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ORIGINAL PAPER

Concurrent Social Communication Predictors of Expressive Language in Minimally Verbal Children and Adolescents with Autism Spectrum Disorder

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Abstract

Numerous studies have investigated the predictors of language in pre-verbal toddlers and verbally fluent children with autism spectrum disorder (ASD). The present study investigated the concurrent relations among expressive language and a set of empirically-selected social communication variables—joint attention, imitation, and play—in a unique sample of 37 minimally verbal (MV) children and adolescents with ASD. Results revealed that imitation and play were significantly correlated with expressive language, even when controlling for non-verbal IQ, but joint attention was not. Imitation was the only predictor variable to reach significance within the regression model. Findings demonstrate that predictors of expressive language vary for subpopulations of the autism spectrum, and have broader implications for intervention design for older, MV individuals with ASD.

Keywords Autism spectrum disorder · Minimally verbal · Expressive language · Joint attention · Imitation · Play

Introduction

Within the population of children and adolescents diagnosed with autism spectrum disorder (ASD), language ability is heterogeneous. While some have above average language abilities, nearly 30% are classified as 'minimally verbal' (Tager-Flusberg and Kasari 2013). Even within this minimally verbal (MV) subpopulation of the autism spectrum, there is variability in expressive language abilities, ranging from no use of spoken language to limited use of words and a few fixed phrases. It is still not known why these MV children and adolescents with ASD do not develop fluent speech, but it is likely the result of a complex, multi-factorial process involving atypical development of various cognitive and social communication variables.

Studies conducted with MV children with ASD have shown that the severity of autism symptoms is related to language outcomes (Lord and Pickles 1996; Thurm et al. 2015). However, it is important to differentiate between autism symptoms through comprehensive behavioral assessment, so that we can more precisely classify those at risk for language deficits, and further recognize which specific variables may be influencing language development in ASD. Previous work conducted with samples of typically-developing children, as well as pre-verbal toddlers and verbally fluent children with ASD, has identified longitudinal and concurrent predictors of expressive language. Indeed, there is strong evidence that social communication variables, including joint attention, play, and imitation, as well as broader cognitive variables (i.e., non-verbal IQ), are involved in language development. Table 1 summarizes existing studies that have used various methods to investigate the relation among these predictor variables and expressive language in ASD.

It is particularly important to study expressive language in MV children and adolescents because expressive language deficits are associated with maladaptive outcomes, such as self-injury, aggression, inattention, and low affect (Dominick et al. 2007; Hartley et al. 2008). Despite this importance, it is unknown whether the same variables that predict language in younger, pre-verbal toddlers and verbally fluent children are related to language ability in older, MV

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Table 1 Summary of studies investigating the relation between social communication variables of interest and expressive language in toddlers and children with ASD

Study	Variable(s) measured	Cross-sectional or longitudinal	Chronological age of sample	Type of statistical analysis—variable(s) significantly related to expressive language
Charman (2003)	IJA, play, imitation	Both	20 months → 45 months	Correlation—IJA, imitation
Charman et al. (2000)	IJA, play, imitation	Both	20 months → 44 months	Correlation—Play, imitation
Hobson et al. (2013)	Play	Cross-sectional	2–9 years	Correlation—Play
Ingersoll and Meyer (2011)	Imitation	Cross-sectional	22–47 months	Correlation—Imitation
Kasari et al. (2008)	IJA, RJA, play	Cross-sectional	36–48 months	Correlation—IJA, RJA, play
Luyster et al. (2008)	IJA, RJA, play, imitation, NVIQ	Cross-sectional	18–33 months	Correlation— IJA, RJA, play, imitation, NVIQ Hierarchical linear regression with forward variable selection—imitation, NVIQ
McDuffie et al. (2005)	Imitation	Longitudinal	24–46 months → 5.3–7.9 months follow up	Correlation—Imitation
Mundy et al. (1987)	Play	Cross-sectional	38–75 months	Correlation—Play
Murray et al. (2008)	IJA, RJA	Cross-sectional	36–60 months	Correlation—RJA
Pickard and Ingersoll (2015)	IJA, RJA, NVIQ	Cross-sectional	22–93 months	Correlation—RJA Hierarchical linear regression—RJA, NVIQ
Pierucci et al. (2015)	Play	Cross-sectional	19–56 months	Correlation—Play
Rogers et al. (2003)	Imitation	Cross-sectional	21–50 months	Correlation—None
Schietecatte et al. (2012)	IJA, RJA	Cross-sectional	36 months	Correlation—RJA
Smith et al. (2007)	IJA, play, imitation	Longitudinal	20–71 months → 6, 12, 24 month follow up	Cluster analysis—IJA, play, imitation
Stone et al. (1997)	Imitation	Longitudinal	23–35 months → 11–18 month follow up	Correlation—Imitation
Thiemann-Bourque et al. (2012)	Play	Cross-sectional	3–6 years	Correlation—None
Thurm et al. (2007)	IJA, RJA, imitation	Longitudinal	24 months → 60 months	Multiple linear regression—Imitation
Toth et al. (2006)	IJA, IBR, RJA, play, imitation	Cross-sectional	34–52 months	Correlation—IJA, RJA, play, imitation Multiple linear regression—IJA, imitation
Van der Paelt et al. (2014)	IJA, IBR, RJA, play, imitation	Cross-sectional	22–75 months	Correlation—IJA, IBR, play, imitation Hierarchical linear regression—IBR, RJA, play, imitation
Whyte and Owens (1989)	Play	Cross-sectional	5–11 years	Correlation—Play
Yoder et al. (2015)	RJA, play, imitation	Longitudinal	24–48 months → 4, 8, 12, 16 month follow up	Growth curve modeling—RJA, play, imitation Growth curve modeling with value-added predictors—RJA

children and adolescents with ASD, because these individuals are often excluded from research (Tager-Flusberg and Kasari 2013). It is possible that the predictors of expressive language may differ for this unique subpopulation of the autism spectrum. Therefore, the present study aimed to investigate the concurrent relations among expressive language, non-verbal IQ, and an empirically-based set of social communication variables within a sample of MV children and adolescents with ASD.

Joint Attention

Joint attention, defined as interaction in which two individuals intentionally focus their attention on the same object or event, is one of the most widely studied social communication variables in ASD (Redcay and Saxe 2013). Many researchers have theorized that joint attention is crucial for language learning, as it helps children map novel words onto the correct objects or events within their environment (e.g., Baldwin 1995). Thus, deficits in the initiation of or response to social joint attention bids may result in reduced vocabulary. It is important to distinguish between the two constructs of joint attention, initiation of joint attention (IJA) and response to joint attention (RJA), because they may play different roles in language development (Mundy and Jarrold 2010). A systematic review and meta-regression analysis conducted by Bottema-Beutel (2016) revealed that the effect size for the relation between RJA and expressive language was greater than the effect size for the relation between IJA and expressive language in toddlers and children with ASD, thus highlighting the importance of measuring these joint attention constructs separately.

IJA can be classified as protodeclarative IJA or protoimperative IJA, which is commonly referred to as initiation of behavioral requests (IBR). Even though protodeclarative IJA and IBR are behaviorally similar (e.g., eye gaze shifts, pointing, reaching), the internal cognitive processes driving these social behaviors are fundamentally different. Protodeclarative IJA behaviors are motivated by a child's desire to share attention, while IBR behaviors are motivated by a child's desire to obtain an object (Toth et al. 2006). Because of these differences, protodeclarative IJA and IBR should be also studied separately, as they may play different roles in language development.

The findings on the relation between protodeclarative IJA and expressive language in toddlers and children with ASD are mixed; some studies have found a significant positive relation between protodeclarative IJA and expressive language (Charman 2003; Kasari et al. 2008; Luyster et al. 2008; Smith et al. 2007; Toth et al. 2006; Van der Paelt et al. 2014) while others have found that the variables are not significantly related (Charman 2003; Charman et al. 2000; Murray et al. 2008; Pickard and Ingersoll 2015; Schietecatte et al. 2012; Thurm et al. 2007). Only two studies have looked at the relation between expressive language and IBR in children with ASD, and again, findings are inconsistent (Toth et al. 2006; Van der Paelt et al. 2014). Findings on the significance of IJA as a predictor of expressive language may vary based on the range of abilities within a sample. For example, a small range in IJA or the absence of IJA may result in non-significant correlations. These discrepant findings may also be the result of sample differences in moderating variables, such as cognitive ability, which were not controlled for in statistical analyses.

Compared to IJA, the literature on the relation between RJA and expressive language in ASD is more consistent. The majority of studies have reported a significant positive relation between RJA and expressive language in toddlers and children with ASD (Kasari et al. 2008; Murray et al. 2008; Pickard and Ingersoll 2015; Schietecatte et al. 2012; Toth et al. 2006; Yoder et al. 2015). One study reported a significant relation between RJA and expressive language in children with low expressive language abilities, but a non-significant relation in children with high expressive language abilities, further demonstrating that the concurrent predictors of language may vary based on the language abilities of the sample (Van der Paelt et al. 2014). Overall, the literature reliably demonstrates that RJA plays a significant role in expressive language development for toddlers and children with ASD.

Play

In typical development, children advance through different play levels which increase in complexity. For instance, young toddlers engage in simple play behaviors, such as throwing balls or stacking blocks, but as they get older, they begin performing more complex play behaviors, such as pretending dolls are agents of thought, feeling, and action. Thus, children typically acquire greater diversity in their play behaviors as they progress from functional to symbolic play. The spontaneous use of objects in both functional and symbolic play has been linked to expressive language (e.g., Lewis et al. 2000). Several studies have also shown a significant positive relation between spontaneous play and expressive language in toddlers and children with ASD (Charman et al. 2000; Hobson et al. 2013; Kasari et al. 2008; Luyster et al. 2008; Mundy et al. 1987; Pierucci et al. 2015; Smith et al. 2007; Toth et al. 2006; Van der Paelt et al. 2014; Whyte and Owens 1989). Two studies reported that play was not significantly related to expressive language, but this could be due to the small sample size (Charman 2003) or the inclusion of modeled (i.e., non-spontaneous) play behaviors (Thiemann-Bourque et al. 2012).

Despite these fairly consistent findings, most of these studies did not consider the developmental appropriateness of play behaviors (see Kasari et al. 2006 for description of developmental play levels). Instead, they simply reported summary scores for the presence or absence of play. These summary scores are limited in range and thus are difficult to use when studying individual differences within a sample. Other studies have measured quantity of play behaviors, as reflected by frequency of play behaviors or total amount of time engaged in play. While these quantitative measures of play have a larger range, they do not consider whether the play is developmentally appropriate given the child's chronological age. For example, an older child may receive a high quantitative play score even if he exhibits the same stereotypic, low level play behavior, such as repeatedly throwing a ball onto the floor. Therefore, rather than relying exclusively on summary scores or quantitative measures of play, it would be beneficial to include measures of play that also consider the developmental appropriateness of play. The number of developmental play levels exhibited (i.e., diversity of spontaneous play) indirectly reflects the developmental-appropriateness of play because typically, a greater number of play levels are acquired with age. Determining whether diversity of spontaneous play correlates with expressive language could provide better insight into the developmental relations between these abilities in ASD.

Imitation

Imitation is one of the most important social communication variables in development, as it serves as the foundation for learning new behaviors (Meltzoff and Moore 1977). It is also fundamentally impaired in toddlers and children with ASD (see Williams et al. 2004 for review). For these reasons, many studies have examined the relation between imitation and expressive language in ASD. Although these studies have used various protocols to measure imitation abilities, most have found that imitation and expressive language are significantly and positively related (Charman 2003; Charman et al. 2000; Ingersoll and Meyer 2011; Luyster et al. 2008; McDuffie et al. 2005; Smith et al. 2007; Stone et al. 1997; Toth et al. 2006; Van der Paelt et al. 2014; Yoder et al. 2015). One study found that early imitation abilities predicted whether toddlers with ASD would develop expressive language by 5 years of age, whereas other social communication variables, such as IJA and RJA, did not (Thurm et al. 2007). One study reported a non-significant relation between imitation and expressive language, but again, this may be because the sample size was relatively small (Charman 2003; Rogers et al. 2003). It is particularly important to consider whether imitation is a predictor of expressive language for older, MV children and adolescence with ASD, as this relation may vary based on the age or language ability of the sample.

Non-verbal IQ

Atypical cognitive abilities, particularly low non-verbal IQ (NVIQ), may also be related to expressive language deficits in ASD. It has been found that NVIQ predicts patterns of language growth, concurrent and longitudinal expressive language outcomes, and acquisition of phrase speech in children with ASD (Anderson et al. 2007; Brignell et al. 2018; Luyster et al. 2008; Norrelgen et al. 2015; Sigman and McGovern 2005; Wodka et al. 2013). While it is common for intellectual disability to co-occur with low expressive language in ASD (Fernell et al. 2010), this relation between language and broader cognitive abilities is seemingly complex, as some children with ASD have low expressive language but high NVIQ (Munson et al. 2008). Nevertheless, like social communication variables joint attention, play, and imitation, NIVQ is likely to play a role in the development of expressive language.

To summarize, most studies have reported that RJA, play, imitation, and NVIQ are significantly related to expressive language, while findings on the relation between IJA and expressive language are more inconsistent. However, because all of these studies were conducted with samples of pre-verbal toddlers and verbally fluent children under the age of 9 years, it is unknown whether the same social communication variables are related to expressive language in older, MV children and adolescents with ASD. Accordingly, the present study had three aims.

(1) Investigate the relation between a comprehensive set of empirically-motivated social communication variables—joint attention (RJA, IJA, IBR), play, and imitation—and expressive language in a sample of MV children and adolescents with ASD;
(2) determine whether these social communication variables remain significantly related to expressive language when controlling for NVIQ;
(3) explore which variables remain significant predictor(s) of concurrent expressive language while accounting for other concurrent predictors within a single regression model.

Based on the findings of previous literature, we hypothesized that joint attention, play, imitation, and NVIQ would all be significantly and positively related to expressive language. Because no studies have included MV children and adolescents, we did not have any a priori hypotheses about which concurrent predictor variables would reach statistical significance within the regression model.

Methods

Sample

Participants for this study were selected from a larger research program on MV ASD. Participants, ages 5 to 19 years old, with a confirmed diagnosis of ASD and minimal to no communicative speech were included in the study. We defined 'minimally verbal' or 'MV' as those with no speech or inconsistent simple phrase speech of less than three units. This definition of MV, based on criteria for Module 1 of the Autism Diagnostic Observation Schedule-Second Edition (ADOS-2), is the most commonly used definition of MV in the literature (Bal et al. 2016). The final sample included 37 MV participants (25 males, 12 females) who had usable data from all measures. 22 of the participants were children, under the age of 12 years, and 15 of the participants are adolescents, over the age of 12 years. Full demographic information is reported in Table 2.

Procedure

Participants completed all measures within a battery of assessments that took place during one to four lab visits. Measures were administered in a pseudo-randomized order with some modifications of standardized administration in order to minimize participant distress and optimize cooperation (Tager-Flusberg et al. 2017). Parents of participants completed questionnaires during the lab visits or at home. Descriptive statistics for each measure are reported in Table 3.

Measures

Autism Diagnostic Observation Schedule-Second Edition and Adapted-Autism Diagnostic Observation Schedule

ASD diagnoses were confirmed using the Autism Diagnostic Observation Schedule-Second Edition (ADOS-2; Lord et al. 2012) or the Adapted-Autism Diagnostic Observation Schedule (A-ADOS; Hus et al. 2011), along with the Autism Diagnostic Interview-Revised (ADI-R; Lord et al. 1994). Participants under the age of 12 years received module 1 of the ADOS-2 ($N=22$), while participants 12 years or older with a language level that met criteria for module 1 on the ADOS-2 received module 1 of the A-ADOS ($N=15$). The A-ADOS was designed to include activities that are age-appropriate and engaging for older, MV adolescents with ASD.

Assessing Diversity of Spontaneous Play

Diversity of spontaneous play was defined as the number of different developmental play levels behaviorally exhibited by each participant, which was scored from video recordings of the ADOS-2/A-ADOS. Play levels were identified using a novel coding scheme based on the play levels described by Kasari et al. (2006). Play levels that were not exhibited by participants (e.g., sociodramatic/thematic fantasy play) were excluded from our coding scheme. Therefore, play levels coded within this study included functional play behaviors—(1) indiscriminate actions, (2) discriminate actions, (3) general combinations, (4) specific combinations, (5) pretend self, (6) participant as agent, and symbolic play behaviors—(7) substitutions with objects, (8) substitutions without objects, (9) doll as agent (see "Appendix A" for full coding scheme). For all nine play levels, participants were given a score of 0 if they did not exhibit that play level during the assessment, and a score of 1 if they did exhibit that play level one or more times during the assessment. Values were then summed to obtain an overall play score. Twenty-five percent of the video recordings were coded by a second independent observer to evaluate coding reliability: ICC = .842 (two way random, absolute agreement, single measures analysis). Portions of video recordings during which the observers could not see the child's behavior, or in which the child's behavior was prompted and/or modeled by the experimenter, were excluded from analyses.

Joint Attention Measure from the ESCS (JAMES)

To assess initiation of joint attention (IJA), initiation of behavioral requests (IBR), and response to joint attention (RJA), we utilized a modified version of the Joint Attention Measure from the ESCS (JAMES; Jahromi et al. 2009). The JAMES is a short, semi-structured assessment of social communication, adapted from the Early Social Communication Scales (ESCS; Mundy et al. 2003). The materials used in the JAMES are better suited for older participants than the materials used in the ESCS, which was originally designed for infants. During the JAMES, participants sat at a table across from an experimenter who introduced a series of objects selected to prompt social communication. The objects included a firefighter hat, a pair of glasses, a mechanical wind-up toy, a jar with a different mechanical wind-up toy inside, a foam rocket toy, bubbles, a book, and four pictures placed on the walls of the testing room. This assessment was video-recorded so that a trained observer could later code for frequency of IBR behaviors, frequency of IJA behaviors, and percentage of RJA behaviors. IBR behaviors included IBR eye contact, give, reach, appeal (reach with IBR eye contact), and point to request. IJA behaviors included coordinated looking, IJA eye contact, show, and point to share.

Table 2 Characteristics of sample

	Mean (SD)	Range
Age (years)	10.08 (4.09)	5.42–18.83
ASD calibrated severity score	7.76 (1.42)	5.00–10.00
Vineland expressive AE (months)	14.40 (7.56)	2.00–27.00
Vineland expressive raw score	23.63 (12.54)	6.00–51.00
ADI-R item 30		
No use of functional 3-word phrases on a daily basis	5.4%	–
Use of < 5 words and/or speech not used on daily basis	35.1%	–
Use of ≥ 5 words on daily basis, but no functional 3-word phrases	48.6%	–
Sex (% male)	67.6%	–
Race		
Asian	18.9%	–
Black or African American	8.1%	–
Hispanic	2.7%	–
White	56.8%	–
More than one race	13.5%	–

Vineland scores and ADI-R scores were missing from $N=2$ and $N=4$ participants, respectively

Table 3 Descriptive statistics

	Mean (SD)	Range
NVIQ	59.08 (17.87)	30.00–112.00
IJA	2.73 (2.95)	0.00–10.00
IBR	6.51 (4.58)	0.00–20.00
RJA	68.04 (17.52)	37.50–100.00
Play	3.51 (1.33)	1.00–7.00
Imitation	14.46 (5.36)	2.00–23.00
Expressive language	24.76 (38.02)	0.00–116.00

$N = 1$ participant received a score of 0.00 for IBR, $N = 11$ participants for IJA, and $N = 13$ participants for expressive language

See "Appendix D" for frequency distributions

RJA behaviors included responding to or not responding to proximal bids for joint attention, during which the experimenter pointed to pictures in a book and said "look," and distal bids for joint attention, during which the experimenter pointed to pictures on the wall and stated the child's name three times (see "Appendix B" for full coding scheme). Trials during which the observers could not see the behavior or trials during which participants were uncooperative were excluded from analyses. Twenty-five percent of the video recordings were independently coded by a second observer to ensure coding reliability: ICC = .883, .898, and .777 for IBR, IJA, and RJA, respectively (two way random, absolute agreement, single measures analysis). Discrepancies in coding were resolved by a third, independent coder.

Elicited Imitation Battery

Participants completed an adapted version of the elicited imitation battery (Rogers et al. 2003) as a measure of imitation ability. During the elicited imitation battery, the experimenter first directed the participant to imitate an unconventional target action by saying "(participant's name), do this." Next, the experimenter performed an unconventional target action; this was repeated three times rapidly in a burst of three actions each, totaling nine repetitions of the same target action. Six different target actions were administered in this manner—three actions involved manual imitation (opening and closing hands, tapping hand on chest, and tapping hand on opposite elbow) and three actions involved object imitation (taking apart two duplo blocks and tapping them together, flipping a toy car over and tapping it with hand, and squeaking a toy rabbit with elbow). Behavior during this assessment was video recorded and later scored by a trained observer. Each action attempt by the participant was scored, such that higher scores reflected more accurate imitation performance of the target action (see "Appendix C" for full coding scheme). Because some participants improved while other participants regressed in imitation accuracy over the three trials for each target action, the highest score from each of the target actions was extracted and then summed to reflect an overall imitation score. Twenty-five percent of the total number of video recordings were coded independently by a second observer to ensure coding reliability: $\kappa = .952$.

Leiter International Performance Scale-Third Edition (Leiter-3)

Non-verbal intelligence (NVIQ) was assessed using the Leiter International Performance Scale-Third Edition (Leiter-3; Roid et al. 2013). Four of the cognitive subtests of the Leiter-3 were used to calculate the NVIQ composite score—Figure Ground, Form Completion, Classification/Analogies, and Sequential Order. The Leiter-3 was selected for this sample because it does not require any spoken language between the participant and experimenter (Roid and Koch 2017). Previous research has demonstrated that this assessment is appropriate to use with MV individuals (Grondhuis et al. 2018; Kasari et al. 2013).

Parent-Report Wordlist-Expressive (PRW-E)

The Parent-Report Wordlist-Expressive (PRW-E) subtest is a measure of expressive vocabulary. The PRW-E asks parents to report on their child's functional use of 500 different words (Plesa Skwerer et al. 2016). The PRW-E includes words from the MacArthur-Bates communicative development inventories (Fenson et al. 2007); additional words were added so that the measure would be developmentally appropriate for older children and adolescents. Words were listed alphabetically and grammatical categories (nouns, verbs, pronouns, and adjectives) were intermixed. Parents reported a wide range of the number of words used by their children (Table 3). To maintain a more homogenous sample and continuous distribution of our outcome variable, participants who parents reported that they used over 125 words (i.e., over 25% of total words listed on the PRW-E) were excluded from the final sample.

The PRW-E was selected as a continuous measure of expressive language because most participants could not complete other standardized language assessments. However, within a sub-sample of MV participants, PRW-E scores correlated significantly with Vineland Expressive Language raw scores ($r_s(35) = .629$, $p < .001$), and with the number of different words per 10 min used during a natural language sample ($r_s(27) = .584$, $p = .001$). To calculate the number of different words per 10 min, we manually transcribed participant speech from video recordings of the ADOS. We then utilized systematic analysis of language transcripts (SALT; Miller and Chapman 2008), which calculated the number of different words used by the participant during the ADOS. We then calculated the number of different words used during the ADOS divided by the total duration of the ADOS video recording to get the number of different words per minute, and then multiplied this value by 10 to get the number of different words per 10 min.

Results

First, to examine the relation among social communication variables, NVIQ, and expressive language we conducted zero-order Spearman's Rho correlations. Spearman's Rho was used because the data did not fit a normal distribution. Results of zero-order Spearman's Rho correlations demonstrated that diversity of play scores ($r_s(35) = .549$, $p < .001$), imitation accuracy scores ($r_s(35) = .638$, $p < .001$), and NVIQ composite scores ($r_s(35) = .406$, $p = .013$) were significantly correlated with PRW-E scores. In contrast, frequency of IJA scores ($r_s(35) = .050$, $p = .771$), frequency of IBR scores ($r_s(35) = .139$, $p = .413$), percentage of RJA scores ($r_s(35) = .091$, $p = .591$), and age ($r_s(35) = -.146$, $p = .389$) were not significantly correlated with PRW-E scores. Results of zero-order Spearman's Rho correlations among all variables are summarized in Table 4. The relations between PRW-E scores and diversity of play scores ($r_s(34) = .542$, $p = .001$), imitation accuracy scores ($r_s(34) = .634$, $p < .001$), and NVIQ composite scores ($r_s(34) = .424$, $p = .010$) remained significant, even when controlling for age.

To determine whether the relations between play and expressive language and imitation and expressive language remained significant when controlling for NVIQ, we conducted partial Spearman's Rho correlations. When controlling for NVIQ composite scores, diversity of play scores ($r_s(34) = .455$, $p = .005$) and imitation accuracy scores ($r_s(34) = .563$, $p < .001$) remained significantly correlated with PRW-E scores (Table 5). The relations between PRW-E scores and diversity of play scores ($r_s(33) = .425$, $p = .011$), and between PRW-E scores and imitation accuracy scores ($r_s(33) = .539$, $p = .001$), remained significant when controlling for both NVIQ and age.

Finally, we selected a regression model of best fit to determine which concurrent predictor variable(s)—play, imitation, or NVIQ—remained significantly related to expressive language while controlling for other predictor variables within the model. To determine the model of best fit, we compared the Bayesian Information Criterion (BIC) values for three regression models under different distributions—negative binomial, zero-inflated negative binomial, and zero-inflated Poisson (Hilbe 2011). These models were selected because the outcome variable, number of different words used, reflected count data; our outcome variable also had a high frequency of zeros (35.1%; Coxe et al. 2009). For all models, the same three concurrent predictor variables (NVIQ, play, imitation) were included. While there were significant correlations among predictor variables, multicollinearity was not a concern for predictor variables used in the regression model (variance inflation factor values ≤ 1.531, condition index values ≤ 9.792, tolerance values ≥ .653). All regression models used robust maximum

Table 4 Zero-order correlations

	NVIQ	IJA	IBR	RJA	Play	Imitation	Age	Expressive language
NVIQ	1.000	–	–	–	–	–	–	–
IJA	.031	1.000	–	–	–	–	–	–
IBR	.253	.559***	1.000	–	–	–	–	–
RJA	.057	.158	.148	1.000	–	–	–	–
Play	.426**	.181	.396*	.294	1.000	–	–	–
Imitation	.426**	.067	.161	.317	.469**	1.000	–	–
Age	− .685***	.177	− .082	.126	− .111	− .096	1.000	–
Expressive language	.406*	.050	.139	.091	.549***	.638***	− .146	1.000

Values in table reflect results of Spearman's Rho zero-order correlations;*p < .05, **p ≤ .01, ***p ≤ .001

Table 5 Partial correlations controlling for NVIQ

	Play	Imitation	Expressive language
Play	1.000	–	–
Imitation	.351*	1.000	–
Expressive language	.455**	.563***	1.000

Values in table reflect results of Spearman's Rho partial correlations; *p < .05, **p ≤ .01, ***p ≤ .001

likelihood estimation with robust standard errors to account for data heteroscedasticity, and were conducted in Version 7.11 of Mplus (Muthén and Muthén 1998–2017).

Fit was best for the negative binomial model (BIC = 261.008) compared to the zero-inflated negative binomial model (BIC = 265.425) and the zero-inflated Poisson model (BIC = 916.185), as indicated by the lower BIC value. Selection of the negative binomial model over the Poisson model was further supported by the estimated natural log of over-dispersion coefficient, which was significantly above zero ($\alpha = 2.493$, $p < .001$).

Results of the negative binomial regression model revealed that imitation was the only predictor variable to reach significance within the model. When controlling for play and NVIQ, a one unit increase in accuracy of imitation was associated with a .310 unit increase in the expected number of different words used ($B = .310$, $p < .001$). NVIQ composite scores and play diversity scores were not significant predictors of concurrent expressive language within this model (Table 6).

Discussion

The present study aimed to investigate the concurrent social communication predictors of expressive language in MV children and adolescents with ASD. While previous studies have shown that joint attention, play, and imitation are related to expressive language in pre-verbal toddlers and verbally fluent children with ASD, this is the first study to investigate all of these variables simultaneously within a sample of older, MV children and adolescents with ASD. Based on previous findings within the literature, we hypothesized that these social communication variables would be significantly related to expressive language. This hypothesis was partially supported, as data demonstrated that play and imitation were significantly correlated with expressive language, even when controlling for NVIQ. Contrary to our predictions, joint attention constructs, IJA, IBR, and RJA, were not significantly related to expressive language within this MV sample. Therefore, it seems that the concurrent predictors of expressive language may vary across the autism spectrum. Furthermore, results revealed that imitation was the only variable to independently predict concurrent expressive language within a regression model. These findings have important implications for how we study language in different ASD subpopulations, as well as for how we design interventions for older MV children and adolescents with ASD.

NIVQ, Play, and Imitation are Significantly Related to Expressive Language in MV Children and Adolescents with ASD

As in previous studies, the current study demonstrates that NVIQ is related to concurrent expressive language in ASD (Fernell et al. 2010; Luyster et al. 2008; Norrelgen et al. 2015; Pickard and Ingersoll 2015; Wodka et al. 2013). Deficits in fluid reasoning, reflected by lower NVIQ scores, may interfere with the extraction of conceptual relations, which is central to language learning. While the majority of MV participants within this sample met NVIQ criteria for co-occurring intellectual disability (composite score below 70), nearly 30% did not, further demonstrating the heterogeneous and complex relation between cognition and language development in ASD. Indeed, low NVIQ is not the only variable

Table 6 Concurrent predictors of expressive language—negative binomial regression model

	B	Robust SE of *B*	*z*
NVIQ	.007	.015	.479
Play	.113	.215	.524
Imitation	.310	.063	4.948***
Intercept	− 3.012	1.369	− 2.201*

Values in table reflect unstandardized estimates; *$p < .05$, ***$p < .001$

influencing expressive language deficits in MV children and adolescents with ASD because we observed significant relations between expressive language and social communication variables, play and imitation, even when controlling for NVIQ. These relations, controlling for NVIQ, have also been observed in younger samples of toddlers and children with ASD (Charman 2003; Ingersoll and Meyer 2011; Luyster et al. 2008).

Our findings suggest that for MV individuals with ASD, diversity of spontaneous play remains related to expressive language throughout childhood and adolescence. Those who exhibited a lower number of play levels, which reflects lower developmental appropriateness of play, had reduced expressive language. This relation between play and language may be indicative of a broader developmental delay within the MV subpopulation of ASD. In particular, this relation may be explained by broader deficits in theory of mind, as both play and language require the ability to form mental representations for objects (Leslie 1987). This symbolic ability that underlies both play and language may be developing on a protracted schedule for this sub-population of MV individuals with ASD. It is important to also note that many of the participants within this study engaged in repetitive play behaviors when interacting with objects (e.g., throwing or mouthing toys). These types of repetitive behaviors were scored as low level play behaviors in our coding scheme. It is therefore possible that participants who had more frequent repetitive behaviors received lower diversity of play scores because the repetitive behaviors may have interfered with the exhibition of higher level play behaviors. While it has been postulated that repetitive behaviors may interfere with learning (Leekam et al. 2011), further research is needed to determine the relations among play, repetitive behaviors, and language.

Furthermore, we observed that those with higher imitation abilities had higher expressive language. It is possible that high imitation scores reflect increased motivation or willingness to socially engage with others. This increased social engagement overtime may provide more opportunities for word learning. It is also possible that the reduced ability to copy fine-tuned motor actions, as reflected by lower imitation accuracy scores, could interfere with typical speech production, leading to reduced expressive language. Future studies particularly interested in investigating the predictors of expressive language should include measures of oral-facial imitation, as this may directly show the relation between imitation and speech production. Moreover, we found that imitation was the only concurrent predictor variable to reach significance within our negative binomial regression model. Thus, out of all the predictor variables included within the model, imitation seems to be the "best" predictor of concurrent expressive language for MV children and adolescents with ASD. Other studies have also found imitation to be the best predictor of expressive language in samples of younger, pre-verbal toddlers and verbally fluent children with ASD (Luyster et al. 2008; Toth et al. 2006; Thurm et al. 2007); therefore it is likely that regardless of language ability or age, imitation plays a critical role in the development of expressive language in ASD.

Joint Attention is not Significantly Related to Expressive Language in MV Children and Adolescents with ASD

The results of the present study further highlight the importance of measuring RJA, IJA, and IBR separately, as scores for these joint attention constructs were differentially related to expressive language, as well as to other social communication variables. Surprisingly, joint attention was not significantly related to expressive language within this sample, which contrasts with the many studies that have found a significant relation between RJA and expressive language (Kasari et al. 2008; Murray et al. 2008; Pickard and Ingersoll 2015; Schietecatte et al. 2012; Toth et al. 2006; Van der Paelt et al. 2014; Yoder et al. 2015) and IJA and expressive language (Charman 2003; Kasari et al. 2008; Luyster et al. 2008; Smith et al. 2007; Toth et al. 2006; Van der Paelt et al. 2014). These findings challenge our understanding of the role of joint attention in language learning. For MV children and adolescents with ASD, other social communication variables, such as imitation, may serve a more fundamental role in language development.

There are several alternative explanations for why joint attention was not a significant predictor of expressive language within this sample. In context of the broader literature, our non-significant findings could be a result of our sample's age. To date, all studies investigating the relation between joint attention and expressive language were conducted with young toddlers and children under 9 years of age, while the current study investigated children ages 5 to 19 years of age. Thus, it is possible that joint attention is significantly and positively related to expressive language early in life, but this relation becomes non-significant in early to middle childhood due to developmental changes in joint attention abilities. This change in significance could occur if those with initially low joint attention abilities experience improvements in joint attention abilities over time. It is important to acknowledge that because of their older age, the children and adolescents within our sample have had different life experiences than younger toddlers and children within samples of previous studies. We must therefore also consider how experience is interacting with our findings. For instance, older individuals who have had extensive therapy that utilizes reinforcement to teach social communicative behaviors (e.g., initiation of behavioral requests) may experience improvements in joint attention abilities without concurrent improvements in expressive vocabulary outside of certain pragmatic functions.

Because all variables within this study were measured cross-sectionally, we cannot draw firm conclusions about developmental changes in the relation between joint attention and expressive language. Nevertheless, the fact that age was not significantly related to expressive language or joint attention within this study, and that these relations remained non-significant even when controlling for age, challenges the argument that joint attention and language abilities in MV individuals change as a function of age. Thus, the non-significant relation between joint attention and expressive language is more likely the result of another moderating variable, such as language ability. Indeed, some studies have found that the correlates of language differ based on the expressive language abilities of the sample (e.g., Strid et al. 2013). Future studies should explore whether the significance of the relations among social communication variables and expressive language varies as a function of the sample's age and language ability.

It is also possible that joint attention is significantly related to expressive language in MV children and adolescents, but that our joint attention measure did not capture the true range of joint attention abilities present within the broader subpopulation of MV ASD. While we attempted to increase participant engagement by using a joint attention measure designed for older children (i.e. JAMES), the adolescent participants in our sample were older than the children in the sample that the JAMES was originally designed for (see Jahromi et al. 2009). Our older participants may have been less motivated to engage with the JAMES, thus decreasing their likelihood of initiating and responding to joint attention bids. Future studies should make an effort to improve engagement of older adolescents with ASD by incorporating age-appropriate materials. Finally, these non-significant findings may have been influenced by our sample's limited range in JA abilities, or by our use of the Spearman's Rho statistic, which has a greater likelihood of type II error than parametric statistical tests (Bishara and Hittner 2012).

Implications for Intervention with MV Individuals

Findings from the present study suggest which variables should be targeted in interventions for older, MV children and adolescents with ASD. Ideally, interventions should target multiple variables, as it is unlikely that one variable is solely responsible for language development. Interventions designed for pre-verbal toddlers and verbally fluent children with ASD that have targeted the improvement of joint attention, play, and imitation have resulted in enhanced expressive language abilities (e.g., Bono et al. 2004; Chang et al. 2018; Ingersoll and Schreibman 2006; Ingersoll and Lalonde 2010; Kasari et al. 2006, 2008, 2012; Whalen et al. 2006). While we know the importance of targeting these early social communication variables during early, sensitive periods of development, there is also evidence that similar interventions can improve language outcomes in MV ASD, even after the age of 4 years. For example, Kasari et al. (2014) enrolled MV school-aged children with ASD in an adaptive intervention called JASP + EMT. This intervention utilized behavioral spoken language intervention methods (enhanced milieu teaching) to target joint attention, symbolic play, engagement, and regulation behaviors. MV children who were provided an augmentative/alternative communication device (AAC) at the beginning of the intervention had greater improvements in spontaneous speech abilities post-intervention compared to MV children who were not initially given an AAC (Kasari et al. 2014). Recent analyses from this dataset demonstrated that MV children also had higher play abilities post-intervention, and these play abilities were associated with improvements in expressive language (Chang et al. 2018). A creative intervention called auditory-motor mapping training (AMMT) utilized a multimodal approach to target a diverse set of variables, including imitation, speech production, and motor abilities. AMMT has been shown to improve expressive language in MV children with ASD (Chenausky et al. 2016a, b; Wan et al. 2011). These findings provide promising evidence that targeting social communication variables in intervention can improve expressive language abilities in school-aged MV children with ASD, especially when AAC devices are used. Further research is needed to determine whether these existing interventions that target social communication variables can be adapted for older MV children and adolescents with ASD.

Study Limitations and Future Research Directions

While our findings demonstrate that play, imitation, and NVIQ are related to expressive language in MV children and adolescents with ASD, there are likely other variables, not included within this study, that explain why some individuals with autism do not acquire typical spoken language. For instance, motor deficits may interfere with the oral-facial motor actions needed for speech production. Indeed, early motor deficits are predictive of reduced expressive language within ASD and the broader autism phenotype (Bedford et al. 2016; LeBarton and Iverson 2013). A limitation of many extant studies, including the present study, is that imitation measures do not distinguish between the constructs of imitation and motor abilities when assessing one's ability to imitate modeled actions. Therefore, deficits in motor planning and execution, rather than deficits in imitation, may prevent individuals from accurately copying the actions of the experimenter (Rogers and Pennington 1991).

Neurobiological differences in brain function and structure may also influence expressive language development in ASD. For example, atypical neural processing of auditory stimuli, as reflected by unspecialized brain activation in response to different auditory inputs, may interfere with a child's ability to learn words (Shinn-Cunningham et al. 2016). Additionally, atypical structure of white matter tracts, such as the arcuate fasciculus, may interfere with speech production in MV individuals with ASD (Broce et al. 2015; Chenausky et al. 2017). Future studies should include measures of brain function and structure when investigating the predictors of expressive language so that we may further understand the mechanisms underlying atypical language development in MV individuals with ASD.

Future studies should also utilize a multi-method approach to language assessment when working with MV individuals (Tager-Flusberg et al. 2009). The current study used a parent-report measure of expressive language because most participants could not complete standardized language assessments. Despite our attempts to validate our language measure within sample, we acknowledge that parent-report measures have limitations (see Caselman and Self 2008 for review). Standardized language measures should be used when possible; they may be adapted for MV individuals to include alternative methods of communication (e.g. American Sign Language, AAC devices). Language samples should also be collected in naturalistic settings. Allowing participants to communicate with familiar partners, such as family members, peers, or educators, will provide ecologically valid assessment of expressive language (Barokova and Tager-Flusberg 2018).

Furthermore, future studies should track the developmental trajectories of toddlers and children with ASD into adolescence and early adulthood, as findings from such longitudinal studies will reveal the directionality of the relations between social communication variables and language. While results of previous longitudinal studies conducted with toddlers and children support the conclusion that early deficits in NVIQ, joint attention, play, and imitation have downstream influences on the development of expressive language (Charman 2003; McDuffie et al. 2005; Norrelgen et al. 2015; Smith et al. 2007; Stone et al. 1997; Thurm et al. 2007; Yoder et al. 2015), it is also possible that early deficits in expressive language are influencing the development of social communication variables (e.g., Howlin et al. 2014).

In conclusion, findings from this study support the argument that language learning relies on the typical development of cognition and social communication. Deficits in cognitive and social communication variables, such as imitation, may partially explain why some children and adolescents with ASD do not acquire spoken language. In the context of the broader literature, concurrent predictors of expressive language may vary based on language ability of the sample. Future research should continue to investigate less commonly studied predictors of language, such as motor ability and brain structure and function, so that we can better understand why MV children and adolescents with ASD do not acquire spoken language.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed involving human participants in this study were in accordance with the ethical standards of the institutional research board at Boston University and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Appendix A

See Table 7.

Table 7 Coding scheme for assessing diversity of spontaneous play behaviors

Play level	Definition	Example
Indiscriminate action	Participant uses object independently (i.e., not in combination with other objects at the same time) in a way that *is not conventional* (i.e., not related to its purpose/function). May include touching, mouthing, banging, lining up, dropping, throwing, or spinning objects	Participant throws block onto the floor
Discriminate action	Participant uses object independently (i.e., not in combination with other objects at the same time) in a way that *is conventional* (i.e., related to its purpose/function)	Participant pushes buttons on pop up toy
Pretend self	Participant relates objects to self or experimenter in a pretend manner	Participant puts cup up to own mouth to drink
General combination	Participant uses two or more objects together to create and/or separate a configuration. The configuration *does not* maintain the *conventional attributes* (i.e., not related to purpose/function) of the objects	Participant puts cell phone into dump truck
Specific combination	Participant uses two or more objects together to create and/or separate a configuration. The configuration *does* maintain the *conventional attributes* (i.e., related to purpose/function) of the objects	Participant puts food on plate
Participant as agent	Participant extends familiar, animate behaviors to doll figures with participant as agent of behavior	Participant brushes doll's hair
Substitution	Participant uses one object to stand in for another object. Behavior may or may not be first performed by participant with conventional object	Participant wears plate as a hat
Substitution without object	Participant pretends to use an object that is not physically there. Behavior may or may not be first performed by participant with conventional object	Participant makes call on imaginary phone
Doll as agent	Participant moves doll figure as if it is capable of independent behavior	Participant puts cup in doll's hand before having doll drink out of cup

Appendix B

See Table 8.

Table 8 Coding scheme for the joint attention measure from the ESCS (JAMES)

Type of joint attention	Behavior	Definition	Exclude
Initiation of behavioral request (IBR)	IBR eye contact	Any instance where the participant looks first at the *inactive* object and then at the tester. The *inactive* object can be an object spectacle that has ceased (e.g., mechanical toy, foam rocket/balloon, bubbles), the jar, or the hat/glasses. The *inactive* object can be in the tester's hands, on the table, or in participant's hands while they are requesting something. *This code should be the default for all ambiguous eye contact behaviors.* If inactive mechanical toy is in participant's possession while he/she tries to wind it up and he/she makes eye contact, code as IBR Eye Contact	• If eye contact is elicited by movement (including gesture), vocalization, or other noise made by tester • If eye contact is elicited during social routine prompted by tester (e.g. "Ready, Set, Go" or "One, Two, Three" during bubble task or foam rocket/balloon task) • If eye contact occurs after the participant puts on the hat/glasses (this would be coded as IJA Eye Contact)
	Give	Any instance where the participant spontaneously pushes or tosses (underhand) an object towards or holds an object out towards the tester's upper body/hand(s) during object spectacle task, jar task, or hat/glasses task	• If the tester makes any vocalization (e.g., "give it to me," "my turn," "all done") or gestures (e.g., open palm or reach) to indicate that the participant should give him/her the object prior to the participant's give • If the participant throws (overhand) the object at the tester
	Reach	Any instance where the participant spontaneously extends his/her arm with an open palm toward an object that the tester is intentionally holding out of the participant's reach. Participant does not use eye contact during the reach or within 3 s of the reach. It is ok to code if the participant gets out of his/her seat before, during, or after the reach	• If the participant uses eye contact during the reach or within 3 s of the reach (this would be coded as an appeal) • If the participant is engaging in a repetitive behavior that looks like a reach (e.g. hand banging)
	Appeal	Any instance where the participant combines eye contact with reach simultaneously or uses eye contact within 3 s of the reach	• If the participant does not use eye contact during the reach or within 3 s of the reach (this would be coded as a reach)
	Point-to-request	Any instance where the participant uses one extended finger (*does not* have to be index finger) to point at an *inactive* object during the object spectacle task, jar task, or hat/glasses task	• If the participant points to an object *after* the tester has pointed to the same object • If the participant points to an object that is not part of the JAMES administration (e.g. snack, parent) • If the participant points at the door to indicate he/she would like to leave
Initiation of joint attention (IJA)	Coordinated looking	Any instance where the participant looks first at an *active* object and then at the tester. The *active* object can be an object spectacle that is *moving on the table or in space* (e.g., mechanical toy, foam rocket/balloon, bubbles). *Any ambiguous codes default to IBR Eye Contact.* If mechanical toy stops while the participant looks up, code as coordinated look	• If eye contact is elicited by movement (including gesture), vocalization, or other noise made by tester • If eye contact is used when the object is *inactive* (e.g., hat/glasses, jar) • If object is in tester's possession or participant's possession

Table 8 (continued)

Type of joint attention	Behavior	Definition	Exclude
	IJA eye contact	Any instance where the *participant is holding or manipulating* an *inactive* object (e.g., hat/glasses) or *active* object (e.g., mechanical toy, foam rocket/balloon, bubbles) and looks first at the object and then at the tester. For hat/glasses task, participant must follow this sequence: look at the object, place the object on his/her head/face, and then look at the tester. *Any ambiguous codes default to IBR Eye Contact.* If inactive mechanical toy is in participant's possession while he/she is just playing with it but not actively trying to wind it up and he/she makes eye contact, code as IJA Eye Contact	• If eye contact is elicited by movement (including gesture), vocalization, or other noise made by tester • If object is in tester's possession or on the table
	Show	Any instance where the participant raises an *inactive* object or *active* object *upward toward the tester's face* before quickly retracting the object. Can code as show if the tester first requests the object, then the participant moves the object closer to him/her, but then quickly retracts it before the tester can obtain the object	• If the participant moves an object toward the tester's upper body or the tester's hand(s) • If the tester obtains the object from the participant
	Point-to-Share	Any instance where the participant uses one extended finger (*does not* have to be index finger) to point at an *active* object (e.g., mechanical toy, foam rocket/balloon, bubbles) or pictures in a book/posters on the wall *before the tester has pointed to any of those things*	• If the participant points to an object *after* the tester has pointed to the same object
Response to joint attention (RJA)	Follows distal point	For each bid initiated by the tester during the Poster Task (at least 4 bids total of "name, name, name" + point), code this when the participant shifts his/her gaze in the direction of the tester's point and *beyond the end of the tester's index finger* (even if the poster is out of view of the camera). It is ok to code as "follows point" if the look towards the poster is brief	• If participant responds *after* tester has finished the bid (i.e. stated name 3 × and finished pointing) • If the participant just looks at the tester's hand and not beyond the end of the tester's index finger • If the participant shifts his/her head but not his/her gaze towards the poster • If RJA behavior occurs during other tasks (e.g., tester uses point to get participant to sit in his/her chair)
	Follows proximal point	For each bid initiated by the tester during the Book Task (at least 4 bids total of "look!" + point), code this when the participant shifts his/her gaze to the location of the picture where the tester is pointing. It is ok to code as "follows point" if the tester points to the same page that the participant is already looking at as long as the participant shifts his/her gaze to the picture that the tester is pointing to. It is ok to code as "follows point" if participant is looking at tester or elsewhere in the room but then looks at the book once the bid is made	• If participant responds *after* tester has finished the bid (i.e. "look!" and finished pointing) • If the participant just looks at the tester's hand and not beyond the end of the tester's index finger • If RJA behavior occurs during other tasks (e.g., tester uses point to get participant to sit in his/her chair)

Appendix C

See Table 9.

Table 9 Coding scheme for the elicited imitation battery

Target action	Scoring
Fingers of one or both hands move in a close/open motion	4 = Two hands above table surface, palms facing forward open/close hands simultaneously and repeatedly 3 = Two hands open/close one time, palms facing participant, arms resting on table surface, or non-synchronous 2 = One or both hands move in open/close motion but 2 or more of above errors apply 1 = Some movement, but does not meet target criteria. 0 = No contingent movement
Hand contacts torso	4 = One flat hand strikes torso between the navel and shoulders repeatedly 3 = Hand strikes torso but participant uses 2 hands, hand isn't open/flat, rubs hands on torso, or pats one time 2 = Hand contacts torso but 2 or more of the above errors apply 1 = Some movement, but does not meet target criteria 0 = No contingent movement
Hand contacts opposite arm	4 = Arm flexed so fist is near shoulder and raised so shoulder points forward, open hand contacts area of elbow joint repeatedly 3 = Arm is not significantly flexed; fingers are flexed or fisted, contact with arm not at joint, or not repeatedly 2 = Hand contacts opposite arm but 2 or more of the above errors apply 1 = Some movement, but does not meet target criteria 0 = No contingent movement.
Attempts to pull apart duplos and fails or pulls apart duplos and claps them together	4 = After pulling apart duplos, the participant calps them together in front of torso repeatedly along horizontal path 3 = Attempts pull-apart and clap duplos together but hit against table, movement is along vertical path, or not repeatedly 2 = Pulls duplos apart and claps together but 2 or more of the above errors apply 1 = Some movement, but does not meet target criteria 0 = No contingent movement
Picks up car with 1 hand and contacts car with other hand	4 = Picks up car with 1 hand, inverts the car, and taps the bottom of the car repeatedly 3 = Uses 2 hands to pick up car, does not invert car, does not tap car (rubs bottom or spins wheels), taps top or side of car, or only taps once 2 = Picks up and taps car but 2 or more of the above errors apply 1 = Some movement, but does not meet target criteria 0 = No contingent movement
Part of arm or hand hits the squeaky toy	4 = Arm is flexed at elbow, forearm vertical, and elbow repeatedly contacts toy with an attempt to make it squeak 3 = Arm not significantly flexed or forearm horizontal, strikes toy but not with elbow, or strikes once 2 = Hits squeaky toy but 2 or more of the above errors apply 1 = Some movement, but does not meet target criteria 0 = No contingent movement

Appendix D

See Fig. 1.

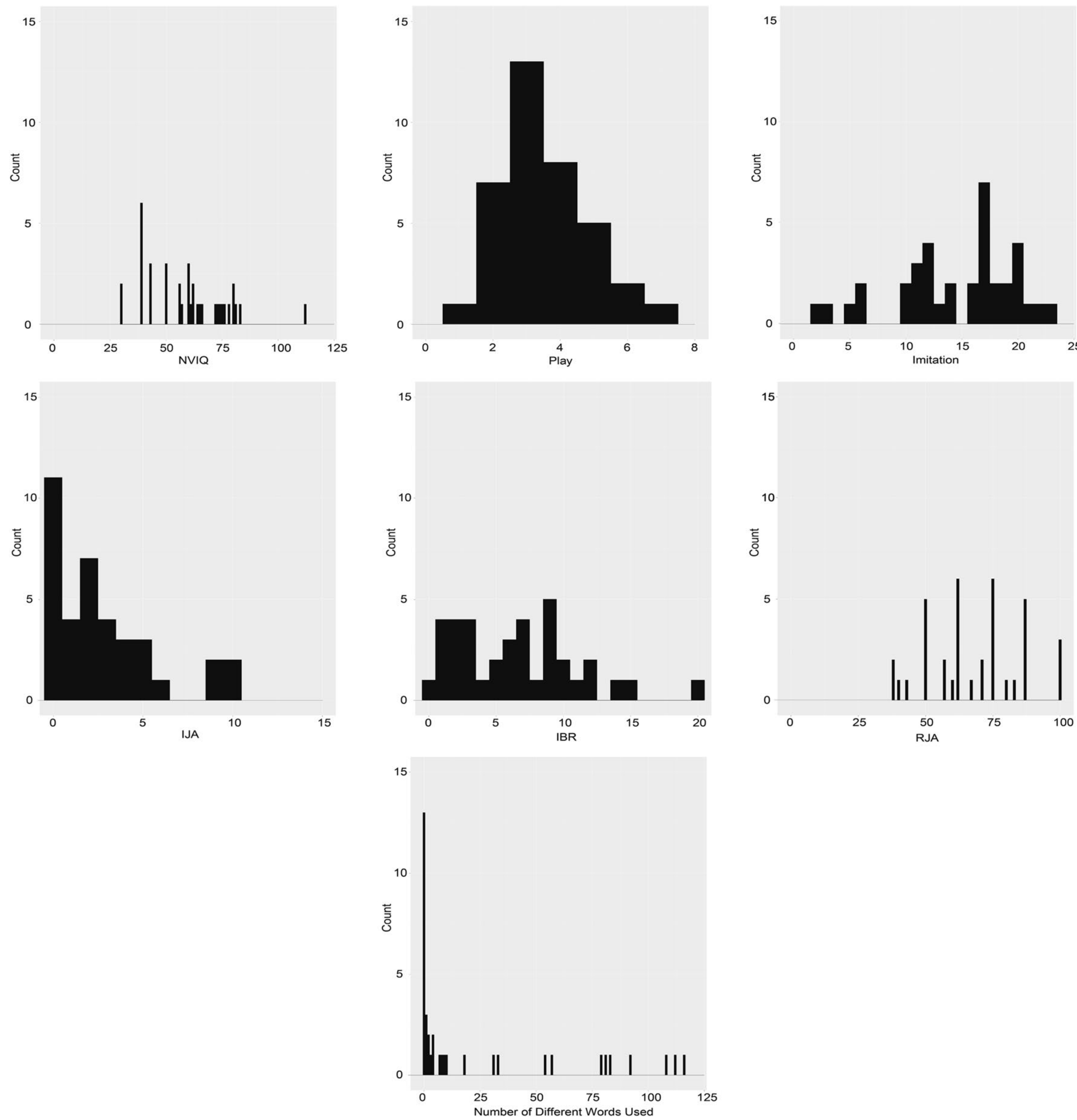

Fig. 1 Frequency distributions for NVIQ, play, imitation, IJA, IBR, RJA, and expressive language/number of different words used

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