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Exploring communicative competence in autistic children who are minimally verbal: The Low Verbal Investigatory Survey for Autism (LVIS)

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Abstract

Approximately 30% of autistic children are considered minimally verbal. The field lacks an efficient and reliable measure of communicative capacity among minimally verbal autistic children. Improved methods are needed to determine which children are at greatest risk for minimally verbal outcomes to better target interventions. Here, we present the Low Verbal Investigatory Survey (LVIS), a brief parent-report measure designed to assess communicative capacity among minimally verbal autistic children. The 36-item easy-to-complete LVIS was developed to capture the atypical language trajectories associated specifically with autism. We report pilot results from a sample of 147 children (1–8 years) whose caregivers completed the LVIS as part of other studies. Principal components analysis was used to assess dimensionality of the LVIS; composite scores were compared with existing measures of communicative capacity, all of which take *significantly more time and training* to administer and score. Scores on the LVIS were strongly correlated with existing gold-standard measures of communication. Presence of atypical vocalizations was determined to be particularly relevant for symptoms of autism as well as language and cognitive abilities. These findings provide initial validation of a tool designed to capture multiple dimensions of communicative capacity in children with minimal or low verbal skills.

Lay abstract

Approximately one in three autistic children is unable to communicate with language; this state is often described as minimally verbal. Despite the tremendous clinical implications, we cannot predict whether a minimally verbal child is simply delayed (but will eventually develop spoken language) or will continue to struggle with verbal language, and might therefore benefit from learning an alternative form of communication. This is important for clinicians to know, to be able to choose the most helpful interventions, such as alternative forms of communication. In addition, the field lacks a standard definition of "minimally verbal." Even when we do agree on what the term means (e.g. fewer than 20 words), describing a child based on their lack of words does not tell us whether that child is communicating in other ways or how they are using those 20 words. To address these concerns, we developed the Low Verbal Investigatory Survey (LVIS), a one-page parent-report measure designed to help us characterize how minimally verbal autistic children *are* communicating. Parents of 147 children (aged 1–8 years) completed the LVIS. Here, we ask (1) whether the survey measures what it was designed to measure, that is, communicative ability in children without much spoken language, and (2) how the LVIS relates to cognitive and language ability, and symptoms of autism. Results suggest that this survey, which takes only 5 min to complete, is a good estimate of the child's communication skills. Furthermore, LVIS survey

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scores are correlated with other measures of language and cognitive abilities as well as autism symptomatology. The LVIS has the potential to save time and money in both clinical and research efforts to assess communication skills in minimally verbal autistic children.

Keywords
autism spectrum disorder, assessment, communication, language, LVIS, minimally verbal

For autistic children and adults[1], mastery of productive language is a key predictor of the ability to live and function independently (Anderson et al., 2007; Mayo et al., 2013). Explorations of interventions targeting communication among minimally or low verbal (MLV) autistic individuals have thus become important research goals (Kasari et al., 2013; Tager-Flusberg & Kasari, 2013). A significant barrier to these efforts is the lack of an efficient measure of communicative capacity among MLV autistic individuals. Definitions of MLV status vary substantially and often use arbitrary thresholds for the number of words a child is producing (Bal et al., 2016; Tager-Flusberg & Kasari, 2013). These cut-offs effectively mask the enormous *range* of communicative abilities observed in MLV children. Existing measures of language capacity are labor intensive and often based on typically developing (TD) norms; they also fail to capture the multi-dimensional and often atypical productions that characterize early language in autism. The current study describes a new survey tool specifically designed to measure communicative capacity in MLV autistic children. Such a tool could support the development of effective interventions by, for example, helping to stratify otherwise heterogeneous samples into groups that may have differential responses to language interventions. This measure also has the potential to help identify critical moderators of response to intervention and predictors of language outcome.

Reliance on a simple threshold (whether it is 5, 10, or 20 spontaneous words) to identify MLV autistic children masks significant and likely clinically-relevant variability in communication skills. "Low verbal" children might produce just a handful of sounds, or recite full scenes from movies fluently (without understanding the content). Some children rarely initiate communication, where others might communicate spontaneously using alternative means (e.g. gestures, or augmentative/alternative communication systems such as picture exchange, electronic communicators, or software based systems of tablet devices; (see White et al., 2021 for review). A number of existing assessment tools have been used to capture language development in this population, with mixed sensitivity to the features of autism. Many clinicians indicate dissatisfaction with the available approaches and report using multiple forms of assessment to overcome this gap (Muller et al., 2020). To further illustrate the need for a measure such as the LVIS, we provide a brief overview of existing measures of language and communicative capacity in text below and in Table 1.

Language Assessment Tools: A study by Kasari et al. (2013) reviewed the recommended assessment tools for MLV children. Only 2 of 9 measures were "well suited" for assessing MLV children. The first was the Peabody Picture Vocabulary Test—IV (PPVT) (Dunn & Dunn, 2004; Dunn et al., 2015), used by a number of groups in studies of MLV autism (e.g. Costanza-Smith, 2010; Kaiser & Roberts, 2013; Rojas & Iglesias, 2010; Romski et al., 2010). See Table 1 for further details. The second best-practice approach identified by Kasari et al. (2013) was collecting and analyzing language samples (e.g. to establish mean length of utterance (MLU)). However, recording, transcribing and analyzing natural language samples requires expertise from a speech-language pathologist or other trained specialist, making this approach both time intensive and cost prohibitive. Recently, Tager-Flusberg and colleagues have introduced the Eliciting Language Samples for Analysis (ELSA) protocol. The ELSA offers an improvement over existing measures, but time for administration and coding requires approximately an hour (Barokova et al., 2021).

Other measures cited by Kasari et al. (2013) were rated to be used with MLV children "with some caution." These include the Preschool Language Scales (PLS), 5th Edition (Zimmerman et al., 2011); the Reynell Developmental Language Scales-III (Edwards et al., 1999), now revised as the New Reynell Developmental Language Scales (Edwards et al., 2011); the Sequenced Inventory of Communicative Development—Revised (Hedrick et al., 1984); the Test of Early Language Development-3 (Hresko et al., 1999), now available in a Fourth Edition (Hresko et al., 2018); the MacArthur-Bates Communicative Development Inventories (Fenson et al., 2007); the Vineland Adaptive Behavior Scales-II, VABS (Sparrow, 2011); and the Language Use Inventory (O'Neill, 2007).

These assessment tools were developed for and validated with normative samples, and only two (VABS-3, Sparrow et al., 2016; PLS, Zimmerman et al., 2011) provide separate descriptive tables specifically for individuals with autism. Most existing language measures lack sufficient sensitivity to variation in the prelinguistic communicative functions that may be most relevant for minimally verbal children with autism. More importantly, these measures are, with one exception, grounded in the typical developmental trajectory of expressive and receptive language (cf. O'Neill, 2007). Autistic children do not necessarily follow the typical trajectory; for example, in contrast

Table 1. Established measures for assessing communicative capacity in low verbal children.

	Name	Age range (years)	Normative samples	Language domains assessed	Time to administer (min.)	Examiner	Reference
Examiner Administered Assessments	Peabody Picture Vocabulary Test-4*	2;6-90	3,540 cases representative of population, including some clinical groups but no MLV autistic sample	Receptive vocabulary	10–15	Trained examiner	Dunn et al., 2015
	Test of Early Language Development-4	3;0-7;11	1,074 typically developing children	Receptive and expressive language	15–45	Trained examiner	Hresko, Reid, & Hammill, 1999
	Preschool Language Scales-5th Edition	0;1-7;11	1,400 children, representative of population	Receptive and expressive language	30-60	Trained examiner	Zimmerman et al., 2011
	New Reynell Developmental Language Scales	2:0-7:6	1,266 typically developing, 25 language-impaired	Receptive and expressive language	35–60	Trained examiner	Edwards et al., 2011
	Sequenced Inventory of Communicative Development—Revised	0;4-4;0	252 typically developing children	Sound and speech discrimination	30–75	Trained examiner	Hedrick et al., 1984
	Mullen Scales of Early Learning	0-5-8;0	1,849 children, representative of the population	Receptive and expressive language	15–60	Trained examiner	Mullen, 1995
Parent Report	MacArthur Bates Communicative Development Inventories	0;8-3;1	1089 infants, 1,461 toddlers, all typically developing	Receptive and expressive language	20–40	Parent/ informant	Fenson et al., 2007
	Vineland Adaptive Behavior Scales-II	0;1-90;0	3,695 plus "autism nonverbal" and "autism verbal" groups	Receptive, expressive, written language; social, daily living, motor skills	20–60	Parent/ informant	Sparrow et al., 2016
	Language Use Inventory	1;6-3;11 (older for developmental delays)	3,500 children, representative of population	Requesting help, sharing attention, asking and commenting; guiding interactions with others; humor; meta-language; changing perspectives; sentences and stories	20–30	Parent/ informant	O'Neill, 2007
Measures of broader communication skills	Communication and Symbolic Behavior Scales Developmental Profile	0;6-2;0 (up to 6 years for developmental delays)	282 typically developing children	Communicative functions, vocalizations, gestures, verbal communication, reciprocity, social-affective signaling, symbolic behavior	50–75; 15 for parent questionnaire	Parent/ informant	Wetherby & Prizant, 2002

(Continued)

Table 1. (Continued)

	Name	Age range (years)	Normative samples	Language domains assessed	Time to administer (min.)	Examiner	Reference
	Communication Complexity Scale	lifespan	178 children including groups with Down syndrome, intellectual disability, autism, nonverbal infants with motor impairments, and multiple disabilities	Presymbolic and symbolic communication	20–30	Trained examiner	Brady et al., 2012
	Early Social Communication Scales	0;8-2;6 (older for developmental delay group)	14 typically developing children	Joint attention, behavioral requests, social interaction	15–25	Trained examiner	Seibert et al., 1982
	Communication Matrix	lifespan	9 typically developing infants 6-20 months	Pre-intentional to mature levels of communication	<60	Parent/ informant	Rowland & Fried-Oken, 2010
	Inventory of Potential Communication Acts	4;0-15;0	30 children with developmental, physical and communication impairments	Social conventions, attention to self, protest, request, requests, comments, choices, answers and imitation	<60	Parent/ informant	Sigafoos et al., 2000
	Functional Communication Profile	3;0—adult	n/a	Sensory/motor, attention, receptive and expressive language, pragmatic/ social, language, speech, voice, oral fluency, non-oral communication	45–90	Trained examiner	Kleiman, 2003
Other	Language Samples*	all ages	n/a	Expressive language, gestures	10–20; 60 + min to transcribe	Trained examiner	Costnaza-Smith, 2010; Rojas & Iglesias, 2010
	ELSA protocol to elicit and code language samples	1;5-19;7	Validated with $n=46$ MLV autistic children ages 6;6-19;7 (ELSA-A), $n=19$ toddlers ages 1;5-5 (ELSA-T)	Number of utterances and independent clauses	30 min elicitation, 35 min to code	Trained examiner	Barokova et al., 2021

*Indicates that this approach was described by Kasari et al. (2013) as "well suited" for language assessment in MLV autistic children.

to typically developing and language delayed children, the development of expressive skills among autistic children may exceed receptive skills (Ellis Weismer et al., 2010; Maljaars et al., 2012). Moreover, the response demands of traditional tests may limit autistic children's ability to demonstrate knowledge that they actually possess.

Assessment of broader communication skills: Other measures of communication do extend beyond typical spoken language development: the Communication and Symbolic Behavior Scales Developmental Profile (Wetherby & Prizant, 2002), the Communication Complexity Scale (Brady et al., 2012), Early Social Communication Scales (Seibert & Hogan, 1982), the Communication Matrix (Rowland & Fried-Oken, 2010), and the Inventory of Potential Communication Acts (Sigafoos et al., 2000). Also summarized in Table 1, these measures differ from the standardized assessments described above in that they may more effectively capture less-typical aspects of communication.

While some of these measures go beyond the expressive and receptive trajectories associated with typical development, they require significant time and examiner training that limits their use in busy clinics and research visits. Furthermore, these measures tend not to include questions about the alternative forms of communication often used by autistic children (e.g. Picture Exchange Communication System (PECS), gestures, or written language) (cf. Brady et al., 2012; Rowland & Fried-Oken, 2010), nor do they probe for more "atypical vocalizations" associated with autism (e.g. high pitched voice, shrieks, repetitive cluster babbling, etc.).

It is possible that atypical forms of production are manifestations of repetitive and stereotyped behaviors, and are unrelated to language development, but this is an empirical question that would benefit from further data. Furthermore, evidence on vocal play and babbling in typically developing infants suggests that these types of productions may in some cases be beneficial for language learning (McGillion et al., 2017; Oller et al., 1998). Recent work by Kang and colleagues (2019) indicates that atypical communication characteristics can be used to subgroup autistic individuals in meaningful ways. These autism-specific features may be the precise factors that predict a child's chances of remaining MLV and could potentially serve as moderators of response to treatment. Because there is little research on these atypical forms of communication, we do not yet know whether they are positively related to language outcomes. It is critical for researchers to establish whether these atypical communicative acts invite (or potentially discourage) parental responses, thereby contributing to a social feedback loop in speech development (Warlaumont et al., 2014).

To address this clinically important gap, this paper introduces the LVIS. The LVIS is designed to assess a range of communicative abilities in autistic children. Rather than an inventory of vocabulary knowledge, or a categorical measure of number of spontaneous words produced, the LVIS provides a summative measure of *multiple* dimensions of communication. This brief assessment of communicative capacity among MLV autistic children was developed to measure features of language development specific to autism. It facilitates data collection at multiple time points by reducing the cost of time and effort associated with data collection; it can be completed online or on paper, within about 5 min. The low participant burden increases feasibility for repeated assessments and with large sample sizes. The LVIS may therefore facilitate future research to evaluate *individual risk factors* for MLV outcomes, as well as studies of *response to treatment* in language interventions, among other critical clinical questions. Our intention is to make the LVIS available at no charge to the research community; please contact the authors for information or visit this website [https://lvis.psych.uconn.edu/].

Here, we describe the methods used to develop the LVIS and preliminary evidence for convergent and divergent validity of the measure compared with both parent-report and formal assessment of language in a sample of 147 1- to 8-year-old autistic children, children with language delays, and typically developing children.

Methods

Form development

The concept for the Low-Verbal Investigatory Survey (LVIS) emerged from a special interest group on minimally verbal autistic individuals at the International Meeting for Autism Research in Atlanta, GA in May, 2014. The need for this tool became apparent during a discussion with researchers and clinicians working with MLV autistic individuals who were frustrated by the lack of clear delineation of what it means to be MLV. This frustration was compounded by the limited research on whether a low-verbal child is simply preverbal (but will go on to develop language), or is likely to remain minimally verbal and warrant interventions targeting the use of augmentative communication devices.

Following this discussion, a panel of clinicians and researchers with expertise in language acquisition in autism began to develop the LVIS. This process occurred in consultation with developers of the Modified Checklist for Autism in Toddlers—Revised (M-CHAT-R) (Robins et al., 2014), a widely used tool for screening children for risk of autism; the LVIS was modeled after the brevity and efficiency of the M-CHAT-R. The choice of items was driven by known and postulated aspects of language in autism (Anderson et al., 2007; Eigsti et al., 2011; Ellis Weismer & Kover, 2015; Thurm et al., 2015; Yoder et al., 2014). These included more typical features of early language development, such as babbling, word and phrase production, language comprehension, and important language correlates such as initiation of and response to joint attention. They also included autism-specific characteristics such as atypical prosody, atypically structured babbling, neologisms, regression, and immediate and delayed echolalia.

The initial version was piloted with parents of autistic and typically developing children to assess accessibility of the language and content of the form as well as informal evaluation of the question formats. Following revision, further feedback was sought from five expert researchers and clinicians in the field who were not involved in the development of the form. Feedback included suggestions on content, wording, and format, and the LVIS was further revised. In its current form, the LVIS consists of 36 categorical questions. It takes 5 min to complete and covers the range of communication strategies typically used by autistic children. To summarize Autism Community involvement: Family members of autistic children were involved in developing the measures in this study.

The current study reports results from parents who completed the LVIS as part of a battery of assessments in one of three ongoing studies (see below). Principal components analysis was used to establish dimensionality and scoring for the LVIS based on the full sample. These scores were compared to existing gold standard measures using Pearson Correlations to assess relations between LVIS scores and language ability as measured by the Preschool Language Scales (PLS-5) (Zimmerman et al., 2011) and the VABS-II (Sparrow, 2011) Communication Scores and cognitive ability as measured by the Stanford Binet Scales of Intelligence, Fifth Edition (SB5) (Roid, 2003) for all participants with available scores on these measures. LVIS scores were also compared to symptoms of autism as measured by the Autism Diagnostic Observation Schedule–2nd Edition (ADOS-2) (Lord et al., 2012) for autistic participants. Finally, to explore the contributions of the individual items on the LVIS, based on the full sample, analyses of variance (ANOVAs) were carried out for each item as a categorical factor with standardized measures (e.g. PLS score) as the outcome variable. This approach was used to determine to what extent variance in each measure was explained by the LVIS item. Specifically, we modeled, for each combination of LVIS items and standardized measure, an ANOVA where the single predictive factor, or "group" was the LVIS item response. These ANOVAs yield standard F-values. As these F-values are dependent on the total variance of the standardized measure, and not the LVIS items, the F-values are comparable within measures, for example, VABS motor domain, and not across measures. To enable us to compare across measures, F-values were converted to a standardized effect size measure, Cohen's f. While this effect size is more readily comparable across measures, we emphasize that comparability across outcomes requires consideration of the similarity of the contracts under investigation. Finally, we point out that the goal of this analysis was estimation and not hypothesis testing. This approach employed 408 univariate analyses toward the goal of understanding the landscape of relationships with items and measures. Future replication in independent samples is necessary for determining the stability of these estimates. Study protocols were reviewed and approved by the Women and Infants Hospital Institutional Review Board (Studies 1 and 2) and the University of Connecticut Institutional Review Board (Study 3)

Participants

Parents of 147 children aged 1 to 8 years completed the LVIS. This age range was selected based on evidence that language abilities are generally considered stable by 8 years (Anderson et al., 2007), and by the age range of one of the primary language measures, the PLS (birth to 7 years, 11 months). Within this sample, there were 64 autistic children (52 male, 12 female, M=4.5 years, SD=1.7), 28 children with developmental or language delay (17 male, 11 female, M=1.9 years, SD=1.08), and 55 typically developing children (34 male, 21 female, M=3.1 years, SD=1.5). Though the LVIS was designed to assess language trajectories specific to autism, typically developing and language delayed participants were included in this sample for measurement development purposes and to establish a normative baseline for comparison.

These families were recruited from three different studies in Connecticut and Rhode Island: (1) an ongoing study of word learning in autism (n=16), (2) a study of psychophysiological response to social stimuli (n=73), and (3) a study of infants who had an elevated likelihood for autism diagnosis after failing an M-CHAT-R screening (Robins et al., 2014) during a well-child pediatric visit (n=58); these latter children were referred for further evaluation by expert clinicians. Studies 1 and 2 included participants recruited from the Rhode Island Consortium for Autism Research and Treatment patient registry (RI-CART); Study 3 included participants recruited from the Early Detection project. Participants across sites were not recruited specifically on the basis of MLV status, but a subset (n=31) was described by their caregivers as minimally verbal. Because demographic information about race, ethnicity, socioeconomic status, and parental age were collected differently across each study or not collected, those data are not included here.

All autistic children had community diagnoses of autism spectrum disorder (ASD) and all but 10 had scores available from research reliable administrations of the ADOS-2 (Lord et al., 2012) Module T (n=9), Module 1 (n=22), Module 2 (n=11), or Module 3 (n=12). ADOS-2 Calibrated Severity Scores were used for comparison across assessment modules (Esler et al., 2015; Gotham et al., 2009). Demographic, cognitive, and language testing differed across studies. Available descriptive data are provided in Table 2. Scores were available on the Preschool

Table 2. Age and test results for all participants with available data.

		ASD				DLD		TD	
		Verbal		Minimally verbal					
		n	Mean (*SD*)	*n*	Mean (*SD*)	*n*	Mean (*SD*)	*n*	Mean (*SD*)
Age (years)		33	4.77 (1.30)	31	4.12 (1.97)	28	1.91 (1.08)	55	3.10 (1.53)
Sex (F/M)		33	8/25	31	4/27		11/17		21/34
	LVIS Communication Abilities	31	23.7 (4.0)	33	17.6 (5.0)	28	18.0 (4.5)	55	24.8 (3.7)
PLS	Receptive Standard Score	29	73.4 (21.2)	21	57.3 (11.8)	4	74.8 (15.5)	32	111.3 (15.0)
	Expressive Standard Score	29	75.1 (21.9)	21	57.9 (12.7)	4	72.0 (13.8)	32	110.6 (17.6)
Vineland	Communication Standard Score	24	81.8 (14.8)	16	63.2 (16.8)	27	81.1 (9.4)	55	102.8 (11.1)
	Daily Living Standard Score	24	79.8 (13.3)	15	71.9 (19.8)	26	87.5 (6.3)	55	100.2 (10.8)
	Social Standard Score	24	75.3 (9.5)	14	63.9 (12.0)	26	88.4 (7.0)	55	100.0 (13.1)
	Motor Standard Score	23	79.5 (8.0)	15	84.8 (15.8)	26	88.6 (9.3)	54	98.7 (11.1)
Binet	Nonverbal IQ Standard Score	24	85.2 (22.9)	12	62.7 (21.8)	4	67.0 (12.3)	33	114.1 (11.4)
	Verbal IQ Standard Score	24	80.1 (24.8)	12	55.9 (10.7)	4	60.5 (9.1)	33	112.8 (14.7)
ADOS	Social Affect Severity Score	30	7.1 (2.3)	24	7.8 (1.5)				
	Repetitive Behaviors Severity Score	30	7.4 (1.9)	24	8.5 (1.6)				
	Comparison Severity Score	30	6.9 (2.2)	24	8.1 (1.3)				

Note. Not included in this table: demographic information about race/ethnicity, socioeconomic status, and parental age; because these variables were collected differently across each study (or not collected), it proved difficult to collapse these dimension while preserving critical information.

Language Scales (PLS-5) (Zimmerman et al., 2011) for 86 participants (M=4.5 years, SD=1.4), the VABS-II (Sparrow, 2011) for 122 participants (M=3.2 years, SD=1.7), and the Stanford Binet Scales of Intelligence, Fifth Edition (SB5) (Roid, 2003) for 73 participants (M=4.3 years, SD=1.3). Missing data (<1% of all data) were imputed with the Multivariate imputation by chained equation (MICE) package in *R* (Zhang, 2016).

Procedure

Participants were administered all measures in the context of the studies in which they were enrolled. In each study, participants visited the laboratory for a battery of assessments. During this visit, parents were invited to complete the LVIS; they received no additional compensation or feedback for this activity. Parents received the following written instructions:

> Please answer these questions about your child. Keep in mind how your child usually behaves. If you have seen your child do the behavior a few times, but it is unusual, answer no. Please circle an answer for every question. Thank you very much!

Parents completed the LVIS form during a break from other testing activities, typically while sitting in the testing suite; examiners were physically present and could answer any questions as needed but did not actively supervise the activity. The LVIS consisted of a single-sided one page paper form, with 36 printed questions with yes/no (33 items) or none-few-some-many (3 items) response options; parents responded by circling the appropriate answer. Respondents also responded to a final open-ended question: "Is there any other information about your child's communication that you would like to share?" We asked respondents to report the child's gender, date of birth, and the respondent's relation to the child, child's age at diagnosis, and the language spoken at home.

Principal components analysis was used for data reduction to identify candidate items for a composite score for comparison with existing measures. Convergent validity was assessed by comparing LVIS scores to standardized measures of social and language development, including the Expressive and Receptive Language scores from the PLS-5, and Communication scores on the VABS-II, and SB5 Verbal IQ. Divergent validity was assessed with Daily Living Skills, Socialization, and Motor Skills on the VABS-II, and

Non-Verbal IQ on the SB5. Correlations between LVIS scores and symptomatology of autism were assessed using scores on the ADOS-2. Finally, individual LVIS item responses were associated with standardized measures to identify those items on the LVIS that were most informative for different domains of social and language development. The analysis code can be accessed in a Github repository, https://github.com/anomalosepia/lvisManuscript.

Results

Data reduction: Data included responses from 147 parents to 36 items for 5,292 possible responses. Of those, 40 were missing (less than 1%). Of the 36 items on the LVIS, two asked about minimally verbal status (i.e. "Would you describe your child as "nonverbal" at this time?" or "Has anyone ever described your child as "nonverbal"?[2]). Of the 34 questions addressing communicative capacity, 31 were yes/no questions ("yes" scored as 1, "no" scored as 0). Three items were categorical (none, few, some, many); these were initially scored as 0/1/2/3. Responses to these 34 content questions were first explored using crosstabs to identify any items that were perfectly collinear in their response patterns. Three sets of items were combined into single partial-credit responses because they exhibited inter-item dependencies. That is, a child that babbles by year one will by definition babble, but a child that babbles might not start babbling until after year one. Thus, responses on the following items were converted from 0/1 to 0/1/2: Compound 1: Babbling (Item 1), Babbling by 1 year ((Item 1i); Compound 2: Use of words (Item 2), Use of words by 2 years (Item 2i); Compound 3: Use of phrases (Item 3), Use of phrases by 3 years (Item 3i).

A principal component analysis (PCA) with oblique rotation was used to assess the dimensionality of the LVIS. Prior to running the PCA, correlations between the 34 content items were assessed. No bivariate correlations exceeded $r = 0.77$. Though recommendations on sample size differ as a function of the magnitude of factor loadings (Guadagnoli & Velicer, 1988) and communalities (MacCallum et al., 1999), we used the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy to confirm that we were appropriately powered for the analysis. The sampling was adequate with KMO = 0.75; one item (Response to Name) had a KMO value of 0.48. All other items had KMO values > .58 (range .58-.88). Bartlett's test of sphericity indicated that PCA was appropriate, $\chi^2(561) = 2389.83$, $p < 0.001$. Monte-Carlo simulation using Horn's parallel analysis method (Çokluk & Koçak, 2016) recommended a six-factor solution, and the scree plot showed inflection points at both two and six factors (eigenvalues for Component 1 = 5.11, 2 = 4.32, and Components 3-6 ranging from 1.68 to 1.04). The two-factor model yielded largely "typical" and "atypical" forms of communication and was selected in light of the leveling off of eigenvalues after the second component and for the purpose of interpretability. Table 3 shows the pattern matrix for the rotated factor loadings in the two factor solutions.

Based on the strongest loading for each item, we interpret the factors as representing (1) Communication Abilities and (2) Atypical Communication. Four items, "Response to Name," "Does your child often use sounds to communicate specific messages" "Does your child often use gestures to communicate specific messages, and "Odd use of words (for example, saying "boxes" to mean "no?")" did not load on any factor greater than 0.3 (indicating lack of correspondence between that item and the factors listed above). Factor 1 from the PCA was used to create a summary score of Communication Abilities for comparison with existing measures of language ability. Given the novelty of the atypical language measure, and challenges with interpreting negative factor loadings for a number of items on the Atypical Communication factor, we opted not to compute a standard score from Factor 2. Though we interpret the second Factor as "Atypical Language" based on the relatively small sample of autistic participants in this study, we did not feel it prudent to calculate a score in which we would potentially be reverse coding items such as "Does your child recognize any printed letters and or numbers?," "Does your child often use pictures (e.g. PECS or an I-PAD?)," "Does your child communicate by grabbing your hand and bringing you somewhere?," and "Does your child communicate with you by placing your hands on things?" These items might be reverse coded in a factor associated with atypical language, given that they all capture alternative communication modes that frequently serve as substitutes for speech; however, such interpretations await a larger data set. Given the theoretically established basis for Communication Abilities, we felt confident proceeding with our analyses based on Factor 1 for assessing convergent and divergent validity of the LVIS as a measure of communicative capacity.

Communication Abilities was calculated as an unweighted summed score of the LVIS items that loaded onto Factor 1 (>0.30) and ranged from 9 to 29, $M = 21.74$, $SD = 5.3$. Communication Abilities on the LVIS were significantly correlated with age $R(147) = .43$, $p < 0.001$. Pearson correlations between LVIS Communication Abilities scores and the gold standard measures of IQ and language abilities are shown in Table 4.

Convergent validity was assessed by correlating LVIS Communication Abilities scores to standardized measures of social and language development across and within diagnostic groups. Significant correlations with large effect sizes (rs > 0.50) were found for LVIS Communication Abilities, Expressive and Receptive Language scores from the PLS, and Communication scores on the VABS-II. Though LVIS Communication Abilities scores were also significantly correlated with the measures used to assess divergent validity (VABS Daily Living Skills, Socialization, and Motor Skills, and Non-Verbal IQ on the SB5), the

Table 3. Pattern matrix for principal components analysis.

Item	Communication abilities	Atypical language
Does your child use phrases flexibly?	0.83	
How many words does your child say?	0.79	
Regularly uses phrases	0.74	
Does your child often use words to communicate specific messages?	0.70	
Does your child follow simple directions without gestures?	0.60	0.40
Does your child recognize any printed letters and or numbers?	0.63	–0.37
How many consonant sounds does your child make?	0.57	
Does your child follow multi-step directions?	0.59	
How many words does your child understand?	0.57	
Does your child follow simple directions with gestures?	0.49	0.43
Does your child write words?	0.51	
Regularly uses words	0.51	
Does your child point to things to draw your attention to them?	0.50	
Does your child read aloud?	0.43	
Babbling	0.40	
Does your child point to things he/she wants?	0.43	
Does your child follow your point to things?	0.35	0.34
Echolalia (for example, repeating what you say word-for-word)?		0.73
Scripting (for example, repeating a TV show from memory)		0.71
Unusual sounds (for example, repeated shrieks)?		0.66
Did your child ever use real words, but then stop using those words?		0.62
Extremely high-pitched, low-pitched or sing-songy?		0.57
Does your child often use pictures (for examples, PECS or an I-PAD?)		–0.56
Rapid repeating of sounds (for example, dugudugudugu?)		0.62
Did your child ever babble but then lose those sounds?		0.57
Frequent humming?		0.50
Monotone voice? (for example, robotic sounding)?		0.53
Did your child ever say phrases (word combinations) but then lose those phrases?		0.53
Does your child communicate by grabbing your hand and bringing you somewhere?		–0.40
Does your child communicate with you by placing your hands on things?		–0.35

Note: Only factor loadings $>$.3 are displayed. Loadings represent the degree to which individual items are related to the two factors.

effect size for these correlations fell in the small ($0.1 < r < 0.3$) or moderate ($0.3 < r < 0.5$) range and were generally much weaker in each case than those obtained for the convergent measures. The exception to this was SB5 nonverbal scores, for which effect sizes were also large. We believe this speaks to the language ability necessary to succeed on putatively nonverbal SB5 tasks, rather than a lack of divergent validity. Of course, it is also likely that the measures intended to capture divergent validity, such as assessments of daily living and socialization, are contingent on communication skills. Correlations may also reflect the Matthew effect, in which stronger skills in an important domain tend to lead to more rapid development and higher long-term scores across multiple domains (e.g. Kempe et al., 2011). Future validation of the LVIS will require additional assessments, such as of motor skills, that may be less strongly coupled to speech and language level. Correlations are reported in Table 4; scatterplots for the PLS, VABS and SB are shown in Figures 1 to 3.

It was noteworthy that, in the TD group, LVIS score was entirely uncorrelated with PLS scores. This result likely reflects ceiling effects on the LVIS and above-average PLS scores in a TD sample that is largely pre-verbal and similar in age to the ASD sample. Interestingly, Vineland Communication and Socialization scores were both significantly correlated with LVIS Communication Abilities scores with large effect sizes. Vineland scores in the DLD-only group were also significantly correlated with the LVIS communication factor, but to a lower degree, $r(27) = .47$. This likely reflects the sample size, as well as the heterogeneity of the DLD group, which reflects a clinical evaluation rather than a more categorical diagnosis.

To explore the relation between the LVIS and ADOS scores, Pearson correlations were calculated between LVIS Communication Abilities scores and the severity and subscale severity scores on the ADOS-2. Only the correlation between the LVIS Communication Abilities and ADOS-2 Social Affect Severity scores was significant with a small

Table 4. Pearson correlations of LVIS Communication Abilities with standardized language, cognitive and adaptive behavior measures for all participants and for ASD, DLD and TD groups.

			LVIS Communication Abilities			
			All	ASD Only	DLD Only	TD Only
Measures of Convergent Validity	PLS Receptive	*r*	**0.70**	**0.61**		–.06
		p	<0.001	<0.001		0.73
		n	86	50		32
	PLS Expressive	*r*	**0.68**	**0.57**		0.08
		p	<0.001	<0.001		0.65
		n	86	50		32
	Vineland Communication	*r*	**0.67**	**0.73**	**0.47**	**0.64**
		p	<0.001	<0.001	<0.05	<0.001
		n	122	40	27	55
	Stanford Binet Verbal	*r*	**0.61**	**0.46**		0.19
		p	<0.001	<0.01		0.28
		n	73	36		33
Measures of Divergent Validity	Vineland Daily Living	*r*	**0.40**	0.39	0.01	0.25
		p	<0.001	0.01	0.95	0.07
		n	120	39	26	55
	Vineland Socialization	*r*	**0.45**	**0.46**	0.17	**0.56**
		p	<0.001	.01	.41	<0.001
		n	119	38	26	55
	Vineland Motor Skills	*r*	**0.21**	0.01	–0.23	0.21
		p	0.02	0.94	0.27	0.12
		n	118	38	26	54
	Stanford Binet Nonverbal	*r*	**0.65**	**0.53**		0.08
		p	<0.001	<0.01		0.60
		n	73	36		33

Note: All scores are calculated as standard scores controlling for age. Significant correlations are shown in **bold** font. Based on Cohen's (1988) conventions, large effect sizes ($r > 0.50$) are shaded.

effect size; see Table 5. The lack of correlation between LVIS and RRB domain scores likely reflects the very limited overlap between the small number of items on the LVIS that tap into features that are typically captured by the ADOS RRB domain (such as echoed or stereotyped speech).

Item-level analyses. Though we did not feel comfortable creating a sum-score for atypical language ability, we were interested in the extent to which each item, individually, explained variance in standardized measures of social and language development. To address this, for each item and measure, we carried out an ANOVA with item score (e.g. 0,1) as a categorical factor and standardized measure (e.g. PLS total score) as the outcome variable. The resulting F statistics indicate to what extent variance is explained by the LVIS item. Importantly, the goal of this approach is an estimation of the *relative* relationship among LVIS items with standardized measures. Figure 4 shows the relationship between each item, arranged along the horizontal axis, with each measure in different panels. Examining the deeply shaded items, it is clear that some items (e.g. #19 "child shrieks") are strongly associated with multiple measures, while other items are strongly related with few scales. These results suggest that LVIS items capture heterogeneous communicative competencies; for example, items most associated with variability in the ADOS are distinct from those contributing to IQ. Different LVIS items are associated with different domains of development in a non-overlapping way. Altogether, these results indicate that the breadth of the items in the LVIS provides an effective survey of communicative development in autism.

Rank analysis. To further characterize the breadth of LVIS items, we present, for each of the nine standardized measures, the three items which explained the most variance (e.g. were most associated with that measure); see Figure 5. Interestingly, one item, "Does your child produce unusual sounds (e.g. repeated shrieks)?" was identified as the first- or second-ranked item for five of the nine measures; the PLS; Vineland Socialization and Daily Living, and both verbal and non-verbal SB5 IQ. While further research is necessary, this item is likely predictive of performance on these measures both because it is associated with language and social development, and also because there is significant consistency in caregiver comprehension of this item. For example, different caregivers may have different interpretations of "often" in the item "often

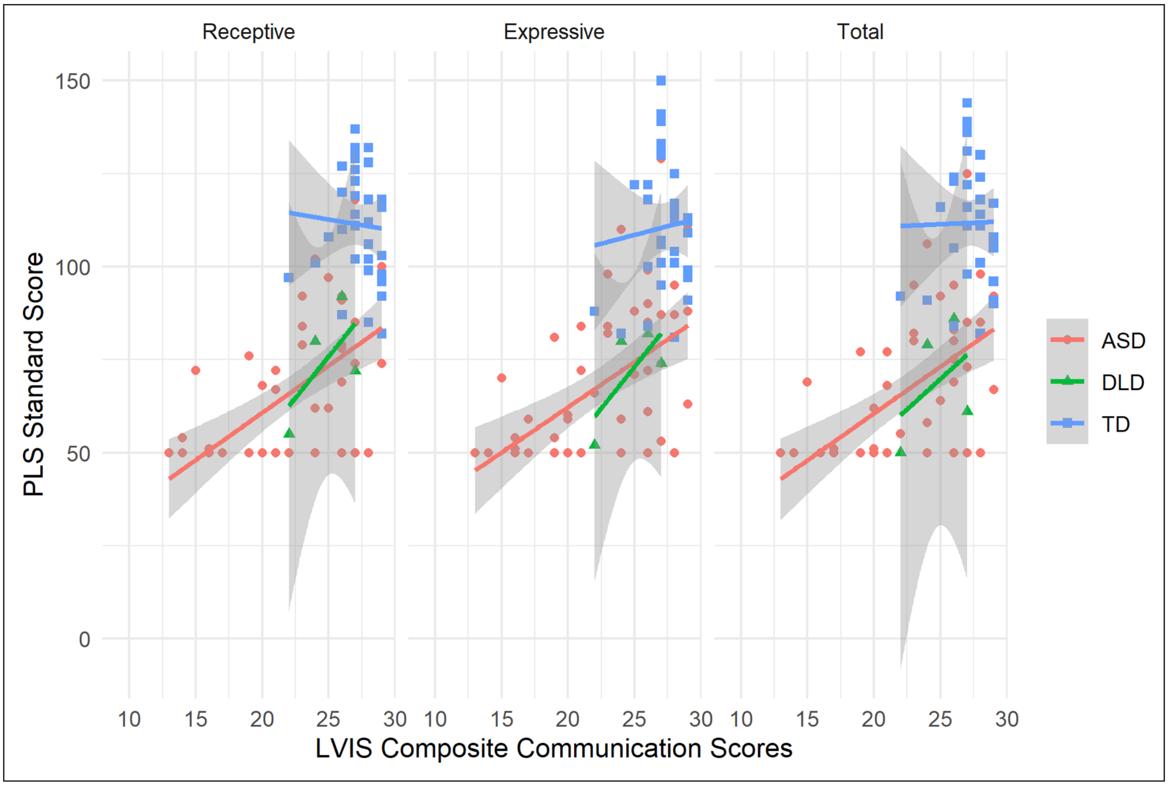

Figure 1. Scatterplot for LVIS communication abilities and preschool language scores.
Shaded area indicates 95% confidence region.

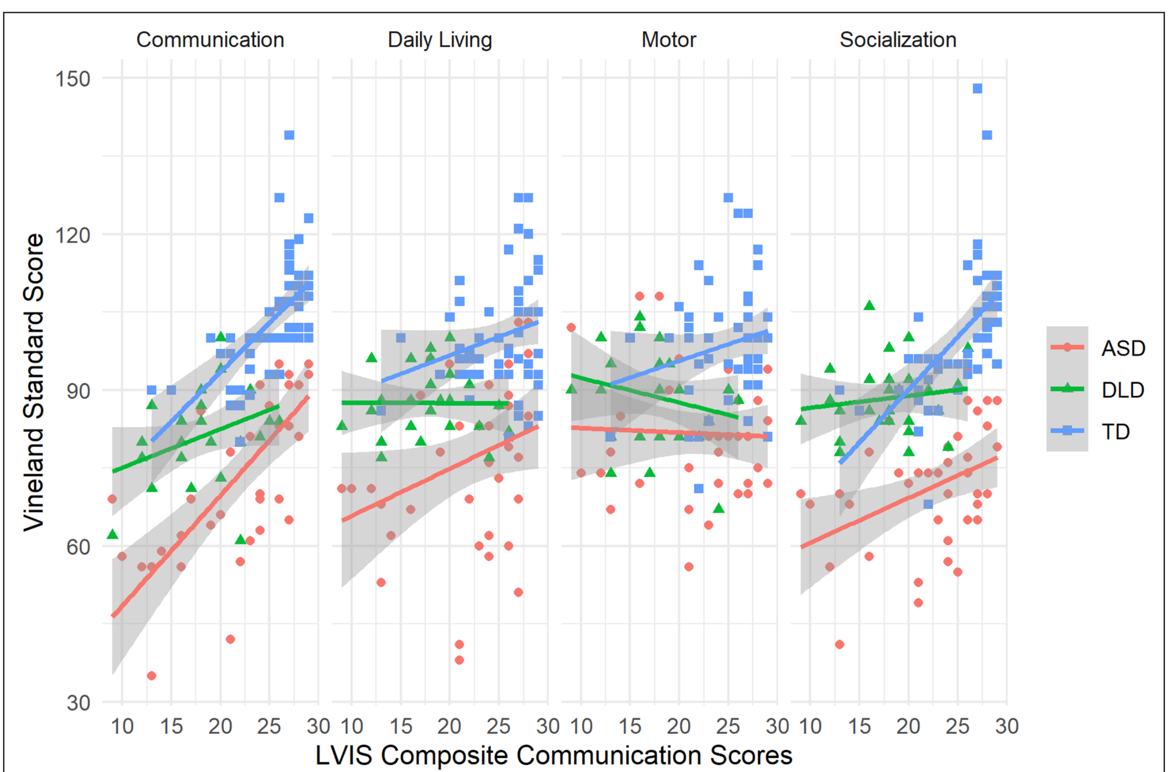

Figure 2. Scatterplot for LVIS communication abilities and Vineland Adaptive Behavior Scales.
Note. Shaded area indicates 95% confidence interval.

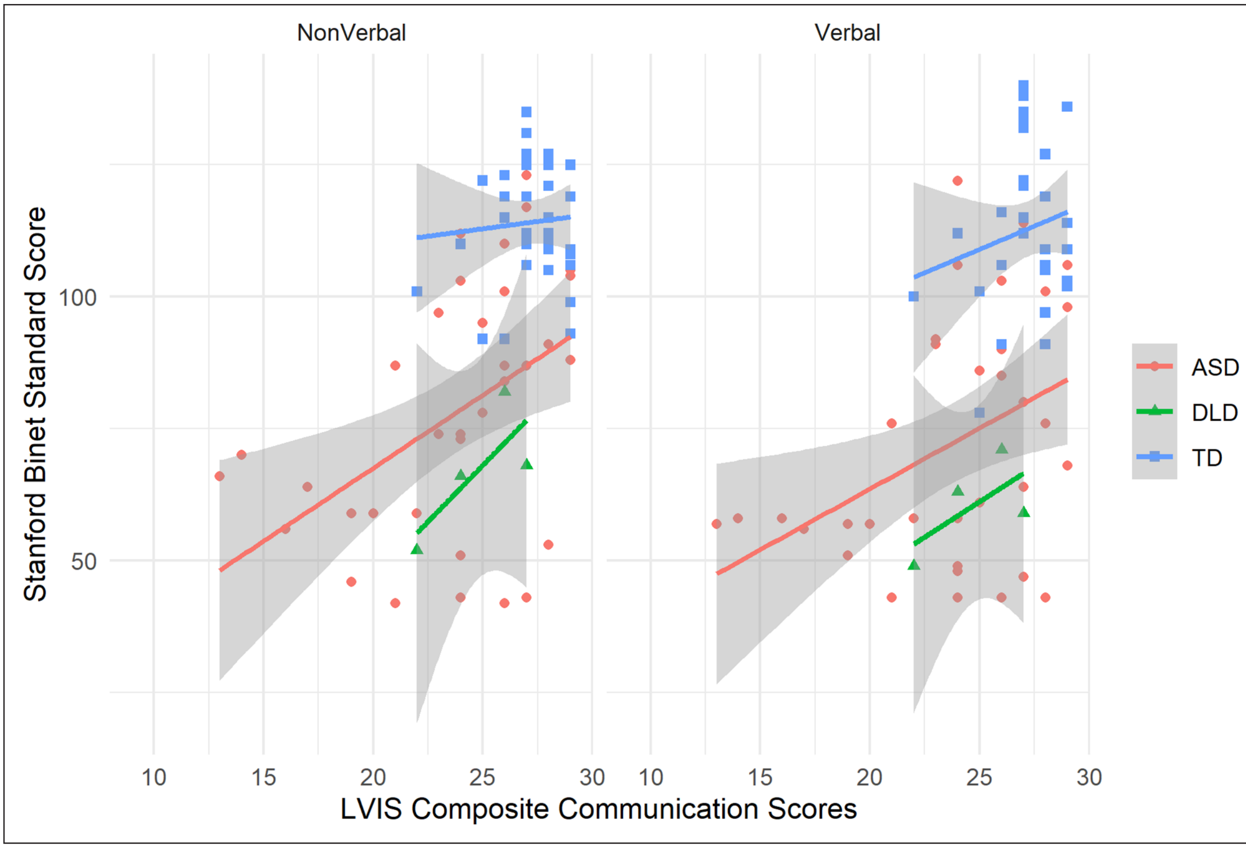

Figure 3. Scatterplot for LVIS communication abilities and Stanford Binet Intelligence Scales.
Note. Shaded area indicates 95% confidence interval.

Table 5. Pearson correlations for LVIS Communication Abilities and ADOS scores for participants with ASD.

ADOS Severity	*r*	–0.24
	p	0.08
	n	54
ADOS Social Affect	*r*	**–0.28**
	p	0.04
	n	54
ADOS RRB	*r*	–0.06
	p	0.67
	n	54

Note. Based on Cohen's (1988) conventions, these are small effect sizes ($0.10 < r < 0.30$).

uses words to communicate," whereas a child's production of unusual sounds is relatively unambiguous. In other words, the item has high precision in measurement. Other items were found to be important in variance on the ADOS-2 repetitive behaviors domain (reduplicated babbling, letter reading); ADOS-2 social domain (joint attention, regression, and following points); overall ADOS-2 scores (regression, letter reading, scripted language). In some cases, these items are identical to information captured in ADOS scoring, but not in all cases.

Discussion

The LVIS was developed to provide researchers and clinicians with a tool to efficiently assess the communicative capacities of minimally verbal autistic children, with a focus on autism-specific developmental trajectories of language. Following multiple rounds of item development and pilot testing, with input from parents and expert clinicians, a 36-item assessment was administered to 147 parents of autistic children, children with language delay,and children with typical developmental histories. Administration required approximately 5 min. Most parents also completed the VABS and, depending on the study in which they were enrolled, most children also completed a standardized clinician-based assessment of language. This allowed us to assess both convergent and divergent validity of the LVIS as a measure of communicative capacity. Available scores on the ADOS also allowed for exploration of the relation between LVIS scores and ASD symptomatology.

Principal components analysis revealed solutions with two and six factors. For purposes of interpretability and parsimony, the two-factor model was selected. One factor, which largely represented "typical communication," was calculated as summed item scores and operationalized as

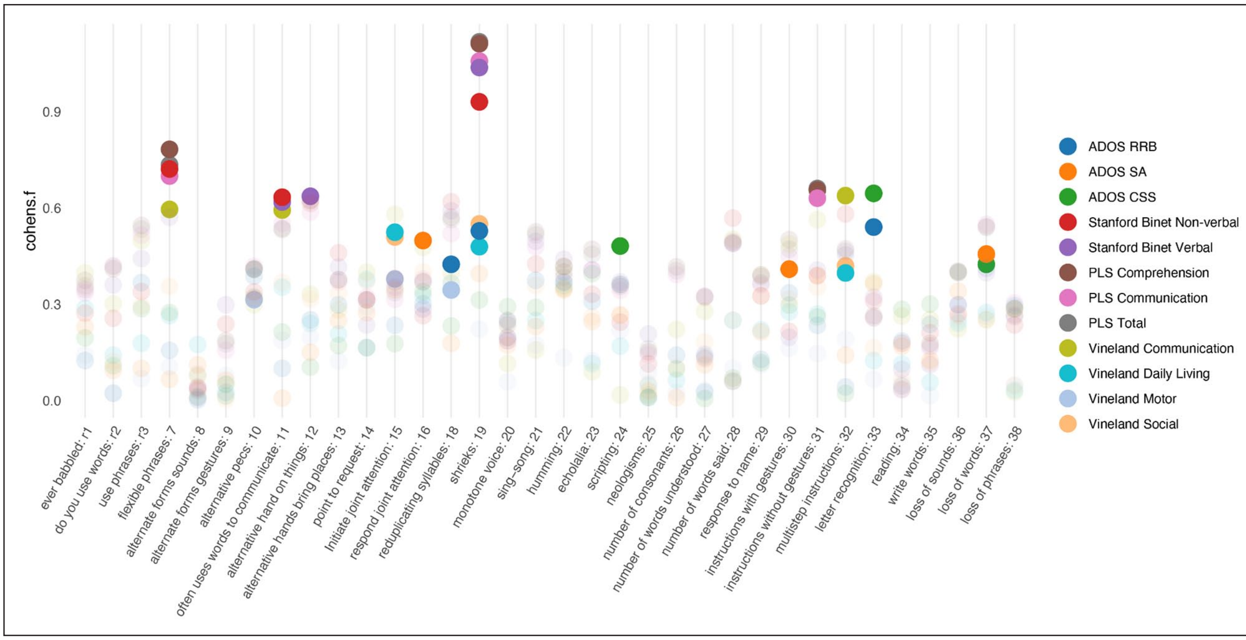

Figure 4. Relationships among LVIS items and measures of social communication.
Note. Each circle indicates effect size of the relationship between a specific LVIS item (X axis) and a specific measure. For each measure, the three largest effect sizes are deeply colored.

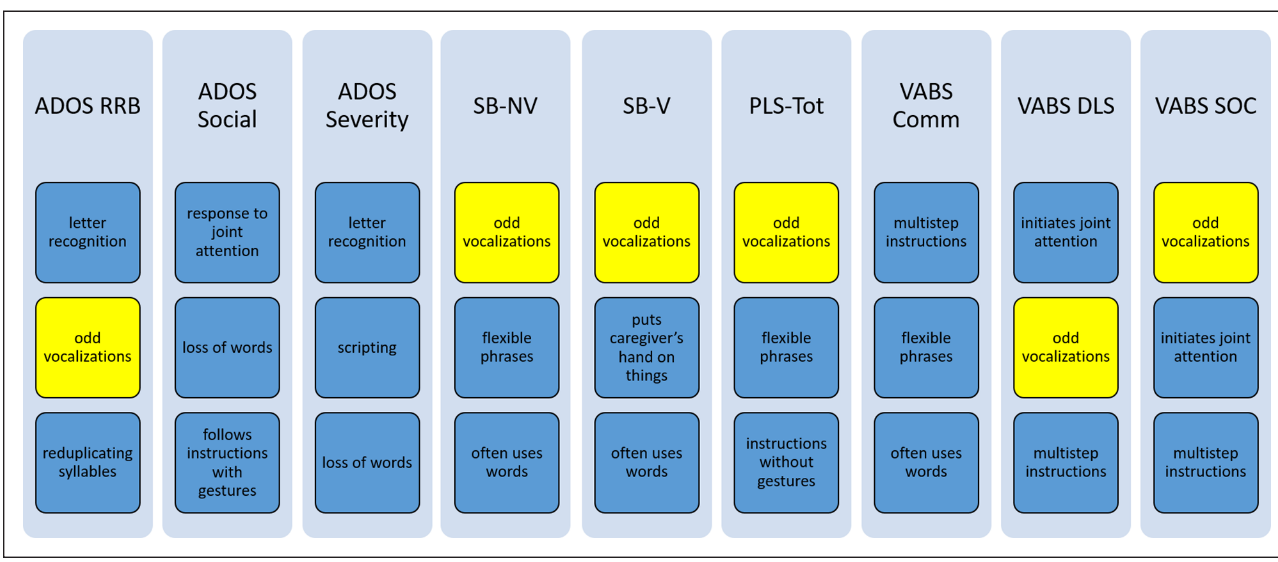

Figure 5. Top three items capturing the most variance for each of nine standardized assessments.
Note. Yellow boxes highlight odd vocalizations as highly predictive of a standardized assessment.

an LVIS Communication Abilities score for comparison with existing measures of language and communication.

Exploration of correlations between the LVIS Communication Abilities score and standardized assessments of language abilities indicated adequate convergent validity. Scores on the LVIS were highly and significantly correlated with both parent-report and standardized examiner administered assessments of communication. This suggests that, for children at the early stages of language acquisition, the LVIS provides information comparable to that obtained with longer parent-report measures (requiring: 20–40 min) or examiner-administered standardized assessments (requiring: 45–60 min and an expert clinician). Though LVIS scores were also correlated with other measures of ability, the correlations were stronger for language- and communication-specific scores than for non-language measures, demonstrating divergent validity.

Exploration of the relations between LVIS Communication Abilities scores and scores on the ADOS-2 indicated correlations between LVIS Communication Abilities scores and ADOS-2 Social Affect but not Severity Scores or Restricted and Repetitive Behaviors. This suggests that the LVIS Communication Abilities score may be capturing communicative capacity as it is assessed on the ADOS-2. On the other hand, measures that were intended to assess divergent validity (e.g. Stanford Binet Nonverbal, Vineland Socialization, Vineland Daily Living) revealed strong correlations, perhaps because socialization, personal care, community, and other experiences are strongly driven by communication skills; indeed, there is strong evidence of mutual coupling between verbal abilities and nonverbal IQ (e.g. Griffiths et al., 2022). In addition, it is possible that core mechanisms that contribute to the autism phenotype impact multiple domains.

To explore the relevance of the items on the LVIS for assessing communicative capacity vs IQ vs symptoms of autism, we conducted an item-level analysis in which we estimated the proportion of variance associated with each measure to each item. Specifically, we estimated a univariate ANOVA for each item and measure and calculated the subsequent Cohen's F value. This approach demonstrated the breadth of the LVIS items and revealed the relevance of one particular item, "Does your child produce unusual sounds (e.g. repeated shrieks)?" for measures across multiple domains. This result is consistent with recent evidence suggesting the relevance of atypical vocalizations for predicting autism diagnoses (Stroth et al., 2021; Tenenbaum et al., 2020). This approach also yielded a number of items that were related to ADOS scores including reduplicated babbling and letter reading for ADOS-2 restricted and repetitive behaviors; joint attention, regression, and following points for social affect; and regression, letter reading, and scripted language for overall severity scores on the ADOS-2. This suggests that the LVIS is associated with both communicative capacity and features of autism.

A brief measure of this sort has the potential to provide useful information when it is not feasible to conduct thorough clinical assessment, for example, due to limited clinician time and/or clinical resources. Critically, this brief measure is not intended to replace formal clinical testing. Rather, the LVIS may provide an accessible alternative for those who would not otherwise be assessing communicative competence. This approach is becoming increasingly relevant as recent evidence suggests that assessment of atypical communication characteristics can contribute to diagnostic information and subgroups within autism (Kang et al., 2019). This measure might also be useful for repeated measurement, that is, in response to intervention studies; of course, given the limitations of the LVIS, it must be administered in combination with other assessments, especially if used in clinical contexts.

This study is limited in several ways. The sample of children with autism identified as minimally verbal is small. Furthermore, our attempts to identify alternative communication approaches could have been limited by poorly worded items. We are currently addressing this in revisions to the measure and will need to reassess the contribution of these items in future work. Our next step is to collect data using the LVIS on a larger sample of autistic individuals. This will allow us to confirm the results of this pilot study and solidify our scoring approach. Another study limitation is the lack of assessment of inter-rater and test–retest reliability, both of which will be important to evaluate in future work. For those interested in obtaining access to the measure in its current form, please visit [https://lvis.psych.uconn.edu/].

The development of a brief but valid measure of communicative capacity in MLV autistic children has the potential to increase our understanding of the moderators of response to treatment in this population, serving clinicians and researchers who seek to develop a database capturing baseline communication abilities and response to treatment over time. Such information would have immediate clinical relevance for the development and assignment of MLV individuals to the various treatment options. Furthermore, the LVIS may be instrumental in research on mechanisms of language development in autistic children. By providing researchers and clinicians with a tool to assess a child's communicative capacity quickly and accurately, we increase the likelihood that this data will be collected. Standardized information that extends beyond the number of words produced or scores on an assessment not designed for individuals with ASD will provide researchers with rich data to explore unresolved and clinically meaningful questions in this field: Who will go on to develop language? Who will benefit most from which intervention? Who might benefit from alternative methods of communication?

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Notes

1. To respect the wishes of many autistic individuals, we use identify-first language (i.e. "autistic individuals" rather than individuals with autism) except when referring to the *DSM*-5 diagnosis of autism spectrum disorder (ASD) (Bottema-Beutel et al., 2021).
2. Though "minimally verbal" is the preferred term in the field, pilot testing indicated that parents were more familiar with "nonverbal." This wording may change in future versions of the form as the term "minimally verbal" becomes more widely recognized.

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