Published in final edited form as:

Am J Intellect Dev Disabil. 2019 January ; 124(1): 11–24. doi:10.1352/1944-7558-124.1.11.

Early Predictors of Later Expressive Language in Boys With Fragile X Syndrome

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Abstract

The predictive ability of early consonant inventory and intentional communication on later expressive language was examined in 36 boys with fragile X syndrome (FXS). Autism symptom severity was included as a potential moderator. Participants were visited in their homes twice over a 6-year period, and mother-child interactions were videotaped, coded, and transcribed behavior by behavior. Consonant inventory and concurrent autism symptom severity were predictive of later number of different words, as was the interaction between the two. Intentional communication was not predictive of number of different words. These findings provide additional specific evidence for differences in foundational language abilities associated with autism symptom severity in boys with FXS. Clinical implications are discussed.

Keywords

fragile X; language; autism

Fragile X syndrome (FXS) is the most common inherited cause of intellectual disability and the most common single gene disorder associated with autism (Cohen et al., 2005). It is caused by excessive repeats of a CGG nucleotide triplet on the FMR1 gene, which is located on the X chromosome (Verkerk, Pieretti, Sutcliffe, Fu, & Kuhl, 1991). The elongated coding sequence causes hypermethylation of the coding region on FMR1, which results in the loss or reduction of proteins (FMRP) produced by the gene (Darnell, Warren, & Darnell, 2004). In males, this can cause a broad range of emotional, cognitive, and linguistic deficits and delays. Eighty-five percent of males with full mutation FXS (> 200 CGG repeats) have low IQs and fall into the intellectually disabled range (Hagerman, 2008). It is estimated that approximately 60% of males with FXS also meet diagnostic criteria for autism spectrum disorders, based on Autism Diagnostic Observation Schedule (ADOS-2; Lord, Rutter, DiLavore, Risi, Gotham, Bishop, 2012) and Autism Diagnostic Interview-Revised (ADI-R; Rutter, Le Couteur, & Lord, 2008) cut-offs (Klusek, Martin, & Losh, 2014). The presence of autistic symptoms may negatively influence cognitive and linguistic abilities in these children (Abbeduto, McDuffie, & Thurman, 2014; Kover, McDuffie, Abbeduto, & Brown, 2012; McDuffie, Kover, Abbeduto, Lewis, & Brown, 2012). The study reported here

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evaluated the influence that early foundational language skills have on later expressive language ability in boys with FXS. We asked two questions:

1. Are early intentional communication and consonant inventory predictive of later expressive language ability in boys with FXS, controlling for nonverbal IQ?
2. To what extent is the effect of the early predictors moderated by concurrent autism symptom severity?

It has been well established that young boys with FXS have delays in language development relative to their chronological age (Brady, Skinner, Roberts, & Hennon, 2006; Roberts, Stoel-Gammon, & Barnes, 2008), but that they perform similarly on expressive and receptive language tasks to younger typically developing children at the same level of cognitive development (Fine-stack, Richmond, & Abbeduto, 2009). Hinton and colleagues reported a 3-month delay in first word production in young boys with FXS, and a delay of 13 months in those with FXS who also met criteria for autism (Hinton et al., 2013). Furthermore, Warren and colleagues found that children with FXS and higher autism symptom severity had slower language development than those with FXS and lower autism symptom severity (Warren et al., 2010). These findings suggest that autism symptomology may play a substantial role in early language development in children with FXS.

As they age, boys with FXS continue to have impaired language skills (Roberts, Chapman, Martin, & Moskowitz, 2008) and are delayed in achieving major linguistic milestones throughout development (Abbeduto, McDuffie, Thurman, & Kover, 2016). Studies of older boys with FXS have shown delayed expressive and receptive language compared to mental age expectations, as well as impaired pragmatic abilities (Roberts, Chapman, et al., 2008). It is hypothesized that, as boys with FXS age, impaired cognition limits language development, resulting in delayed and impaired language comprehension (McDuffie, Chapman, & Abbeduto, 2008). Research further supports a difference in receptive language abilities associated with autism symptom severity (Lewis et al., 2006; McDuffie et al., 2012; Philofsky, Hepburn, Hayes, Hagerman, & Rogers, 2004). For instance, McDuffie et al. (2012) found that autism symptom severity was predictive of receptive vocabulary and syntax in boys between 10 and 15 years old with FXS. Additionally, Kover et al. (2012) demonstrated that autism symptom severity relates to expressive language in boys with FXS. In their study, amount of talk during conversation was associated with autism symptom severity, controlling for nonverbal cognition. Boys with FXS who demonstrated higher autism severity scores produced fewer complete and intelligible utterances (Kover et al., 2012). Thus, it seems that autism symptom severity not only impacts early language ability in boys with FXS but may also have lasting effects on later language ability.

Current Study

Successful acquisition of expressive language relies on the ability to produce speech sounds (Vihman, 2014) and combine them into purposeful communicative speech used during a conversational interchange. However, children with intellectual disability struggle to acquire language at the same pace and proficiency as their typically developing peers (Bernstein Ratner, 2009). These children often have restricted early consonant inventories (Sokol &

Fey, 2013) and intentional communication impairments. These early impairments can have lasting effects, which may limit an individual's communicative, social, and daily living skills.

Early-developing consonants, such as those expressed during babbling, are important building blocks of later complex speech sounds (Oller, Eilers, Neal, & Cobo-Lewis, 1998). Children's early and frequent use of consonants during babbling "correlates with earlier onset of words, [and] a larger productive vocabulary" (Menn & Stoel-Gammon, 2009, p. 72). Consonant inventory is a measure of the diversity of the total number of complex speech sounds a child produces. It is suggested that larger consonant inventories increase children's potential to acquire and produce vocabulary items and may lead to stronger expressive language ability. Paul and colleagues found a significant correlation between early consonant inventory and later expressive language, as measured by the Mullen Scales of Early Learning (MSEL; Mullen, 1995) in infants at high risk for autism (Paul, Fuerst, Ramsay, Chawarska, & Klin, 2011). Moreover, Yoder, Watson, and Lambert (2015) found that expressive language growth was predicted by consonant inventory in a sample of toddlers with autism. Thus, the ability to use a diverse range of consonant speech sounds is a prerequisite for expressive language development and vocabulary growth.

In addition to diverse consonant inventories, children also need the ability to use language purposefully during communicative interactions. Intentional communication encompasses purposeful communication acts produced by the child, including initiations and responses across modalities (verbal, gestural, etc.). Intentional communication is a basic skill that starts with early gestures and coordinated attention within the first few months of life (Iacono, Carter, & Hook, 1998; Stoel-Gammon, 1998). In their use of intentional communication, children demonstrate the means-end and social agency functions of communication (Warren & Yoder, 1998). When children make requests, they implicitly understand that a communicative partner can fulfill that request. As Warren and Yoder (1998) suggest, delays in the onset of intentional communication can result in delayed onset of expressive language.

Intentional communication and voluntary control of consonant sounds typically develop in tandem, and only once the two skills are unified can meaningful word production begin (Vihman, 2014). More frequent use of intentional communication is linked to faster consonant inventory growth in young children with autism (Woynaroski et al., 2016). Ultimately, intentional communication using correctly formed words is necessary to achieve fluent expressive language and social competence. Despite their central importance to early language development, early consonant inventory and intentional communication are understudied in children with FXS.

Consonant inventory and intentional communication are relatively simple to measure and, by doing so, we can easily identify certain areas of weakness in early language ability that are known to impact later expressive language ability. Identification of early weaknesses and their effect on later language outcomes can aid clinicians assessing and treating children with FXS (Bernstein Ratner, 2009). Furthermore, with a known delay in first words and continued language difficulties throughout childhood and adolescence, it is important to determine therapeutic targets likely to improve language outcomes in boys with FXS. Thus, this study examined early intentional communication and consonant inventory and their relationship with later expressive language ability in boys with FXS. Nonverbal IQ was included as a covariate, to be consistent with previous studies and to control for the effect of nonverbal IQ on language ability (Abbeduto et al., 2014). Finally, autism symptom severity was included as a moderator because there is a high rate of comorbidity between FXS and autism, and because there is evidence that autism symptom severity impacts language ability in children with FXS (Abbeduto et al., 2014; Kover et al., 2012; McDuffie et al., 2012; Roberts, Mirrett, & Burchinal, 2001).

Number of different words was chosen as the outcome variable because it represents the child's language use in contexts without the use of standardized assessments or testing. Therefore, it is subject to the child's mood, interest, and general talkativeness, which demonstrates how the child uses language when interacting with a conversational partner—in this study, the mother. Number of different words was also chosen for the outcome because it is strongly and significantly correlated to Expressive Vocabulary Test raw score in this sample (r =642, $p < 0.001$). Finally, number of different words was preferred over standardized vocabulary assessments because it is immune to practice effects seen in a population who are frequently given standardized assessments.

Methods

Participants

The current study utilized a pre-existing database from the Fragile X Research Lab at the University of Kansas (PIs: Steven F. Warren and Nancy Brady). Fifty-five children with full-mutation FXS and their biological mothers were enrolled in a longitudinal study spanning a 10-year period (see Warren et al., 2010). Researchers visited each family five or six times during the larger study. Data from two of those visits are included in this analysis. The participants represent a sample of convenience recruited from across the United States, and there was substantial variance in the sample on race, socioeconomic status, and maternal education. Of the original 55 children in our study, 11 were girls and were not included in this analysis. Additionally, seven boys were not included in the current analysis because they were older than 36 months at the time of their first home visit and their language was too advanced for our study of early language ability. One child's data was incomplete and thus did not contribute to the current analysis.

Child characteristics.

Thirty-six boys with full mutation FXS participated in the study, beginning in toddlerhood (see Table 1 for participant characteristics). At Time 1, the boys were between 19 and 36 months of age (M_{age} = 30.6, SD = 5.6), and at Time 2, roughly six and a half years later, they were between 107 and 119 months (M_{age} = 113.8, SD = 2.8).

Eleven boys in the current analyses had consistently high autism symptom severity based on average results from the Childhood Autism Rating Scale (CARS; Schopler, Reichler, &

Renner, 1988) measured across five or six home visits extending from early through middle childhood. We did not administer diagnostic assessments as part of this study.

Five boys, 14% of the sample, were still nonverbal at Time 2. These boys had fewer than five spoken words at Time 2 and could not complete the Expressive Vocabulary Test (EVT; Williams, 2007). Additionally, their mothers reported that their sons were nonverbal. Nevertheless, we retained the nonverbal boys in our analyses, as they are representative of the broad spectrum of abilities in males with FXS.

Maternal characteristics.—Maternal age at the first observation ranged from 20.0 to 41.0 years, with a mean of 32.8 (*SD* = 4.7) years. Age at the final observation ranged from 27.0 to 48.0 years, with a mean of 39.8 (*SD* = 4.4) years. All mothers in this sample carried the FXS premutation (55 to 200 repeats).

Procedure

For the current study, data came from an early childhood visit, hereafter referred to as Time 1, and from a home visit roughly six and a half years later, hereafter referred to as Time 2. At each home visit, the research team administered standardized assessments of child language and cognitive ability. Then the child and mother were videotaped during three structured, interactive contexts that each lasted 5 minutes. During Time 1 the contexts were: playing together, making a snack together, and reading a book together. At Time 2 the contexts were similar: making a craft together, making a snack together, and reading a book together. Table 1 shows child demographics and scores on standardized assessments, including the MSEL (Mullen, 1995) at Time 1 and the Peabody Picture Vocabulary Test (Dunn & Dunn, 2007) and EVT at Time 2.

Trained graduate research assistants coded the videotaped mother-child interactions using the Noldus Observer software (Noldus Information Technology, 2008). This software allows for behavior-by-behavior coding of the child’s communicative acts. Child verbal (both vocalizations and verbalizations) and nonverbal (gestures, points, and signs) communication acts were identified based on their clear communicative intent. These were further broken down into initiations and responses. Transcripts from the Noldus observations were reformatted and entered into Systematic Analysis of Language Transcripts software (SALT; Miller & Chapman, 2000). This software determines mean length of utterance (MLU), total number of utterances, and total number of different words used, among other counts. Utterances were transcribed by C-units, and words in the SALT transcripts were segmented by morpheme. During Time 1, structured mother-child interactions, number of intentional communicative acts, and number of partially acquired consonants for the child were obtained from 15 minutes of videotaped interactions. For the Time 2 interactions, total number of different words was obtained, again from 15 minutes of interaction. All Noldus and SALT transcripts were coded by two trained graduate researchers, one primary and one secondary.

Measures

Intentional communication.—Intentional communication was the total sum of all child communicative acts across the three mother-child interactions at the Time 1 visit. Communicative acts included verbalizations (words), vocalizations (nonword sounds), gestures, and signs that had clear communicative intent. Communicative intent required meaning or function as well as attention (eye gaze or physical touch) directed towards the communicative partner, in this case the mother. The intraclass correlation for the total sum of communication acts collapsed across modalities between the primary and secondary coder was 0.99.

Consonant inventory.—Consonant inventory was measured using the pre-identified communicative verbalizations and vocalizations. A trained coder listened to each communicative act up to three times to determine which, if any, consonant was present in the act. Consonant inventory was coded by the first author, a graduate student with a background in linguistics and autism, and 31% of files were coded by a reliability coder, a graduate student with a background in linguistics, speech-language pathology, and autism. A total count of different consonants heard by the coder was obtained. If the consonant was unclear after three listens, it was not counted in the consonant inventory. The intraclass correlation for the total number of consonants in each child's consonant inventory as determined by each coder was 0.99.

The maximum consonant inventory for this coding system was 14, and the inventory of English consonants used for coding is available from the first author. Glottal stops and glottal fricatives were not considered consonants. However, glides were considered consonants, as is common in studies of early consonant production (Sokol & Fey, 2013). Voicing distinctions were not accounted for, such that /p/ and /b/ and other voiced/voiceless minimal pairs were considered a single consonant. This was due to difficulties in distinguishing voicing encountered by the coders. The child was given credit for each consonant produced during the mother-child interactions regardless of the locations within the verbal/vocalization (syllable-initial, etc.). Although a more stringent method for including consonants in one's consonant inventory is used for acquisition studies, the current study took all consonant productions into account. This way, the child was credited for each consonant they produced regardless of how often or where in the syllable the consonant was produced.

Nonverbal IQ.—Early nonverbal IQ was measured using the MSEL (Mullen, 1995) at Time1. This is a standardized developmental assessment for children between zero and 68 months. There are five domains that combine to create a standard score representing an overall developmental functioning estimate. Rather than using the overall standard score, we used a nonverbal cognitive ability score to remove confounding language abilities. This score is calculated by combining the Visual Reception and Fine Motor domains (Mullen, 1995). We used raw scores due to floor effects and limited variability in standard scores. This assessment was administered by trained researchers during the home visits.

Number of different words.—Number of different words was determined using the number of different words the child spoke during the Time 2 interactions. All three structured contexts were used to measure number of different words, and the count came from Noldus transcripts that were analyzed using SALT software. Number of different words was collected from three 5-minute samples, rather than from a certain number of utterances. The intraclass correlation between the primary and secondary coders on number of different words used by the child during the three interactions was 0.99.

Autism symptom severity.—We were interested in the effect of concurrent autism symptom severity on number of different words. Autism symptom severity was measured at each data collection visit using the CARS (Schopler, Reichler, & Renner, 1988). The CARS is a measure that provides a general impression of autistic behavior as scored on 15 rating-scale items. Scores less than 30 indicate no autistic symptoms. Children with a score over 30 display mild to moderate autistic symptoms. Children who score over 37 display symptoms consistent with severe autism. Although the CARS alone should not be used to diagnose autism, it has been frequently used in research settings to describe autism symptom severity and quantify behaviors that are consistent with a diagnosis of autism (Schopler, Van Bourgondien, Wellman, & Love, 2010). CARS score at the Time 2 visit was used for analyses, because at Time 1 multiple children were too young to reliably assess using this measure, given that the CARS is normed for children 2 years and older. Furthermore, CARS scores from Time 1 were highly and significantly correlated with CARS scores from Time 2 ($r = .615$, $p < 0.001$). CARS score was determined by two trained researchers who attended the home visits. The score was agreed upon item-by-item through consensus between the two coders immediately following the home visit based solely on behaviors and symptoms witnessed during the in-home observation.

Analysis

The analyses for this article were performed using SAS software (version 9.4). General linear models were estimated using residual maximum likelihood in SAS PROC MIXED to determine the additive and interactive effects of early consonant inventory (centered at the mean, 3.44), intentional communication, nonverbal IQ, and autism symptom severity (CARS score, centered at the mean, 27.5) on later number of different words.

Results

Descriptive Characteristics

Table 2 presents descriptive summaries of each variable and Table 3 provides correlational information between the variables. All the early predictors were significantly correlated with the dependent variable and with one another. Importantly, when controlling for the effect of Time 2 nonverbal IQ, Time 2 autism symptom severity and number of different words were significantly negatively correlated, $r = -0.63$, $p < 0.001$. The mean consonant inventory was 3.44 ± 3.73. The mean number of intentional communication acts was 29.61 ± 29.68. Autism symptom severity was significantly negatively correlated with consonant inventory, intentional communication, nonverbal IQ, and concurrent number of different words. At Time 1, 13 boys did not use consonants in their babbling or speech, which may have affected the analysis. All participants demonstrated use of intentional communication, but there was large variation in the amount used. Five boys used five or fewer words at Time 2 but were retained in the analyses because they are representative of the population and they only comprised 14% of our sample.

Regression Models

We began with a model with main effects of the early predictors: consonant inventory, intentional communication, and nonverbal IQ. This model had a total R^2 of 0.14, $p = 0.000$. The main effect of consonant inventory approached significance (F[1, 32] = 3.08, $p = 0.08$), but the main effects of intentional communication and nonverbal IQ did not (F[1, 32] = 0.39, $p = 0.53$ and F[1, 32] = 0.15, $p = 0.70$, respectively). Next, autism symptom severity was added as a covariate. The model total R^2 increased to 0.44, $p = 0.000$. The main effects of consonant inventory, intentional communication, and nonverbal IQ in this model were not significant (F[1, 31] = 2.02, $p = 0.16$; F[1, 31]) = 0.77, $p = 0.39$; and F[1, 31] = 0.29, $p = 0.59$, respectively). However, the main effect of autism symptom severity was significant (F[1,31] = 18.33, $p < 0.001$). Given the significance of autism symptom severity, we restructured the model to include autism symptom severity as a moderator of the early predictors.

A model that included consonant inventory, intentional communication, nonverbal IQ, and the moderating effect of autism symptom severity yielded a total R^2 of 0.56, $p < 0.001$. In this model, the simple main effects of consonant inventory (F[1, 28] = 5.55, $p = 0.03$) and the interaction term between consonant inventory and autism symptom severity (F[1, 30] = 4.67, $p = 0.04$) were significant predictors of later number of different words. The effect of the interaction of intentional communication and autism symptom severity approached significance (F[1, 30] = 3.87, $p = 0.06$).

The most parsimonious model, considering our small sample size, was one that included a two-way interaction between consonant inventory and autism symptom severity. This model yielded a total R^2 of 0.53, $p < 0.001$, which was not meaningfully different from the previous model. Table 4 presents a summary of the models. Table 5 presents effect sizes of each predictor, reported as local Cohen's f^2 using the calculation methods presented in Selya, Rose, Dierker, Hedeker, and Mermelstein (2012) where:

$$f^2 = \frac{R_{AB}^2 - R_A^2}{1 - R_{AB}^2} \quad (1)$$

Benchmarks for small, medium, and large effect sizes, according to Cohen (1988) are 0.2, 0.5, and 0.8, respectively. Consonant inventory had a small effect size, $f^2 = 0.12$; autism symptom severity had a large effect size, $f^2 = 0.82$; and the interaction between consonant inventory and autism symptom severity had a small effect size, $f^2 = 0.16$. The interaction of consonant inventory and autism symptom severity (F[32] = 6.33, $p = 0.02$) revealed that the effect of autism symptom severity was significantly less detrimental when the individual actually had a consonant inventory (i.e., the individual used consonants). The simple main effect of consonant inventory was 5.57 and was significant (F[32] = 5.13, $p = 0.03$). This indicated that, for each additional consonant the child produced beyond the group mean, number of different words increased by 5.57 specifically when autism symptom severity equaled the mean (CARS score 27.5). The simple main effect of autism symptom severity was −3.95 and was also significant ($F(32) = 7.15$, $p = 0.01$). This indicated that for each additional point scored on the CARS, the child's number of different words decreased by 3.95, specifically when the consonant inventory was equal to the mean.

For individuals with consonant inventories one standard deviation above the mean, the effect of autism symptom severity on number of different words was reduced. This suggests that when the individual has a higher consonant inventory, autism symptom severity has less impact on their number of different words. Based on the final model, expected number of different words was estimated at three levels (mean, ± 1 *SD*) for autism symptom severity and consonant inventory to illustrate the two-way interaction (see Figure 1). The predicted number of different words for an individual with average early consonant inventory and high autism symptom severity (+ 1 *SD*) was 83.50. The predicted number of different words for an individual with average early consonant inventory and low autism symptom severity (−1 *SD*) was 131.96. Individuals with smaller than average consonant inventories, where the number of consonants equals zero, and high autism symptom severity were predicted to produce fewer number of different words (NDW) than individuals with small consonant inventories and average or lower autism symptom severity (NDW = 39, 87, and 134, respectively). Finally, the model predicted that individuals with above average consonant inventories (+ 1 *SD*) have a larger number of different words regardless of autism symptom severity level (NDW = 127.67, 128.60, and 129.52 for high, average, and low severity, respectively). Figure 1 illustrates the effect of the interaction of autism symptom severity and consonant inventory on number of different words.

Discussion

This study examined the predictive ability of early consonant inventory and early intentional communication on number of different words expressed by boys with FXS as they aged from 2.5 to 9 years. We also explored the effect of the interactions of concurrent (Time 2) autism symptom severity and the early predictors on number of different words. Intentional communication and nonverbal IQ were not significantly predictive of number of different words. The simple main effects of consonant inventory and autism symptom severity were significantly predictive, as was the interaction between the two. These findings suggest that autism symptom severity moderates the effect of early linguistic ability on later expressive language skills.

To our knowledge, this is the first study to examine early consonant inventory in boys with FXS. Our data suggest that boys with FXS have impairments in early consonant inventory, as our participants averaged just 3.44 consonants at 31 months of age. A similar delay has been demonstrated in 25-month-old toddlers with Down syndrome, who average four consonants (Sokol & Fey, 2013). Additionally, Schoen and colleagues reported that 28-month-olds with autism produce on average 6.73 consonants, significantly fewer than age-matched typically developing peers, who produce 13.82 on average (Schoen, Paul, &

Chawarska, 2011). Autism symptom severity may impact how boys with FXS acquire and use consonants (Schoen et al., 2011).

As McCune and Vihman (2001) reported, having voluntary control of at least two consonants early in development is an important precursor to onset of expressive language. This held true in our sample, as there was a moderate positive correlation between consonant inventory and number of different words ($r = .45$, $p = .006$). This effect was moderated by autism symptom severity. Specifically, those with higher autism symptom severity (1 *SD* above the mean) produced a smaller number of different words if they had restricted consonant inventories, but higher number of different words if they had relatively large consonant inventories. However, boys with lower autism symptom severity (1 *SD* below the mean) do not show a large difference in number of different words based on the size of their early consonant inventory. Because our measure of autism symptom severity was concurrent with the measure of number of different words, we could not determine whether early consonant inventory and early autism symptom severity also interacted. However, our data suggest that these two variables may interact, due to the high correlation between early and late autism symptom severity. This conclusion should be interpreted with caution as it is also the case that concurrent autism symptom severity and number of different words were significantly correlated.

Contrary to findings from previous research on children with autism (Yoder et al., 2015), intentional communication was not a significant predictor of later expressive language ability. There could be several reasons for this discrepancy. First, the measure of expressive language ability used in this study was number of different words gathered from just 15 minutes of structured mother-child interaction. Yoder and colleagues (2015) used an aggregate of results from the MacArthur Communicative Development Inventory expressive vocabulary size, Communication and Symbolic Behavior Scales word scale, and number of different words from an unstructured speech sample as their measure of expressive language growth. These distinct differences in measurement may account for the differences in cross-study comparisons of intentional communication. Diagnosis may also be a contributing factor. Although there is a high degree of overlap between symptoms and a high rate of comorbidity, our sample included boys with FXS, not boys with non-syndromic autism. Furthermore, only two boys in our study had received clinical diagnoses of co-morbid autism by Time 2. These two disorders present with dissimilar social communication impairments and have different etiologies, which complicates comparisons between them. Finally, it is possible that intentional communication may have been predictive of expressive language ability at an outcome period closer to Time 1. On average, 6.5 years elapsed between Time 1 and 2 in this study. An intermediary time point may have yielded different results. Nonverbal IQ was also not significantly predictive of later expressive language ability. Given that nonverbal IQ is a measure of cognition distinct from verbal ability, this finding was expected.

Autism symptom severity stability over time in boys with FXS is contested in the literature, with some research suggesting that autism symptom severity may increase or remain stable over time (Hernandez, Feinberg, Vaurio, Passanante, Thompson, & Kaufmann, 2009; Lee, Martin, Berry-Kravis, & Losh, 2016). However, some research suggests that autism symptom severity may decrease somewhat as children with FXS age (McDuffie et al., 2010). If this is the case, this decline in symptom severity may be particularly apparent in reciprocal social interaction and communication domains. Kover et al. (2012) found that concurrent autism symptom severity was negatively correlated with talkativeness in 10-to 17-year-old boys with FXS. If autism symptom severity is worse during early childhood, this might suggest that talkativeness is even more impaired in early childhood for boys with FXS and high autism symptom severity. This would limit early social interaction and conversational opportunities that are requisites of intentional communication and subsequent language development. Similarly, boys with FXS are known to have challenges with inattention and hyperactivity, and social anxiety and avoidance (Thurman, McDuffie, Hagerman, & Abbeduto, 2014). Intentional communication develops through social interaction with communicative partners (Laakso, Poikkeus, Katajamaki, & Lyytinen, 1999). Inattention and social avoidance likely affect how boys with FXS interact with conversational partners, which in turn may impact the linguistic knowledge they can gain from their environment. If input from the environment and conversational partners is limited, either through social avoidance, inattention, or reticence to converse, this could affect subsequent language development. For boys with FXS who demonstrate high autism symptom severity, this may disrupt language interaction with pronounced cumulative effects over lengthy periods of time.

Many factors can have long-lasting effects on the language development of children with neurodevelopmental disorders. Nevertheless, an aggregate of multiple early factors may provide the best prediction of expressive language ability in children with FXS. The findings from our study suggest that consonant inventory is an early ability that should be targeted for intervention, as it is significantly predictive of later expressive language ability in boys with FXS. Additionally, boys with higher autism symptom severity may be at increased risk for impaired language ability if they have restricted early consonant inventories. Additional work is needed to identify other early predictors of later expressive language in boys with FXS. Specifically, an examination of response to bids for joint attention and parent linguistic responses is warranted. A study of consonant inventory development through multiple occasions could be analyzed through multilevel modeling, which may provide more insight into consonant acquisition in boys with FXS.

The primary strengths of the current study are the systematic analysis of previously overlooked variables in this population, and the true longitudinal nature of our data. Other studies have followed their participants for 18 months or more, or through several shorter data collection periods (such as Woynaroski et al., 2016; Yoder et al., 2015). This study followed participants from toddlerhood through middle childhood, with Time 2 following Time 1 by roughly six years. In addition, this study examined early variables that were measured with high reliability and at an age when these skills are important to later language development (McCune & Vihman, 2001).

This study is limited by the sample size, which limits our statistical analytic power. Additionally, our selection of number of different words as the measure of expressive language ability may limit the generalizability of our findings. The sampling context for this variable is unique to our study and may have impacted the talkativeness of the child. The mother-child interactions were videotaped by researchers, which may have increased social anxiety and reduced the child's talkativeness. Finally, our decision to retain the full sample rather than exclude boys who were not using consonants at Time 1 and boys who were nonverbal at Time 2 may be controversial. However, had we excluded these individuals, we would have misrepresented the broad spectrum of early language ability in boys with FXS. Consequently, we believe our results to be representative of the heterogeneity of our sample and of boys with FXS in general.

Our findings suggest that young boys with FXS have impaired early consonant inventories, which may be further impacted by autism symptom severity. Complex babbling and consonant use are building blocks of later language. Therefore, we recommend that clinicians target consonant development and diversification in young boys with FXS, particularly those with high levels of autism symptom severity. However, as is the case with many neurodevelopmental disorders, there was variability in our sample. Although it may be the case that consonant inventory should be an intervention target, it may also be the case that targeting the broader construct of intentional communication skills will increase an individual's expressive language ability throughout development. Furthermore, there may exist an underlying language learning problem in boys with FXS, such that therapeutic targeting of early consonant inventory and intentional communication may not remedy language learning difficulties in this population. Further research is needed to identify other early predictors of language learning in boys with FXS.

Acknowledgments

This research is funded by NICHD P30 HD00310, P30 HD02538, and R01 HD084563 (PIs: Steven F. Warren and Nancy Brady). The first author is directly supported by a NIH grant awarded to the University of Kansas: T32 DC000052, Training Researchers in Language Impairments (PI: Mabel Rice). We thank Kandace Fleming and Lesa Hoffman for their assistance with data analysis, Lindsay Williams for her assistance in transcription, and Mabel Rice and Rob Fiorentino for their valuable input. Finally, we thank the families for welcoming us into their homes and for their continued participation in our study.

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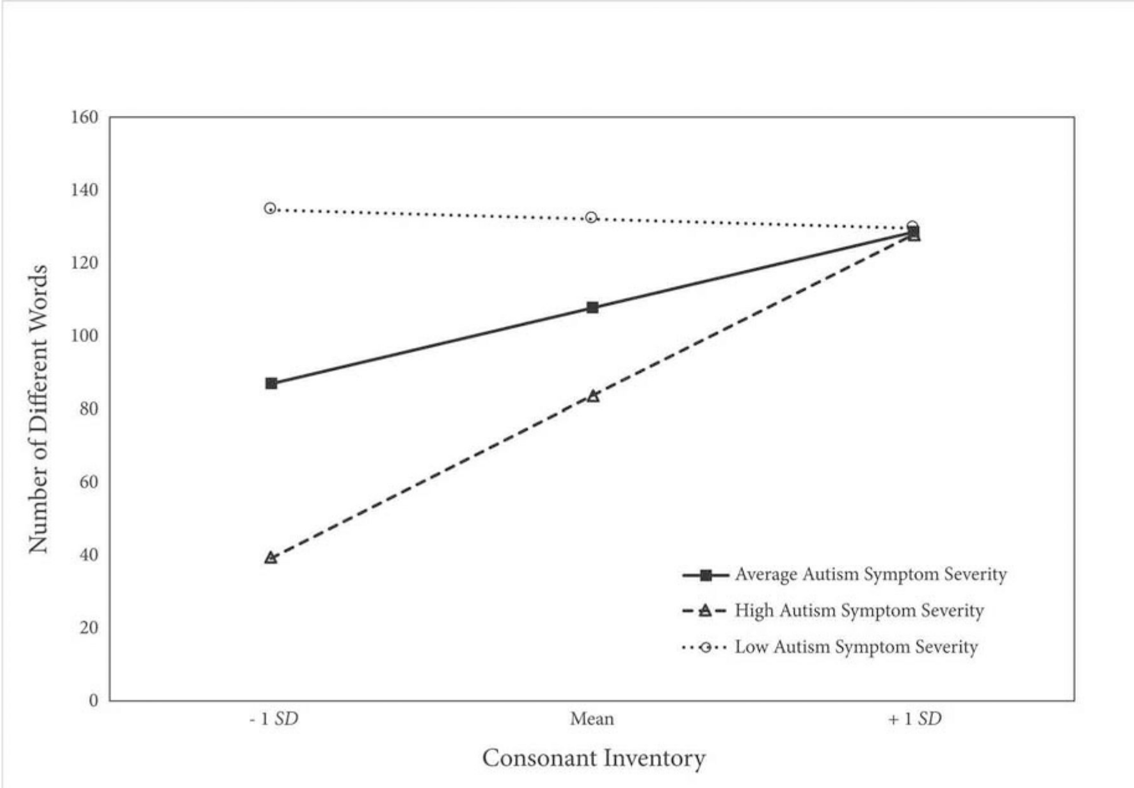

Figure 1.
Expected number of different words by consonant inventory and autism symptom severity.

Table 1

Child Characteristics and Demographics

		Mean / %	*SD*	Range
Age (months)	Time 1	30.6	5.6	19 – 36
	Time 2	113.8	2.8	107 – 119
EVT Raw Score		47	30.5	0 – 97
PPVT Raw Score		71.1	32.6	15 – 129
Mullen Nonverbal Raw Score		39.6	8.3	21 – 58
Ethnicity	Caucasian	91.7		
	Other	8.3		
Household Income	< $30,000	16.7		
	$30,000 – $80,000	33.3		
	> $80,000	47.2		
	No Report	2.8		

Note. EVT = Expressive Vocabulary Test; PPVT = Peabody Picture Vocabulary Test.

Table 2

Child Scores on Measured Variables

Variable	***n***	**Mean (*SD*)**	**Range**
Consonant Inventory	36	3.44 (3.73)	0 – 12
Intentional Communication	36	29.61 (29.68)	2 – 128
Nonverbal IQ	36	39.61 (8.29)	21 – 58
CARS score	36	27.50 (6.17)	18 – 42.50
Number of Different Words	36	96.64 (58.75)	0 – 193

Note. CARS = Childhood Autism Rating Scale.

Table 3

Correlations Among Measured Variables

Correlations	Cons.	Intent.	NVIQ	CARS	NDW
Consonant Inventory	-	.82†	.66†	−.49*	.45*
Intentional Communication		-	.54†	−.42‡	.32
Nonverbal IQ			-	−.48*	.33‡
CARS score				-	−.69†
Number of Different Words					-

Note. Cons. = Consonant Inventory; Intent. = Intentional Communication; NVIQ = nonverbal IQ; CARS = Childhood Autism Rating Scale; NDW = number of different words.

$^{\ddagger}p < 0.05$

$^{*}p < 0.01$

$^{\dagger}p < 0.001$.

Table 4

Hierarchical Regression Analyses Predicting Number of Different Words From Early Linguistic Predictors and Concurrent Autism Symptom Severity

Predictor	ΔR^2	β
Step 1	.14†	
Consonant Inventory		8.50‡
Intent. Communication		−.34
Nonverbal IQ		.56
Step 2	.30†	
Consonant Inventory		5.63
Intent. Communication		−.39
Nonverbal IQ		−.66
Autism		−6.08†
Step 3	.11†	
Consonant Inventory		8.56*
Intent. Communication		−.49
Nonverbal IQ		−.93
Autism		−10.36
Consonant Inventory X Autism		1.55*
Intent. Communication X Autism		−.15‡
Nonverbal IQ X Autism		0.27
Step 4	−.03	
Consonant Inventory		5.57*
Autism		−3.95†
Consonant Inventory X Autism		1.02*
Total R^2	.53†	
N	36	

Note: Betas are unstandardized.

‡ $p<.10$

* $p < 0.05$

† $p < 0.001$.

Table 5

Effect Sizes for Predictors of Number of Different Words

	R^2_{AB}	R^2_A	f^2	**Strength of effect**
Consonant Inventory	0.53	0.48	0.12	Small
Autism Symptom Severity	0.53	0.15	0.82	Large
Interaction	0.53	0.46	0.16	Small