Research Article

Validation of a Parent Report Tool for Monitoring Early Vocal Stages in Infants

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Purpose: Tracking of infants' progression through early vocal stages supports the identification of children at risk for language delays and guides early intervention for children with disabilities. However, few clinical tools are available to support systematic assessment of infants' early vocal development. This study sought to develop and conduct a preliminary evaluation of the validity of a parent report tool designed for this purpose, the Vocal Development Landmarks Interview (VDLI).

Method: The participants were caregivers of 160 typically developing 6- to 21-month-old infants. Caregivers participated in the VDLI, which uses audio samples of authentic infant vocalizations to query parents regarding their children's vocal behaviors. The VDLI yields 3 subscale scores (Precanonical, Canonical, and Word) and a total score. Caregivers also completed sections of the Communication and Symbolic Behavior Scales Developmental Profile Caregiver Questionnaire that yielded a speech composite score.

Results: Cross-sectional analyses showed that the VDLI is sensitive to age and captures the expected developmental trajectories of vocal behaviors. A strong, positive correlation ($r = .93$) was found between VDLI total scores and the Communication and Symbolic Behavior Scales Developmental Profile speech composite score, indicating concurrent validity. Subscales were found to be internally consistent.

Conclusion: Preliminary findings of sensitivity to age, concurrent validity, and internal consistency provide support for the eventual use of the VDLI as a clinical tool for tracking vocal and early verbal milestones. Future research will explore the level of concordance between parent report and researcher observations of child vocal behaviors.

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Typically developing infants progress through orderly stages of prelinguistic vocal development that have been carefully described through decades of rigorous, laboratory-based research (for reviews, see Oller, 2000; Vihman, 2014). The extant literature provides ample evidence of these orderly stages that could guide the creation of clinical measurement tools for tracking vocal milestones in infants and toddlers (Koopmans-van Beinum & van der Stelt, 1986). However, most parent report measures and observational protocols that do exist include very few items regarding vocal development in the prelinguistic stage (instead focusing more on early gesture use and

understanding and use of words) or are designed for use in a research context as opposed to clinical context. Yet, the monitoring of prelinguistic vocal development milestones is critical in early intervention, because it supports the identification of children at risk for later language delays (Koopmans-van Beinum & van der Stelt, 1986; Lohmander, Holm, Eriksson, & Lieberman, 2017; Oller, Eilers, Neal, & Schwartz, 1999) and aids evaluation of early intervention outcomes and planning (Cantle Moore, 2008; Ertmer & Jung, 2012; Ertmer, Jung, & Kloiber, 2013; Kishon-Rabin & Segal, 2017; Nathani, Ertmer, & Stark, 2006).

The monitoring of vocal development has relevance for clinical settings because vocal milestones are known to be foundational to later language development. For example, *canonical babble*, defined as an infant's production of well-formed combinations of consonants and vowels that have speechlike syllabic timing (single or combined: [ba, mama, dada]), is a critical landmark in infant vocal development leading to infant vocal-motor practice that supports lexical development (Oller, 2000). Syllables practiced and produced in babble are essential components of later word production (McCathren, Yoder, & Warren, 1999),

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and the consonants in babbled syllables are known to overlap with those in children's early words, demonstrating continuity between canonical babble and early lexical development (Stoel-Gammon, 1998, 2011; Vihman, Macken, Miller, Simmons, & Miller, 1985). Furthermore, both babble onset and the consistent production of babble are known to precede the production of infants' earliest set of words by several months (McGillion et al., 2017; Oller, Levine, Cobo-Lewis, Eilers, & Pearson, 1998).

The monitoring of vocal milestones is also justified by virtue of its sensitivity to the presence of a range of developmental disabilities. For example, altered timing and/or quality of vocal milestones have been reported in infants with hearing loss (Fagan, 2015; Oller & Eilers, 1988; Oller, Eilers, Bull, & Carney, 1985), autism (Patten et al., 2014), neurodevelopmental disorders including cerebral palsy (Levin, 1999; Nyman & Lohmander, 2018), and cleft palate (Scherer, Williams, & Proctor-Williams, 2008). Lower syllable shape complexity and/or fewer consonant types have also been observed in children with slow expressive language development (Fasolo, Majorano, & D'Odorico, 2008; Watt, Wetherby, & Shumway, 2006) and in infants with hearing loss (Moeller et al., 2007; Stoel-Gammon, 1988; von Hapsburg & Davis, 2006). These findings demonstrate the value of monitoring babble onset and productivity, syllable shapes and complexity, and consonant inventories across disability types. Speechlike vocalizations other than babble (e.g., glides, vocants) also provide developmental insights but are not commonly incorporated in research or clinical assessments (Lee, Jhang, Relyea, Chen, & Oller, 2018). Ideally, a clinical measure of vocal development would incorporate a comprehensive, hierarchical set of specific speechlike vocal behaviors (from prebabble to early word stages) to serve as a guide for practitioners and parents in tracking major vocal milestones (see summary in Supplemental Material S1) and forecasting next steps in early intervention. Parent report measures may be well suited for this purpose.

Parent Report in the Measurement of Early Language Abilities

Although relatively few clinical, parent report tools are available that allow for detailed tracking of vocal development beginning in the prelinguistic stage, parent report tools are routinely used to monitor early language development, including gesture and early word production. Parent report is regarded as especially useful considering the practical constraints on infants' cooperation with structured evaluations and given parents' familiarity with their children's abilities. Parents are known to provide accurate estimates of their children's vocabulary and early grammatical abilities (Dale, 1991). Parental observations are often used to validate the findings of other assessments, and in some instances, parent report has been found to be more representative of infants' and toddlers' language abilities than laboratory-based samples (Dale, 1991; Feldman et al., 2005; Lynch et al., 1995). Parent report is widely accepted within the field of

early intervention as an efficient, cost-effective, and ecologically valid approach to assessment (Dale, 1991; Dale, Bates, Reznick, & Morisset, 1989; Feldman et al., 2005).

Parent report is not without limitations, including potential for biased reporting. However, Dale (1991) argues that many of the limitations associated with parent report, such as bias, may result from shortcomings in elicitation techniques (e.g., unclear terminology or inadequacy of verbal descriptions to explain target behaviors) rather than an intrinsic flaw in use of parents as reporters. For example, studies suggest that parents can have difficulty distinguishing certain abilities of their infants based solely on verbal questioning and may not have an adequate referent on which to base their judgments (Fenson et al., 1994; Law & Roy, 2008; Oliver et al., 2002). This is an issue we sought to overcome in the format of the parent report tool, the Vocal Development Landmarks Interview (VDLI), examined in the current work.

Parent Report Measures of Vocal Development in Research Settings

Despite the limited clinical measures available for tracking infants' vocal development, in research contexts, asking parents to report on their infants' vocal development has been particularly effective for identifying the onset of canonical babbling and the types of common syllables produced by children. Oller and colleagues demonstrated that parents were highly accurate in reporting the onset of their children's ability to produce canonical babble, and they did so with minimal training (Eilers et al., 1993; Oller, Eilers, & Basinger, 2001; Oller et al., 1999). There were high levels of concordance between parental report and trained-observer judgments (Oller et al., 2001). Caregivers were also able to report on their children's functional syllable categories or "templates." Templates were described as regular prelinguistic productions in children's babble that parents often interpreted and encouraged as possible words. Some argue that parents are in the best position to recognize the functional syllabic repertoires of their infants due to their role in fostering development through intuitive responsiveness in interactions with their children (Oller et al., 2001; Ramsdell, Oller, Buder, Ethington, & Chorna, 2012). These results support asking parents to report the sounds they commonly hear their infants produce.

Parent report checklists incorporating a comprehensive range of vocal behaviors have also been incorporated in the research context. Koopmans-van Beinum and van der Stelt (1986) asked parents a series of questions aligned with hierarchical stages of vocal development. They found that the majority of parental responses aligned well with six developmental stages, prompting the researchers to suggest the need for a clinical tool to monitor vocal stages. In another study, parent report on consonant production yielded clear age effects, with older children producing more consonants than young children, which further supports the usefulness of parent report (Miller, 1998). Parents were also found to be reliable in reporting a range of vocalizations

resembling speech, including sustained vocalizing with and without pauses, cooing, two kinds of vocalizing (squeals and blowing), vocal imitation of parents, and babbling (reduplicated and variegated; Lyytinen, Poikkeus, Leiwo, Ahonen, & Lyytinen, 1996). Collectively, these studies support the extension of parent report methods of vocal development to early intervention settings (Koopmans-van Beinum & van der Stelt, 1986).

Parent Report Measures of Vocal Development in Clinical and Early Intervention Settings

Clinical protocols for tracking vocal development have been recommended for some time (Proctor, 1989); however, few parent report instruments designed for this purpose are currently available. Three tools that do exist were developed with the goal of tracking the vocal development of children with hearing loss, because monitoring such changes provides important insights about auditory growth and device effectiveness in this population.

The first two measures are the Production Infant Scale Evaluation Questionnaire (PRISE; Kishon-Rabin & Segal, 2017; Kishon-Rabin, Taitelbaum-Swead, Ezrati-Vinacour, & Hildesheimer, 2005) and the Infant Monitor of Vocal Production (Cantle Moore, 2008). These scales are designed to evaluate infants' prelexical vocalizations using parent report, and validation studies indicate their sensitivity to age and developmental change (Cantle Moore, 2014; see Kishon-Rabin & Segal, 2017, for a review). The developers of both the PRISE and the Infant Monitor of Vocal Production work to provide comprehensive verbal descriptions of the targeted vocal behaviors incorporated in their scales. However, verbal descriptions may not provide the information parents need to determine if their child is producing the vocal behaviors in question. Furthermore, early intervention providers often lack familiarity with early vocal development, creating challenges for their administration and interpretation of these scales. We created the VDLI to circumvent these limitations.

The VDLI was first developed as a measure of outcomes in infants and toddlers with or without hearing loss in the context of a multisite, longitudinal investigation, the Outcomes of Children with Hearing Loss project (Moeller, Bass-Ringdahl, Ambrose, VanDam, & Tomblin, 2011). The VDLI introduced a novel interactive interview format, incorporating audio files of authentic infant vocalizations to make target behaviors and developmental contrasts clear and recognizable for parents. The goal was to reduce the need for verbal descriptions and adult modeling of infant vocalizations and to limit terms that could be misinterpreted by parents (e.g., "babble" is sometimes interpreted as any infant vocalization). The tool often juxtaposes samples in paired comparison to make important contrasts (e.g., marginal vs. true babble) clear. This use of contrastive samples is based on the work of Eilers et al. (1993), who trained parents to recognize babble by playing audio-recorded samples of real infants producing canonical syllables (single and in sequences) contrasted with precanonical forms

(e.g., raspberries, single vowels). We saw value in expanding this approach beyond babbled forms to a comprehensive range of early vocal behaviors at the precanonical, canonical, and early word stages. Furthermore, we incorporated strategies known to support the validity and accuracy of parent report in other ways. For example, Dale et al. (1989) suggested that parent report can be optimized when the behaviors they are reporting on are (a) currently occurring (not retrospective), (b) emerging and relatively frequent, and (c) identified through recognition memory (presenting an example/referent on which they can base their judgment) rather than simple recall. These features are incorporated in the VDLI. Preliminary research using an experimental version of the VDLI (Vocal Development Landmarks Interview—Experimental Version; VDLI-E) suggested the VDLI-E was sensitive to age in the range of 6–18 months and hearing status at 18 months (Ambrose, Thomas, & Moeller, 2016). VDLI-E scores were positively and significantly related to concurrent measures of auditory skills, expressive vocabulary, and overall expressive language. Research utilizing the VDLI-E led to changes in the tool that resulted in a clinical version of the VDLI and provided justification for testing its validity. These validation efforts are reported in the current article.

Research Questions

Our long-term goal is to develop a reliable, valid, and accessible parent report tool that supports clinicians and practitioners in monitoring the achievement of prelexical vocal stages through first words in the early intervention context. Our immediate goal is to examine the validity of the clinical version of the VDLI through three research questions.

1. Does the VDLI capture the expected developmental progression from precanonical to canonical to word stages in infants and toddlers who are typically developing?
2. Are VDLI scores significantly related to a concurrent measure of early communication skills?
3. Is there internal consistency among the items in each of the VDLI subscales (Precanonical, Canonical, and Word)?

Method

Participants

Parents (155 mothers, five fathers) of 160 typically developing infants participated in this study. Participants were recruited through a variety of community settings (e.g., churches, childcare centers, primary care offices) and social media sources (e.g., e-mail, Facebook, Twitter). Invitations were extended to parents whose infants met six inclusion criteria: (a) chronological age between 6 and 21 months, (b) reported to have passed newborn hearing screening or follow-up screening in both ears, (c) no known

family history of hearing loss, (d) no identified disabilities or developmental concerns, (e) standard score of 85 or greater on the cognitive or the overall general development score of the Developmental Profile 3 (DP-3; described below), and (f) English was the primary language spoken in the child's home. To capture environmental features relevant to language exposure, parents were asked to report on the number of children (< 18 years of age) in the home, including the participating child; birth order; involvement in day care settings; and number of adults in the home. For children in the home, 86 (54%) parents reported there was one child in the home, 43 (27%) had two children in the home, 18 (11%) had three children in the home, and 13 (8%) had four to 10 children in the home. In regard to birth order, 94 (54%) children were first born, 35 (22%) were second born, 18 (11%) were third born, and 13 (8%) were fourth to 10th born. Regarding day care settings, 90 (56%) parents reported that the child was "at home," 69 (43%) indicated "day care," and one parent did not respond. Finally, only two participants lived in a home with only one adult; the remainder reported two to four adults in the home ($M = 2.04$, $SD = 0.32$).

Additionally, parents had to confirm that they had access to a phone, a working laptop or desktop computer, and a high-speed Internet connection. For ethnicity, the majority of parents identified as non-Hispanic/Latino ($n = 155$). For race, the majority of parents, including the five who identified as Hispanic/Latino for ethnicity, reported identifying as Caucasian ($n = 148$), with the remaining parents identifying as Black ($n = 1$), other ($n = 2$), or more than one race ($n = 9$). Only 8% of participants had a high school education or less (see Table 1), indicating that this sample of research volunteers was better educated, on average, than the U.S. population.

The infants (85 boys, 75 girls) of these parents were stratified into eight age groups with 20 infants per age group (6–7, 8–9, 10–11, 12–13, 14–15, 16–17, 18–19, and 20–21 months) and were further clustered into four groups (6–9, 10–13, 14–17, and 18–21 months) for selected analyses. These four age bins were selected because they are reasonable from a developmental perspective, with each comprising distinct landmarks in vocal development (e.g., 6–9 months, precanonical and early canonical; 10–13 months, canonical and early words; 14–17 months, vocal repertoire expansion; 18–21 months, word combinations). Furthermore, categorical age bins were selected to build a statistical model that could address nonlinearities in the data. Four age bins provided enough separation in the age groups to see how age affects the relationships between scores while leaving enough observations within each bin to create a statistically meaningful test. Demographic and descriptive data related to the parents and children are contained in Table 1.

Procedure

Screening interviews were conducted by telephone with all prospective parent participants to determine

Table 1. Demographic characteristics for parents and infants.

Characteristic	Parents ($n = 160$)	Infants ($n = 160$)
Gender		
Female	155 (96.9%)	75 (46.9%)
Male	5 (3.1%)	85 (53.1%)
Age		
M	31.16 years	13.51 months
SD	4.17 years	4.60 months
Range	22–45 years	6–21 months
Maternal education level		
High school or less	13 (8.1%)	
Some college	9 (5.6%)	
College degree	65 (40.6%)	
Postgraduate degree	73 (45.6%)	
DP-3 Cognitive SS (raw)		
M		108.87 (10.00)
SD		12.03 (3.71)
Range		75–131 (2–20)
CSBS-DP Speech SS (raw)		
M		11.74 (19.92)
SD		2.64 (10.92)
Range		5–17 (2–40)

Note. DP-3 Cognitive SS = Developmental Profile 3 Cognitive subscale standard score; CSBS-DP Speech SS = Communication and Symbolic Behavior Scales Developmental Profile Caregiver Questionnaire speech composite scaled score.

inclusion in the study. Qualifying families were mailed packets containing consent and HIPAA forms, a parent-child demographic questionnaire, and the DP-3 (Alpern, 2007). Parents who returned the completed consent packet were contacted to complete the VDLI interview. The study methods were approved by the internal review board of Boys Town National Research Hospital.

All parent interviews were conducted by the second author over the telephone. The interviewer knew the interviewee name, relationship to the child, and gender, as well as the child's name and current age going into the interview. She was blind to other family demographic factors. Parents accessed the VDLI slides and associated audio files by linking to a researcher-provided website on their personal computers. Prior to the start of the interview, parents were instructed to test their audio and speakers to ensure they were working. Parents were given a technology orientation prior to beginning the actual interview to ensure they could access, play, and hear the audio files. At the end of the interview, parents were administered the Sounds and Words subscales of the Communication and Symbolic Behavior Scales Developmental Profile (CSBS-DP) Caregiver Questionnaire (Wetherby & Prizant, 2002). The instructions, phone interviews, and additional procedures took approximately 40 min.

VDLI

The VDLI is a parent report interview that is conducted with the support of a series of digital (PowerPoint) slides, many of which contain audio files of authentic infant vocalizations that model target forms and contrastive

landmarks. The VDLI was designed to be inclusive of the developmental age range of 6–21 months, with items that sample from prebabble vocalizations to early word production stages. It contains a warm-up section and 18 individual items, seven at the precanonical level, five at the canonical level, and six at the word level (see Table 2; a complete description of the VDLI with technical, administrative, and scoring details is contained in Supplemental Material S1). The VDLI may be administered over the telephone as in the current study or in a face-to-face setting. Our experience in the face-to-face setting suggests that it takes approximately 20–30 min to administer (Ambrose et al., 2016).

Prior to beginning the interview, parents are informed that the goal is to gain an understanding of their daily observations of their child's sound-making and speech behaviors. They are told that they will be listening to examples of infants making various sounds and talking and that their task is to think about the sounds their child produces on a typical day and consider whether or not their child's productions are similar to the ones played. Parents are allowed to listen to each audio example as many times as desired.

Basal and ceiling decision rules are included in the VDLI to avoid asking parents of advanced children who are producing words to report on vocalizations that no longer provide relevant information about their child's developmental phonological level or asking parents of children at the precanonical level about word productions, which may be several months off developmentally. Decision rules for determining starting and end points (basal and ceiling) of the interview are provided in Supplemental Material S1. For the youngest infants (ages 6–12 months),

the rules involve determining whether or not the child is producing more than two true words, which guides the administration of canonical and word scales versus precanonical and canonical scales. For infants older than 13 months, the decision rules are based on the number of words reported to be produced, which guides the administration of only the precanonical and canonical scales (if the child produces zero or one word), only the canonical and word scales (if the child produces two to 49 words), or only the word scale (if the child produces 50 or more words).

Parents respond to the interview questions in three ways. In the first response type, parents are presented with a paired comparison or multiple examples of a single vocal behavior, and they report the presence or absence of the behavior and rate its frequency. When paired comparisons of behaviors are presented, the parent is asked if their child produces sounds “more like the children in the top row or the bottom row, both equally, or not producing either.” An example would be a contrast in which the children in the top row are producing marginal syllables and the children in the bottom row are producing canonical syllables. Parents then estimate the frequency of the target behavior (e.g., canonical syllables) using a 4-point Likert scale (*never, rarely, sometimes, and frequently*; adapted from Kishon-Rabin et al., 2005). Other items of this response type offer multiple audio examples of a single vocal behavior. For example, the parent hears three examples of infants imitating vocalizations of their parent. The parent is asked to report whether or not their child tries to copy what they say and then to report how often using the 4-point Likert scale. The second response type is open-ended; parents

Table 2. Vocal Development Landmarks Interview items and descriptions.

Item number and vocal behavior	Description of target
PC 2-1: Pitch variation	Pitch contours that rise, fall, or are varied (vs. stable, nonvaried pitch)
PC 2-2: Mixed vowels	Two or more well-formed vowels in a row or glide + vowel (vs. single vowel)
PC 2-3: Bilabial trills or fricatives	Raspberries: sounds produced by vibration of lips or lips and tongue
PC 2-4: Marginal syllables	Approximates syllable, but timing is slow and syllable is not well formed (vs. vowel or glide + vowel)
PC 2-5: Reduplicated glides + vowel	Repetitive string of /j, w, h/ + vowel(s) (vs. vowels only)
PC 2-6: Imitations of vocalizations	Clear attempts to imitate vocal behaviors/words
PC 2-7: Variety of vowels	Count of vowels produced in isolation or with glides
CB 3-1: Single canonical syllables	Clear well-formed syllable (e.g., /ba, gi, uk/; vs. marginal syllable)
CB 3-2: Reduplicated canonical sequences	Repetitive strings of well-formed syllables such as /bababa/ (vs. single canonical form)
CB 3-3: Variegated canonical sequences	Repetitive strings with varied vowels/consonants such as /bagugi/ (vs. reduplicated canonical sequences)
CB 3-4: Jargon-like utterances	Strings of complex variegated syllables with changing intonation (vs. variegated canonical sequences without changing intonation)
CB 3-5: Variety of consonants	Count of consonants in babble
WP 4-1: Imitation of single words	Child imitates adult words, and accuracy is judged
WP 4-2: Closed syllables	Final consonant is present on words (vs. open syllable at end of word)
WP 4-3a: Variety of consonants in words	Count of consonants produced consistently in words
WP 4-3b: Variety of vowels in words	Count of vowels produced consistently in words
WP 4-4: Variety of words	Number of spontaneous words produced
WP 4-5: Variety of word combinations	Number of spontaneous true word combinations (vs. frozen forms such as all-done or bye-bye)

Note. Parenthetical comments include the contrastive pairs that are presented when items use a paired comparison format. PC = Precanonical subscale; CB = Canonical subscale; WP = Word subscale.

report on consonants, vowels, words, or word combinations they currently hear their child produce. Finally, a single item on the VDLI asks the parent to report on the accuracy of their child's word imitations. In this instance, the parent hears audio examples of children producing imitations that are presented along a visual scale from "far off the model" to "somewhat close" to "very close." The parent indicates whether or not their child imitates words and then uses the visual scale to estimate how close the child's imitations are to the model. For all items, parents' responses correspond to a score of 0, 1, 2, or 3. If an item is not administered due to basal or ceiling rules, a child receives a score of 3 or 0, respectively, for the item. Additional details about the item formats, response types, and item-by-item scoring are contained in Supplemental Material S1. Total scores for each subscale are summed, divided by the total number of possible points (21 for Precanonical, 15 for Canonical, and 18 for Word), and multiplied by 100, yielding a percent score for each subscale. The total VDLI score was calculated by averaging the percent scores for each of the three subscales.

CSBS-DP Caregiver Questionnaire

This norm-referenced questionnaire (Wetherby & Prizant, 2002) asks parents of 6- to 24-month-old infants about their children's abilities in seven domains related to broad categories of social communication, expressive speech and language (including sounds and words), and symbolic functioning. For the purposes of the current study, parents reported on children's sound production and word use, which yielded a raw score and scaled score for a speech composite.

DP-3

The DP-3 (Alpern, 2007) is a norm-referenced caregiver questionnaire that is designed to assess development in five developmental domains: physical, adaptive behavior, social-emotional, cognitive, and communication. Parents completed all sections, yielding raw scores and standard scores. Standard scores for the cognition or general development domain were utilized as an inclusion criterion. Raw scores from the cognitive scale are utilized in the current study's analyses as a covariate.

Statistical Analyses

The first research question explores the sensitivity of the VDLI to age, controlling for factors expected to influence developmental outcomes. This question was examined using a multiple regression analysis with correlated errors. Correlated errors, using an unstructured matrix, were included to account for within-participant correlations between Precanonical, Canonical, and Word subscale scores via different variances per subscale and different correlations between subscales. Model assumptions were tested, and no violations were detected. Variable selection was determined using the Bayesian information criterion (BIC; Schwarz, 1978). The second research question examined the construct validity of the VDLI. This was assessed using a Pearson correlation to examine the association between

parent-reported total scores on the VDLI and the CSBS-DP speech composite raw score. We also examined the slopes of CSBS-DP as a function of VDLI scores adjusting for age bin using a regression model. Age bins were used instead of modeling age as a continuous variable to adjust for nonlinearities in the relationship between the CSBS-DP and the VDLI. The model selection criterion BIC also favored the categorical model. The final research question examined the internal consistency of the items on each subscale of the VDLI. This was assessed using Cronbach's alpha in SPSS Version 22. All other analyses were performed using SAS Version 9.4.

Results

Sensitivity of the VDLI to Age (Question 1)

Descriptive results for the four age clusters (6–9, 10–13, 14–17, and 18–21 months) are presented in Table 3. Average percent scores for the respective subscales (Precanonical, Canonical, Word) and the total scores show incremental increases as a function of age group. Consistent with developmental expectations, the magnitude of changes across the age bins is greater for the Canonical and Word subscales than that for the Precanonical subscale. A Pearson correlation revealed a strong, positive relationship between age and VDLI total scores ($r = .874, p < .001$).

To determine if the VDLI captures the expected developmental trajectory of vocal behaviors in typically developing infants ranging from 6 to 21 months of age, a regression analysis with correlated errors was conducted. The correlated error structure captures the correlation for the within-participants' vocal behaviors effect. The outcome variable was the percent correct score for each subscale of vocal behaviors (Precanonical, Canonical, Word).

No transformation was used because the residuals from the analysis showed no signs of assumption violations. The predictor variables and covariates were VDLI subscale, age, gender, mother's education, and cognitive development (raw score on the DP-3). Raw scores were chosen from the DP-3 instead of standard scores because models containing raw scores yielded lower BIC values. To determine whether age should be treated as a continuous variable or a categorical variable using age bins (6–9, 10–13, 14–17, 18–21 months), we ran a full model (including all of the aforementioned covariates and interaction terms) with age as a categorical variable and then, again, with age as a continuous variable. The BIC value for the model with age as a categorical variable was 3834.3, and the BIC value for the model where age was a continuous variable was 3861.4, suggesting strong evidence for the categorical model. This can be seen in Figure 1, which demonstrates nonlinear trajectories. Interactions included in the model were subscale with cognitive raw score (DP-3) and subscale with age group. The model-estimated correlation between precanonical and canonical was .410, between precanonical and word was .357, and between canonical and word was .272. Results of the regression model are shown in Table 4.

Table 3. Means and standard deviations in percent for the Vocal Development Landmarks Interview scores as a function of age (represented as four groups with $n = 40$ in each group).

Score	6–9 months <i>M (SD)</i>	10–13 months <i>M (SD)</i>	14–17 months <i>M (SD)</i>	18–21 months <i>M (SD)</i>
Precanonical	76.25 (16.04)	91.25 (9.94)	97.10 (9.49)	100 (0.0)
Canonical	32.55 (23.92)	64.98 (19.19)	84.65 (14.40)	90.52 (12.45)
Word	1.65 (7.28)	20.55 (24.56)	49.33 (23.43)	78.55 (18.37)
Total	36.80 (12.54)	59.03 (14.60)	77.08 (13.27)	89.65 (9.20)

Regression results indicate that Precanonical, Canonical, and Word subscales were significantly different, $F(2, 151) = 85.62$, $p < .001$, but the significant interaction of the VDLI subscale and age group, $F(6, 151) = 12.22$, $p < .001$, indicates that the amount of difference between them depends on age. Post hoc comparisons with Tukey–Kramer–adjusted p values were conducted to compare the VDLI subscales at each age bin. Precanonical and Canonical subscales were significantly different from each other at 6–9 months, difference = -40.95 , $t(151 \text{ df}) = -10.81$, $p < .001$; 10–13 months, difference = -25.58 , $t(151 \text{ df}) = -9.51$, $p < .001$; and 14–17 months, difference = -13.32 , $t(151 \text{ df}) = -4.90$, $p < .001$; but not at 18–21 months, difference = -12.24 , $t(151 \text{ df}) = -3.30$, $p = .053$. Precanonical and Word subscales were significantly different from each other at 6–9 months, difference = 61.05 , $t(151 \text{ df}) = 15.97$, $p < .001$; 10–13 months, difference = 67.28 , $t(151 \text{ df}) = 24.81$, $p < .001$; 14–17 months, difference = 51.87 , $t(151 \text{ df}) = 18.91$, $p < .001$; and 18–21 months, difference = 34.43 , $t(151 \text{ df}) = 9.21$, $p < .001$. Canonical and Word subscales were significantly different from each other at 6–9 months, difference = 20.10 , $t(151 \text{ df}) = 4.13$, $p = .003$; 10–13 months, difference = 41.70 , $t(151 \text{ df}) = 12.09$, $p < .001$; 14–17 months, difference =

38.55 , $t(151 \text{ df}) = 11.04$, $p < .001$; and 18–21 months, difference = 22.19 , $t(151 \text{ df}) = 4.67$, $p < .001$. In general, these results are consistent with developmental expectations. Growth curves predicted by the model for Precanonical, Canonical, and Word subscales for females with caregiver education centered at 4 (which corresponds to a postgraduate degree) and cognitive development centered at 10 are shown in Figure 1. Canonical and word growth curves accelerate at expected ages and continue to accelerate with age. The precanonical growth curve may appear to be an exception to the expected developmental pattern, in that precanonical

Figure 1. Growth curves predicted by the model for the Precanonical, Canonical, and Word subscales of the Vocal Development Landmarks Interview for females with a caregiver education value of 4 (postgraduate degree) and a cognitive development value of 10.

Table 4. Results of Regression Analysis with Correlated Errors

Effect	$\hat{\beta}$ (SE)	df	t or F	p
VDLI Subscale		2, 151	85.62	< .001
Canonical	45.08 (5.76)	151	7.83	< .001
Precanonical	92.66 (4.53)	151	20.48	< .001
Word (reference)				
Age Group (months)		3, 151	16.76	< .001
10–13	3.85 (4.41)	151	0.87	.384
14–17	21.42 (5.39)	151	3.98	< .001
18–21	37.00 (6.85)	151	5.40	< .001
6–9 (reference)				
Gender (male = reference)	-0.95 (1.56)	151	-0.61	.544
Caregiver education		3, 151	0.25	.862
High school or less	2.42 (2.96)	151	0.82	.415
Some college	0.51 (3.51)	151	0.15	.884
College degree	0.81 (1.67)	151	0.49	.628
Post graduate degree (reference)				
DP-3 Cognitive (Raw)	4.76 (0.67)	151	7.06	< .001
VDLI Subscale * Age Group		6, 151	12.22	< .001
Canonical 10–13	21.60 (5.40)	151	4.00	< .001
Canonical 14–17	18.45 (6.58)	151	2.80	.006
Canonical 18–21	2.10 (8.39)	151	0.25	.803
Canonical 6–9 (reference)				
Precanonical 10–13	6.23 (4.24)	151	1.47	.144
Precanonical 14–17	-9.18 (5.17)	151	-1.78	.078
Precanonical 18–21	-26.62 (6.59)	151	-4.04	< .001
Precanonical 6–9 (reference)				
Word All Age Groups (reference)				
Subscale * Cognitive Development		2, 151	11.92	< .001
Canonical	-2.50 (0.82)	151	-3.03	.003
Precanonical	-3.16 (0.65)	151	-4.88	< .001
Word (reference)				

Note. VDLI = Vocal Development Landmarks Interview; DP-3 = Developmental Profile-3rd Edition.

forms would be expected to decline in the later months relative to canonical and word forms. However, this is an artifact of application of ceiling rules in the measure.

In regard to covariates that explain variance in VDLI scores, results indicate that gender and caregiver education were not statistically significant predictors of VDLI scores (see Table 4). For the other effects, since they also included significant interaction terms, the interaction terms are interpreted rather than the main effects. Cognitive development significantly affects VDLI subscale score, but the extent of the impact depends on the subscale, as seen in the significant interaction of cognitive development with subscale, $F(2, 151) = 11.92, p < .001$. The beta coefficient for cognitive development was 4.76 for the Word subscale, 1.60 for the Precanonical subscale, and 2.26 for the Canonical subscale, suggesting that a one-unit increase in cognitive development, on average, results in a 1.6%–4.8% increase in percent correct VDLI score, depending on the subscale. These data indicate that cognitive development was most strongly associated with the Word subscale and less so with the two other subscales. Higher cognitive raw scores were associated with higher scores on the word scale across the age range.

Concurrent Validity of the VDLI With the CSBS-DP Speech Composite (Question 2)

Concurrent validity was assessed by comparing the VDLI results to those of a standardized parent report measure of early speech development. Both measures were collected at the same time. A Pearson product-moment correlation coefficient was computed to assess the relationship between the VDLI total scores and the CSBS-DP speech composite raw score. A significant, positive correlation was found between the two variables, $r = .933, p < .001$. Although there is a strong relationship between the two scores, we further examined how that relationship varies by age. To determine if the VDLI is capturing information that the CSBS-DP does not at the earliest ages, we examined the slopes of the regression lines as a function of age. This was evaluated by using a regression model that includes age bin and an interaction between age and the VDLI to predict the CSBS-DP. The interaction was statistically significant, $F(3, 152) = 18.20, p < .001$. The slope clearly increases with age group, as reflected in the individual slope estimates (6–9 months = 0.215, 10–13 months = 0.355, 14–17 months = 0.454, 18–21 months = 0.707). Scatter plots summarize the individual results and slopes for each age group in Figure 2. Results suggest that the VDLI captures unique information about early stages of vocal development relative to the CSBS-DP.

Internal Consistency of the VDLI Subscales (Question 3)

To verify the internal consistency of items within each VDLI subscale, a reliability analysis was carried out on the Precanonical subscale comprising seven items, the Canonical

subscale comprising five items, and the Word subscale comprising six items. Cronbach's alpha showed the subscales reached acceptable levels of reliability with $\alpha = .82, .87$, and $.96$, respectively. Although scores above $.90$ suggest redundant items in a subscale (Tavakol & Dennick, 2011), the items within the Word subscale (see Supplemental Material S1) reflect unique steps in development that are commonly measured at this stage (e.g., single words vs. two-word combinations). Most items resulted in a decrease in the alpha if deleted, which indicates they should be retained in the measure. The one exception to this was the precanonical item focused on variety of vowels produced (PC 2-7), which would slightly increase the alpha to $\alpha = .83$. As such, revision or removal of this item could be considered. In addition, the interitem correlations for the remaining items in the Precanonical subscale were consistently lower (ranging from $.29$ to $.69$) than for the other two subscales, where correlations averaged $.59$ for Canonical and $.80$ for Word.

Discussion

In this study, we report on a revised version of the VDLI, a parent report tool designed to measure prelexical vocalizations and early lexical development in infants and young children. Our purpose was to implement first steps in testing the validity of the VDLI. We sought to determine whether the measure was sensitive to age, to establish concurrent validity of the measure, and to test internal consistency of items in three subscales. The VDLI was found to be sensitive to age in a cross-sectional sample of 6- to 21-month-old infants; older children consistently demonstrated higher scores than younger children, and age was positively correlated with VDLI subscale scores. The three subscales (Precanonical, Canonical, and Word) were differentially sensitive to age ranges. Further evidence of the developmental sensitivity of the VDLI comes from the strong, positive correlation between the VDLI scores and the CSBS-DP caregiver questionnaire speech composite scores, suggesting concurrent validity. Internal reliability of the subscales was found to be acceptable. Main results are consistent with our earlier findings from the VDLI-E (Ambrose et al., 2016) and provide additional support for the potential of the VDLI as a clinical/early intervention measure of early vocal development.

Sensitivity of the VDLI to Age

Our first research question explored the sensitivity of the VDLI to age in a sample of 160 typically developing children, 6–21 months of age. The VDLI accurately captures the expected developmental trajectories of vocal stages across the age range examined. Both subscale and total scores were appropriately aligned with a developmental progression from precanonical to canonical to word production-related behaviors. Our results are consistent with validation findings reported for another parent report scale of prelexical development, the PRISE (Kishon-Rabin et al., 2005),

Figure 2. Scatter plots a of the relationship between the Vocal Development Landmarks Interview (VDLI) total scores and the Communication and Symbolic Behavior Scales Developmental Profile (CSBS-DP) speech composite raw scores for each age group. Lines reflect the slopes of the relationship for the respective age bins.

and suggest that both tools (PRISE and VDLI) yield parental responses that align with age-related developmental trajectories in infants and toddlers. These results can also be interpreted to mean that the VDLI parent report tool is effective in eliciting reports of prelinguistic vocal and early lexical behaviors that reflect age-related developmental stages.

The individual VDLI subscales (Precanonical, Canonical, and Word) were differentially sensitive to selected age ranges, which provides guidance about the respective item sets that are most informative depending on a child's age. For example, the Precanonical subscale scores are particularly informative through at least 13 months of age. Although the precanonical scores differed from canonical scores through 17 months of age and from word scores at every age, from 6 to 13 months of age, the precanonical scores also showed growth with age (see Figure 1). The youngest children (6–9 months) demonstrated fairly high scores on the Precanonical subscale on average. Future research efforts incorporating item analysis will be pursued in an effort to identify a precanonical item set that is most sensitive to developmental changes under 12 months of age.

However, our results support the administration of both the Precanonical and Canonical subscales of the VDLI at young ages to monitor the onset and maturation of increasingly speechlike behaviors over time in intervention. The Canonical and Word subscale scores differed from each other at every age bin, suggesting that the subscales are providing unique information across the age range. Inclusion of both subscales is appropriate, given that the first word stage includes overlapping use of babble and word productions (Robb, Bauer, & Tyler, 1994). Notably, the canonical scores approached ceiling levels for the 18- to 21-month-olds, but considerable variability in scores suggests that this subscale may be helpful in tracking vocal development in some individual children in this age range. The Word subscale, in contrast, did not reach ceiling by 21 months. We previously made modifications to the Word subscale of the VDLI to increase its sensitivity compared to the VDLI-E, where ceiling performance was observed at 18 months of age (Ambrose et al., 2016). Given that the subscales are differentially informative in various age ranges, the use of basal and ceiling rules in the VDLI is supported,

so that parents are reporting on current behaviors and developmentally relevant milestones (Dale et al., 1989). Also, VDLI total scores showed incremental changes through the entire age range, supporting potential use of the tool for tracking vocal changes in early intervention. Given the cross-sectional nature of these data, we recognize the need for longitudinal data to confirm this conclusion.

Although we controlled for caregiver education level in the analysis, this variable was not significantly associated with the VDLI scores of the children. However, it is likely that our study sample lacked sufficient variance in caregiver education to detect an influence of this variable. We would expect maternal education levels to be associated with early vocal development, particularly achievement of early word milestones. A recent study showed that babble onset and maternal education contributed uniquely to children's vocabulary scores at 18 months of age (McGillion et al., 2017), reinforcing both the continuity of babble and word production as well as maternal influences on lexical development. In further support of the notion that maternal education is expected to influence vocabulary, Hoff (2003) found that 2-year-old children from families with higher socioeconomic status (SES) had stronger vocabulary abilities than children from mid-SES families. SES effects were explained by qualitative differences in maternal speech to these children; children from high-SES families had more language experience than children from mid-SES families by virtue of richer language exposure from their mothers. Further analysis of the potential influence of SES on parental reports of developmental landmarks on the VDLI is needed with a broader, more representative sample of families across a range of income levels.

Cognitive skills were also examined as a covariate, and those scores emerged as a factor that explained variance in children's VDLI scores over and above the effects of age. This influence was strongest in relation to the Word subscale, with less influence detected for the Precanonical and Canonical subscales. Given the symbolic nature of the items on the Word subscale, this result was not entirely surprising. McCune and Vihman (2001) proposed a dynamic systems model to explain factors that are foundational to children's transitioning to word use. They identified children's cognitive representational advances, recognition of the communicative potential of their verbal productions, and emergent vocal-motor control as interacting systems that support early word use. The finding of a contribution of cognition in the current study may have been reflecting representational advances. These results also suggest clinical applications of the VDLI for children with developmental disabilities. Profiles from children in different disability groups, for example, would be expected to be unique, and such findings would inform clinical goals. For example, infants with Down syndrome develop fairly typically in prelinguistic stages, yet show slow lexical development (see Stoel-Gammon, 2001, for a review). For this group of infants, monitoring with the word scale will be most informative for tracking development. In contrast, an infant with suspected cerebral palsy may show a

profile that is distinct from an infant with Down syndrome. The infant with cerebral palsy may show delays at the prelinguistic level, including delays in babble onset, restricted phonetic repertoire, and reduced length of vocal productions due to limited motoric control of expiration (Levin, 1999; Nyman & Lohmander, 2018). For infants with hearing loss, a profile reflecting reduced auditory sensitivity, perception, and experience is expected. The precanonical level may be intact, but deficits would be observed at the canonical and word levels (Ambrose et al., 2016). The VDLI results in these three disability contexts would lead to unique, individualized intervention goals. Further research examining the utility of the VDLI with various disability groups is needed to confirm these expectations.

Concurrent Validity of the VDLI

We examined concurrent validity of the VDLI as the second research question. Further evidence of the developmental sensitivity and validity of the VDLI comes from the strong, positive correlation between the VDLI scores and the speech composite scores from the CSBS-DP caregiver questionnaire. However, the high correlation between the measures may lead some to question whether the VDLI conveys any advantage over the CSBS-DP and, thus, whether another tool is actually needed. We contend that the tools are complementary, with the VDLI offering more detailed analysis of vocal stages at the earliest ages compared to the CSBS-DP. This conclusion is supported by the finding that the slope relating the two measures differs significantly according to age bin. The slope estimates between the VDLI and the CSBS-DP at the early age bins (e.g., 6–9 and 10–13 months) are much flatter than at the latest age bin. This suggests that the VDLI may be capturing something about the earliest vocalizations that the CSBS-DP does not. If future research shows that the VDLI captures aspects of early vocalizations that predict later communication skills, then it will contribute something unique to the battery of measures useful for early identification of communication disorders.

There are other unique properties of the VDLI that make it attractive to pursue as a clinical tool. The first advantage is that the tool is supported by an interactive, technology-driven format. This conveys benefits both for the clinician and the parent. Regarding the clinician, the interactive format with audio files standardizes the method for vocal behavior description across clinicians and guides their understanding of the developmental milestones and future developmental stages. Because the paired comparisons illustrate key developmental contrasts (e.g., marginal vs. true syllables), clinicians may become attuned to vocal changes that are especially meaningful. We see clear advantages to the ways in which the tool design calibrates and informs the clinician or practitioner and promotes a standard administration format across clinicians with limited need for training. From the standpoint of the parents, the provision of vocal samples supports them in

clearly understanding the targeted milestones in vocal development being asked about. The vocal sample exemplars obviate the need to use terminology that parents could misinterpret, and avoid the need for the adult interviewer to mimic infant vocalizations. Lyytinen et al. (1996) concluded that parents could reliably report such milestones if given concrete examples of vocal behavior. The vocal samples presented in the VDLI provide concrete, real examples that help to ensure that the parent and clinician are talking about the same behaviors. In addition to scaffolding accurate reporting, the VDLI format appears to educate parents about next developmental steps they should focus on with their child.

In this study, families were administered the VDLI over the phone and thus had to have Internet access. This format of administration could limit the VDLI to use with families who have Internet access and are comfortable using technology. During the current study, the vast majority of parents experienced no issues with accessing the audio files and often commented that it was helpful and enjoyable to listen to them. Problems with access were rarely experienced and were easily resolved through troubleshooting. In the current study, all parents listened to the audio files, and most played the audio files only once. A few parents played selected audio files twice, but they typically only did this with a few of the items, and it only took a few seconds. These observations suggest that the parents in our sample easily accessed and used the audio samples provided by the VDLI. However, the VDLI needs to be tested in a broader, more representative sample to determine if these observations extend beyond our advantaged sample. In order to make the VDLI tool and technology accessible to a wider range of families, it is being made available in multiple formats (tablet app website access), which means that clinicians could access the tool in a variety of homes and settings on their devices. This obviates the need for families to own or operate the technology. Clinical administration in a face-to-face setting takes approximately 20–30 min, suggesting feasibility for use in early intervention and other clinical settings.

Internal Consistency of the VDLI Subscales

Our final research question was designed to examine the internal consistency of the three subscales of the VDLI. Based on the findings, we conclude that each of the subscales achieved acceptable levels of reliability. However, further detailed item analyses will inform the final selection of items for the clinical version of the VDLI.

Study Limitations

The educational, racial, ethnic, and SES sampling in the current study was narrow and unrepresentative of a diverse U.S. population. This limits the ability to generalize the VDLI validity findings beyond a well-educated group of advantaged parents. As noted in the next section, we are addressing this limitation by extending our research in a broader demographic sample. Furthermore,

there may be additional demographic factors that influenced the vocal development outcomes in this study that remain untested. We collected descriptive information on day care, home care, number of adults, and number of siblings in the home. It is expected that factors such as siblings or quality of day care may influence the language learning environment in a number of ways that may impact prelinguistic and early linguistic development (Benigno, Clark, & Farrar, 2007; Woollett, 1986). Given that our sample is fairly homogenous on these factors, we defer their analysis until a larger and diverse sample is recruited.

VDLI: Future Directions

We have pursued a second step in validation of the VDLI to determine if there is concordance between parent reports and researcher observations of infant vocalizations. To support this analysis, we simultaneously collected full-day digital recordings from a subsample of the children in the current study, and this analysis is nearly complete. We undertook this step second in an effort to further refine and improve the VDLI before testing it in a larger sample. However, it is also critical that we validate the VDLI in a larger, more diverse demographic sample of families. We have developed a beta version of an accessible VDLI app, and we are in collaboration with other laboratories to collect data on a broad and representative sample. This will include exploration of a wider range of demographic influences than we were able to analyze in the current study sample.

During administration of the VDLI, some parents indicated a desire to be informed about the target behaviors ahead of time so they could more carefully observe their children before the interview. This approach is used in the PRISE (Kishon-Rabin & Segal, 2017), and we plan further research to explore the effects of priming and preparatory observations on parent report with the VDLI. Once the VDLI is revised in response to our research findings, future studies will examine its usefulness with various groups of children with disabilities. Further development of this measure will focus on making it readily accessible to professionals working with young children and researchers studying early vocal development. Plans include development of the aforementioned app and a web-based platform to support interview administration and refinement of the administration manual, including descriptions of how to administer, score, and interpret the measure.

Summary

This study describes and reports on preliminary steps in the validation of a clinical parent report measure, the VDLI. This interactive interview provides authentic infant vocalizations in audio files in an effort to make target behaviors and developmental contrasts clear to parents. The VDLI accurately captures the expected developmental trajectory of early vocal behaviors for typically developing

infants and toddlers, ages 6–21 months. The VDLI was strongly correlated with a concurrent measure of early communication skills (CSBS-DP speech composite) and demonstrated internal consistency. The VDLI shows promise as a clinical tool, which could also be useful in research contexts, for tracking prelinguistic and early linguistic development in infants and toddlers.

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