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Short communication

Infants' vocalizations at 6 months predict their productive vocabulary at one year

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ABSTRACT

Long before their first words, children communicate by using speech-like vocalizations. These protophones might be indicative of infants' later language development. We here examined infants' ($n = 56$) early vocalizations at 6 months (vocal reactivity scale of the IBQ-R) as a predictor of their expressive and receptive language at 12 months (German version of the CDI). Regression analyses revealed vocalizations to significantly predict expressive, but not receptive language. Our findings in German-learning 6-month-olds extend previous predictive evidence of early vocalizations reported for older infants. Together these findings are informative in light of early assessments monitoring typical and atypical language development.

Infants are communicating from birth, having remarkable receptive and expressive skills. Newborns' readily recognize their mother's voice (DeCasper & Fifer, 1980; Hepper et al., 1993), differentiate between different speech sounds (Dehaene-Lambertz & Pena, 2001; Partanen et al., 2013), and discriminate the rhythmic sound properties of different languages (Abboub et al., 2016; Mehler et al., 1998). Similarly, newborns' cries are their first means to produce sound and communicate their needs (Michelsson & Michelsson, 1999). Within a few months, infants' early expressive abilities advance from very basic speech-related vocalizations (Nathani et al., 2006; Oller et al., 2019; Ramsdell-Hudock et al., 2019) to prelexical vocalizations (e.g., babbling, Lang et al., 2020; Oller et al., 1999; Ramsdell-Hudock et al., 2019; Smith et al., 1989). These prelexical vocalizations already closely resemble language and are developmental precursors of children's first words at the end of the first year of life (Nathani et al., 2006; Oller et al., 1999; Ramsdell-Hudock et al., 2019). In the present study, we aimed to investigate the predictive relationship of infants' early vocalizations during the first months of life and children's later language skills at one year.

Previous studies reported first indications of infants' prelexical vocalizations to predict inter-individual differences in subsequent language development. For example, Lyakso et al. (2014) found a correlation between the frequency of infants' vocalizations at 9 months (e.g., babbling) and word production onset in Russian-learning infants. Similarly, in infants from monolingual English-speaking families, McGillion et al. (2017) found babble onset from 9 months as the only of their tested predictors to explain word onset and expressive vocabulary at 18 months (as compared to infant pointing and maternal education). Moreover, Donnellan et al. (2020) showed gaze-coordinated (i.e., children looking at their caregiver within one second of producing the behavior) vocalizations at 9 months, indicating communicative intent, to be a predictor of expressive vocabulary at 24 months for a sample of

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monolingual English-learning infants. This consistent association of vocalization and expressive language has also been observed in children with autism and developmental disorders (e.g., Lang et al., 2019; McCathren et al., 1999; McDaniel et al., 2018), indicating that vocalizations can account for inter-individual differences in typical and atypical language acquisition. In contrast to expressive language, there is no evidence showing infant vocalizations as a predictor for receptive language development. Specifically, Majorano et al. (2014) found the age of the first use of vocal motor schemes (i.e., frequently and reliably used consonants) to be unrelated to receptive vocabulary at 12 and 18 months in monolingual Italian infants. Similarly, in the study of McGillion et al. (2017), babbling onset did not predict receptive vocabulary at 18 months. Taken together, previous studies found infant vocalizations to predict expressive, but not receptive language development.

Notably, the studies described above have all focused on vocalizations emerging in the second half of the first year, from 9 months of age (Locke, 1989; Majorano & D'Odorico, 2011; McGillion et al., 2017; Oller et al., 1999). This rationale is well-founded in the fact that canonical babbling (i.e., the systematic production of consonants and consonant-vowel combinations) typically emerges in the second half of the first year of life. Canonical babbling is considered a critical milestone in phonological development and a typical example of protophones (i.e., speech-related vocalizations; Lang et al., 2020; Oller et al., 1999; Ramsdell-Hudock et al., 2019; Smith et al., 1989). Yet, speech-like vocalizations arising much earlier are also classified as protophones and have been linked to later language development (e.g., squeals, quasivowels, cooing; Nathani et al., 2006; Oller et al., 2019; Ramsdell-Hudock et al., 2019). Specifically, quasivowels (i.e., brief periods of voicing) are observed directly after birth, and speech-like vocalizations called cooing occur between 2 and 5 months of age, when infants gain control over their phonation (Capute & Accardo, 1978; Nathani et al., 2006; Ramsdell-Hudock et al., 2019). Due to the functional flexibility of these early vocalization (i.e., expressing positive, negative and neutral emotional states), they have also been proposed to link to later language development (Oller et al., 2013; Oller et al., 2019). Although research on vocalizations emerging in the first six months of life could provide further insight into trajectories of typical and atypical language development, this proposal has not yet been followed up empirically. The months between the emergence of functional flexibility of infant vocalizations at 3–4 months (Jhang & Oller, 2017; Oller et al., 2013) and the beginning of the instrumental use of these vocalizations at 6–8 months (Stark et al., 1993) are particularly relevant in this regard. During the critical period of 4–8 months, infants' vocalizations gain more speech-like communicative function. Therefore, the current study aimed to longitudinally evaluate the predictive value of infant vocalizations at 6 months for children's expressive and receptive language at the age of 12 months in a sample of monolingual infants from German-speaking families. We here aimed to replicate previous findings of a positive association between infant vocalizations and expressive language in a German-learning sample and to examine this association at an earlier age. Based on previous findings showing associations between early infant vocalizations and expressive, but not receptive language development (e.g., Donnellan et al., 2020; Lyakso et al., 2014; Majorano & D'Odorico, 2011; McGillion et al., 2017), we hypothesized the amount of vocalizations at 6 months to positively predict expressive, but not receptive language at the age of 12 months.

Infants were recruited from the Infant Database of the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig. Sixty-five infants were originally assessed (age at timepoint 1, t1: *mean (M)* = 212.31 days, *standard deviation (SD)* = 24.32; age at timepoint 2, t2: $M = 376.71$ days, $SD = 28.86$; 30 girls). From this initial participant sample, data of infants exceeding the extreme value criterion set a-priori ($M \pm 2\,SD$) regarding the scores in one of the two parental questionnaires were excluded ($n = 5$). In addition, data from infants outside the age windows of 163–260 days (t1, $M \pm 2\,SD$) and 318–434 days (t2, $M \pm 2\,SD$) at the time of questionnaire completion were excluded ($n = 4$). This resulted in a final sample size of $n = 56$ infants (29 girls), with a *mean* age of 207.73 days ($SD = 15.38$) at t1 and 373.07 days ($SD = 15.87$) at t2.

All infants were born full-term (gestation week 37 or later, $M = 39.57$ weeks, $SD = 1.29$) with normal birth weight (>2700 g, $M = 3549.96$ g, $SD = 421.89$) and were raised in monolingual, German-speaking families. All infants were healthy and not reported to have any diagnosed hearing deficits or neurological problems.

The study followed American Psychological Association (APA) standards in accordance with the declaration of Helsinki from 1964 (World Medical Association Declaration of Helsinki, 2013) and was approved by the ethics committee of the Medical Faculty of the University of Leipzig (protocol number: 082/15-ek).

After receiving written instructions and providing informed consent, parents completed one questionnaire regarding their infant's temperament at 6 months, including a scale of infants' vocalization (t1; German translation of the Infant Behavior Questionnaire – Revised; IBQ-R; Gartstein & Rothbart, 2003; Kristen et al., 2007) and one questionnaire on their infant's language development at 12 months (t2; German version of the MacArthur-Bates Communicative Development Inventories, CDI; ELFRA-1; Grimm & Doil, 2000). Parents received the first questionnaire upon their research visit at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig and were reimbursed for their travel expenses by 7.50 Euro. A week before their child's first birthday, parents were sent the second questionnaire together with a prepaid envelope.

The quantity of infants' vocalizations at 6 months was assessed by the German version (Kristen et al., 2007) of the IBQ-R, a parent report questionnaire originally developed by Rothbart (1981) and revised by Gartstein and Rothbart (2003). For each of the 191 items, parents are asked to indicate on a seven-point-rating scale (ranging from "never" to "always") how often their child expressed a certain behavior in an everyday situation ranging from feeding the infant, putting the infant to sleep, getting the infant dressed, to playing and interacting with others during the last one or two weeks (e.g., "When being dressed or undressed during the last week, how often did the baby coo or vocalize?") on 14 different scales. For the purpose of our study, we used the scale "Vocal Reactivity" (Cronbach's $\alpha = 0.78$ for 6- to 9-month-olds, 12 items), which is defined as the "amount of vocalization exhibited by the baby in daily activities" (Gartstein & Rothbart, 2003). Although the IBQ-R was originally designed for the assessment of infant temperament, the subscale of vocal reactivity has been frequently used in previous studies as a measure of infant vocalization (Crawford, 2003; Gartstein et al., 2008; Tamm et al., 2020). However, construct validity of this specific scale has not yet been evaluated. A mean score (ranging from 1 to 7) of

the ratings on the individual items was calculated by dividing the sum score of all items by the number of included items. In case parents provided the answer "X – does not apply" for a given item, this item was excluded from analysis (see manual of the IBQ-R, Gartstein & Rothbart, 2003).

For the assessment of children's language development, parents completed the German version (Elternfragebogen für die Früherkennung von Risikokindern, ELFRA-1; Grimm & Doil, 2000) of the CDI (Fenson et al., 1993) one year after birth. This questionnaire comprises scales on speech production, speech perception, gestures, and fine motor skills. For the purpose of our study, we focused on children's speech production (Cronbach's α = .84; maximum points: 181) and perception values (Cronbach's α = .96; maximum points: 171). The speech production scale assesses infants' expressive vocabulary and imitation abilities, whereas the speech perception scale evaluates receptive vocabulary and reactions to other people's utterances.

For the statistical analysis, *mean* and *standard deviation* scores of vocal reactivity, expressive and receptive language, as well as zero-order correlations (Pearson's r) between all three variables were calculated first. To evaluate the relation between early vocalizations and expressive and receptive language, two regression analyses were performed. The requirements for regression analyses, that is, homoscedasticity, linearity, and normal distribution of residuals, were all met. The first analysis included vocalization scores as predictor of expressive language scores; the second analysis, vocalization scores as predictor of receptive language scores. In both models, sex (boys, girls) and age at t1 and t2 were included as covariates, to control for effects of sex or age at time of questionnaire completion on vocalizations or language abilities. Overall model fit (indicated by R^2 and corrected R^2) as well as individual regression coefficients of the two models were then compared. The analyses were corrected for multiple comparisons by adjusting the critical *p*-value to .025.

Statistical analyses were conducted with the statistic software R-Studio version 1.1.456 (RStudio, Inc., 2018).

The *mean* score for vocal reactivity at 6 months (vocal reactivity scale, IBQ-R, Gartstein & Rothbart, 2003) was 3.82 ($SD = 0.96$), deviating less than one *standard deviation* from the *mean* score reported for a sample of 7- to 9-month-old German infants ($n = 119$; $M = 4.45$, $SD = 0.98$; Vonderlin et al., 2012). Descriptive statistics of the individual questions of the vocal reactivity scale are listed in Table A1 in the Appendix. Infants' language development scores at 12 months (ELFRA 1; Grimm & Doil, 2000) yielded a *mean* score of 10.75 ($SD = 4.65$) for expressive and 44.46 ($SD = 27.61$) for receptive language skills, which is within the $M \pm 1$ *SD* interval reported in a sample of normally developing German infants at the age of 12 months ($n = 120$; expressive: $M = 11.25$, $SD = 5.23$; receptive: $M = 37.21$, $SD = 21.20$; Grimm & Doil 2000). Scores were calculated after outlier exclusion ($n = 56$).

Vocal reactivity at 6 months and expressive language at 12 months were positively correlated, $r(54) = 0.36$, $p = .007$, whereas the correlation of vocal reactivity and receptive language did not reach statistical significance, $r(54) = 0.16$, $p = .249$. Note that expressive and receptive language were not significantly correlated, $r(54) = 0.25$, $p = .059$. In the regression model of expressive language (controlling for sex and age at t1 and t2; Fig. 1A), vocal reactivity was found to be a significant predictor of expressive language scores, $\beta = 0.35$, $t(51) = 2.79$, $p = .007$. Although vocal reactivity was the only significant predictor, R^2 for the overall expressive language model reached statistical significance, $R^2 = .208$, $R^2_{corr} = .146$, $F(4, 51) = 3.36$, $p = .016$ (Table 1). In contrast, the language perception model (controlling for sex and age at t1 and t2; Fig. 1 B) did not reveal vocal reactivity to significantly predict receptive language, $\beta = 0.14$, $t(51) = 1.04$, $p = .305$. The overall model fit of the receptive language model did also not reach statistical significance, $R^2 = .082$, $R^2_{corr} = .010$, $F(4, 51) = 1.144$, $p = .346$ (Table 1).

Our study aimed to investigate infants' early vocalizations as a predictor of their language development. We found parent-reported vocalizations at 6 months to be predictive of infants' expressive, but not receptive language skills at 12 months. Our findings thus extend previous research by demonstrating a relationship of preverbal vocalizations and later expressive language in a sample of

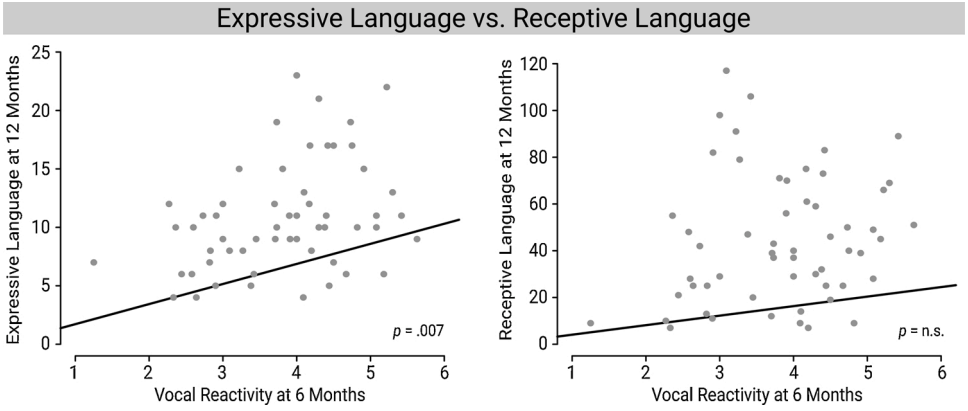

Fig. 1. Association between vocalizations at 6 months and expressive and receptive language abilities at 12 months. Left panel) Illustrates the association between vocalizations at 6 months (vocal reactivity scores measured with the German translation of the Infant Behavior Questionnaire – Revised; IBQ-R; Gartstein & Rothbart, 2003; Kristen et al., 2007) and expressive language at 12 months (measured with the German version of the MacArthur-Bates Communicative Development Inventories, CDI; ELFRA-1; Grimm & Doil, 2000) – controlling for age at t1, t2, and sex. Right panel) Illustrates the association between vocalizations at 6 months (vocal reactivity scores, IBQ-R) and language reception abilities at 12 months (ELFRA-1) – controlling for age at t1, t2, and sex.

Table 1
Linear regression models showing the relation between vocal reactivity and expressive and receptive language, respectively (controlling for age and sex).

Model	Predictors	β	*t*(51)	*p*
Expressive language at 12 months	Vocal reactivity at 6 months	0.35	2.79	.007*
	Age at t1	0.02	0.18	.856
	Age at t2	0.22	1.83	.073
	Sex	0.15	1.22	.225
Receptive language at 12 months	Vocal reactivity at 6 months	0.14	1.04	.305
	Age at t1	−0.03	−0.23	.817
	Age at t2	0.24	1.77	.083
	Sex	−0.05	−0.40	.694

Note. *statistically significant at $p < .025$ (adjusted for multiple comparisons).

German-learning infants. Additionally, our results point to a much earlier predictive relationship between preverbal vocalizations, namely from infants' first half year of life, and later expressive language than had been examined in previous studies (see Donnellan et al., 2020; Karousou & López-Ornat, 2013; Majorano et al., 2014; McGillion et al., 2017).

During their first year of life, infants developing verbal language undergo different stages of phonological development in a defined order (Nathani et al., 2006; Oller et al., 1999; Ramsdell-Hudock et al., 2019), with vocalizations occurring from early on. Although there is large inter-individual variability in the speed of verbal development and the duration of different phases, this typical order of phonological stages, together with our results, imply vocalizations to be one of the prerequisites of later expressive language. Thus, infants vocalizing more might tend to enter subsequent phonological stages earlier and tend to show more advanced expressive language skills at 12 months compared to infants vocalizing less, assuming other factors influencing language development are comparable. Here, one could argue that infants who are more advanced in their articulatory vocal tract adjustments vocalize more at 6 months and, consequently, produce words at a higher rate at 12 months. Yet, studies looking at this association found vocalizations to be indicative of language abilities beyond motoric skills. Specifically, infants were found to use vocalizations to communicate certain intentions and vocalizations with communicative intent best predicted later language development (Carpenter et al., 1983; Donnellan et al., 2020; Papaeliou et al., 2002). Thus, children with a higher vocalization rate earlier in life are most likely more advanced in their overall linguistic development and consequently produce their first words earlier than others.

If early vocalizations are indicative of children's general linguistic abilities, the question arises why only expressive, but not receptive language is associated with infant vocalizations. This differential finding implies that vocalizations are either indicative of or influential for factors distinctly related to expressive speech. For instance, infant babbling elicits contingent responses from caregivers (Donnellan et al., 2020) that are then used by the infant to learn new vocal forms and phonological patterns (Goldstein & Schwade, 2008). Consequently, infants gain more variety in their utterances, advancing subsequent expressive speech. Another possible reason of the dissociation between expressive and receptive language can be grounded in the challenge of reliably measuring receptive language (e.g., Dockrell & Marshall, 2015). Yet, particular factors were also found to exclusively influence receptive language, namely infant pointing behavior or maternal education (McGillion et al., 2017). Expressive and receptive language thus seem to be predicted by different factors in children's early development.

Our finding of early infant vocalizations to predict children's expressive language abilities advances research on the assessment and promotion of early language development well before children produce their first words. Infant vocalizations have also been shown to be a valid predictor of expressive language skills in children with autism spectrum disorder (McDaniel et al., 2018), with developmental delays (McCathren et al., 1999), and preterm children with low birth weight (Stolt et al., 2012). Apart from the possibility of examining preverbal vocalizations in children at risk of language delays as indicator of later linguistic skills, these measurements could be used for designing language-focused interventions, applicable well before language delays become apparent in a child's speech. Indeed, interventions aiming in part at increasing the vocalization rate in 1- to 3-year-old children positively impacted on children's vocalizations (Fey et al., 2006; McCathren, 2000, 2010). Thus, utilizing early vocalizations as a developmental indicator and target of intervention could be beneficial for promoting expressive language abilities, especially in children at risk for delayed language development. Future research should focus on the association of early vocalizations and subsequent language development in children at risk of such difficulties. Here, our study takes the first step in showing that vocalizations are associated with language from the age of 6 months, suggesting that language-focused assessments and interventions might be beneficial at a substantially younger age than so far assumed.

Author contributions

Annika Werwach: Conceptualization, Investigation, Formal analysis, Writing - Original draft. **Dirk Mürbe**: Writing - Reviewing and Editing. **Gesa Schaadt**: Conceptualization, Investigation, Writing - Reviewing and Editing. **Claudia Männel**: Conceptualization, Investigation, Writing - Original draft, Supervision, Funding acquisition.

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Appendix A. Supplementary data

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