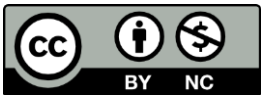

Cite as: Haebig, E., Jimenez, E., Cox, C. R., & Hills, T. T. (In press). Characterizing the Early Vocabulary Profiles of Preverbal and Minimally Verbal Children with Autism Spectrum Disorder. *Autism.*

Characterizing the Early Vocabulary Profiles of Preverbal and Minimally Verbal Children with Autism Spectrum Disorder

Eileen Haebig[1], Eva Jiménez[2], Christopher R. Cox[3], Thomas T. Hills[2]

[1] Department of Communication Sciences and Disorders, Louisiana State University

[2] Department of Psychology, University of Warwick

[3] Department of Psychology, Louisiana State University

Author Emails: Eileen Haebig (ehaebig1@lsu.edu), Eva Jiménez (e.jimenez-mesa@warwick.ac.uk), Christopher R. Cox (chriscox@lsu.edu), Thomas T. Hills (t.t.hills@warwick.ac.uk)

Correspondence concerning this article should be addressed to Eileen Haebig, Department of Communication Sciences and Disorders, Louisiana State University, 80 Hatcher Hall, Baton Rouge, 70803, United States, phone: (225) 578-5356, ehaebig1@lsu.edu.

Abstract

Children with autism spectrum disorder (ASD) often have significant language delays. But do they learn language differently than neurotypical toddlers? We compared the lexical skills of 64 preverbal and minimally verbal children with ASD, to 461 vocabulary-size-matched typically developing (TD) toddlers. We also examined social features of verb knowledge using a novel collection of social ratings. Children with ASD produced proportionally more verbs than TD toddlers. Children with ASD produced proportionally more action and food words, while TD toddlers produced proportionally more animal, people words, and animal sounds and sound effects. Children with ASD also produced "mommy" and "daddy" at lower rates. We discuss how these differences may reflect an association between lexical development and weaknesses in social communication.

Keywords: Autism Spectrum Disorder, Preverbal, Minimally Verbal, Vocabulary

Lay Abstract

Although preverbal and minimally verbal (PV-MV) children with autism spectrum disorder (ASD) represent a significant portion of the ASD population, we have a limited understanding of and characterization of them. Though it is a given that their lexical profiles contain fewer words, it is important to determine whether: a) the words PV-MV children with ASD produce are similar to the first words typically developing (TD) children produce, or b) there are unique features of the limited words that PV-MV children with ASD produce. The current study compared the early word profiles of PV-MV children with ASD to vocabulary-matched TD toddlers. Children with ASD produced proportionally more verbs than TD toddlers. Also, children with ASD produced proportionally more action and food words, while TD

toddlers produced proportionally more animal words, animal sounds and sound effects, and people words. Children with ASD also produced “mommy” and “daddy” at lower rates. Our findings identified several areas of overlap in early word learning; however, our findings also point to differences that may be connected to core weaknesses in social communication (i.e., people words). The findings highlight words and categories that could serve as useful targets for communication intervention with PV-MV children with ASD.

Characterizing the Early Vocabulary Profiles of Preverbal and Minimally Verbal Children with Autism Spectrum Disorder

Current research underscores the importance of early language abilities for positive life outcomes for children with autism spectrum disorder (ASD; Anderson et al., 2009; Howlin et al., 2004; Tager-Flusberg, 2016). It is therefore problematic that we have a limited understanding of the nature of language delays and impairments in children with ASD, especially among those who show extensive language delays, i.e., preverbal children (typically age < 5 years-old with very limited spoken language) and minimally verbal children (typically age > 5 years-old and a lack of flexible and spontaneous spoken language). Although there are evidence-based interventions that promote language skills in children with ASD (e.g., Carter et al., 2011; Dawson et al., 2010; Kasari et al., 2006; Roberts & Kaiser, 2011), a significant portion of the ASD population does not attain useful spoken language abilities despite participating in early intensive intervention (Tager-Flusberg & Kasari, 2013).

To more appropriately address early communication goals in children with ASD who have minimal language skills, our research aims to provide more thorough insight into their lexical profile and how this compares to typical language development. Such an approach can help promote our understanding of differences in the language acquisition process and the learning mechanisms that drive it (Beckage et al., 2011; Schneider et al., 2015), which may in turn imply targets for assessment and intervention. For example, if we identify semantic features that preverbal and minimally verbal (PV-MV) children with ASD have difficulties learning, future language intervention might be able to adapt the intervention to facilitate their acquisition.

Lexical profiles of young children with ASD

Previous studies examining children with ASD with more advanced language abilities have found that their lexical knowledge mirrors typically developing (TD) children in many respects. Like TD children, they exhibit a noun bias and learn words from various semantic categories in similar proportions (Charman et al., 2003; Luyster, Lopez, & Lord, 2007; Rescorla & Safyer, 2013). However, the receptive vocabulary advantage (i.e., understanding more words than children produce) is reduced in children with ASD relative to TD children (Charman et al. 2003; Luyster et al. 2007).

Language research in the broader ASD population has led to important insights into autism spectrum disorder more generally and learning in individuals with ASD; however, the minimally verbal ASD subgroup has been greatly understudied. In fact, Tager-Flusberg and Kasari (2013) have referred to this subgroup as the "neglected end of the spectrum". Part of the challenge in studying minimally verbal children with ASD is that they form a highly variable group and the research literature lacks consistently used criteria to classify children as minimally verbal (Koegel, Bryan, Su, Vaidya, & Camarata, 2020; Tager-Flusberg & Kasari, 2013). Tager-Flusberg and colleagues (2009) collaborated within a working group organized by the National Institute on Deafness and Other Communication Disorders to more clearly describe levels of spoken language abilities in children with ASD. In their report, they advocated for following a developmental framework and using development language terms, such as preverbal communication stage, and discouraged the term "functional speech." According to Tager-Flusberg et al. (2009), the Preverbal Communication phase typically includes 6-12-month-old TD children, and includes children who primarily communicate using a small number of single words. Yoder, Watson, and Lambert (2015) classified children as minimally verbal if they were between the ages of 20 and 48 months, were reported to produce between 0 and 20 words on the

CDI, and produced no more than five different word roots in a 15-minute language sample (in later publications of this subsample of children, they are referred to as "initially preverbal" e.g., McDaniel, Yoder, & Watson, 2017; Woynaroski et al., 2017). Lastly, while other researchers reserve the term minimally verbal for school-age children with ASD (e.g., Bal, Katz, Bishop, & Krasileva, 2016), others have proposed that it be used when there is a clear indication that the child has a severe language deficit by age 36 months (Koegel et al., 2020).

In the first detailed examination of early lexical profiles demonstrated by children with ASD with limited language skills, Charman et al. (2003) reported the proportion of nouns, predicates, and closed class words produced by a subsample of 25 children with ASD who produced 10 words or less. In their descriptive comparison to the CDI normative sample, Charman et al. concluded that the distribution of words across the syntactic and semantic categories did not differ between the groups. However, recent work suggests there are subtle differences in lexical profiles between children with ASD and TD toddlers who know fewer than 25 words (removed for blind review; Lazenby et al., 2016). The lexical profiles of such children with ASD were found to contain a higher number of verbs relative to TD toddlers, while nouns comprised a similar proportion of the vocabularies of both groups (removed for blind review). Similarly, a differential item functioning analysis of the vocabularies of 43 12-month-old infants at heightened risk of ASD who went on to receive an ASD diagnosis indicated that, in addition to having smaller vocabularies, they were more likely to produce some words on the CDI relative to 12-month-old TD infants (i.e., baabaa, block, bye, hello, uncle, bite; Lazenby et al., 2016). Beyond the six words for which differences were identified, the remaining words on the CDI were equally likely to occur in the vocabulary of either group. Although two other studies have compared word-level data between TD toddlers and older children with ASD with larger

vocabulary sizes (Bruckner et al., 2007; Rescorla & Safyer, 2013), Lazenby et al. (2016) were the first to document that lexical profile differences at the *onset* of lexical development could distinguish a high risk ASD group from a TD comparison group. The Lazenby et al. (2016) and (removed) results differ from prior work focusing on children with ASD with more developed language abilities, which did not identify differences groups in lexical profiles (Luyster et al., 2007; Rescorla & Safyer, 2013).

Given that PV-MV children with ASD sometimes have nonverbal cognitive skills that are relatively more advanced than their verbal skills (Bal et al., 2016), and will be considerably older than TD children with similar vocabular sizes, one might assume that any lexical profile differences they exhibit should be attributed to general developmental differences. For instance, some have proposed that patterns in early word learning may be influenced by maturational influences and cognitive processing capacities specific to early stages of development (Gentner, 2006; Halford et al., 1998). However, research with foreign adopted children learning English has shown older adopted children mirrored the same lexical patterns of early expressive vocabulary production (Snedeker et al., 2007). This would indicate limited influence of maturational processes on language acquisition and therefore motivates a comparison between TD and ASD groups matched on their level of language development.

Social Attention

As a part of their social communication deficits, children with ASD infrequently initiate or respond to joint attention (Dawson et al., 2004; Mundy et al., 1990). Importantly, early joint attention and social orienting abilities correlate with language abilities in young children with ASD and predicts their language development (Charman, 2003; Dawson et al., 2004). Thus, early social abilities may link to later language abilities. A recent study tracked eye-gaze patterns

of minimally verbal and verbally fluent children with ASD while they viewed social scenes and found minimally verbal children with ASD spent less time looking at faces at critical moments that provided insight into the actor's behaviors (Plesa Skwerer et al., 2019). The study also found that, during a social scene with an adult, a moving object, and static object, minimally verbal children spent a similar amount of time looking at the moving object, but verbally fluent children spent more time looking at the adult's face. Relatedly, (removed for blind review) reported that children with ASD with small vocabularies (but not specifically minimally verbal) were less likely to produce verbs that imply social interaction. Taken together, the evidence is consistent with some of the language impairments observed in children with ASD being rooted in their social deficits, rather than a specific language impairment or aberrant learning mechanism per se. Although social engagement and attention have been emphasized as important intervention targets in minimally verbal children with ASD (DiStefano et al., 2016; Plesa Skwerer et al., 2019), it is important to note that other child characteristics, such as motor skills, also have shown associations with social skills and language skills in broad samples of children with ASD (Bhat, Galloway, & Landa, 2012; LeBarton & Landa, 2019; Mody et al., 2017). In a recent study of minimally verbal children with ASD, Pecukonis and colleagues demonstrated that motor imitation abilities, a skill classified as a social communication variable, was associated with concurrent expressive vocabulary abilities even after controlling for nonverbal cognitive skills (Pecukonis, Plesa Skwerer, Eggleston, Meyer, & Tager-Flusberg, 2019). Thus, although the language deficits in PV-MV children with ASD are likely influenced by a complex combination of factors, social deficits remain a consistent variable of interest.

Current Study

To better address early communication goals in PV-MV children with ASD, our research investigates the composition of their productive vocabularies with respect to word meaning (semantics) and function within expressive language (syntax) in a much larger sample of children than previous work. We test whether these lexical profiles differ from those exhibited by TD children matched on productive vocabulary size to help identify differences in the language acquisition process, which may in turn imply targets for assessment and intervention. Finally, we consider whether distinctive aspects of the atypical lexical profiles of PV-MV children with ASD could be related to deficits in social communication—one of the most studied ASD symptoms. Specifically, we examined the social features of the verbs that the children were reported to produce. Verbs can contain semantic information related to the number of participants associated with an event (e.g., 'sleep' requires one participant in comparison to 'hug', that usually requires two; Horvath, Rescorla and Arunachalam, 2018). The focus on verbs may offer insight into activities that the child attends to and participates in, which may be influenced by social motivation differences between the groups.

Although receptive vocabulary knowledge is an important component of linguistic abilities, the current study will focus on expressive vocabulary. We aimed to first focus on expressive language because we are examining our research question using a parent-report vocabulary measure. As such, we have higher confidence in the accuracy of the parent reports, especially given that social deficits in children with ASD may obscure children's true receptive vocabulary knowledge. Furthermore, previous work has demonstrated that parents tend to underestimate emerging vocabulary comprehension skills in both typically developing children and children with ASD (Houston-Price, Mather, & Sakkalou, 2007; Tomasello & Mervis, 1994; Venker, Haebig, Edwards, Saffran, & Ellis Weismer, 2016).

Guided by prior work, we predicted that many aspects of early lexical development found in TD toddlers would be present in the lexical profile of PV-MV children with ASD (e.g., sound effects, people names, animals; Schneider et al., 2015). However, we also expected to identify lexical features that distinguished the groups -- specifically, that our PV-MV ASD sample will show a higher proportion of verbs in their productive vocabularies (removed for blind review). Furthermore, we hypothesized that some variance in the lexical profile differences between groups could be explained by independently estimated social ratings, such that the vocabularies of children with ASD would be less likely to contain verbs with high social ratings relative to TD toddlers. Support for this hypothesis would be consistent with an integral relationship between language impairment in ASD and a core feature of ASD.

Methods

Participants

We examined the expressive vocabularies of 64 children with ASD and 461 TD toddlers using word-level data collected using the CDI. The sample of 64 children with ASD was obtained from the National Database for Autism Research (NDAR; National Institute of Mental Health, n.d.; for a description see Payakachat et al., 2016). Although the participants came from different studies, all children participated in assessment procedures that included an administration of one or both of the gold-standard assessments of ASD, the Autism Diagnostic Observation Schedule (Lord et al., 1999; Lord et al., 2012) and the Autism Diagnostic Interview–Revised (Rutter, et al., 2003), with two exceptions for whom the Childhood Autism Rating Scale was used (Schopler, Van Bourgondien, Wellman, & Love, 2010). The comparison sample consisted of toddlers with typical language development, which was downloaded from the Wordbank public repository (Frank et al., 2017).

All children were reported to produce at least one word, but no more than 10 words on the CDI. Toddlers in the TD group scored above the 15th percentile according to the CDI – Words and Gestures normative data (Fenson et al., 2006). Children in the ASD group scored below the 5th percentile, demonstrating significant expressive vocabulary delays. Within the ASD group, 22 of the 64 children were 5-years-old or older, falling within the traditional "minimally verbal" criteria (Bal et al., 2016). The remaining 42 children with ASD were considered to be "preverbal". Although minimally verbal children and preverbal children show different degrees of language delay, their lexical profiles did not differ (except for one instance, which will be noted below); thus, they will be reported as a single group.

The children with ASD and TD toddlers were well-matched on expressive vocabulary, $t(523) = -0.32$, $p = .747$, variance ratio = 0.93 (ASD: $M = 4.56$ words, $SD = 2.87$; TD: $M = 4.45$ words, $SD = 2.66$). Also, given that ASD is more prevalent in males, we gender ratio matched the TD group to the gender ratio in our PV-MV ASD group. Thus, to be included in the ASD sample, each child needed to have a complete CDI with word-level information, have clear documentation of an ASD diagnosis, produce between 1 and 10 words, and to score below the 5th percentile according to CDI normative data. To be included in the TD group, each toddler had to have a complete CDI with word-level information, produce between 1 and 10 words, fall within or above a standard deviation from the mean normative data, and fit within the gender ratio limits set by the ASD group.

These inclusionary criteria yielded the current sample sizes. Specifically, within the NDAR database, word-level CDI data were available for 255 children with ASD who were reported to produce at least one word. Of the 255 children with ASD, only 64 children were reported to produce between 1 and 10 words and to score below age expectations (i.e., below the

5th percentile; two additional children were excluded because their expressive vocabulary size placed them at or above the 50th percentile). For each child in the ASD group, we documented an ASD diagnostic classification from an assessment (i.e., ADOS, ADI-R, CARS) that was administered at the age that the CDI data were collected. In addition, for children with ASD who contributed CDI data before the age of 36 months, longitudinal data within NDAR provided confirmation of a persistent ASD classification for all but four children (for those four children, longitudinal data were not collected). Children in the TD group consisted of toddlers who met the inclusionary criteria specified above and had a gender specified; this originally resulted in data from 682 TD toddlers. In order to gender ratio match the samples, we created a function in the R statistical software (RStudio Team, 2019) that randomly excluded 221 females. Lastly, although we only included toddlers who scored above the 15th percentile in expressive vocabulary knowledge to ensure that the toddlers did not have a potential language deficit, there are no other developmental data available to confirm that the children were or continued to be typically developing across other developmental skills.

As would be expected, the children with ASD were significantly older than the TD toddlers $t(523) = -33.21$, $p < .001$; however, within each group males and females did not significantly differ in age (ASD group $p = .737$, TD group $p = .448$). Lastly, we obtained estimates of nonverbal mental age for the children in the ASD group using the Fine Motor subtest and the Visual Reception subtest of the Mullen Scales of Early Learning (Mullen 1995), with the exception of two children with ASD. Although nonverbal mental ages were significantly below chronological age expectations within the ASD group, they were significantly higher than the chronological ages for TD group, $t(521) = -35.29$, $p < .001$. See Table 1 for participant characteristics.

[Insert Table 1 here.]

Communicative Development Inventory

Word production was measured using the CDI – Words and Gestures form (W&G) and the CDI – Words and Sentences form (W&S) in American English. The CDI was developed from parent diaries documenting early lexical development and therefore include commonly reported and developmentally appropriate vocabulary items. To allow for individual differences in the specific form of the word, the CDI specifies that if a child produces a variant of a word that represents the same meaning, the child's production should still be documented (e.g., mom, momma, mommy). The CDI-W&G form contains 396 words and was normed on children between 8 and 18 months. The CDI-W&G was used to collect word-level data for the whole TD group because their age ranged between 8 and 15 months, and for 37 children with ASD (57.8%). The CDI-W&S form consists of 680 words (including the 396 words from the Words and Gestures form) and was normed on children between 16 and 30 months. Word-level data for 27 children with ASD (42.2%) were collected using the CDI-W&S form. The specific CDI form used for the ASD sample was determined by the parent study's testing protocol.

Social Features in Verbs

To assess whether differences among lexical profiles in our sample are associated with deficits in social communication, we quantified the social features of the Action Words listed on the CDI-W&S form. To do this, we collected social ratings for each verb from a sample of 54 adults using Amazon's Mechanical Turk. The participants lived in the United States and self-reported to be native English speakers. Twenty-one participants identified as female, 31 as male, and two as "other". The average age of the participants was 35.9 years (range: 22-72 years) and the average household income was $47,444 (range: $7,000-$120,000). Forty-seven participants

reported to be White, four to be Asian, two reported to be Black, and one to be "other". Additionally, four individuals reported to be Hispanic. The participants were given the following prompt: "For each of the following words, please type in a number between 1 and 10 to rate how social each word is (1 = Not Social, 10 = Extremely Social). A word is more social if it typically involves interacting with other people. A word is less social if it typically does not involve other people." This approach was similar to a semantic dimension measure used by Horvath, Rescorla, and Arunachalam (2018). We presented the verbs in pseudorandom order so that the verbs were not in alphabetical order. Additionally, we included three items to test participant attention to the task; each attention item listed three words and asked the participant to click on a specific word in that list. Every participant passed the attention items; therefore, no participants were excluded. Once the data were collected, we calculated a mean social rating score for each word. The highest social rating value was 9.2, corresponding to the verbs "kiss" and "hug". Other verbs with high social ratings included "help" (8.3) and "tickle" (8.1). The verb "rip" had the lowest social rating score (1.6), and other verbs with low scores included "sweep" (1.8) and "jump" (2.0). The average social rating value was 3.9; words with similar scores included "see" (3.7), "cry" (4.0), and "look" (4.3). To examine cross-rater reliability, we conducted 1,000 randomly sampled split-half reliability tests. Within each test, we calculated the mean scores for each split-half and conducted a Pearson correlation. The average correlation was $r = 0.97$ and the 95% confidence interval was (0.95, 0.98), indicating participants provided consistent rating scores for the words. The specific social rating scores for each of the 103 CDI-W&S verbs, are provided in Appendix A.

Analysis Plan

Following previous studies of lexical development (Charman et al., 2003; Luyster et al., 2007), we examined the words that children produced according to two dimensions: syntactic class and semantic categories. Given the early stage of lexical development, we limited our syntactic class analyses to nouns and verbs. Following methods of previous studies, we used the Bates et al. (1994) classification system to categorize nouns; thus, nouns were comprised of words that were in the following CDI categories: Animals, Vehicles, Toys, Food and Drink, Clothing, Body Parts, Furniture and Rooms, and Small Household Items. Verbs consisted of the words categorized as Action Words on the CDI-W&S. Although words acquired in the earliest stage of language development typically consist of people words (mommy, daddy) and sound effects and animal noises, Bates and colleagues (1994) did not include them as nouns because it has been suggested that these words may follow a different developmental course relative to "true nominals" (Bates et al., 1988; Snyder et al., 1981). Similarly, Rescorla and Safyer (2013) also omitted people words and animal sounds and sound effects from their noun category when examining lexical profiles of children with ASD.

Semantic categories were organized using the 22 semantic groupings that appear on the CDI-W&S form (e.g., animals, toys, food and drink). Given the small vocabulary sizes of our samples, the proportion of words produced within each semantic category varied greatly. Therefore, we limited the semantic categories to those for which at least 5% of children in at least one group was reported to produce at least one word. Thus, the following semantic categories were included in the analyses: Action Words, Animals, Food and Drink, Games and Routines, People, Sound Effects and Animal Sounds, and Toys. Since we examine Action Words in our syntactic analyses (verbs), we will not evaluate this category in our semantic analyses. We evaluated whether children with ASD and TD toddlers have different syntactic and semantic

lexical profiles using Wilcoxon rank-sum tests because the data violated the assumption of normal distributions. Statistical significance was determined using Bonferroni-corrected *p*-values.

To assess whether potential group differences are associated with reduced attention to social factors, we compared the mean social rating scores of the verbs produced by the children in the ASD and TD groups using the same statistical procedures described above. Lastly, to further examine whether PV-MV children with ASD demonstrated characteristically different word-learning patterns, we used descriptive and quantitative (chi-square test) methods to examine word-level data.

Results

Syntactic Classes

We first assessed the proportion of nouns and verbs within children's vocabularies (see Figure 1). As might be expected, children's earliest words heavily consist of words that fall outside of the noun and verb classifications. The categories that contributed the most to the Other classification for both groups were People words, Sound Effects and Animal Sounds, and Games and Routines (e.g., "hi", "bye", "no").

[Insert Figure 1 here.]

We conducted Wilcoxon rank-sum tests to investigate group differences in children's productions of nouns and verbs. There was a significant group difference in the proportion of verbs produced ($W = 18111$, $p < .001$, $d = 0.52$); children with ASD produced a significantly higher proportion of verbs relative to the TD toddlers. There were no group differences in the proportion of nouns produced ($W = 16232$, $p = .503$).

Given that children tend to learn nouns earlier than verbs (Bates et al., 1994; Gentner, 2006), we conducted follow-up analyses to examine whether age is associated with the proportion of verbs produced. Because of the large differences in chronological age between the ASD and TD groups, we examined the association between age and verb production by conducting a Spearman's correlation within each group. There was no association between chronological age and the proportion of verbs produced in any of the groups (ASD r_s = .04, TD r_s = .03, all *p*s > .45). Furthermore, because some have proposed that more advanced cognitive abilities facilitate verb learning (Halford et al., 1998), we also assessed the association between nonverbal mental age and the proportion of verbs produced in the PV-MV ASD group; this association was not significant (r_s = -.08).

As can be seen in Figure 1, both groups demonstrated a noun bias, with a higher proportion of nouns being produced than verbs. To assess whether there were differences in the extent of the noun bias between the two groups, we subtracted the proportion of verbs from the proportion of nouns for each child in our sample and compared these verb-noun differences between the two groups. The size of the noun bias did not differ among the groups (W = 14454, p = .780).

In summary, PV-MV children with ASD were reported to produce a higher proportion of verbs relative to TD toddlers. The lack of an association between age and the proportion of verbs produced indicates it is unlikely that age is driving this finding. Despite this difference in verb production, both groups demonstrate a noun bias.

Semantic Categories

We next examined whether the proportion of words produced across the semantic categories differed by group. The proportion of words produced across the seven semantic

categories that were identified to contain sufficient data (see Analysis Plan) were compared between the groups using separate Wilcoxon rank-sum tests, with Bonferroni-corrected *p*-values. There were no significant group differences for toy words ($p > .95$) or games and routine words ($p > .95$). There were group differences in proportion of animal words ($W = 12144$, $p = .020$, $d = 0.30$), food and drink words ($W = 17015$, $p = .003$, $d = 0.30$), people words ($W = 11434$, $p = .014$, $d = 0.32$), and sound effects and animal sounds ($W = 11282$, $p = .011$, $d = 0.38$). PV-MV children with ASD produced a smaller proportion of animal words, people words, and sound effect and animal noises relative to TD toddlers. Also, children with ASD produced a higher proportion of food and drink words relative to TD toddlers (see Figure 2). Lastly, the only difference between the preverbal and minimally verbal ASD subgroups was for the animal sounds and sound effects category ($W = 662.5$ $p = .01$), with the preverbal children having higher rates of production.

[Insert Figure 2 here.]

Social Verb Rating Group Comparisons

We calculated the mean social rating score for the verbs reported to be produced by each child. Given that we examined the very earliest stage of lexical development, verb production was very low. Only 17 of the 64 children with ASD (26.6%) and 17 TD toddlers (3.7%) were reported to produce at least one verb. Within this subsample, one TD toddler and one child with ASD were reported to produce two verbs, two children with ASD were reported to produce three verbs, and the rest were reported to produce only one. The ASD group had slightly lower verb social rating scores (ASD: $M = 3.55$, $SD = 1.46$; TD: $M = 4.40$, $SD = 2.21$). However, this difference did not reach significance ($W = 187$, $p = .146$, $d = 0.45$; see Figure 3).

[Insert Figure 3 here]

Word-Level Group Comparisons

Lastly, we examined words that each group of children were reported to produce. Table 2 lists the most commonly reported words for each group and the proportion of children within the groups who were reported to produce each word. There was significant overlap; nine of the ten most commonly reported words overlapped between the ASD and TD groups. Interestingly, although the two most frequently reported words for each group were "mommy" and "daddy", the proportion of children who were reported to produce these words was strikingly different between the groups. Following up on this observation, we categorized each participant into one of four groups: Produces Mommy, Produces Daddy, Produces Both, Produces Neither. We aggregated over the subjects in each group, which resulted in a distribution of subjects over these four categories. We then compared the group distributions using a chi-square analysis. TD toddlers were reported to produce the words "mommy" and "daddy" significantly more than the PV-MV children with ASD ($\chi^2(3) = 13.59$, $p = .004$). Across the groups, children were no less likely to produce one of the parent names than the other ($p > .60$).

[Insert Table 2 here.]

Our verb difference finding also prompted us to further examined the specific verbs that the children were reported to produce. The PV-MV children with ASD were reported to produce 13 different verbs, four of which were reported to be produced by more than one child. The TD toddlers were reported to produce 11 different verbs, also with four verbs being reported for more than one child. The four most commonly reported verbs for the PV-MV ASD group were: go (6/17), stop (3/17), eat (2/17), and tickle (2/17). The four most commonly reported verbs for the TD group were: go (4/17), see (3/17), kiss (2/17), and look (2/17). Descriptively, of these words, the two most social words were kiss (social rating: 9.2) and tickle (social rating: 8.1).

Notably, although the word tickle can be classified as a highly social word, it also can be connected to sensory-seeking features that many children with ASD display rather than a social game.

Discussion

This research makes two novel contributions towards understanding the earliest point of verbal communication skills in preverbal and minimally verbal children with ASD. First, we identified areas of distinction in early syntactic and semantic lexical development between PV-MV children with ASD and TD toddlers. Second, we identified some differences in lexical knowledge that may be associated with the social communication deficits of ASD. Because five out of the seven semantic categories and one of the two syntactic classes resulted in differences between the groups, we can rule out a simple instance of developmental slowing. However, our examination of the ten most frequently reported words demonstrates there also is substantial overlap. To our knowledge, this is the first study that uses the NDAR language data to examine language profiles in ASD and therefore serves as a model for using this under-utilized resource.

Emerging Syntactic and Semantic Composition

Our sample of PV-MV children with ASD were reported to produce a higher proportion of verbs than TD toddlers who are in the initial phase of lexical development. This group difference replicates and extends the verb findings reported by (removed for blind review). Importantly, this relative over-production of verbs has not been observed in samples of children with ASD that were not specifically selected to meet criteria for classification as minimally verbal (Charman et al., 2003; Rescorla & Safyer, 2013). It is worth noting that the rate of verb production in our TD sample is consistent with Bates and colleagues (1994), who documented that early verb development lags behind noun learning. In the current study, only 3.7% of the TD

toddlers were reported to produce one or more verbs; this contrasts with 26.6% of our PV-MV ASD group. Correlational analyses suggest these differences in early verb production are not associated with chronological age in either our ASD or TD sample, nor with nonverbal cognitive abilities in the PV-MV ASD sample. Although early lexical structure has been reported to be unstable at points in which children produce only 1 to 10 words (Bates et al. 1994), our findings document moderately sized differences that exist between children with ASD and TD toddlers who are at this lexical stage (d = 0.52). Because age and nonverbal cognitive scores were not associated with verb production, our findings suggest other factors may play a role in promoting early verb learning in PV-MV children with ASD; however, future work is warranted to better understand verb learning over time through longitudinal studies of PV-MV children with ASD and TD toddlers.

Recent work with young children with ASD with more developed language abilities has demonstrated that, like TD children, they are capable of syntactic bootstrapping within a transitive sentence frame to guide attention in causal scenes (Horvath et al., 2018). Other work in this area suggests that children with ASD may have a greater attentional bias to object function rather than object shape (Field et al., 2016) and that children with ASD may have a reduced shape bias (Potrzeba et al., 2015; Tek et al., 2008). A reduced shape bias may influence object learning (i.e., nouns) and thus account for some of the verb preference in children with ASD with low levels of language development. It remains to be seen if the profile we report is typical for early language learners who will later receive an ASD diagnosis, or if this is particular to those who will remain minimally verbal.

Parent use of verbs during instances of joint attention (i.e., follow-in comments) significantly predict expressive verb growth in preschool children with ASD (Crandall et al.,

2019). Although previous studies have found that parents of children with ASD produce broadly similar types of linguistic input (Siller & Sigman, 2002, 2008; Walton & Ingersoll, 2014), future studies could specifically examine whether parent use of nouns and verbs during follow-in comments differentially predict noun and verb growth in young children with ASD at early stages of lexical development. Furthermore, given the well-documented deficits in joint attention, it is possible that parents of children with ASD may use more active language and provide more verb input to promote joint interactions than parents of TD toddlers. Such an empirical comparison could enhance our understanding of the language learning environment that children with ASD experience.

In addition to the verb/Action Words finding, our semantic analyses revealed that TD toddlers produced significantly more animal words, people words, and sound effects and animal sounds relative to PV-MV children with ASD. In contrast, PV-MV children with ASD produced a higher proportion of food and drink words. These findings may have been influenced by the age differences between the groups. For instance, the TD toddlers likely have much less exposure to solid foods and different drinks relative to the older PV-MV children with ASD. Although several studies have demonstrated that parents tend to adapt their language input according to their child's expressive language skills (Hani et al., 2013; Paul & Elwood, 1991), age-related effects may still influence exposure to certain words or word categories (e.g., sound effects). Additionally, the lower proportion of people words produced by the PV-MV children with ASD relative to the TD toddlers was especially interesting given the social deficits that are characteristic of ASD symptomatology.

Relatedly, the semantic differences also may be associated with the well-documented group differences in rates of protoimperatives and protodeclaratives. Children with ASD have

been found to produce more protoimperatives (requests) and fewer protodeclaratives (comments) relative to TD children (Dawson et al., 2004; Özçalisikan, Adamson, & Dimitrova, 2016). Although we do not have additional information about the way in which the children used each of the reported words, it seems plausible that the food and drink word class that was found to be more frequently produced by the children with ASD may be driven by the higher likelihood of requesting behaviors. This may also be related to the commonly reported verb 'stop' by PV-MV children with ASD. In contrast, the higher proportion of animal words and animal sounds and sound effects, and possibly people words, may be more likely to be produced in protodeclarative communication acts or to seek social attention, which are more likely to be produced by TD children relative to children with ASD. To support this suggestion, future work would need to specifically measure individual words and the corresponding communicative functions.

Associations between ASD Social Deficits and Lexical Features

Beyond characterizing the lexical profile of PV-MV children with ASD, we tested whether the observed differences could be attributed to social weaknesses that are characteristic of ASD. The lower proportion of people words could be related to lower rates of social orienting and reduced attention to people's faces that have been identified in children with ASD and specifically minimally verbal children with ASD (Dawson et al., 2004; Plesa Skwerer et al., 2019). Our word-level data also provide extra detail to the reduced proportion of people words that we identified. Although the words "mommy" and "daddy" were the most likely to be included in the productive vocabulary of children in both groups, the likelihood that a child with ASD produced these words was much lower than a TD child. In addition to our people words finding, our word-level examination of the verbs that the children produced was notable. Within the most commonly reported verbs, two highly social verbs were reported: kiss (social rating:

9.2) and tickle (social rating: 8.1). Although the word tickle was rated as a highly social word, it also can be connected to sensory-seeking features that many children with ASD display rather than a social game. We are not able to determine how these words were used or the underlying motivation for their use, but it is interesting that the most commonly reported highly social word by children in the ASD group (albeit only by two children with ASD) also has a strong sensory component.

The argument that language development is influenced by the core features of ASD is not new. Brucker and colleagues (2007) suggested ASD symptomatology, such as restricted object use and deficits in social orienting and social communication skills, may be related to word-level vocabulary differences they observed in children with ASD with more advanced language skills. While not all our results are consistent (i.e., social verb ratings were not reliably lower for verbs produced by children with ASD), the collection of findings we report support the hypothesis that the lexical profiles in our ASD group are shaped in part by social communication deficits that are a core feature of ASD. To strengthen this assertion, additional research is needed. Future work could examine the social verb rating scores for a larger group of children who have begun to produce verbs. Although our sample size was fairly large relative to the PV-MV literature, only a small proportion of these children were reported to produce at least one verb. The social verb rating scores that we share can serve as a resource for such future studies.

Limitations and Future Directions

Although the current study contributes new insights into the early spoken language profile of PV-MV children with ASD, several limitations must be kept in mind. First, the age range in our ASD sample was very large. Although it is likely that some of the preverbal children with ASD in our group went on to develop more advanced language abilities that would exceed

the stringent criteria for "minimally verbal", their early language delays are notable and should not be dismissed. Producing at least 10 words by 18 months of age has been linked to more favorable functional outcomes in children with ASD (Hedvall et al., 2015). In the current sample, our youngest preverbal participants with ASD included two 19-month-old children who each produced six words, one 21-month-old child who produced seven words, and one 23-month-old child who produced three words. All have missed this important lexical milestone. Second, by the nature of having a PV-MV group of children with ASD, there was a significant age difference from the TD toddlers. An important future extension of this work will be to incorporate a comparison group that is more closely matched in age to the ASD group, such as children with idiopathic intellectual disability, children with Down syndrome, or children with hearing impairment. Such a comparison group would provide a better control for age-related differences in language environment, motor development, and general life experiences. A third limitation is that our TD sample was obtained from WordBank, which is a publicly available database comprised of data from various research labs. While these labs screened for developmental delays, extensive developmental testing to confirm typical development is unlikely.

Fourth, though we followed procedures for classifying syntactic and semantic classifications that have been used by several studies, it is possible, especially at this earliest point of lexical development, that these words serve different functions, possibly altering the syntactic or semantic class in which we have categorized them in the current study. In only using the CDI in the current study, we were not able to gather additional information about the variety of contexts in which the words are used, the linguistic context and the communicative function in which the words are used, or the frequency of each word's use. These details could point to

potential differences in use of the words that were not captured in the current study. As such, it would have been preferable to use a multi-method approach that incorporates the CDI data with observational data, especially given that we are examining emerging lexical knowledge (Broome, McCabe, Docking, & Doble, 2017; Tager-Flusberg et al., 2009). Finally, although our social verb rating scores provided some additional insight into potential lexical differences between our groups and can serve as a resource for future studies, these scores were only collected for verbs. Future studies may wish to examine social features of words across multiple word classes, though different procedures will likely need to be used to quantify such a feature for CDI words (e.g., cup, tree, horse).

The majority of the extant literature has focused on noun learning and processing in young children with ASD (e.g., Ellis Weismer, et al., 2016; Luyster & Arunachalam, 2018; Tek et al., 2008). Verb learning and processing studies would fill an important gap in the ASD word-learning literature. Additionally, future studies that target initial expressive communication or alternative and augmentative communication skills in minimally verbal children with ASD may wish to investigate interventions that target the differences between early first words in our ASD and TD samples, which may help further elucidate why these differences arise and what influences they have on future development.

Conclusions

The current study focused on the critically understudied population of minimally verbal children with ASD. Despite the limited size of their expressive vocabulary, we identified interesting areas of overlap and distinction relative to the early expressive vocabulary of TD toddlers who are in the earliest stage of lexical development. Our findings suggest that lexical development in preverbal and minimally verbal children with ASD does not merely reflect a

large language delay, and set the base for future research to understand how social and cognitive processes yield lexical differences in early development.

References

Anderson, D. K., Oti, R. S., Lord, C., & Welch, K. (2009). Patterns of growth in adaptive social abilities among children with autism spectrum disorders. *Journal of Abnormal Child Psychology*, *37*, 1019–1034.

Bal, V. H., Katz, T., Bishop, S. L., & Krasileva, K. (2016). Understanding definitions of minimally verbal across instruments: Evidence for subgroups within minimally verbal children and adolescents with autism spectrum disorder. *Journal of Child Psychology and Psychiatry*, *57*, 1424–1433.

Bates, E., Bretherton, I., & Snyder, L. S. (1988). *From First Words to Grammar: Individual Differences and Dissociable Mechanisms*. New York, NY: Cambridge University Press.

Bates, E., Dale, P. S., & Thal, D. J. (1995). Individual differences and their implications for theories of langauge development. In P. Fletcher & B. Mac Whinney (Eds.), *Handbook of Child Language*. Oxford: Basil Blackwell.

Beckage, N., Smith, L. B., & Hills, T. T. (2011). Small worlds and semantic network growth in typical and late talkers. *PLoS ONE*, *6*, 1–6.

Bhat, A. N., Galloway, J. C., & Landa, R. J. (2012). Relationship between early motor delay and later communication delay in infants at risk for autism. *Infant Behavior and Development*, *35*, 838–846.

Broome, K., McCabe, P., Docking, K., & Doble, M. (2017). A systematic review of speech assessments for children with autism spectrum disorder: Recommendations for best practice. *American Journal of Speech-Language Pathology*, *26*, 1011–1029.

Bruckner, C., Yoder, P., Stone, W., & Saylor, M. (2007). Construct validity of the MCDI-I receptive vocabulary scale can be improved: Differential item functioning between toddlers with autism spectrum disorders and typically developing infants. *Journal of Speech, Language, and Hearing Research*, *50*, 1631–1638.

Carter, A. S., Messinger, D. S., Stone, W. L., Celimli, S., Nahmias, A. S., & Yoder, P. (2011). A randomized controlled trial of Hanen's "More Than Words" in toddlers with early autism symptoms. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *52*, 741–752.

Charman, T. (2003). Why is joint attention a pivotal skill in autism? *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *358*, 315–324.

Charman, T., Drew, A., Baird, C., & Baird, G. (2003). Measuring early language development in preschool children with autism spectrum disorder using the MacArthur Communicative Development Inventory (Infant Form). *Journal of Child Language*, *30*, 213–236.

Crandall, M. C., McDaniel, J., Watson, L. R., & Yoder, P. J. (2019). The relation between early parent verb input and later expressive verb vocabulary in children with autism spectrum disorder. *Journal of Speech, Language, and Hearing Research*, *62*, 1787–1797.

Dawson, G., Rogers, S., Munson, J., Smith, M., Winter, J., Greenson, J., … Varley, J. (2010). Randomized, controlled trial of an intervention for toddlers with autism: The early start denver model. *Pediatrics*, *125*, e17–e23.

Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., & Liaw, J. (2004). Early social attention impairments in autism: Social orienting, joint attention, and attention to distress. *Developmental Psychology*, *40*, 271–283.

DiStefano, C., Shih, W., Kaiser, A., Landa, R., & Kasari, C. (2016). Communication growth in minimally verbal children with ASD: The importance of interaction. *Autism Research, 9,* 1093–1102.

Ellis Weismer, S., Haebig, E., Edwards, J., Saffran, J., & Venker, C. E. (2016). Lexical processing in toddlers with ASD: Does weak central coherence play a role? *Journal of Autism and Developmental Disorders, 46,* 3755–3769.

Fenson, L., Marchman, V., Thal, D., Dale, P., Reznick, J. S., & Bates, E. (2006). *The MacAurthur-Bates Communication Development Inventories: User's guide and technical manual* (2nd ed.). Baltimore, MD: Brookes Publishing.

Field, C., Allen, M. L., & Lewis, C. (2016). Are children with autism spectrum disorder initially attuned to object function rather than shape for word learning? *Journal of Autism and Developmental Disorders, 46,* 1210–1219.

Frank, M. C., Braginsky, M., Yurovsky, D., & Marchman, V. A. (2017). Wordbank: An open repository for developmental vocabulary data. *Journal of Child Language, 44,* 677–694.

Gentner, D. (2006). Why verbs are hard to learn. In K. Hirsh-Pasek & R. M. Golinkoff (Eds.), *Action Meets Word: How Children Learn Verbs* (pp. 544–564). Oxford University Press.

Halford, G. S., Wilson, W. H., & Phillips, S. (1998). Processing capacity defined by relational complexity: Implications for comparative, developmental, and cognitive psychology. *Behavioral and Brain Sciences, 21,* 803–864.

Hani, H. B., Gonzalez-Barrero, A. M., & Nadig, A. S. (2013). Children's referential understanding of novel words and parent labeling behaviors: Similarities across children

with and without autism spectrum disorder. *Journal of Child Language*, *40*, 971–1002.

Hedvall, Å., Westerlund, J., Fernell, E., Norrelgen, F., Kjellmer, L., Olsson, M. B., … Gillberg, C. (2015). Preschoolers with autism spectrum disorder followed for 2 Years: Those who gained and those who lost the most in terms of adaptive functioning outcome. *Journal of Autism and Developmental Disorders*, *45*, 3624–3633.

Horvath, S., McDermott, E., Reilly, K., & Arunachalam, S. (2018). Acquisition of verb meaning from syntactic distribution in preschoolers with autism spectrum disorder. *Language, Speech, and Hearing Services in Schools*, *49*, 668–680.

Horvath, S., Rescorla, L., & Arunachalam, S. (2018). Semantic features of early verb vocabularies. In K. Syrett & S. Arunachalam (Eds.), *Semantics in Language Acquisition* (Vol. 24, pp. 67–94). Philadelphia, PA: John Benjamins Publishing Company.

Houston-Price, C., Mather, E., & Sakkalou, E. (2007). Discrepancy between parental reports of infants' receptive vocabulary and infants' behaviour in a preferential looking task. *Journal of Child Language*, *34*, 701–724.

Howlin, P., Goode, S., Hutton, J., & Rutter, M. (2004). Adult outcome for children with autism. *Journal of Child Psychology and Psychiatry*, *45*, 212–229.

Kasari, C., Freeman, S., & Paparella, T. (2006). Joint attention and symbolic play in young children with autism: A randomized controlled intervention study. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *47*, 611–620.

Koegel, L. K., Bryan, K. M., Su, P. L., Vaidya, M., & Camarata, S. (2020). Definitions of nonverbal and minimally verbal in research for autism: A systematic review of the

literature. *Journal of Autism and Developmental Disorders*, *50*, 2957–2972.

LeBarton, E. S., & Landa, R. J. (2019). Infant motor skill predicts later expressive language and autism spectrum disorder diagnosis. *Infant Behavior and Development*, *54*, 37–47.

Lord, C., Rutter, M., DiLavore, P. C., & Risi, S. (1999). *Autism diagnostic observation schedule*. Los Angeles, CA: Western Psychological Services.

Lord, C., Rutter, M., DiLavore, P., Risi, S., Gotham, K., & Bishop, S. (2012). *Autism diagnostic observation schedule* (2nd ed.). Torrence, CA: Western Psychological Services.

Luyster, R. J., & Arunachalam, S. (2018). Brief Report: Learning language through overhearing in children with ASD. *Journal of Autism and Developmental Disorders*, *0*, 1–9.

Luyster, R., Lopez, K., & Lord, C. (2007). Characterizing communicative development in children referred for Autism Spectrum Disorders using the MacArthur-Bates Communicative Development Inventory (CDI). *Journal of Child Language*, *34*, 623–654.

McDaniel, J., Yoder, P., & Watson, L. R. (2017). A path model of expressive vocabulary skills in initially preverbal preschool children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *47*, 947–960.

Mody, M., Shui, A. M., Nowinski, L. A., Golas, S. B., Ferrone, C., O'Rourke, J. A., & McDougle, C. J. (2017). Communication deficits and the motor system: Exploring patterns of associations in autism spectrum disorder (ASD). *Journal of Autism and Developmental Disorders*, *47*, 155–162.

Mullen, E. M. (1995). *Mullen Scales of Early Learning (MSEL)*. Circle Pines, MN: AGS.

Mundy, P., Sigman, M., & Kasari, C. (1990). A longitudinal study of joint attention and

language development in autistic children. *Journal of Autism and Developmental Disorders*, *20*, 115–128.

National Institute of Mental Health. (n.d.). Welcome to the NIMH Data Archive. Retrieved from https://nda.nih.gov/

Özçalisikan, S., Adamson, L. B., & Dimitrova, N. (2016). Early deictic but not other gestures predict later vocabulary in both typical development and autism. *Autism*, *20*, 754–763.

Paul, R., & Elwood, T. J. (1991). Maternal linguistic input to toddlers with slow expressive language development. *Journal of Speech and Hearing Research*, *34*, 982–988.

Payakachat, N., Tilford, J. M., & Ungar, W. J. (2016). National Database for Autism Research (NDAR): Big data opportunities for health services research and health technology assessment. *PharmacoEconomics*, *34*, 127–138.

Pecukonis, M., Plesa Skwerer, D., Eggleston, B., Meyer, S., & Tager-Flusberg, H. (2019). Concurrent social communication predictors of expressive language in minimally verbal children and adolescents with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *49*, 3767–3785.

Plesa Skwerer, D., Brukilacchio, B., Chu, A., Eggleston, B., Meyer, S., & Tager-Flusberg, H. (2019). Do minimally verbal and verbally fluent individuals with autism spectrum disorder differ in their viewing patterns of dynamic social scenes? *Autism*. https://doi.org/10.1177/1362361319845563

Potrzeba, E. R., Fein, D., & Naigles, L. (2015). Investigating the shape bias in typically developing children and children with autism spectrum disorders. *Frontiers in Psychology*,

06, 1–12.

Rescorla, L., & Safyer, P. (2013). Lexical composition in children with autism spectrum disorder (ASD). *Journal of Child Language*, *40*, 47–68.

Roberts, M. Y., & Kaiser, A. P. (2011). The effectiveness of parent-implemented language interventions: A meta-analysis. *American Journal of Speech-Language Pathology*, *20*, 180–199.

Rutter, M., Le Couteur, A., & Lord, C. (2003). *Autism Diagnostic Interview—Revised*. Los Angeles, CA: Western Psychological Services.

Schneider, R. M., Yurovsky, D., & Frank, M. C. (2015). Large-scale investigations of variability in children's first words. *Proceedings of the 37th Annual Meeting of the Cognitive Science Society*, 1–6.

Schopler, E., Van Bourgondien, M., Wellman, G., & Love, S. (2010). *Childhood autism rating scale* (2nd ed.). Los Angeles: CA: Western Psychological Services.

Siller, M., & Sigman, M. (2002). The behaviors of parents of children with autism predict the subsequent development of their children's communication. *Journal of Autism and Developmental Disorders*, *32*, 77–89.

Siller, M., & Sigman, M. (2008). Modeling longitudinal change in the language abilities of children with autism: Parent behaviors and child characteristics as predictors of change. *Developmental Psychology*, *44*, 1691–1704.

Snyder, L. S., Bates, E., & Bretherton, I. (1981). Content and context in early lexical development. *Journal of Child Language*, *8*, 565–582.

Tager-Flusberg, H. (2016). Risk factors associated with language in autism spectrum disorder: Clues to underlying mechanisms. *Journal of Speech, Language, and Hearing Research, 59,* 143–154.

Tager-Flusberg, H., & Kasari, C. (2013). Minimally verbal school-aged children with autism spectrum disorder: The neglected end of the spectrum. *Autism Research, 6,* 468–478.

Tager-Flusberg, H., Rogers, S., Cooper, J., Landa, R. J., Lord, C., Paul, R., … Yoder, P. (2009). Defining spoken language benchmarks and selecting measures of expressive language development for young children with autism spectrum disorders. *Journal of Speech, Language, and Hearing Research, 52,* 643–652.

Tek, S., Jaffery, G., Fein, D., & Naigles, L. R. (2008). Do children with autism spectrum disorders show a shape bias in word learning? *Autism Research, 1*, 208–222.

Tomasello, M., & Mervis, C. B. (1994). The instrument is great, but measuring comprehension is still a problem. *Monographs of the Society for Research in Child Development, 59*, 174–180.

Venker, C. E., Haebig, E., Edwards, J., Saffran, J. R., & Ellis Weismer, S. (2016). Brief Report: Early lexical comprehension in young children with ASD: Comparing eye-gaze methodology and parent report. *Journal of Autism and Developmental Disorders, 46,* 2260–2266.

Walton, K. M., & Ingersoll, B. R. (2014). The influence of maternal language responsiveness on the expressive speech production of children with autism spectrum disorders: A microanalysis of mother-child play interactions. *Autism, 19*, 421 –432.

Woynaroski, T., Oller, D. K., Keceli-Kaysili, B., Xu, D., Richards, J. A., Gilkerson, J., … Yoder, P. (2017). The stability and validity of automated vocal analysis in preverbal preschoolers with autism spectrum disorder. *Autism Research*, *10*, 508–519.

Yoder, P., Watson, L. R., & Lambert, W. (2015). Value-added predictors of expressive and receptive language growth in initially nonverbal preschoolers with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *45*, 1254–1270.

Figure Captions

Figure 1. Proportion of words produced across nouns, verbs, and other words. Error bars represent standard deviations.

Figure 2. Proportion of words produced across the seven most highly reported CDI semantic classifications. Error bars represent standard deviations.

Figure 3. Individual variation in verb social rating scores. The black dot represents the mean for each group and error bars represent standard deviations.

Table 1

Child Characteristics

	Children with ASD (*n* = 64, 13 females)			**Typically Developing Toddlers** (*n* = 461, 94 females)		
	Mean	**(SD)**	**Range**	**Mean**	**(SD)**	**Range**
Vocabulary Size	4.56	2.87	1-10	4.45	2.66	1-10
Chronological Age (in months)	47.50	22.70	19-118	12.15	1.51	8-15
Nonverbal Mental Age (in months)[1]	23.32	5.45	8.5-35			

Note. [1]Nonverbal mental age was obtained from the Mullen Scales of Early Learning (Fine Motor and Visual Reception subtests). Nonverbal mental age data were not obtained for two children with ASD and were unavailable for the TD toddlers.

Table 2

Most Commonly Reported Words

	Children with ASD		**TD Toddlers**	
1.	Mommy	0.297	Daddy	0.523
2.	Daddy	0.281	Mommy	0.488
3.	No	0.203	Baabaa	0.262
4.	Ball	0.203	Uhoh	0.230
5.	Bye	0.188	Bye	0.228
6.	Baabaa	0.156	Hi	0.191
7.	Hi	0.156	Grr	0.182
8.	Uhoh	0.156	Ball	0.156
9.	Yum	0.125	Dog	0.150
10.	Grr	0.109	Yum	0.139

Note. The values represent the proportion of children within each group reported to produce each word.

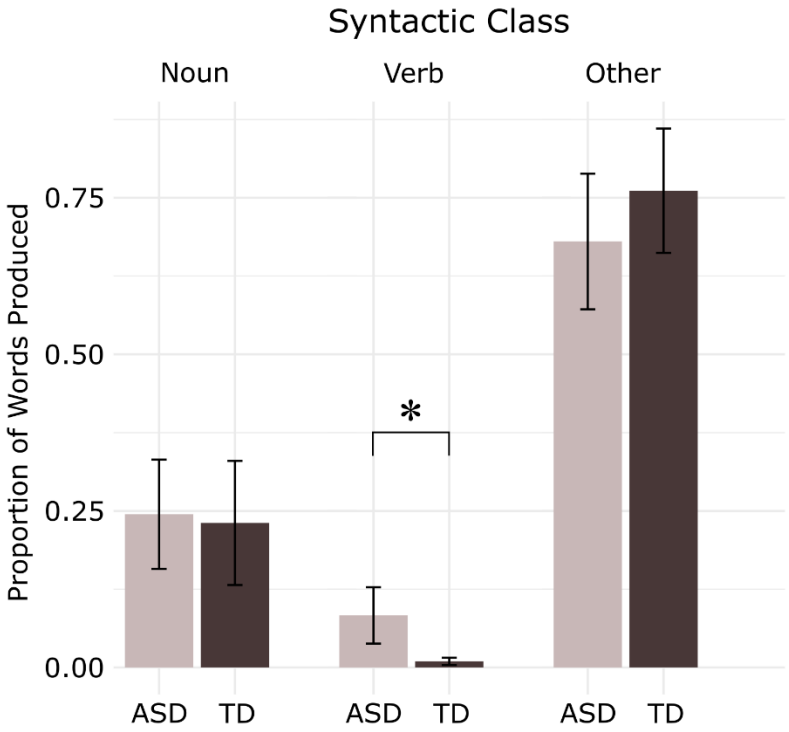

Figure 1. Proportion of words produced across nouns, verbs, and other words. Error bars represent standard deviations.

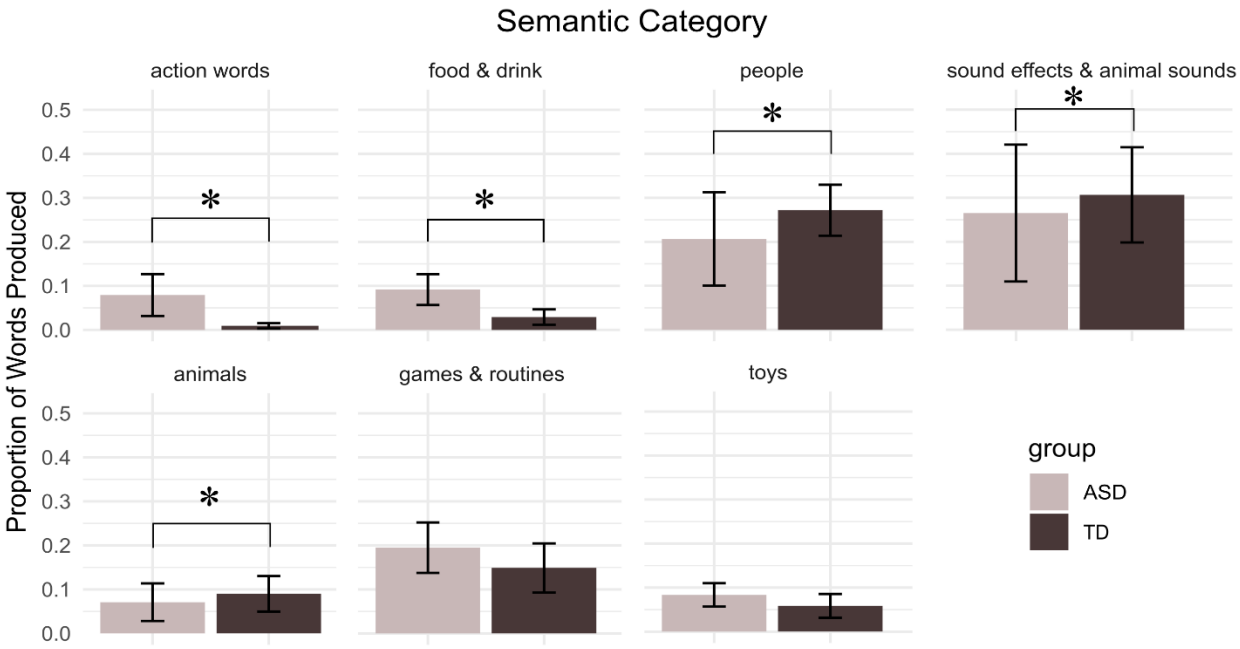

Figure 2. Proportion of words produced across the seven most highly reported CDI semantic classifications. Error bars represent standard deviations.

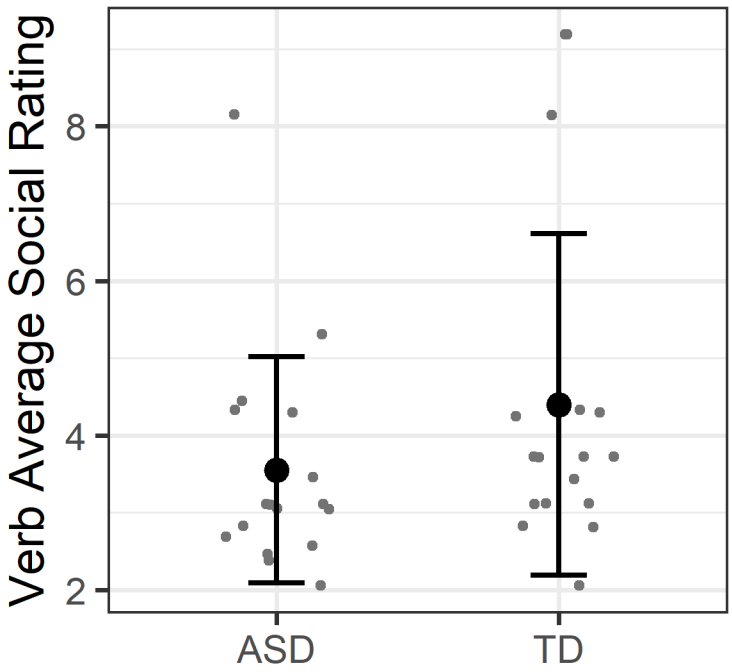

Figure 3. Individual variation in verb social rating scores. The black dot represents the mean for each group and error bars represent standard deviations.

Appendix A

Verb Social Ratings

Word	Mean Social Rating	Word	Mean Social Rating	Word	Mean Social Rating
Bite	2.81	Hate	4.59	Share	8.63
Blow	2.46	Have	2.37	Show	6.65
Break	2.15	Hear	5.43	Sing	4.89
Bring	4.61	Help	8.20	Sit	2.35
Build	4.11	Hide	3.13	Skate	3.76
Bump	3.61	Hit	4.20	Sleep	1.81
Buy	4.15	Hold	5.04	Slide	2.19
Carry	2.85	Hug	9.19	Smile	6.37
Catch	5.39	Hurry	2.69	Spill	1.69
Chase	5.78	Jump	1.98	Splash	3.54
Clap	5.54	Kick	3.59	Stand	2.09
Clean	2.57	Kiss	9.19	Stay	2.33
Climb	2.37	Knock	3.87	Stop	2.06
Close	3.59	Lick	3.59	Sweep	1.78
Cook	4.14	Like	5.04	Swim	3.69
Cover	2.83	Listen	6.81	Swing	2.83
Cry	3.98	Look	4.33	Take	4.74
Cut	1.80	Love	8.50	Talk	9.04
Dance	7.26	Make	3.02	Taste	2.57
Draw	2.39	Open	3.06	Tear	2.70
Drink	3.89	Paint	2.30	Think	2.04
Drive	3.24	Pick	2.72	Throw	4.11
Drop	1.76	Play	6.94	Tickle	8.15
Dry	1.70	Pour	2.28	Touch	7.00
Dump	2.70	Pretend	3.74	Wait	2.69
Eat	4.30	Pull	2.61	Wake	2.31
Fall	1.94	Push	3.44	Walk	3.41
Feed	5.57	Put	2.17	Wash	2.26
Find	3.06	Read	2.20	Watch	4.15
Finish	2.39	Ride	4.24	Wipe	2.02
Fit	2.46	Rip	1.59	Wish	2.06
Fix	2.65	Run	3.04	Work	5.83
Get	3.46	Say	6.87	Write	2.61
Give	7.67	See	3.72		
Go	3.11	Shake	3.69		