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ORIGINAL PAPER

A Path Model of Expressive Vocabulary Skills in Initially Preverbal Preschool Children with Autism Spectrum Disorder

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Abstract We examined direct and indirect paths involving receptive vocabulary and diversity of key consonants used in communication (DKCC) to improve understanding of why previously identified value-added predictors are associated with later expressive vocabulary for initially preverbal children with autism spectrum disorder (ASD; $n=87$). Intentional communication, DKCC, and parent linguistic responses accounted for unique variance in later expressive vocabulary when controlling for mid-point receptive vocabulary, but responding to joint attention did not. We did not confirm any indirect paths through mid-point receptive vocabulary. DKCC mediated the association between intentional communication and expressive vocabulary. Further research is needed to replicate the findings, test potentially causal relations, and provide a specific sequence of intervention targets for preverbal children with ASD.

Keywords Autism spectrum disorder · Language · Vocabulary · Preverbal · Predictors · Path modeling

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Introduction

Spoken expressive language skills strongly predict social and adaptive outcomes in children with autism spectrum disorder (ASD) and are primary targets and outcome measures for most intervention studies (Billstedt et al. 2005; Howlin 2000; Tager-Flusberg et al. 2009). Researchers have identified numerous child and parent predictors of later expressive language in preverbal children with ASD (e.g., Siller and Sigman 2008; Toth et al. 2006; Wetherby et al. 2007). However, a growing list of predictors provides insufficient information for professionals making daily decisions regarding how to improve expressive language skills in preverbal children with ASD. Professionals must select a limited number of specific skills to target due to limited resources and the need to reduce demands on families. One way to aid clinicians in selecting treatment goals among this large number of predictors is to deepen the knowledge base of why these preverbal variables predict expressive vocabulary. Developing statistical models that examine direct and indirect paths of association between multiple predictors and later expressive vocabulary could help investigators understand why associations between the predictors and later expressive vocabulary occur. This understanding might suggest a logical sequence of treatment goals for preverbal children with ASD.

The current investigation is an extension of previous efforts to create a parsimonious model of language development in children with ASD that identified value-added predictors of expressive language growth (i.e., variables that continue to predict expressive language after controlling for intercorrelations between the predictors). This process effectively reduces the number of predictors without decreasing the model's predictive accuracy. Yoder et al. (2015) identified four value-added predictors of expressive

vocabulary growth in initially preverbal preschool children with ASD, as described in the next section. Taking a different but related approach, the current study evaluated the magnitude and significance of proposed indirect effects between value-added predictors and later expressive vocabulary through putative mediator variables in the Yoder et al. (2015) study sample. The current study used path modeling and controlled for receptive vocabulary, which surprisingly was not found to be a value-added predictor by Yoder et al. (2015). After describing the previously identified value-added predictors of expressive language growth, we present the rationale for further evaluation.

Value-Added Predictors of Expressive Language Growth in Preverbal Preschool Children with ASD

In preparation for identifying value-added predictors of expressive language growth, Yoder et al. (2015) first identified nine putative predictor variables. Theory and empirical evidence from at least two studies supported the selection of these nine putative predictors in children with ASD who were preverbal or in the earliest stages of language learning at study entry. Expressive language growth, as measured by expressive vocabulary and communicative word use, was modeled via individual growth curve modeling in a sample of 87 preverbal children with ASD. After statistically controlling for two background variables (i.e., ASD symptom severity and nonverbal cognitive functioning) and the intercorrelations between the nine predictor variables, four predictor variables accounted for significant unique variance in expressive language growth: (a) intentional communication, (b) responding to joint attention (RJA), (c) parent linguistic responses, and (d) diversity of key consonants used in communication (DKCC). These variables are *value-added predictors*.

Intentional Communication

Conceptually, intentional communication is the use of gestures, vocalizations, and gaze to convey meaning to a communicative partner. Theoretically, intentional communication may influence expressive vocabulary growth because children with ASD who frequently initiate expression of their wants, needs, and thoughts demonstrate an underlying reason to communicate (Bruner 1974). These intentional communication acts might elicit linguistic input from communicative partners, which in turn might affect the semantic basis for expressive language (Yoder 2006). Empirically, rate or frequency of intentional communication repeatedly has accounted for unique variance in expressive language above and beyond other predictors in children with ASD (Charman et al. 2005; Plumb and Wetherby 2013; Yoder 2006).

Responding to Joint Attention

Conceptually, we define responding to joint attention (RJA) as when the child shifts his or her gaze to the referent of the adult's attention directive that the adult gives while the child is attending to something else. Theoretically, RJA might be associated with expressive vocabulary because children with ASD who attend to their communicative partners' bids for attention also may attend to and benefit from linguistic mapping and other forms of language provided by these partners within that interaction and more generally (Siller and Sigman 2008). Empirically, RJA at 2 years of age significantly predicted language skills at 5 years of age in children with ASD (Paul et al. 2008; Thurm et al. 2007). Further, Siller and Sigman (2008) reported that RJA was "the strongest child characteristic to predict subsequent linguistic development" (p. 1702) in children with ASD.

Parent Linguistic Responses

Conceptually, parent linguistic responses are parent utterances that follow the child's attentional focus or communicative lead. Theoretically, parent linguistic responses to child attentional or communicative leads may be associated with expressive vocabulary because these responses provide a means for children with ASD to pair words with referents to which the children are already attending. In turn, these pairings might improve the semantic basis for functional spoken word use (Adamson et al. 2009). Because children with ASD exhibit deficits in RJA, linguistic input that does not require a shift in attention to pair words and referents accurately may be particularly useful in expanding receptive vocabulary directly and expressive vocabulary indirectly (McDuffie and Yoder 2010). Parent linguistic responsiveness to child communication and parent follow-in comments with initially minimally verbal children with ASD are associated with language growth even when controlling for other key child variables (Haebig et al. 2013a, b; McDuffie and Yoder 2010; Siller and Sigman 2008).

Diversity of Key Consonants Used in Communication

Conceptually, diversity of key consonants used in communication (DKCC) is an inventory of 13 consonants (i.e., m, n, b, p, d, t, g, k, y, w, l, s, sh) produced during communication acts (Wetherby et al. 2007; Woynaroski et al. 2016a).

These 13 consonants can be reliably coded and most are early developing. The procedure used to derive DKCC is described in more detail under "Measures, Procedures, and Variables." Theoretically, DKCC may be associated with expressive vocabulary in children with ASD because consonant production in vocal communication may indicate an oral motor ability shared with spoken language and may indicate attempts to say words prior to being understood Woynaroski et al. (2016a). For children with ASD, Wetherby et al. (2007) identified DKCC at 18–24 months of age as one of the "best predictors" (p. 971) of verbal and nonverbal outcomes at 3 years of age.

Rationale for Mediation Analyses with Previously Identified Value-Added Predictors

Mediation analyses address questions about how associations occur and provide preliminary evidence for potential mechanisms of causal effects of predictors on outcomes. In mediation models, direct paths extend from the predictor variable (*X*) to the criterion variable (*Y*) without passing through the mediator variable (*M*). In contrast, indirect paths comprise two paths that extend from *X* to *Y* through *M*. The "*a* path" represents the association between *X* and *M* and the "*b* path" represents the association between *M* and *Y* controlling for *X*. Including the direct path from *X* to *Y* controls for *X* in the "*b* path." *M* is the predicted mechanism through which *X* effects *Y*. A putative mediator is judged to be statistically significant when the confidence interval around the indirect effect (i.e., the product of the unstandardized coefficients of the *a* and *b* paths) does not include zero (Hayes 2013) or when the *p* value associated with significance test of the indirect effect is smaller than the selected alpha (e.g., 0.05; Hair et al. 2013). If the indirect path is significant, it indicates that controlling for *M* significantly reduces the association between *X* and *Y* and represents longitudinal correlational evidence that *M* is partly responsible for association between *X* and *Y*. Because correlational research designs provide insufficient evidence for drawing casual conclusions, resultant models are interpreted as consistent with or inconsistent with the theorized mechanism. The potential mediating effects of (a) receptive vocabulary on the association between the value-added predictors and later expressive vocabulary and (b) DKCC on the association between intentional communication and later expressive vocabulary might provide insight into how expressive vocabulary skills develop in children with ASD. We describe the rationale for proposing these mediation effects in the next two sections.

Rationale for Proposing that Mid-Point Receptive Vocabulary is a Mediator

The indirect effects of the early value-added predictors (i.e., intentional communication, responding to joint attention, parent linguistic responses, and DKCC) on later expressive vocabulary through *mid-point* receptive vocabulary are of particular interest to this study. Theoretically, intentional communication and DKCC elicit parent linguistic responses, which, in turn, affect the receptive vocabulary basis for expressive language. In addition, when a child responds to bids for joint attention from his or her parents, these responses signal the child's ability to use input that does not follow his or her attentional or communicative lead (i.e., non-ostensive contexts). When this non-ostensive input is linguistic, it broadens the number of contexts in which linguistic input might affect the receptive vocabulary basis for expressive language. Thus, receptive vocabulary is predicted to have an important role in understanding the association between each of the value-added predictors and expressive language growth in children with ASD. Relative to parent linguistic responses, the mid-point receptive vocabulary is the more proximal putative mediator to expressive vocabulary. Testing the indirect path of intentional communication and DKCC through mid-point receptive vocabulary is more parsimonious and results in a more statistically powered test of the theory than is testing a two-path indirect effect through parent linguistic responses and then through mid-point receptive vocabulary.

Measuring receptive vocabulary at the mid-point of the research design is important. Receptive vocabulary at the initial preverbal time point was *not* associated with later expressive vocabulary after controlling for its intercorrelation with value-added predictors (Yoder et al. 2015). Based on the strong association between early receptive and later expressive vocabulary, these findings surprised us and we hypothesized that the value-added nature of receptive language might not occur until later in development (Luyster et al. 2007; Paul et al. 2008; Thurm et al. 2007; Woynaroski et al. 2016b). Thus, we examined the predictive value of the early value-added predictors on later expressive vocabulary through receptive vocabulary skills measured at a mid-point between early value-added predictors and later expressive vocabulary.

Two predictions regarding receptive vocabulary are important. First, if statistically controlling for mid-point receptive vocabulary significantly weakens the relation between preverbal value-added predictors and end-point expressive vocabulary, receptive vocabulary is judged to be partially responsible for that association (i.e., a mediator). Second, if the value-added predictor continues to

have a significant *direct* effect on expressive vocabulary after controlling for mid-point receptive vocabulary, then the rationale for selecting that value-added predictor as a treatment goal is strengthened.

Rationale for Proposing DKCC as a Mediator Between Intentional Communication and Later Expressive Vocabulary

Communication development in the preverbal stage involves increases in vocal communication and increases in the diversity of consonant use in vocal communication (Oller et al. 1999). Consonant use in vocal communication has been shown to elicit parents' language-facilitating responses (Gros-Louis et al. 2006). Finally, high diversity of consonant use in vocal communication may represent attempts to talk prior to readiness to speak clearly formed words (Woynaroski et al. 2016a). Empirically, Woynaroski and colleagues reported that the association of intentional communication to DKCC (the *a* path) was significant and large in preschool children with ASD (Woynaroski et al. 2016a). Additionally, the association between early DKCC and expressive language, controlling for intentional communication (the *b* path) has been found to be significant and large in the same children (Woynaroski et al. 2016a). The indirect path of association between intentional communication and later expressive vocabulary (the product of *a* times *b*) through DKCC has not yet been tested. This step is necessary to determine whether covarying DKCC is a likely explanation for the association between intentional communication and expressive vocabulary.

Application to the Transactional Theory of Language Development

These indirect effects are important because establishing their role in explaining variation in expressive language in children with ASD would support the transactional theory of language development, which already has some empirical support from studies of children with ASD, specific language impairment, and Down syndrome (Camarata and Yoder 2002; Woynaroski et al. 2014). The transactional theory considers child factors (e.g., cognitive, social and motor abilities), parent factors (e.g., linguistic input), and dyadic (i.e., parent–child) factors with particular emphasis on the bidirectional nature of the interactions between child and parent factors across development. It posits that as a child's language level increases, parents provide more complex language input that scaffolds the child's continued language growth. The theory asserts that the manner in which specific parent and child variables influence each other changes over time and may vary across populations. Thus, continued tests of predictions based on the transactional theory are needed.

Research Questions

Three research questions not previously addressed in the literature were examined in a group of initially preverbal preschool children with ASD. First, we asked whether the associations between the previously identified value-added predictors and later expressive vocabulary are mediated by mid-point receptive vocabulary. Second, we asked whether the associations between the previously identified value-added predictors (i.e., intentional communication, parent linguistic responses, RJA, and DKCC) and later expressive vocabulary are still significant when mid-point receptive vocabulary is controlled. Finally, we asked whether DKCC mediates the association between intentional communication and later expressive vocabulary.

Methods

Participants

This study involved extant data from a recent longitudinal correlational study of speech development in 87 preschool children (71 male and 16 female) with ASD who were preverbal at study entry (Yoder et al. 2015). Clinical diagnoses of ASD based on criteria in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition-Text Revision (American Psychiatric Association 2000) were confirmed by the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 1999) Module 1. A licensed clinician who had experience with young children with ASD and was research reliable on the ADOS administered the ADOS. We used revised algorithms to improve diagnostic accuracy (Gotham et al. 2007). At Time 1, each child (a) was between 20 and 48 months of age chronologically, (b) used no more than 20 different words per parent report on the MacArthur Bates Communicative Development Inventory—Words and Gestures Form (MB-CDI; Fenson 2007), (c) produced no more than five different words during a 15-min communication sample, and (d) was living in a primarily English-speaking household. See Table 1 for participant characteristics, including age, developmental level and vocabulary skills, at the first and last measurement time points (i.e., Time 1 and Time 4, respectively). Children with severe sensory or motor impairments or identified metabolic, progressive neurological, or genetic disorders were excluded. Per parent report, 4 children were identified as Hispanic and 83 as non-Hispanic. Parents

Table 1 Description of participants at time 1 and time 4

	M	SD	Min	Max
Time 1 chronological age (months)	34.7	7.2	20	47
Time 1 MSEL ELC (standard score)	50.9	4.1	<50	122
Time 1 mental age (months)	12.1	4.7	3.8	26.5
Time 1 developmental ratio	0.4	0.2	0.2	0.8
Time 1 MB-CDI comprehension scale (raw score)	75.8	85.4	0	385
Time 4 MB-CDI comprehension scale (raw score)	169.8	116.4	0	396
Time 1 MB-CDI number of words said (raw score)	3.7	5.0	0	18
Time 4 MB-CDI number of words said (raw score)	76.4	96.9	0	396
Time 1 UCS number of different words	0.7	1.2	0	5
Time 4 UCS number of different words	10.4	15.0	0	61

Adapted from Woynaroski et al. (2016a) and Yoder et al. (2015). *Developmental ratio* mental age divided by chronological age; *Mental age* mean age equivalent across subtests of the MSEL; *MB-CDI* MacArthur-Bates Communicative Development Inventory—Words and Gestures Form (Fenson 2007); *MSEL ELC* Mullen Scales of Early Learning, Early Learning Composite (Mullen 1995); *Time 1* study entry; *Time 4* 16 months after entry; *UCS* unstructured communication sample with examiner

reported 65 participants to be White/Caucasian, 16 to be Black/African American, 5 to be Asian, and 1 to be American Indian or Alaska Native. See Yoder et al. (2015) for details. The Vanderbilt University and University of North Carolina at Chapel Hill Institutional Review Boards approved all study methods.

Research Design

Data used in these analyses were drawn from four measurement time points spanning 16 months in the original longitudinal study (i.e., Time 1 = study entry; Time 2 = 4 months after entry; Time 3 = 12 months after entry; Time 4 = 16 months after entry; Yoder et al. 2015). Table 2 summarizes the measures and indicator variables (i.e., variables

Table 2 Measures, variables and measurement time for each latent construct

Latent construct	Measure	Variable	Time
Early receptive vocabulary	MB-CDI	Comprehension scale raw score	1
	CSBS	Comprehension subscale score (Scale 16)	1
Intentional communication	UCS	Number of intentional communication acts	1
	ESCS	Number of communication acts summed across pragmatic functions	2
Responding to joint attention (RJA)	CSBS	RJA subscale score (Scale 3)	1
	ESCS	Number of correct responses to eight presses	2
Parent linguistic responses	PCFP	Number of 5-s intervals with child's attentional lead followed by adult utterance talking about child's referent without an accompanying responsive play action	2
	PCFP	Number of 5-s intervals with child's attentional lead followed by adult utterance talking about child's referent with an accompanying responsive play action	2
	PCS	Number of 5-s intervals with child's attentional or communication lead followed by adult utterance talking about child's referent	2
Diversity of key consonants used in communication (DKCC)	CSBS	Consonant subscale score (Scale 11)	2
Mid-point receptive vocabulary	MB-CDI	Comprehension scale raw score	3
	CSBS	Comprehension subscale score (Scale 16)	3
Later expressive vocabulary	MB-CDI	Number of words said	4
	UCS	Number of different words	4
	CSBS	Words subscale score (Scales 12–15)	4

CSBS Communication and Symbolic Behavior Scales—Developmental Profile Behavior Sample (Wetherby and Prizant 2002); *ESCS* Early Social Communication Scales (Mundy et al. 2003); *MB-CDI* MacArthur-Bates Communicative Development Inventory—Words and Gestures Form (Fenson 2007); *PCFP* parent–child free play; *PCS* parent–child snack; *Time 1* study entry; *Time 2* 4 months after entry; *Time 3* 12 months after entry; *Time 4* 16 months after entry; *UCS* unstructured communication sample with examiner

that are aggregated to quantify a latent construct) for the path model's latent constructs. The putative mediators were measured after the predictor variables and before the criterion variable, expressive vocabulary. Maintaining this temporal precedence provides one required aspect for making causal inferences and helps control for bidirectional effects. Covariation of the variables and elimination of all other possible explanations for their covariation also are required for causal inferences (Hayes 2013). The latter requirement cannot be obtained via correlational data. However, longitudinal correlation designs and path modeling of direct and indirect effects are useful to test whether data is consistent with proposed explanatory models in preparation for more expensive experimental tests of explanatory models.

Measures, Procedures, and Variables

Indicator variables were aggregated (i.e., standardized and averaged) for all latent constructs, except DKCC, to increase stability and content validity of latent construct measures (Sandbank and Yoder 2014). Only one measure was available to quantify DKCC; other measures of speech-like vocal communication were not assessed in the total sample ($N=87$). Below, we briefly describe measures for the confirmatory measurement model. Details on coding and more information on procedures are available in Yoder et al. (2015).

MacArthur-Bates Communicative Development Inventory—Words and Gestures Form (MB-CDI; Fenson 2007)

We used data from caregiver-completed MB-CDIs at Times 1, 3, and 4. Raw score for the total words understood (i.e., sum of number of words understood only plus number of words understood and said) was used as an indicator receptive vocabulary measure at Times 1 and 3. The number of words understood and said was used as an indicator expressive vocabulary measure at Time 4. Time 1 expressive vocabulary had very little variability due to selection criteria (Yoder et al. 2015).

Communication and Symbolic Behavior Scales—Developmental Profile Behavior Sample (CSBS; Wetherby and Prizant 2002)

The standardized, structured Behavior Sample of the CSBS is used to assess communication skills of children up to approximately 6 years, 6 months with functional communication skills between 6 and 24 months developmentally. Comprehension, use of words, DKCC, and RJA were assessed using different subscales collected at strategic time points as listed in Table 2. Scores were derived using the procedure indicated in the CSBS manual (Wetherby and Prizant 2002). DKCC is the weighted raw score of the CSBS Scale 11. Thirteen 'key' consonants that can be reliably coded are inventoried for DKCC (i.e., m, n, b, p, d, t, g, k, y, w, l, s, and sh). Including three later developing consonants (i.e., l, s, and sh) among the other early developing consonants minimizes the risk of a ceiling effect (Wetherby and Prizant 2002; Woynaroski et al. 2016a).

Unstructured Communication Sample (UCS)

During a 15-min unstructured session with a standard set of toys, the examiner used topic-following comments and topic-following questions to elicit child communication. The examiner was discouraged from redirecting the child's attention. The number of different words and number of intentional communication acts produced by each child were analyzed from the samples collected at Times 1 and 4. Intentional communication acts included unconventional gestures, non-word vocalizations, imitative sounds with coordinated attention to an adult and object, conventional gestures with attention to an adult, spoken words or word approximations, and American Sign Language signs or sign approximations.

Early Social Communication Scales (ESCS; Mundy et al. 2003)

During the ESCS 15- to 25-min structured observation, the examiner provided opportunities to increase the likelihood that the child would exhibit specific communicative behaviors, particularly nonverbal behaviors. Of interest to this study, the examiner attempted to direct the child's attention to a poster by saying, "Look," and pointing eight times across the session to measure RJA. The number of times the child looked at the correct referent out of these eight opportunities was totaled for the ESCS observation at Time 2. In addition, the number of communication acts summed across pragmatic functions (i.e., behavioral regulation, joint attention and social interaction) within this observation was calculated at Time 2.

Parent–Child Free Play (PCFP)

The child interacted with his or her parent in a 15-min unstructured session with a standard set of toys. Parents were asked to, "play as you would at home if you had no interruptions and had time to play with your child." The Time 2 videotaped sessions were coded via 5-s partial interval sampling to identify intervals with follow-in utterances (i.e., adult utterances that label the referent of the child's preceding attentional lead).

Parent–Child Snack (PCS)

While seated at the table with his or her child during a 10-min snack session, each parent was told, "We want to see how your child communicates during snack times. Just interact with him as you would at home if you wanted to elicit his communication." The Time 2 videotaped snack sessions were coded via 5-s partial interval sampling to calculate the number of intervals with follow-in utterances to the child's attentional or communication leads.

Reliability

Interobserver agreement was collected for 20% of coded sessions. A second observer independently coded sessions randomly selected without the primary coder's knowledge. Intraclass correlation coefficients (ICCs) computed using a two-way random model ranged from 0.94 to 0.99 across all measures. See Yoder et al. (2015) for ICCs for each measure.

Analysis Approach

We used partial least squares path modeling (PLS-PM) to test the predicted explanatory model and simplify the model to the most parsimonious yet most explanatory model. The principles of statistical control and multiple regression underpin PLS-PM. PLS-PM maximizes the association among linked latent constructs through iterative changes in the loadings (i.e., indices of association with proposed latent constructs) of indicator variables for each latent construct. In addition to indices relevant to evaluating the measurement model, the result is a path diagram that displays the significance and size of the proposed associations in the form of standardized multiple regression coefficients and their p values. Coefficients of determination (R^2) indicate the proportion of variance in the latent construct explained by the paths leading to that latent construct. Compared with covariance-based path modeling, such as structural equation modeling, PLS-PM is preferred for developing theories in small samples. It makes fewer assumptions about the data set and permits models that test many paths in small samples (Hair et al. 2013).

PLS-PM also offers an advantage over the approach Yoder et al. (2015) used to aggregate indicator variables. PLS-PM uses a process of determining the weights for these indicators that accounts for the relative strength of the intercorrelations among the indicator variables and maximizes the association among linked latent constructs. In contrast, Yoder et al. (2015) averaged standardized indicator variables with intercorrelations greater than 0.39 via unit weighting. That is, each indicator variable had an equal weight in the resultant aggregate variable regardless of how closely correlated it was with the latent construct. Theoretically, the iterative process for weighting in PLS-PM offers potentially more construct valid estimates of the latent constructs and more accurate statistical models than unit weighting (Hair et al. 2013).

Path models were created in WarpPLS (Kock 2015). After estimating the paths in the full model composed of all predicted associations, non-significant direct and indirect paths were removed to simplify the model while retaining the amount of variance accounted for in expressive vocabulary. The measurement model for the retained paths was assessed using indices of internal consistency reliability, convergent validity, and discriminant validity. The measurement model is considered *confirmatory* because the indicator variables thought to measure a particular latent construct were decided prior to this set of analyses.

Results

Preliminary Results

The percent of missing data ranged from 0 to 12.64% for the indicator variables. Missing data were imputed using stochastic regression imputation, which has demonstrated greater accuracy than other options available in WarpPLS (Enders 2010). For example, compared to arithmetic mean imputation and regression imputation, stochastic regression imputation provides less biased parameter estimates for data missing at random (Gold and Bentler 2000). Little's test of missing completely at random was met (Little 1988).

Evaluation of the Measurement Model

The measurement model for this study demonstrated adequate internal consistency reliability, convergent validity, and divergent validity for the latent constructs. As shown in Table 3, the composite reliability coefficients for the final model's latent constructs with multiple indicator variables were 0.78–0.94. These levels of reliability exceed the recommended minimum values (Hair et al. 2013).

Convergent validity is the extent to which multiple indicators are correlated positively with the latent construct they are thought to measure (Hair et al. 2013). As shown in Table 3, all associations between indicator variables and their corresponding latent construct were at or above 0.65. Follow-in comments with responsive play and parent linguistic responses had the lowest association. Following the recommendations of Hair et al. (2013), we retained follow-in comments with responsive play based on its contribution to content validity and the acceptable average variance extracted (i.e., a measure of variance accounted for) for its latent construct (i.e., 0.54 for parent linguistic responses).

Table 3 Internal consistency reliability, convergent validity and divergent validity of measurement model

Measure	Latent variable						
	Early receptive vocabulary	RJA	Intentional comm	Parent linguistic responses	DKCC	Mid-point receptive vocabulary	Later expressive vocabulary
Composite reliability coefficient	0.85	0.85	0.84	0.78	1.00	0.88	0.94
Average variance extracted	0.74	0.74	0.72	0.54	1.00	0.79	0.85
Indicator outer loadings and cross loadings							
Time 1 MB-CDI comprehension	**0.85**	−0.17	0.06	−0.14	−0.03	0.28	−0.15
Time 1 CSBS comprehension	**0.87**	0.15	−0.06	0.13	0.02	−0.25	0.14
Time 1 CSBS RJA	−0.02	**0.84**	−0.17	−0.25	−0.09	0.02	0.16
Time 2 ESCS RJA	0.02	**0.88**	0.15	0.22	0.08	−0.01	−0.14
Time 1 UCS intentional communication acts	0.16	−0.16	**0.88**	0.03	0.13	0.01	−0.06
Time 2 ESCS communication acts	−0.20	0.19	**0.82**	−0.04	−0.16	−0.01	0.07
Time 2 PCFP FI comments	−0.09	−0.34	0.34	**0.82**	−0.19	0.23	−0.06
Time 2 PCFP FI comments with responsive play	0.46	0.48	−0.60	**0.65**	−0.04	−0.64	0.48
Time 2 PCS linguistic responses	−0.27	0.05	0.06	**0.73**	0.28	0.18	−0.33
Time 2 CSBS consonant scale	0.00	0.00	−0.00	−0.00	**1.00**	−0.00	0.00
Time 3 MB-CDI comprehension	−0.18	−0.30	0.15	0.07	0.19	**0.87**	−0.21
Time 3 CSBS comprehension	0.15	0.25	−0.12	−0.06	−0.15	**0.91**	0.17
Time 4 MB-CDI words said	0.08	−0.08	−0.04	0.04	0.09	0.14	**0.90**
Time 4 UCS number of different words	−0.10	0.03	0.14	0.03	−0.12	0.02	**0.91**
Time 4 CSBS words	0.03	0.06	−0.10	−0.08	0.03	−0.18	**0.95**

Outer loadings are in bold type. All p values < 0.001

CSBS Communication and Symbolic Behavior Scales—Developmental Profile Behavior Sample (Wetherby and Prizant 2002); *DKCC* Diversity of key consonants used in communication; *ESCS* Early Social Communication Scales (Mundy et al. 2003); *FI* follow-in; *Intentional comm.* intentional communication; *MB-CDI* MacArthur-Bates Communicative Development Inventory—Words and Gestures Form (Fenson 2007); *PCFP* parent–child free play; *PCS* parent–child snack; *RJA* responding to joint attention; *Time 1* study entry; *Time 2* 4 months after entry; *Time 3* 12 months after entry; *Time 4* 16 months after entry; *UCS* unstructured communication sample with examiner

Discriminant validity describes the distinctiveness of one latent construct from other latent constructs. A latent construct's validity is supported when indicator variables are only weakly correlated in the expected direction (i.e., positive or negative) with the latent constructs they are *not* thought to measure (Campbell and Fiske 1959; Hair et al. 2013). Table 3 displays that the correlations between each indicator and latent constructs they are not thought to measure in the expected direction (i.e., positive correlations for this analysis) are indeed small. Thus, the model indicates strong discriminant validity.

Simplifying the Path Model

The initial full model was evaluated to address all components of the three research questions. Even though early receptive vocabulary was not a value-added predictor, a direct path from early receptive vocabulary to mid-point receptive vocabulary was included to control for early receptive vocabulary when testing the predictive strength of the other value-added predictors on mid-point receptive vocabulary. After removing the nonsignificant paths, the final simplified model summarizes the significant findings of the study (Fig. 1). Importantly, the nonsignificant direct path from RJA to later expressive vocabulary ($\beta = -0.11$, $p < 0.16$) was removed. The latter is important to interpreting the findings with regards to presence or absence of an indirect effect of RJA to expressive vocabulary through receptive vocabulary. Contemporary mediation analysis requires that the b path of an indirect effect must control for the direct path (Hayes 2013). Thus, the paths from (a) RJA to midpoint receptive vocabulary and (b) midpoint receptive vocabulary to later expressive vocabulary no longer create an indirect path because the direct path has been removed from the model. The a paths from intentional communication, DKCC, and parent linguistic responses paths to mid-point receptive vocabulary were removed when creating the simplified model due to nonsignificant results.

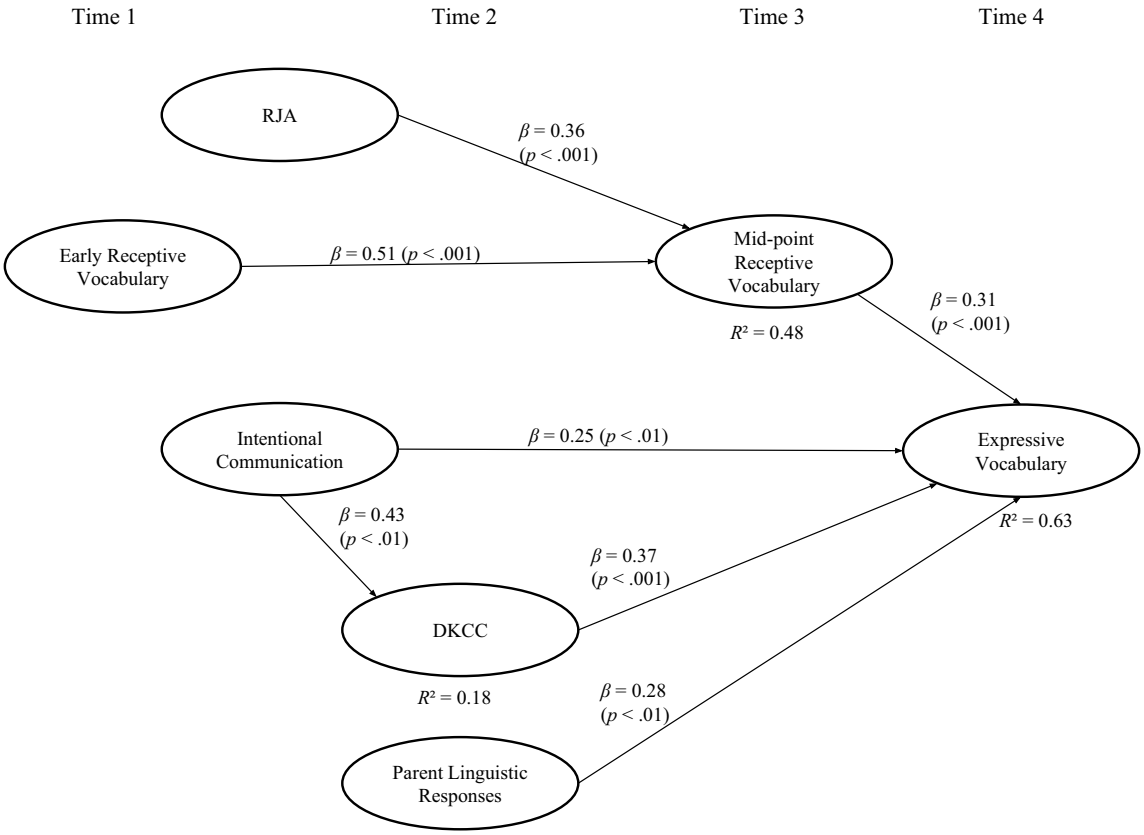

Fig. 1 Path model for expressive vocabulary skills in initially preverbal preschool children with autism spectrum disorder. *DKCC* diversity of key consonants used in communication; *RJA* responding to joint attention

The final simplified model included the following paths: (a) direct paths from intentional communication, DKCC, and parent linguistic responses (i.e., the three remaining value-added predictors) to later expressive vocabulary, (b) direct paths from RJA and early receptive vocabulary to mid-point receptive vocabulary, (c) the direct path from mid-point receptive vocabulary to later expressive vocabulary, and (d) the indirect path from intentional communication to expressive vocabulary through DKCC. This latter effect differs from the findings for the putative indirect path of RJA to expressive vocabulary through mid-point receptive language in one important way. The *b* path for the intentional communication to expressive vocabulary association through DKCC was significant even when controlling the direct effect of intentional communication on expressive vocabulary. The final model accounted for 63% of the variance in later expressive vocabulary. This value compares favorably to that found in the Yoder et al. (2015) study, which was about 50% of the variance in expressive language growth.

Are the Associations of the Value-Added Predictors with Later Expressive Vocabulary Mediated Through Mid-Point Receptive Vocabulary?

Contrary to our predictions, all of the indirect paths involving the value-added predictors of later expressive vocabulary through mid-point receptive vocabulary were nonsignificant (range $p = 0.08$–0.22). Importantly, the direct path from mid-point receptive vocabulary to later expressive vocabulary was significant in the initial model ($\beta = 0.34$, $p < 0.001$).

Are the Value-Added Predictors of Later Expressive Vocabulary Still Significant After Controlling for Mid-Point Receptive Vocabulary?

The direct paths from intentional communication ($\beta = 0.29$, $p < 0.01$), DKCC ($\beta = 0.37$, $p < 0.001$), and parent linguistic responses ($\beta = 0.30$, $p < 0.01$) to later expressive vocabulary were significant after controlling for mid-point receptive vocabulary. In contrast, the direct path from RJA to later

expressive vocabulary after controlling for mid-point receptive vocabulary was not significant ($\beta = -0.11$, $p < 0.16$). Interestingly, the direct path from early RJA to mid-point receptive vocabulary was significant, even when controlling for *early* receptive vocabulary ($\beta = 0.36$, $p < 0.001$).

Is the Association of Intentional Communication with Later Expressive Vocabulary Mediated Through DKCC?

As predicted, intentional communication had a direct path ($\beta = 0.25$, $p < 0.01$) and an indirect path through DKCC ($ab = 0.160$, $p = 0.015$) to expressive vocabulary. These results indicate that DKCC accounts for a portion of the variance in the association between intentional communication and later expressive vocabulary.

Discussion

We evaluated three research questions in a sample of initially preverbal preschool children with ASD: (1) Are the associations between the previously identified value-added predictors and later expressive vocabulary mediated through mid-point receptive vocabulary? (2) Are the previously identified value-added predictors of later expressive vocabulary still significant after controlling for mid-point receptive vocabulary? (3) Is the association between intentional communication and later expressive vocabulary mediated through DKCC?

Receptive Vocabulary Mediation Analysis

We did *not* confirm the predicted indirect paths involving the value-added predictors' association with expressive vocabulary through mid-point receptive vocabulary. Measurement error and inaccurate theory are the two primary reasons for nonsignificant findings. Each may have contributed to the nonsignificant indirect effects through mid-point receptive vocabulary.

Of particular concern for our path model analysis is the difficulty measuring receptive vocabulary, especially in young children with ASD. We employed a direct-observation assessment of receptive vocabulary (i.e., CSBS Comprehension subscale score) and a parent report measure of receptive vocabulary (i.e., MB-CDI Comprehension scale raw score). Both types of measures have weaknesses in assessing receptive vocabulary. Performance effects and deficits in social skills can reduce a child's demonstration of his or her understanding on direct assessment tasks (Muller and Brady 2016). The primary concern for parent report receptive vocabulary measures is the degree to which parents can accurately infer their child's understanding of individual words. Parents may have difficulty differentiating comprehension from awareness of spoken words (e.g., turning in response to a word being said), taking into account the nonverbal cues available to the child, and distinguishing knowledge of an object from knowledge of the spoken word for that object (Tomasello and Mervis 1994). Despite these potential difficulties in measuring receptive vocabulary, we observed reasonable stability in the receptive vocabulary latent construct across 12 months, a psychometric strength. Stability across time is expected and necessary when measuring generalized skills including receptive vocabulary. Nonetheless, a measure may be reliable without being valid for a given purpose.

More likely, covarying receptive vocabulary might not be an important explanation for the associations between value-added predictors and expressive vocabulary in children with ASD. The extant literature does not yet provide consensus on the nature of the relation between receptive and expressive vocabulary in children with ASD. For example, in a recent meta-analysis of receptive and expressive vocabulary in children with ASD, Kwok et al. (2015) reported "no evidence that an expressive advantage (i.e., expressive scores greater than receptive scores) is common in ASD" (p. 214). However, this review included relative differences in the means of receptive and expressive language measures, mixed results from studies using different metrics, and did not examine whether results varied by developmental level. Different conclusions have been drawn when receptive and expressive language were examined within individuals, particularly at the early stage of language acquisition (Hudry et al. 2010, 2014; Luyster et al. 2008; Woynaroski et al. 2016b).

For instance, Woynaroski et al. (2016b) reported two findings suggesting an atypical relation for the sample of participants used in the current study. First, participants demonstrated higher expressive vocabulary *age equivalent* scores than expected based on their receptive vocabulary age equivalent scores. Second, the longitudinal association between early expressive vocabulary *raw scores* and later receptive vocabulary raw scores was stronger than that between early receptive vocabulary raw scores and later expressive vocabulary raw scores. A more complete understanding of the relation between vocabulary modalities in children with ASD is expected to shape our theories of language development in children with ASD, hypothesized relations between vocabulary skills and predictor variables, and recommendations for the optimal sequence of intervention goals.

A Stringent Test of Value-Added Predictors of Later Expressive Vocabulary

Intentional communication, DKCC, and parent linguistic responses accounted for unique variance in expressive vocabulary measured 12–16 months later for initially preverbal preschool children with ASD when controlling for receptive vocabulary measured only 4 months prior to expressive vocabulary. The same three value-added predictors had the largest effect sizes in the Yoder et al. (2015) analysis. The findings of this stringent test underscore the strong associations between these three predictors and expressive vocabulary in children with ASD.

Contrary to our prediction, RJA did not account for unique variance in expressive vocabulary. This finding could have occurred due to our measurement of RJA using procedures with insufficient opportunities to show RJA. Combined with its covariation with early receptive vocabulary, restricted variance in the RJA measures may have reduced the likelihood of observing a significant correlation in the current analysis. The frequency of RJA is constrained by the number of adult attentional directives because RJA is by definition a response to another individual's action. The ESCS includes only eight opportunities and the CSBS provides only two. Thus, our RJA measures may be weak. In contrast to the other three value-added predictors, the effect size for the value-added association of RJA on expressive language growth in the Yoder et al. (2015) analysis was small. If replicated studies use improved measurement methods for RJA and find that RJA predicts unique variance above and beyond other value-added predictors, it may be considered for inclusion in the list of prioritized intervention goals alongside intentional communication, DKCC, and parent linguistic responses.

DKCC Mediation Analysis

DKCC mediated the association between intentional communication and later expressive vocabulary, indicating that DKCC accounts for variance in the association between intentional communication and later expressive vocabulary. This correlational study does not provide sufficient evidence for drawing causal conclusions. Nonetheless, these results were consistent with our hypothesis and provide additional evidence for the importance of promoting use of a greater variety of consonants during communicative acts in treatment for preverbal children with ASD. Future treatment studies are required.

Limitations

Prior to discussing the implications of the findings, four study weaknesses are acknowledged. First, as with all correlational studies, we cannot rule out third variable explanations for the identified associations. Second, although 87 is a large sample size compared to most prior studies of preverbal children with ASD, it is a relatively small sample size for a path model with the number of predicted associations in our initial model. To address this weakness, we used PLS-PM, which is better suited to analyses with small samples than covariance-based path modeling. The sample size in this study exceeded sample size requirements for the PLS-PM method (Hair et al. 2013). Third, because these findings have not been cross-validated on another sample, they could be sample specific. Fourth, PLS-PM does not yet accommodate growth-curve estimates for predictors of outcome latent constructs. Therefore, the current study used single time points for each measure rather than growth rates across multiple time points of the same measure. The use of multiple points in growth curve analysis affords more precise estimations of expressive vocabulary than those from single points in time. Imprecise estimates attenuate associations and might account for unexpectedly low associations with expressive vocabulary (e.g., the RJA to expressive vocabulary association).

Strengths

Four strengths of this study are apparent. First, the longitudinal correlational design offers more convincing evidence that the significant paths represent causal effects than evidence from a concurrent correlational design. Second, the study included data from a 16-month span, which provides sufficient time for variations in expressive vocabulary skills among these initially preverbal participants to surface. Third, we evaluated the value-added predictors of expressive vocabulary measured 12–16 months prior to expressive vocabulary in an especially rigorous test by controlling for receptive vocabulary only 4 months prior. Fourth, we used multiple indicators for all variables except DKCC to increase the stability and therefore potential validity of the estimates.

Theoretical Implications

The pattern of results contributes additional support to the transactional theory of language development. Each of the value-added predictors can fit within the transactional theory of language development, which includes child, parent and dyadic variables. The associations surrounding DKCC provide an example of how this model might explain some of the associations in the current study. If we integrate the findings from the current study with those of Woynaroski et al. (2016a), we see evidence that DKCC mediates the association of intentional communication to expressive language and that the growth of DKCC is predicted by parent

linguistic input in young children with ASD. The parent linguistic responses variable is considered dyadic because the parent responds to the child's attentional and communicative leads. Theoretically, these parent responses change as the child's communication level increases (e.g., uses increasingly more consonants in communication) in a manner that facilitates continued language growth. Empirical evidence, such as child consonant use in vocal communication eliciting parent use of language-facilitating responses, supports this assertion (Gros-Louis et al. 2006). In addition, children who more frequently exhibit intentional communication acts may participate in more interactions that facilitate increased object knowledge, a cognitive basis for many early words. This said, experimental evidence is required to confirm these possible mechanisms.

Clinical Implications

If the present correlational findings are replicated or confirmed through an internally-valid treatment study, clinicians should prioritize intentional communication, DKCC, and parent linguistic responses as goals for increasing expressive vocabulary skills in preverbal preschool children with ASD. Even without the limits on financial and educational resources that play a role in most intervention efforts, clinicians and caregivers could not feasibly target every language skill that a child with ASD needs to learn. Instead, they need empirical evidence to prioritize language goals based on anticipated gains. For expressive vocabulary in preverbal preschool children with ASD, the above three skills demonstrate robust predictive value. The non-significant findings for the tested mediation analyses for mid-point receptive vocabulary development suggest that teaching receptive vocabulary through compliance to directives and pointing to named objects may not be a necessary intermediate target for achieving increased expressive vocabulary growth in preverbal preschool children with ASD. These results highlight the importance of considering child factors, parent factors, and the interactions between them.

Future Research

Experimental studies are needed to rule out alternative explanations for the findings of this longitudinal correlational study. Only manipulating these value-added predictors in well-controlled, internally-valid experiments will sufficiently test whether these associations are causal. For example, the indirect path of intentional communication to expressive vocabulary through DKCC could be tested in an internally-valid treatment study. A future study might target increasing intentional communication in preverbal preschool children with ASD to achieve a short-term goal of increased DKCC and a long-term goal of expressive vocabulary growth. Confirming the predicted mediation relation would provide more direct evidence that targeting intentional communication is expected to result in early DKCC gains and later expressive vocabulary growth.

Because of the numerous implicit and explicit references to parent linguistic input in the extant literature and current analysis, deeper investigation of how this variable influences receptive and expressive vocabulary skills in children with ASD is warranted. Treatment studies that actively manipulate parent linguistic responses should consider the engagement state in which linguistic responses are given. A recent study of children with ASD found that linguistic responses were associated with receptive language only when provided in parent–child exchanges in which the child shows implicit attention to the parent and explicit attention to the object with which they are playing (Bottema-Beutel et al. 2014). Future studies should expand upon the use of path modeling to advance understanding of why preverbal skills and social environmental factors impact language development in children with ASD. Over time these lines of research should include children of different ages and developmental levels to capture the variations in key variables for language growth across development postulated by the transactional theory of language development.

Conclusion

Use of path modeling to evaluate predictors of expressive vocabulary skills in children with ASD yielded two findings novel to the literature that contribute to a parsimonious model of language development in children with ASD. First, intentional communication, DKCC, and parent linguistic responses predicted unique variance in expressive vocabulary even in a particularly stringent test controlling for receptive vocabulary. Second, DKCC mediated the association between intentional communication and later expressive vocabulary. Further research is needed to replicate the current findings, to test these potentially causal relations directly, and to provide a specific sequence of intervention targets for preverbal children with ASD. If the findings are replicated, clinicians and families should strongly consider prioritizing intentional communication, DKCC and parent linguistic responses when selecting initial therapy goals for preverbal preschool children with ASD.

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Compliance with Ethical Standards

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

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