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SHORT REPORT

How does social contingency facilitate vocabulary development?

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Abstract

Previous research shows that infants of parents who are more likely to engage in socially contingent interactions with them tend to have larger vocabularies. An open question is *how* social contingency facilitates vocabulary growth. One possibility is that parents who speak in response to their infants more often produce larger *amount of language input*, which accelerates vocabulary growth. Another possibility is that the *simplicity of contingent language input* is especially suitable to support early word learning. A third possibility is that more evidence of the communicative nature of language, achieved through *frequent contingent responses*, helps infants build a link between their own words or vocalizations and others' behaviors. This link may lead to a better understanding of the communicative nature of language and further language advances, including vocabulary growth. To distinguish between these hypotheses, we analyzed the relations between parent–infant interactions when infants were 9 months and their vocabulary size at 12 months, using a naturalistic corpus. Our findings show that the frequency of parents' verbal contingent responses predicts receptive vocabulary size at 12 months and this predictive relation is unlikely to be due to the amount of language input or the simplicity of language within socially contingent interactions.

KEYWORDS
language development, social contingency, vocabulary growth, word input

RESEARCH HIGHLIGHTS

- Infants of parents who respond to their vocalizations more often during the first year of life tend to have larger vocabularies in the second year.
- It is an open question what drives the predictive relation between parents' responsiveness and infants' vocabulary; we tested three hypotheses that offer competing explanations.
- More responsive parents might provide (1) more language input, (2) simpler language input, (3) more evidence of the communicative nature of language (via frequent responses).

Elena Luchkina and Fei Xu contributed equally to this work.

- We find support for the third hypothesis; the frequency of parents' responses predicts infants' vocabularies above and beyond the amount and simplicity of language input.

1 | INTRODUCTION

Word learning—one of the most significant accomplishments in early language and cognitive development—is tightly linked to infants' early communicative environment. Numerous studies demonstrated that properties of language input, such as the number of words an infant hears and the simplicity of utterances, as well as the amount of infant-directed speech in the first years of life, are linked to children's subsequent vocabulary development. For example, Hart and Risley (1995) demonstrated that children who hear more words end up having larger vocabularies themselves. Weisleder and Fernald (2013), among many others, showed that this facilitative effect of language input is driven by speech that parents direct at children rather than all ambient speech. This effect holds across different cultures, including those in which child-directed speech is relatively scarce (e.g., Shneidman et al., 2013; Shneidman & Goldin-Meadow, 2012), suggesting a critical role of child-directed speech in early language development. Notably, child-directed speech is more likely to be *contingent* on child's actions and vocalizations than adult-directed or otherwise overheard speech (e.g., Marklund et al., 2015). Contingent speech happens soon after (typically, within 2 s) and is related to the child's actions and vocalizations. This suggests that socially contingent interactions may be uniquely facilitative of early language development.

Consistent with this conjecture, research on the role of parent-infant interactions provides strong support that infants who experience more socially contingent exchange during the first year of life end up having larger receptive (e.g., Baumwell et al., 1997; Olson et al., 1984) and productive (e.g., Donnellan et al., 2020; Ferjan Ramírez et al., 2020; Gros-Louis et al., 2014; Tamis-LeMonda et al., 2001) vocabulary in the second year. Moreover, words uttered within caregivers' contingent speech, but not within noncontingent speech, predict infants' vocabulary size (Rollins, 2003). Research on young children's learning from media provides complementary evidence, demonstrating that word learning is achieved in socially contingent interactions via screen media but not during passive viewing (e.g., Roseberry et al., 2014). Combined, these findings suggest that social contingency facilitates vocabulary growth. However, a key question remains open: What is *the mechanism or mechanisms underlying this facilitative effect*?

To approach this question, in this paper we examine specific hypotheses about how socially contingent interactions facilitate vocabulary development. Following established practices, we identified parent's behavior as contingent if it was *within 2 s of the infant's action and related* to that action, (e.g., Bornstein & Tamis-LeMonda, 1989; Gros-Louis et al., 2014; Hilbrink et al., 2015; McGillion et al., 2013). We considered three possibilities inspired by extant research (Figure 1).

One possibility (**Hypothesis 1: amount of language input**) is that parents who speak in response to their infants more often produce *more word types and tokens*, which would facilitate vocabulary growth. This possibility is consistent with prior research showing that larger amount of language input results in larger vocabularies in young children (e.g., Hart & Risley, 1995).

Another possibility (**Hypothesis 2: simplicity of input**) is that parents who speak in response to their infants more often produce *more simple utterances* that are shorter and contain fewer unique word types (e.g., Elmlinger et al., 2019). These simple utterances may be easier to parse and help the learner identify individual words, which would facilitate vocabulary growth.

A third possibility (**Hypothesis 3: frequency of contingent responses**) is that the *frequency of parents' socially contingent responses* has a distinct effect on early vocabulary development. By accumulating experience with parents' reactions to their own vocalizations, infants may realize that vocalizations influence their social environment, and this realization may in turn help them infer the communicative nature of speech. Such an inference enables a wide range of language advances, including enhanced speech processing, increased attention to language, and more rapid word-referent mapping (see Luchkina & Xu, 2022; Masek et al., 2021, for reviews), all of which will facilitate vocabulary growth.

These hypotheses, while providing competing explanations, are not mutually exclusive: each of our three hypotheses can be true or false, a subset of them could be true, and all hypotheses can be true or false at the same time. For example, increased language input (Hypothesis 1), more simple utterances (lower type/token ratio and MLU; Hypothesis 2), and advances in communicative development (Hypothesis 3) as a result of more contingent responses may all fuel vocabulary growth at the same time. Importantly, the three sets of measures do not intrinsically depend on each other. We measured the duration of contingent and noncontingent speech, word input and in parents' speech per minute, type-to-token ratio and MLU within and outside of socially contingent speech, and frequency of contingent responses per infant vocalization (see Table 1). A highly contingent parent might or might not speak for longer periods of time (i.e., responses can be long or short), with or without producing more words per minute of speech, and with or without simplifying speech within contingent responses. Thus, while the three sets of parameters *may* correlate (which we test), they are designed to measure distinct aspects of infants' communicative experience.

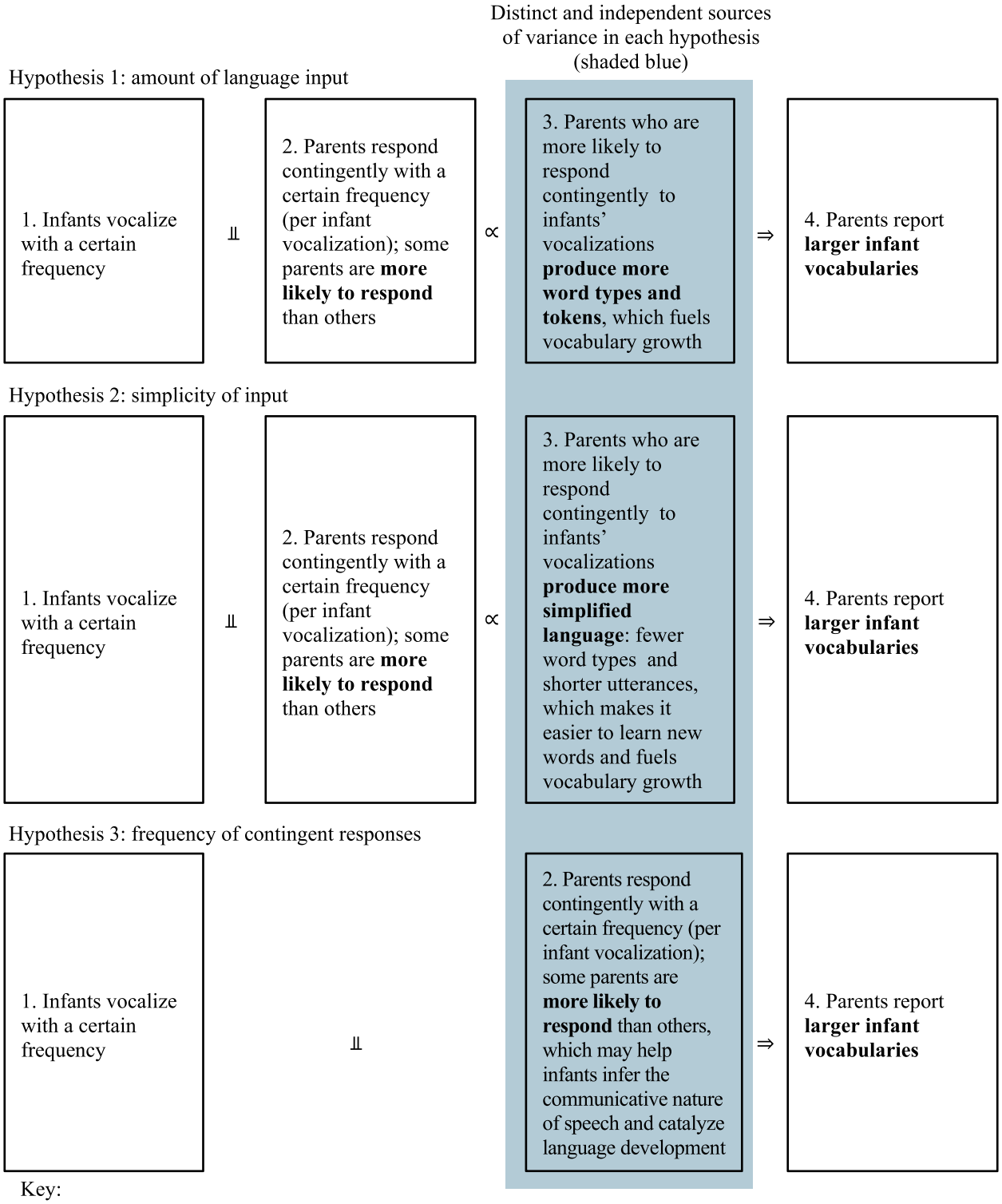

FIGURE 1 Schematic presentation of three non-mutually exclusive hypotheses.

TABLE 1 Descriptive statistics of language input when infants were 9 months old.

Language input measures	M(SD) <--This one should be centered and appear in the middle of the merged cell above Contingent input and non-contingent input	
	Contingent input	Non-contingent input
Number of word tokens over the duration of the recording	77.29 (53.74)	1084.82 (578.38)
Number of word types over the duration of the recording	44.38 (27.63)	294.91 (127.70)
Duration of parent's speech (minutes; across the entire recording)	0.73 (0.46)	8.85 (3.71)
Mean number of word tokens per minute of speech	112.83 (35.69)	119.96 (33.02)
Mean number of word types per minute of speech	69.64 (27.53)	34.22 (8.05)
Type-to-token ratio	0.62 (0.13)	0.29 (0.07)
Mean length of utterance, words (MLUw)	5.25 (2.09)	6.84 (2.90)

To distinguish between the three hypotheses, we analyzed a corpus of naturalistic parent-infant interactions when infants were 9 months old. We estimated the amount of infants' word input, its simplicity, and the frequency of socially contingent interactions. We asked if each of these measures observed at 9 months predicts infants' receptive and productive vocabulary size at 12 months.

2 | METHOD

2.1 | Data source

We used a corpus of 20-min-long video-recordings of infant–parent interactions – the Rollins Corpus (Rollins, 2003), which is publicly available on CHILDES (MacWhinney, 2000) and Databrary (Gilmore et al., 2016). Parent–infant interactions were semiscripted—each dyad was recorded in the same laboratory space and given the same set of toys and books. Aside from these constraints, parents interacted with their infants as they normally would. This uniformity of space, objects, and duration of sessions minimizes differences in parent–infant interactions prompted by the context (e.g., home and household size, level of noise, number of toys and books, etc.) and helps identify differences inherent in each dyad's interaction style and routine.

For our analyses we used video-recordings from 9-month-olds ($N = 23$) and vocabulary measures collected at 12 months. All infants acquired English as their native language with no known developmental disorders or delays. We selected to analyze 22 parent-infant dyads. One additional dyad was excluded from analysis because the reported receptive vocabulary was 2.5 standard deviations higher than the sample mean and in the 90th percentile according to Fenson et al. (1994). Trained research assistants created detailed frame-by-frame (1 frame = 33 ms) annotations in Datavyu. These annotations included over 15 types of infants' and parents' behaviors (see Appendix 1 for an example). All annotations have been shared with the broader research community on Databrary. All research assistants were trained on the same eight one-minute segments from eight different videos until reaching 90%–95% reliability. For videos that have been previously transcribed in CLAN (18 of 22), we imported existing CHAT transcriptions. For videos that have not been transcribed, we created time-locked transcriptions in Datavyu. Following Rollins (2003), we used intonation contours and pause duration to identify utterance boundaries.

2.2 | Independent variables

1. We estimated the amount (for H1) and the simplicity of language input (for H2):
   1) duration of contingent speech, in minutes,
   2) duration of noncontingent speech, in minutes,
   3) word types (number of unique words) produced by parents, per minute of contingent and noncontingent speech,
   4) word tokens (number of all words) produced by parents, per minute of contingent and noncontingent speech,
   5) type/token ratio, which was calculated by dividing (1) by (2),
   6) mean length of utterance in words (MLUw: the number of words per sentence).

All measures of language input were evaluated within and outside of socially contingent interactions. *Per minute* measures enabled us to account for differences in the total duration of parent's contingent and noncontingent interactions (see Table 1).

Next, we calculated the **frequency of parents' socially contingent behaviors, per infant vocalization** (Table 2). To do so, we divided the number of parents' socially contingent behaviors by the number of infant nondistress vocalizations, which excluded crying and grunting (following, e.g., Bornstein et al., 1992). We split parents' contingent behaviors into verbal (utterances, imitations of infant's vocalizations, etc.) and nonverbal (actions towards the object or towards the infant, claps, gestures, etc.). Nonverbal behaviors were analyzed because they may also provide critical insights about the communicative properties of language (e.g., Luchkina & Xu, 2022; Tauzin & Gergely, 2019, 2021). Verbal and nonverbal responses were treated as independent predictors, even if they co-occurred (24% of all nonverbal responses co-occurred with verbal responses).

These measures, calculated per infant vocalization, allowed us to account for differences in the number of opportunities parents have to respond to their infants within a 20-min session, which is driven by

TABLE 2 Descriptive statistics of infant's and parent's verbal and vocal communication at 9 months.

Measure	M (SD)
Mean number of infant vocalizations	40 (24)
Frequency of parent's contingent verbal responses to infant vocalizations, per infant vocalization	58% (23%)
Frequency of parent's non-verbal contingent responses to infant vocalizations, per infant vocalization	16% (10%)

the number of infant vocalizations. That is, two parents may be equivalently contingent, say responding 50% of the time when their infant vocalizes, but infants may produce different number of vocalizations. Without norming parents' responsiveness by the number of infant vocalizations, the parent whose infant vocalizes more often (e.g., a parent who responded 50 times out of 100 infant vocalizations) would be characterized as more contingent than a parent whose infant vocalizes less often (e.g., 20 times out of 40 infant vocalizations).

2.3 | Dependent variables

The dependent variables were MacArthur-Bates CDI (Fenson et al., 2000) receptive (M = 78.35, SD = 41.38) and productive (M = 7.94, SD = 5.26) vocabulary recorded at 12 months.

2.4 | Predictions

Hypothesis 1. Amount of language input. If parents who speak in response to their infants more often produce larger amount of language input, which in turn facilitates vocabulary growth, then we should observe that (1) parents' contingent responsiveness correlates with the number of word types and word tokens they produce and (2) the number of word types and word tokens in parents' contingent responses at 9 months predicts infants' vocabulary at 12 months.

Hypothesis 2. Simplicity of input. If the properties of socially contingent language input are especially suitable to support early word learning, which in turn facilitates vocabulary development, then we should observe that (1) the type-to-token ratio and MLUw are lower within socially contingent interactions than outside such interactions and (2) these measures of simplicity of input within socially interactions at 9 months predict vocabulary at 12 months.

Hypothesis 3. Frequency of contingent responses. If experience with socially contingent responses facilitates vocabulary growth, then we should observe that (1) the frequency of socially contingent responses, per infant vocalization, at 9 months predicts vocabulary at 12 months and (2) this effect holds even when predictors from Hypothesis 1 or Hypothesis 2 are included in the model.

3 | RESULTS

Before conducting our main analyses, we ran a set of preliminary analyses to ensure that the frequency of parent's responses, per infant vocalization, varied independently of the number of infant vocalizations. Considering the observational nature of our investigation, we aimed to ensure that the effects of our independent variables in each hypothesis were separable from the effects of infant vocalizations. For example, if parents of more vocal infants were more likely to respond to any given vocalization (e.g., because they felt encouraged to respond), then it is not clear whether variability in the frequency in parents' responses could be considered a predictor of infants' vocabulary. Given the observational nature of the investigation, we cannot make causal claims about the observed longitudinal relations, but we can minimize the chance that the observed relation is entirely driven by a third variable.

There were no significant correlations between the number of infant's vocalizations and the frequency of parent's verbal (r = −0.23, p = 0.31) or nonverbal responses (r = −0.03, p = 0.89), per infant vocalization.

We also fitted generalized linear models to receptive and productive vocabulary measures. The results of this model fitting revealed no significant effects of mother's years of education (M = 16.07, SD = 1.83), father's years of education (M = 15.67, SD = 2.09) and infant's sex (12 boys). These measures were not included in our main analysis testing the three hypotheses.

Hypothesis 1: amount of language input. First, we tested the hypothesis that parents who speak in response to their infants more often produce larger amounts of word types and tokens, which would facilitate vocabulary growth. To see whether more contingent parents produced more language input, we evaluated Spearman correlations between the frequency of their *verbal* responses, per infant vocalization, and measures of contingent and total language input when infants were 9 months. To see whether language input predicted infants' vocabulary, we fitted generalized linear models with the properties of language input per minute when infants were 9 months to receptive and productive vocabulary at 12 months. One model tested the effects of the number of word types and tokens calculated for noncontingent language input, normed per minute. The other model tested the effects of the same predictors calculated for contingent language input, normed per minute.

The duration of parents' contingent and noncontingent speech and the number or word types and tokens per minute of speech within or outside socially contingent interactions did not significantly correlate with the frequency of parent's verbal contingent responses, per infant vocalization. Further, neither measure had a significant effect on receptive or productive vocabulary at 12 months. These results suggest that parents who respond to their infants contingently more often do not produce more word types and tokens, and the effects of socially contingent responses on vocabulary are unlikely to be due to the overall talkativeness of parents.

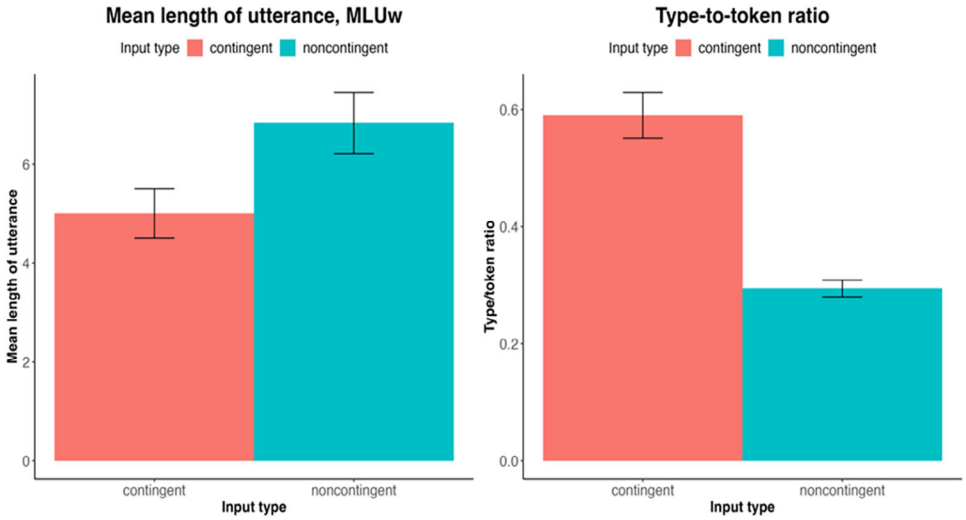

FIGURE 2 Measures of language simplicity within and outside socially contingent interactions at 9 months.

TABLE 3 Longitudinal effects (9–12 months) of parent's contingent responsiveness on receptive vocabulary size.

Predictor	Beta	SE	*t*-value	*p*-value
(Intercept)	43.80	16.10	2.72	.014*
Frequency of parent's verbal/vocal responses to infant vocalizations, per infant vocalization	80.20	29.60	2.71	.014*
Frequency of parent's non-verbal responses to infant vocalizations, per infant vocalization	−108.90	68.50	−1.59	.128

Hypothesis 2: simplicity of input. Second, we tested the hypothesis that more contingent parents tend to simplify their speech in interactions with their infants, which may enhance its processing and facilitate vocabulary growth. We conducted Wilcoxon rank sum tests to compare MLUw and type-to-token ratio within and outside socially contingent interactions (see Figure 2).

We chose Wilcoxon tests because Shapiro–Wilk tests of language simplicity measures indicated significant deviations of their distributions from normal ($W = 0.9$, $p = 0.003$ and $W = 0.9$, $p = 0.04$ for MLUw and type-to-token ratio, respectively). Thus, we chose a nonparametric test, which revealed a significant difference in MLUw when infants were 9 months old: MLUw was significantly higher for the noncontingent than the contingent input, sum T-statistic = 141, p-value = 0.02. In contrast, type-to-token ratio was significantly lower for the noncontingent than the contingent input, sum T-statistic = 458, p-value < 0.001.

These results are partially consistent with prior literature: although parents tended to produce significantly shorter utterances within contingent responses to their infants, the proportion of unique words to the total word count was higher (Elmlinger et al., 2019). This pattern, although not entirely consistent with our predictions, may have contributed to infants' word learning: it may be easier for infants to parse lexically rich yet short utterances and learn new words.

However, GLMs fitted to vocabulary measures revealed that neither measure of language simplicity, contingent or noncontingent, significantly predicted infant's receptive and productive vocabulary at 12 months. In addition, neither measure of language simplicity, within or outside socially contingent interactions, significantly correlated with the frequency of parent's verbal contingent responses, per infant vocalization. This suggests that the simplicity of language input is unlikely to explain the facilitative effect of social contingency on vocabulary.

Hypothesis 3: frequency of contingent responses. Finally, we tested the hypothesis that the frequency of parents' socially contingent responses facilitates vocabulary growth. We evaluated the effects of parent's contingent responsiveness to infant vocalizations on vocabulary size by fitting generalized linear models. We fitted additional models to ensure that these effects hold if measures of language amount or simplicity are included in the model.

Our model fitting revealed a significant effect of the frequency of parent's verbal/vocal responses at 9 months on *receptive* vocabulary size at 12 months (Table 3 and Figure 3) but no significant effect on *productive* vocabulary (Table 4). Surprisingly, we also found a significant negative effect of the frequency of parent's nonverbal responses on *productive* vocabulary at 12 months.

3.1 | Follow-up exploratory analyses

Further analyses revealed that the effects of the frequency of parent's verbal/vocal responses on infant's receptive vocabulary remained significant and its effects on productive vocabulary remained nonsignificant when measures of the amount of contingent input (Tables 5 and 6) and its simplicity (Tables 7 and 8) are included in the model.

TABLE 4 Longitudinal effects (9 to 12 months) of parent's contingent responsiveness on productive vocabulary size.

Predictor	Beta	SE	*t*-value	*p*-value
(Intercept)	7.47	2.65	2.82	.011*
Frequency of parent's verbal/vocal responses to infant vocalizations, per infant vocalization	8.50	4.86	1.75	.097
Frequency of parent's non-verbal responses to infant vocalizations, per infant vocalization	−29.89	11.27	−2.65	.016*

TABLE 5 Longitudinal effects (9–12 months) of parent's contingent responsiveness on receptive vocabulary size, including the effects of the amount of contingent word input.

Predictor	Beta	SE	*t*-value	*p*-value
(Intercept)	68.21	32.32	2.11	0.05
Number of word types, per minute	0.19	0.36	0.53	0.60
Number of word tokens, per minute	−0.44	0.27	−1.62	0.123
Frequency of parent's verbal/vocal responses to infant vocalizations, per infant vocalization	67.57	31.37	2.15	0.046*

TABLE 6 Longitudinal effects (9–12 months) of parent's contingent responsiveness on productive vocabulary size, including the effects of the amount of contingent word input.

Predictor	Beta	SE	*t*-value	*p*-value
(Intercept)	9.14	5.99	1.53	.14
Number of word types, per minute	−0.01	0.21	−0.04	.97
Number of word tokens, per minute	−0.03	0.05	−0.48	.64
Frequency of parent's verbal/vocal responses to infant vocalizations, per infant vocalization	3.19	5.68	0.56	.58

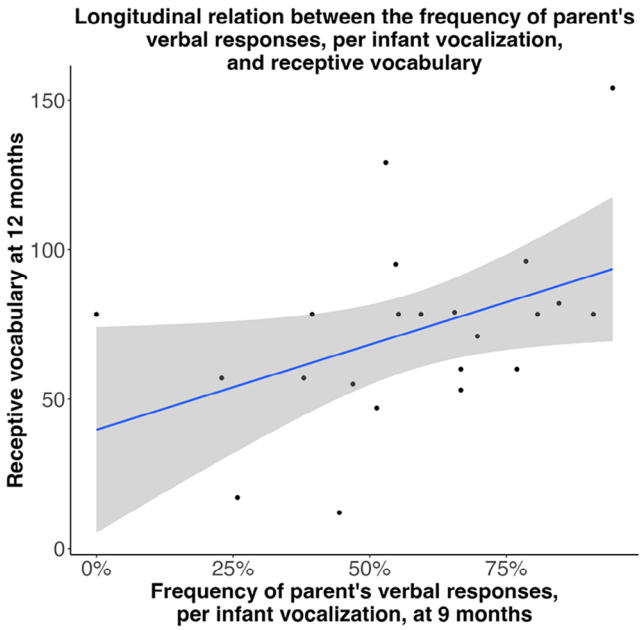

FIGURE 3 Predictive relation between the frequency of parent's verbal responsiveness, per infant vocalization, and receptive vocabulary.

Although our preliminary analyses revealed that there was no relation between the number of infant vocalizations and the frequency of parent's responses, there remains a possibility that the number of infant vocalizations at 9 months was directly related to their vocabulary at 12 months. Perhaps, infants who vocalize more often at 9 months are more advanced in their communicative development and end up with larger productive vocabulary at 12 months (see, e.g., Donnellan et al., 2020; Lyakso et al., 2014; McGillion et al., 2017; Werwach et al., 2021). Alternatively, parents of more vocal infants may have reported larger productive vocabularies. Given the observational nature of the data, our analysis cannot distinguish between these alternatives, but can identify a predictive relation between infant vocalizations and their productive vocabulary.

We evaluated this relationship by adding the number of infant vocalizations to the GLMs that tested the effects of parents' responsiveness. There were no significant effects of infant vocalization *receptive* vocabulary (Table 9). In contrast, *productive* vocabulary at 12 months was significantly predicted by the number of vocalizations at 9 months (Table 10 and Figure 4). Predictably, adding the number of infant vocalizations to the models had no substantial impact on the effect size or significance of the frequency of parent's responses to infant vocalizations.

TABLE 7 Longitudinal effects (9–12 months) of parent's contingent responsiveness on receptive vocabulary size, including the effects of the simplicity of contingent word input.

Predictor	Beta	SE	*t*-value	*p*-value
(Intercept)	1.67	52.65	0.03	.98
Type-to-token ratio	29.71	55.96	0.53	.60
Mean length of utterance, words (MLUw)	–0.09	3.46	–0.03	.98
Frequency of parent's verbal/vocal responses to infant vocalizations, per infant vocalization	87.28	32.07	2.72	.01*

TABLE 8 Longitudinal effects (9–12 months) of parent's contingent responsiveness on productive vocabulary size, including the effects of the simplicity of contingent word input.

Predictor	Beta	SE	*t*-value	*p*-value
(Intercept)	11.22	6.71	1.67	.11
Type-to-token ratio	–0.05	0.07	–0.62	.54
Mean length of utterance, words (MLUw)	–0.01	0.06	–0.12	.90
Frequency of parent's verbal/vocal responses to infant vocalizations, per infant vocalization	0.52	6.51	0.08	.94

TABLE 9 Longitudinal effects (9–12 months) of parent's contingent responsiveness and infant' vocalizations on receptive vocabulary size.

Predictor	Beta	SE	*t*-value	*p*-value
(Intercept)	55.07	18.91	2.91	.01*
Frequency of parent's verbal/vocal responses to infant vocalizations, per infant vocalization	81.11	29.37	2.76	.01*
Frequency of parent's non-verbal responses to infant vocalizations, per infant vocalization	–113.68	68.18	–1.67	.11
Number of infant vocalizations (total, per session)	–0.28	0.25	–1.12	.28

We further explored the relation between parents' contingent responses and infant vocabulary by considering all communicative responses as a one category and all noncommunicative as the other (vs. verbal and nonverbal). It is possible that the communicative nature of the responses, rather than their verbal implementation is what influenced infants' vocabulary development. The only communicative type of nonverbal responses that we considered were gestures. It is quite possible that in some contexts parents and infants can use holding, kissing, touching, or exchanging toys as communicative. However, the communicative value of those behaviors is highly variable, depending on the dyad, and the context. Thus, consistent with most developmental literature, we classify only gesture as an unambiguously communicative behavior, in addition to speech. Effectively, the change in our predictors involved taking gestures out of nonverbal responses (now named "noncommunicative") and adding it to verbal responses.

We fitted models with the frequency of parents' communicative and noncommunicative behaviors to infants' vocabulary (Tables 11 and 12). The results of these analyses indicate that the frequency of parents' communicative contingent behaviors when infants were 9 months had a significant positive effect on receptive vocabulary when infants were 12 months. The frequency of parents' noncommunicative

TABLE 10 Longitudinal effects (9–12 months) of parent's contingent responsiveness and infant' vocalizations on productive vocabulary size.

Predictor	Beta	SE	*t*-value	*p*-value
(Intercept)	3.529	2.703	1.306	.21
Frequency of parent's verbal/vocal responses to infant vocalizations, per infant vocalization	8.166	4.199	1.945	.07
Frequency of parent's non-verbal responses to infant vocalizations, per infant vocalization	–28.218	9.747	–2.895	.01*
Number of infant vocalizations (total, per session)	0.097	0.036	2.738	.014*

TABLE 11 Longitudinal effects (9–12 months) of parent's contingent responsiveness on receptive vocabulary size.

Predictor	Beta	SE	*t*-value	*p*-value
(Intercept)	47.54	14.74	3.22	.00*
Frequency of parent's communicative responses to infant vocalizations, per infant vocalization	75.64	23.41	3.23	.00*
Frequency of parent's non-communicative responses to infant vocalizations, per infant vocalization	−140.30	61.05	−2.30	.03*

TABLE 12 Longitudinal effects (9–12 months) of parent's contingent responsiveness on productive vocabulary size.

Predictor	Beta	SE	*t*-value	*p*-value
(Intercept)	8.28	2.94	2.82	.01*
Frequency of parent's communicative responses to infant vocalizations, per infant vocalization	2.98	4.67	0.64	.53
Frequency of parent's non-communicative responses to infant vocalizations, per infant vocalization	−17.40	12.17	−1.43	.17

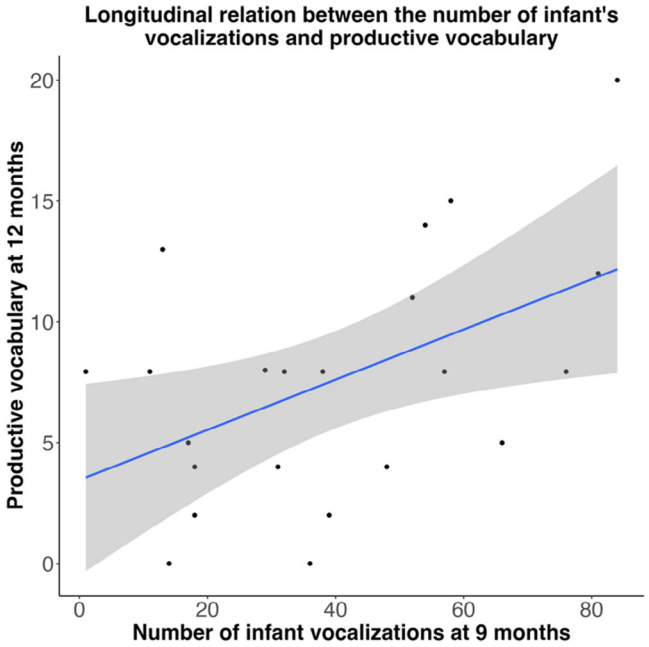

FIGURE 4 Predictive relation between the number of infant vocalizations and productive vocabulary.

contingent behaviors had a significant negative effect on infants' productive vocabulary.

4 | DISCUSSION

In this study, we explored several potential mechanisms underlying the facilitative effect of social contingency on infant's vocabulary development. We considered three hypotheses: (1) that more contingent parents provide infants with more words (H1: amount of language input), which in turn facilitates vocabulary growth, (2) that socially contingent input is simplified relative to the rest of infant-directed speech (H2: simplicity of language input), supporting language processing and thus facilitating vocabulary growth, and (3) that the frequency of socially contingent responses fuels language development, including vocabulary growth (H3: frequency of contingent responses). Our correlation analyses did not reveal any significant relations among the frequency of parents' contingent responses, per infant vocalization, and any measure of the amount of language or its simplicity. This lack of significant correlations rendered our hypotheses independent of each other and not mutually exclusive.

Our results did not support the amount of language input hypothesis: parent's rate of contingent responsiveness did not correlate with the amount of their language input at 9 months, and neither measure of contingent or noncontingent language input predicted infant's receptive and productive vocabulary at 12 months.

With regard to the simplicity of input hypothesis, we found that parents produced shorter utterances and more word types, relative to the number of tokens, within socially contingent responses to their infants when infants were 9 months old. These results are partially consistent with prior research showing that parents tend to simplify contingent language input (Elmlinger et al., 2019). A key feature of our analyses is that we used per-minute estimates of word types and tokes that parents produced within contingent and noncontingent utterances to account for disparities in their total duration within a 20-min videorecording. Using raw numbers of word types and tokens produces results that are consistent with prior work. At the same time, neither measure of simplicity of language input at 9 months was a significant predictor of infant's receptive or productive vocabulary at 12 months, suggesting that it is unlikely that the properties of contingent input explain the facilitative effect of social contingency on infants' vocabulary.

Finally, with regard to the frequency of contingent responses hypothesis, we found supportive evidence that the frequency of verbal/vocal, but not nonverbal, socially contingent responses to infant vocalizations at 9 months predicted *receptive* vocabulary at 12 months. We also found a nonsignificant predictive relation between the rate of parents' verbal/vocal responses at 9 months and infants' productive

vocabulary at 12 months. In addition, productive vocabulary was negatively predicted by the rate of nonverbal responses. It is not clear why productive vocabulary is negatively associated with parents' nonverbal responses. Our follow-up analyses, which show even stronger effects of parents' communicative (positive effect) and noncommunicative (negative effect) responses, suggest that perhaps noncommunicative responses to infants' communicative bids slowed down infants' language development (though our data allows us only to speculate; there is no confirming evidence of this).

Taken together, the results of our investigation show that experience with frequent socially contingent responses facilitates vocabulary growth, and this growth is not due to the amount of word input produced by more responsive parents or their tendency to simplify socially contingent language. Instead, it is the frequency of parents' verbal responsiveness to infant's behaviors at 9 months that predicted advances in their vocabulary at 12 months.

Two limitations of our study are (1) a relatively small sample size and (2) the correlational nature of the evidence. Additional corpus investigations would increase our confidence in the reported results. Another way to investigate the hypothesis that socially contingent responsiveness influences infants' understanding of the communicative nature of speech is to conduct an empirical investigation (e.g., by manipulating social contingency in word learning experiments as in Tauzin & Gergely, 2018). This would allow us to make inferences about the causal structure of the effects we observed in the current study.

It is also important to note that in contrast with our findings, Rollins (2003) finds a positive association between the total number of word tokens uttered within socially contingent comments at 9 months and infant's receptive vocabulary at 12 months. This divergence may be due to a different sample size in Rollins (2003), where only 11 infant-parent dyads were included and a 10-minute portion of the entire duration of recordings was analyzed.

Lastly, it remains an open question whether frequent socially contingent responses indeed inform infant's understanding of the communicative nature of language, as we have suggested. Previous investigations lend support to this conjecture showing that contingent interactions facilitate infant's inferences about communication. For example, Tauzin and Gergely (2018) demonstrated that young infants interpret turn-taking exchange of variable tone sequences between unfamiliar agents as communicative. Similarly, Ferguson and Waxman (2016) showed that despite not normally treating sine-wave tones as language, after a period of exposure to those tones used in a socially contingent exchange, infants extend language-like properties to them (see Fulkerson & Waxman, 2007). These findings suggest accumulating experience with socially contingent exchange may help infants infer that language is communicative. Indeed, by 12–14 months, infants exhibit unambiguous signs of understanding that language can communicate—they begin to comprehend utterances about objects or phenomena that they cannot see (Osina et al., 2013, 2014; Saylor & Baldwin, 2004; Vouloumanos et al., 2012). As a potential consequence of these advances, infant's word knowledge (e.g., Bergelson, 2020) and word learning capacity (e.g., Woodward et al., 1994) begin to expand at an accelerating rate at around the same age (see Luchkina & Xu, 2022, for a more detailed review). Although the present investigation does not directly test the possibility that experience with socially contingent interactions helps infants understand the communicative nature of words, our results are consistent with it. Future research will more directly test this hypothesis.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The video annotation data that support the findings of this study are available on Databrary: https://nyu.databrary.org/volume/1722. The videos that have been annotated are part of the Rollins corpus, publicly available on CHILDES: https://childes.talkbank.org/access/Eng-NA/Rollins.html

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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