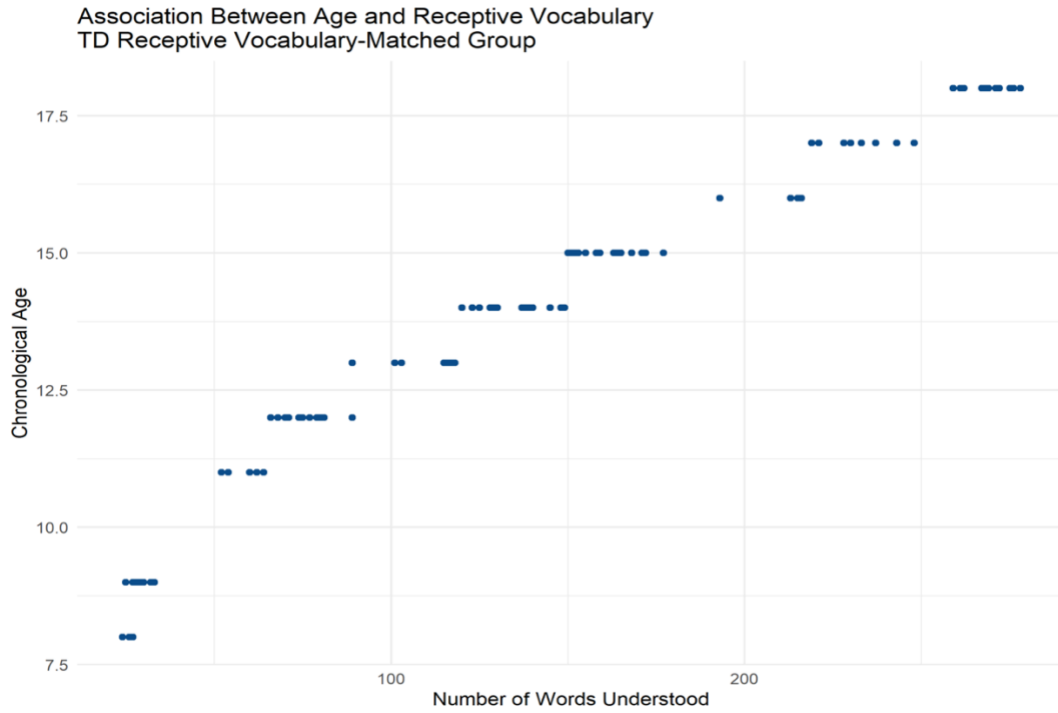


Figure 6. TD receptive vocabulary matched group: Association between age and receptive vocabulary scatterplot

Association Between Age and Receptive Vocabulary
TD Expressive Vocabulary-Matched Group

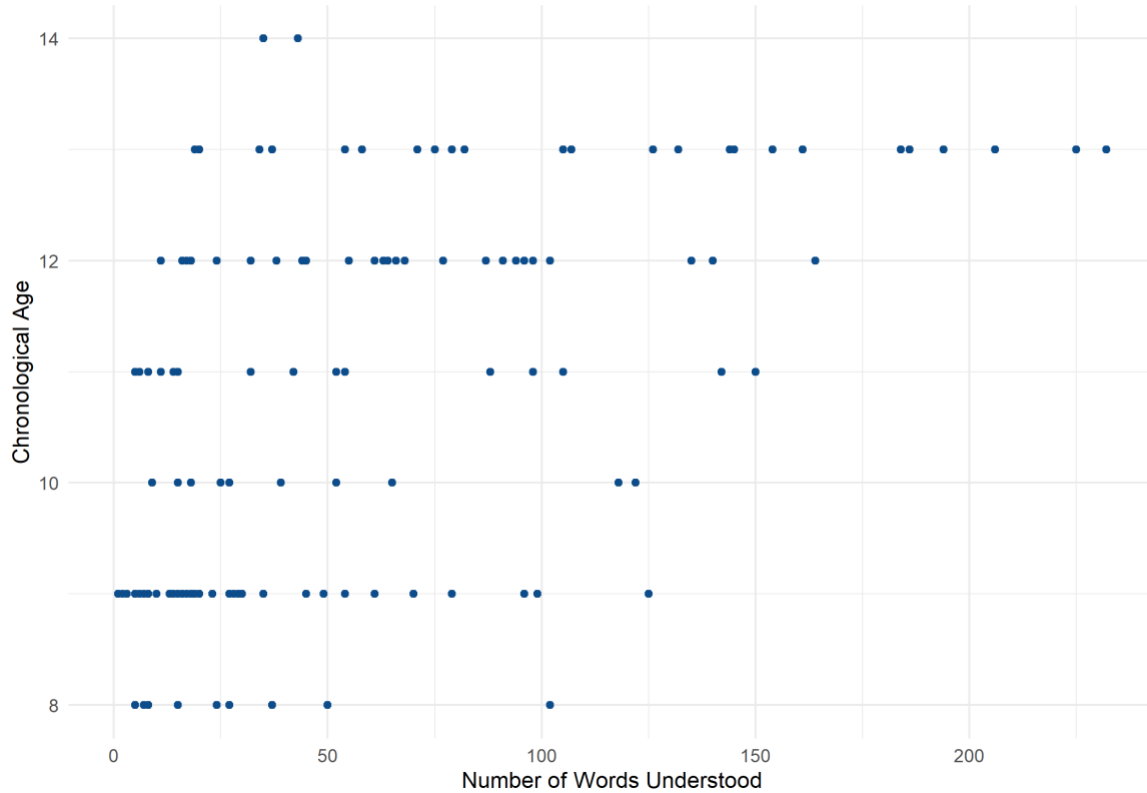


Figure 7. TD expressive vocabulary matched group: Association between age and receptive vocabulary scatterplot

CHAPTER 4. DISCUSSION

The current study compared the early receptive vocabulary profile of minimally verbal children with ASD to two separate groups of typically developing toddlers who were matched on either expressive or receptive vocabulary size. We defined receptive vocabulary profile in terms of syntactic and semantic categories according to the CDI Words and Gestures form. In addition, we examined the association between mental age and receptive vocabulary size. We found several differences within the semantic profile relative to the expressive-matched TD group, but only one difference in the receptive-matched TD comparison group. When comparing syntax, both comparison groups showed a difference in verbs; however, the expressive-matched TD group also displayed differences in nouns. Additionally, we saw a difference in relationships between developmental stage and receptive vocabulary size. In the text that follows, we will discuss our results relative to the extant literature.

Semantics

Our first research question asked if there were differences in the semantic classifications of receptive vocabulary knowledge between minimally verbal children with ASD and typically developing toddlers. When matched on expressive vocabulary, minimally verbal children with ASD understood a greater proportion of action words, body parts, furniture, quantifiers, prepositions and location words, and outside words relative to TD toddlers. Minimally verbal children with ASD understood a smaller proportion of games and routine words, people words, and sound effects and animal sounds compared to the TD-expressive matched group. When matched on receptive vocabulary, minimally verbal children with ASD understood a smaller proportion of sound effects and animal sounds compared to the TD group. Our initial predictions

were that if comprehension mirrors production in minimally verbal children with ASD, results will mirror those from Haebig et al. (2020). Haebig et al. reported that minimally verbal children with ASD produced a smaller proportion of sound effects and animal sounds, animal words, and people words; they also produced a proportion of food and drink words. In the current study, both comparison groups found differences in sound effects and animal sounds, but only the expressive group found differences in people words. Neither group found differences in food or drink words, and this difference would still not be significant for either group even if we did not control for multiple comparisons using a Bonferroni correction. These results imply that comprehension in minimally verbal children may not perfectly mirror their production. Interestingly, the two comparison groups revealed very different overlap between the MV ASD group. The receptive-vocabulary matched group almost mirrored the MV ASD group exactly, with the exception of one category. The expressive-vocabulary matched group, however, displayed several differences in the receptive vocabulary profiles compared to the MV ASD group. This suggests expressive vocabulary matching may not be the most appropriate comparison.

As previously discussed, there is large variability in receptive language knowledge in the current literature. Additionally, verbal children with ASD tend to display a reduced receptive advantage (Davidson & Ellis Weismer, 2017; Haebig & Sterling, 2017), as well as initially preverbal children (McDaniel et al., 2018). Demonstration of this atypical gap in initially preverbal children provided large motivation for our study; however, interestingly in our very strict criteria for the minimally verbal group, these older kids, on average, do not show a reduction in a receptive advantage. The MV-ASD sample had a receptive age equivalency of 14 months and expressive age equivalency score of 11 months. Both the expressive-vocabulary

matched and receptive-vocabulary matched comparison groups had average receptive and expressive age equivalency scores within 1 month of each other, while the MV-ASD group displayed receptive vocabulary age equivalency scores that were around 3 months more advanced than expressive vocabulary age equivalency scores. While it is clear that minimally verbal children with ASD display reduced receptive and expressive skills, they did not display a reduced receptive advantage. Therefore, it may be best to consider skills of typically developing children who are matched on receptive vocabulary size when evaluating or setting goals for receptive vocabulary knowledge in minimally verbal children with ASD. Our findings that the minimally verbal children with ASD demonstrated similar semantic knowledge relative to the TD receptive vocabulary-matched group also suggests that matching on receptive vocabulary knowledge is likely the most appropriate approach.

Syntax

Our second research question asked if there were differences in the syntactic classifications of receptive vocabulary knowledge between minimally verbal children with ASD and typically developing toddlers. When matched on expressive vocabulary, the ASD group understood a larger proportion of nouns and verbs relative to the TD group. When matched on receptive vocabulary, the ASD group understood a larger proportion of verbs relative to the TD group. Our initial predictions were that if comprehension mirrors production skills documented in minimally verbal children with ASD the current sample of minimally verbal children with ASD would understand a greater proportion of verbs than typical developing toddlers (Haebig et al., 2020), and if comprehension mirrors some reports of verbally fluent children with ASD we would see no group differences in syntactic class (Charman et al., 2003). While the receptive-matched group mirrors results from Haebig et al. (2020), we see differences in both verbs and

nouns in the expressive-matched group. It was observed that all groups displayed a noun bias, however both the expressive and receptive matched comparison groups understood a large proportion of “other words”. Other words included people words and sound effects and animal sounds. As may be expected, children’s earliest words fall under the other category and the smaller overall receptive vocabulary size for the TD expressive-vocabulary matched group influenced the observed proportions. The difference in the denominator values for each child’s receptive vocabulary knowledge influenced the proportions; this detail led us to descriptively examine the raw word counts across each category and group. Although group proportions may have differed substantially, these proportional differences sometimes only equated to small differences in raw word counts.

In addition, there were notable differences in the proportion of verbs understood by minimally verbal children with ASD compared to typical developing toddlers. Minimally verbal children with ASD understood a larger proportion of verbs in both comparison groups. This aligns with previous studies (Haebig et al., 2020, Jimenez, Haebig, & Hills, 2020); however, there is a large gap in the literature about how minimally verbal children with ASD learn verbs. Age differences may explain why minimally verbal children with ASD understand proportionally more verbs; the MV ASD group was older and could have experienced more exposure to verbs. Children in the MV ASD group may also have more exposure to full sentences that include verbs from adults and other children due to their increase age. This emphasizes the need to further examine language patterns in this specific population, specifically what factors influence verb learning.

Receptive Language Profiles

As discussed above, there were a number of differences between the minimally verbal ASD group and the expressive-vocabulary matched TD group in the semantic category. The receptive-vocabulary matched TD group, however, only displayed differences in one semantic category. Given our results displayed similarities and differences, what does this tell us? With the exception of two categories across syntax and semantics, minimally verbal children with ASD display a similar receptive vocabulary profile to typical developing toddlers matched on receptive vocabulary skills. While these groups had large differences in mental age, chronological age, and expressive vocabulary sizes, their receptive profiles were similar. This suggests minimally verbal children with ASD develop receptive vocabulary knowledge in a similar pattern as typically developing children, just delayed. By examining both expressive and receptive matched comparison groups, we were able to demonstrate the importance of choosing an appropriate comparison group for future studies. These results provide insight to what the most appropriate point of comparison is when determining what to expect for a minimally verbal child, and that future studies should consider using a receptive vocabulary-matched comparison group when examining receptive vocabulary.

Nonverbal IQ

For our third research question, we asked if there was a relationship between nonverbal cognitive abilities and receptive vocabulary knowledge in minimally verbal children with ASD and if this association differs from that of typically developing toddlers. We found no association between mental age and receptive vocabulary for the minimally verbal ASD group. Previous studies examining NVIQ have reported mixed results. Ellis-Weismer et al. (2015) found a relationship between a mixed group of verbally fluent and minimally verbal children with ASD and IQ. Bal et al. (2016) found that minimally verbal children with ASD varied by NVIQ,

ranging from severe to average. The average mental age of the MV ASD group was 24.79 and the average chronological age was 75.71 months. While this mental age is considerably below chronological age, there was large variability between mental age and receptive vocabulary size, demonstrating no association. The range of mental age was 8.5-35 months, further demonstrating large variability and lower mental age relative to chronological age. The current study demonstrated that the relationship between mental age and receptive vocabulary size in minimally verbal children with ASD and typically developing children does not look the same.

Clinical Implications

The current study provides valuable information on how to guide clinical practice of professionals working with minimally verbal children with ASD. Few studies have focused on receptive knowledge, especially in the specific population of minimally verbal children with ASD, and results from the current study provide information about what type of words minimally verbal children with ASD understand. When thinking of targets while treating this population, clinicians should refer to what is known about a child's receptive vocabulary knowledge and pick targets that are appropriate for the receptive vocabulary level instead of targets that may be based only on the child's expressive vocabulary knowledge. It also seems important for clinicians to target receptive and expressive vocabulary separately so that they do not target words the child already understands. Our results also showed that the MV-ASD group did not display a reduced receptive advantage, as we might have expected. This can guide clinicians to more closely examine receptive knowledge when working with minimally verbal children with ASD and determine appropriate goals given each child's specific receptive knowledge. While there is a clear reduced mental age and delayed receptive and expressive

skills, it is important to consider receptive and expressive skills separately when determining specific goals.

Limitations

There were several limitations in this study. First, the study included a small ASD sample size ($n = 31$). Second, comprehension can be hard to measure relative to production. The current study used the CDI Words and Gestures form to measure comprehension, which is a parent questionnaire. While there are many benefits to parent questionnaires, it is harder to control biases that could influence accuracy as opposed to production. Third, we did not have information regarding the nonverbal IQ of the typically developing comparison groups due to using WordBank, a public repository, to obtain our comparison group. We addressed this limitation by using a strict range of percentile scores for vocabulary knowledge and assumed that nonverbal mental age scores are similar to chronological age.

Conclusion

This study contributed to a current gap in the literature of minimally verbal children with ASD. By examining the semantic and syntactic categories understood by minimally verbal children with ASD, we were able to determine that there were many similarities to typically developing children who understood a similar number of words. This was not the case when comparing minimally verbal children with ASD to typically developing children who were matched on expressive vocabulary abilities. Notably, there was a distinction between the MV-ASD group and the TD groups in verb knowledge, aligning with findings from Haebig and colleagues (2020); minimally verbal children with ASD were reported to understand more verbs relative to both TD groups. Our results give new insight into future research using receptive-

vocabulary matched groups as a point of comparison, as we identified significant overlap between the two groups. Our findings suggest the receptive profile of minimally verbal children with ASD follows a similar path to typically developing toddlers when matched on receptive-vocabulary knowledge. Due to the limitations of this study and limited findings in the current literature, further research is needed to understand how minimally verbal children with ASD learn verbs and how their language patterns differ from typically developing toddlers.

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