Maternal Responsiveness and the Development of Directed Vocalizing in Social Interactions

Julie Gros-Louis
Department of Psychology
University of Iowa

Meredith J. West and Andrew P. King
Department of Psychological and Brain Sciences
Indiana University

For effective communication, infants must develop the phonology of sounds and the ability to use vocalizations in social interactions. Few studies have examined the development of the pragmatic use of prelinguistic vocalizations, possibly because gestures are considered hallmarks of early pragmatic skill. The current study investigated infant vocal production and maternal responsiveness to examine the relationship between infant and maternal behavior in the development of infants’ vocal communication. Specifically, we asked whether maternal responses to vocalizations could influence the development of prelinguistic vocal usage, as has been documented in recent experimental studies exploring the relation between maternal responses and phonological development. Twelve mother–infant dyads participated over a six-month period (between 8 and 14 months of age). Mothers completed the MacArthur Communicative Development Inventory when infants were 15 months old. Maternal sensitive responses to infant vocalizations in the previous months predicted infants’ mother-directed vocalizations in the following months, rather than overall response rate. Furthermore, mothers’ sensitive responding to mother-directed vocalizations was correlated with an increase in developmentally advanced, consonant–vowel vocalizations and
some language measures. This is the first study to document a social shaping mechanism influencing developmental change in pragmatic usage of vocalizations in addition to identifying the specific behaviors underlying development.

INTRODUCTION

Starting in the 1970’s, researchers began to recognize the potential extent of the relationship between vocalizations used in social exchanges and the development of language (e.g., Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Bruner, 1977). Since that time, studies have considered the role of maternal responsiveness in the development of language milestones in the second year (e.g., Baumwell, Tamis-LeMonda, & Bornstein, 1997; Nicely, Tamis-LeMonda, & Bornstein, 1999; Rollins, 2003; Tamis-LeMonda, Bornstein, & Baumwell, 2001); however, prior to learning language, infants progress through the prelinguistic period, during which they develop a range of communicative skills, including the production of speech sounds of language, in addition to the pragmatic usage of vocalizations: how to use vocalizations for effective social interactions (Dore, 1974; Halliday, 1975).

Studies in both animal and human communicative development indicate that the development of the acoustic structure of a signal is not predictive of the development of its pragmatic use and vice-versa (Locke, 1993). That is, vocal development can progress without the corresponding development of usage of vocalizations or language in social interactions (Freeberg, King, & West, 1995; Surian, Baron-Cohen, & Van der Lely, 1996; Tanguay, Robertson, & Derrick, 1998). In support of this view, many studies have demonstrated that vocalizations can affect others’ behavior before they have speech-like structure or specific meaning (e.g., Goldstein & West, 1999; Green, Jones, & Gustafson, 1987; Hsu & Fogel, 2003; Keller & Scholmerich, 1987; McCune, Vihman, Roug-Hellichius, Delery, & Gogate, 1996; Papousek, 1989). Thus, vocalizations have pragmatic function, that is, perlocutionary effect (Austin, 1962), before infants develop their vocal repertoire. Oller and colleagues provide further evidence for early pragmatic development by showing that prespeech vocalizations in the first year, including growls, squeals, and protophones, have a range of pragmatic functions (Oller et al., 2013). Importantly, the variability is not systematic, so that all vocal types are produced across different contexts and with variable positive and negative affect. It is precisely
this functional flexibility—the ability to produce vocalizations of different types combined with different affect across situations—that allows for pragmatic and language development.

For infants’ vocal usage to further develop, however, they must learn that vocalizations have specific consequences and can influence caregivers’ behavior in predictable ways (Papousek & Bornstein, 1992; Papousek, 1992; Locke, 1996). Infants begin to show a rudimentary understanding of the consequences of vocalizing to engage a social partner as young as 5 months of age (Goldstein, Schwade, & Bornstein, 2009). Using the still-face paradigm to probe infants’ behavior, Goldstein and colleagues found that infants increased their vocalizations when adults adopted a still face. That is, when adults stopped responding, infants produced an extinction burst, which indicates that infants have learned the association between their vocalizations and the outcome. A similar study using the still-face procedure found that maternal smiles that were contingent on infants’ behavior predicted infants’ social bids during the still-face episode (Mcquaid, Bibok, & Carpendale, 2009). These findings suggest that infants’ early social experience lays the foundation for the development of vocal usage because infants develop expectations of receiving responses to their behavior.

At present, there is a gap between studies of vocal development and pragmatic usage of vocalizations. By pragmatic usage of vocalizations, or vocal usage, we mean infants’ production of vocalizations to caregivers in interactions. Recent experimental studies suggest that maternal responses to infant vocalizations could influence phonological development. Goldstein, King, and West (2003) found that nonvocal social feedback contingent on infant vocalizations in moment-to-moment interactions led to an increase in infants’ phonologically advanced speech-like syllables (termed “canonical syllables”—Oller, Eilers, & Basinger, 2001) whereas the equivalent, but noncontingent, feedback did not have this effect. Also, Goldstein and Schwade (2008) found that infants showed an increase in vocalizations that were phonologically similar to their mothers’ vocalizations when they received contingent vocal feedback compared to noncontingent vocal feedback. Furthermore, there was no evidence for imitation by infants of the phonemes in mothers’ vocalizations. These experimental results were provocative in that they suggested that a social shaping mechanism, based on contingent responses to vocalizations, may drive communicative development rather than innate motor programs or imitation (Bloom, 1993; Kent, 1981; Kuhl & Meltzoff, 1996); however, because the experimental studies only documented change within an experimental session, it remains an open question whether social shaping influences developmental change.

In contrast to advancements in understanding the mechanism underlying vocal development, studies of prelinguistic vocal usage are largely
descriptive and do not examine developmental origins (Bates, 1976; Carpenter, Mastergeorge, & Coggins, 1983; Dore, 1974; Ninio, Snow, Pan, & Rollins, 1994; Sugarman, 1984; Wetherby, Cain, Yonclas, & Walker, 1988). Furthermore, gestures, such as giving, showing, offering, reaching, and pointing, are often the anchor behavior of interest and vocalizations or eye gaze are considered in conjunction with gestures (e.g., Bates, Camaioni, & Volterra, 1975; Blake, McConnell, Horton, & Benson, 1992; Franco & Butterworth, 1996; Masur, 1983; Ninio & Snow, 1996). Few studies examine the usage of prelinguistic vocalizations alone or in combination with eye gaze in the absence of gestures (but see Harding & Golinkoff, 1979). This is a significant oversight given that during the first half of the first year of life, caregiver-infant communication is largely based on vocal exchanges and facial expression (e.g., Hsu, Fogel, & Messinger, 2001; Papousek, 1992; Treharthen, 1974, 2001; Tronick, 1989), whereas gestural communication develops later in the first year.

An important finding from studies of prelinguistic communication is that the integration of eye gaze (attentional focus toward objects or social partners) with vocal behaviors and/or nonverbal gestures is considered to be indicative of infants’ intention to communicate (Bates, 1976; Bates et al., 1975; Golinkoff, 1986; Harding & Golinkoff, 1979; Iverson & Goldin-Meadow, 2005; Ninio & Bruner, 1978; Wetherby et al., 1988). The development of intentional communication marks a significant change because infants are capable of eliciting responses that, in turn, can influence language development (Colonnesi, Stams, Koster, & Noomb, 2010; Laakso, Poikkeus, Katajamäki, & Lyytinen, 1999; Liszkowski, Albrecht, Carpenter, & Tomasello, 2008; Paavola, Kunnari, & Moilanen, 2005; Wu & Gros-Louis, 2014; Yoder & Warren, 2001).

Although influences on the development of pragmatic use of prelinguistic vocalizations have not been well-studied, recent studies have identified pragmatic functions of directed vocalizations in the absence of gestures. For example, vocalizations produced when infants are looking at an object that is held or within reach, that is, object-directed vocalizations, have been found to facilitate interactions around objects that provide word learning opportunities. Infants’ attentiveness to objects and maternal responsiveness contribute to successful word learning in part because it allows infants to realize that sounds are linked to objects (Goldstein, Schwade, Briesch, & Syal, 2010). Less is known about caregiver-directed vocalizations; but, just as infants have to realize that sounds are linked to objects, infants must learn the function of vocalizing in social interaction. One prior study found that adults respond differentially to vocalizations depending on whether an infant is directing the vocalization to them or if the infant is interacting with objects (West & Rheingold, 1978). This sug-
gests that infants' attentional focus when they vocalize influences caregivers' responses, providing an opportunity for infants to learn about the effectiveness of vocalizations in influencing caregivers' behavior. In addition, studies of interactions between preverbal children and mothers have shown that that eye gaze helps mothers interpret intentions of their children (Golinkoff, 1986). Therefore, regardless of infants' intent to communicate, parents use eye gaze in combination with vocalizations to glean intent and respond accordingly.

We propose that responses to vocalizations produced in social interactions shape the development of pragmatic usage of vocalizations, as has been suggested for phonological development (Goldstein & Schwade, 2008; Goldstein et al., 2003). Specifically, we hypothesize that maternal sensitive responses are positively associated with an increase in vocalizations produced to mothers in social interactions. Sensitive responses, first defined in attachment studies (Ainsworth, 1973), refer to contingent responses appropriate to a child's behavior or focus of attention (e.g., Baumwell et al., 1997). Sensitivity is positively associated with communicative, attentional, and cognitive development (e.g., Belsky, Goode, & Most, 1980; Bornstein & Tamis-LeMonda, 1997; Landry, Smith, Miller-Loncar, & Swank, 1997). Most relevant to the current study, sensitive maternal responses to infants' behavior have been shown to relate to communicative behavior and language development (e.g., Baumwell et al., 1997; Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007; Miller & Gros-Louis, 2013).

The current study provides a preliminary exploration of the effects of maternal contingencies on long-term change in infant vocal communication. The purpose of the study is twofold: (1) to validate the social shaping mechanism of vocal development that has been documented in short-term experimental sessions over a longer developmental period and (2) to examine how social feedback may influence the development of the pragmatic usage of vocalizations. Specifically, we documented moment-to-moment interactions between infants and mothers, focusing on infants' vocal production and maternal responses, to determine effects of responsiveness on changes over time in communicative behavior. We also report related findings on early language measures as they relate to the interaction between infants' vocal production and maternal responses. Based on recent experimental findings demonstrating the influence of caregiver sensitive responsiveness on prelinguistic communication (Goldstein & Schwade, 2008; Miller & Gros-Louis, 2013; Miller & Lossia, 2013), we hypothesize that maternal sensitive responses to infants’ vocalizations will be positively related to an increase in infants' syllable-like vocalizations and caregiver-directed vocalizations.
METHODS

Participants

Twelve infants and their mothers were recruited using a database comprising birth records for Monroe County, Indiana, USA. Participants included five mother–son pairs and seven mother–daughter pairs. Participants ranged from lower-middle to upper-middle class, with a mean SES status of 45.6 (SD = 18.5) based on the Hollingshead four-factor index (Hollingshead, 1975). Eleven of the infants were Caucasian and one was African-American. Six of the infants were firstborn and six of the infants were second-born. All infants were monolingual, full-term with no developmental delays and had normal hearing, based on hearing screenings done at birth. Participants were given a prize after each visit (book, stuffed animal, toy) and a photo album containing pictures taken at each lab visit at the end of the study.

Procedure

Mothers and infants visited the laboratory every other week for 6 months, starting within 1 week after infants’ eighth month birthday, for a total of 12 visits. Mothers and infants played for ½ hr in unstructured interactions in a large playroom (3.9 m × 4.6 m) with a wide selection of toys in a toy box in the corner of the playroom (such as pop-up toy, ring stacker, balls, school bus, shape sorter, stuffed animals, puppets). In addition, there were two mobiles hanging from the ceiling. Mothers were instructed to play with their infants as they would at home and they were unconstrained in their activities and their movement around the room. Behavioral interactions were recorded using one or two of three remote-controlled wall-mounted cameras (SONY TR-100 handycam, Sony, Tokyo) routed to an SVHS video tape recorder (AG1980, Panasonic, Secaucus, NJ) by a video mixer (Videonics MX-1, Focus Enhancements, Campbell, CA) to allow for selection of the best camera angle or split-screen images of dyads. High-quality audio recordings were obtained using a wireless microphone (FMR-150, Telex Communications, Burnsville, MN) sewn into overalls worn by the infant. Audio input was routed to the left stereo channel of the SVHS video tape recorder by an audio mixer (1604 VLZ, Mackie Designs, Woodinville, WA). Therefore, audio and video channels were synched and videos contained time code accurate to the video frame for later coding. One month following the end of the study, parents were given the MacArthur Communicative Development Inventory: Words and Gestures (MCDI) (Fenson et al., 1993), to fill out and return to the lab.
Nine of the twelve subjects completed the MCDI within a week of their infants turning 15-months old and were included in analyses of early language development.

**Coding**

All coding was done using an SVHS video tape recorder (AG1980, Panasonic) with jog-shuttle controller to allow for frame-by-frame coding. Data were typed into Excel on a Macintosh G4 computer with columns for the time of the infant vocalization and the categories of infant vocal behaviors and maternal responses that were coded (see below). The middle 10 min. of the \( \frac{1}{2} \) hr play session was coded for infant vocal behavior and maternal responses to allow for a period of warm-up and to ensure that infants were not fatigued at the end of the 30-min session.

*Infant vocalizations* were coded for phonological properties using a broad classification that differentiates less developmentally advanced and more developmentally advanced vocalizations (Oller, 1980). We coded vocalizations that contained a consonant-like sound paired with a vowel-like sound as “CV” and vocalizations that contained just a vowel-like sound as “V”. Coding was based on the fact that parents readily identify differences between syllable-like and vowel-like vocalizations (Oller et al., 2001). We also coded the “directedness” of vocalizations based on the direction of infants’ visual gaze at the start of the vocalization. *Infant vocal directedness* categories included (see also Goldstein et al., 2010; Miller & Gros-Louis, 2013) (1) mother-directed (looking to their mother when they vocalize, including looking to mothers’ body, face or hands, with or without physical contact and eye contact is not necessary), (2) object-directed (looking to an object that they are holding or that is within reach when they vocalize), and (3) undirected (not focused on any object or mom, e.g., looking around the room). Given the broad definition of mother-directed vocalizations, we also assessed whether mother-directed vocalizations occurred with mother–infant mutual gaze.

*Maternal contingent responses* to infants’ vocalizations were coded. Contingent responses were defined as maternal vocal or nonvocal behaviors that occurred within 2 sec of the offset of infants’ vocalizations following prior studies (Goldstein & Schwade, 2008; Gros-Louis, West, Goldstein, & King, 2006). In addition, in coding pilot data, although responses often occurred within 1 sec of the offset of the vocalization, a 2 sec window ensured that we captured the majority of responses (see also Keller, Lohaus, Volker, Cappenberg, & Chasiotis, 1999). These contingent responses were classified as either (1) *sensitive*: acknowledge or imitate
below), comment and/or act on object in infant’s line of visual regard (Bornstein & Tamis-LeMonda, 1989; Tomasello & Farrar, 1986) or (2) redirective: comment and/or act on object outside of infant’s line of visual regard (Baumwell et al., 1997).

Maternal verbal responses were further coded in seven categories (following Gros-Louis et al., 2006): (1) acknowledgments (“mmm-hmm,” “uh-huh”), (2) attributions (“it’s pretty”), (3) directives (“push that”), (4) naming (“it’s a ball”), (5) play vocalizations (“gotcha!”), (6) questions (“do you want that?”), and (7) imitations/expansions (Gros-Louis et al., 2006). Imitations rarely took the form of imitating the sound that the infant made, but more often involved the mother modeling the word that the sound approximated and expanding on it (e.g., if the infant uttered “da-da-da,” the mother would say “Da-da is working. I am ma-ma.”).

The first author and four assistants trained in the coding procedure coded the observation sessions. Assistants were trained by the first author and had to reach 85% agreement across all behaviors before they coded independently. To calculate interobserver reliability, observers coded 2 of the 12 sessions for each of the 12 subjects. Average interobserver reliability was 87% for infant vocal directedness (mother-directed, object-directed, undirected), 90% for maternal contingent responses (sensitive versus redirective), and 85% for maternal vocal responses. Cohen’s $k$ ranged from .76 to .84 across these coding categories. The first author coded the broad infraphonology of vocalizations (consonant–vowel versus vowel-like). A second coder coded broad infraphonology of vocalizations for three subjects. Average interobserver reliability was 92%.

Analyses

Data from every two visits were combined to obtain monthly values for each infant. Monthly values were used in analyses. Correlations and repeated measures analysis of variance with Bonferroni corrections were done using PASW, SPSS Inc., Chicago, IL, USA Statistic 17 software. Where violations of sphericity occurred, Greenhouse–Geiser corrections were used. To examine the relationship between previous cumulative maternal responses and infant vocal production in the current visit, a generalized linear mixed model analysis was performed using the GLIMMIX, SAS Institute Inc., Cary, NC, USA procedure in SAS, version 9.1. This analysis was used to be able to account for the multiple responses over time for each infant. The model that was fitted is a logistic model (see Jaeger, 2008).
RESULTS

Preliminary analyses revealed no differences in total vocal production or directed vocalizations (mother-directed, object-directed, undirected) between males and females (all $p$’s > .3). Therefore, we collapsed the data across sex. We first report results for infant vocal behavior, then maternal responsiveness. Lastly, we assess the relationship between maternal responsiveness and changes in infant communicative and language measures. Descriptive data for infants’ directed vocalizations and maternal responsiveness to infants’ directed vocalizations are presented in Table 1.

Infant vocal behavior

Infants primarily produced nonverbal utterances consisting of vowel-like and consonant-vowel vocalizations, producing only a handful of words and word approximations during play sessions ($M = 2.8$, $SD = 2.5$). Infants significantly increased their overall production of vocalizations as they got older (Table 1). A 2 (time: first 3 months, last 3 months, within-subject) $\times$ 2 (vocal type: vowel-like, consonant–vowel, within-subject) repeated measures ANOVA found a significant main effect of time ($F(1,11) = 10.623$, $p = .008$, $\eta^2 = .491$), but no significant main effect of vocal type ($F(1,11) = 0.000$, $p > .9$). In addition, there was an interactive effect of time and vocal type ($F(1,11) = 6.359$, $p = .028$, $\eta^2 = .366$). Infants produced significantly more vocalizations in the last 3 months compared to the first 3 months ($M_{first3} = 85.0$, $SD = 66.1$ vs. $M_{last3} = 159.0$, $SD = 104.7$, $t(11) = -3.259$, $p = .008$). Specifically, there was a significant increase in consonant–vowel vocalizations between the first three and the last 3 months ($t(11) = -2.676$, $p = .022$).

Infants showed variation in their overall amount of vocalizing in addition to their attentional focus when they vocalized (Table 1 and Figure 1); however, the pattern of vocal directedness was not consistent across the 6 months. There was no association between the combined categories of object-directed and mother-directed vocalizations for the first 3 and the last 3 months ($r = .190$, $n = 12$, $p > .5$). Considering object-directed and mother-directed vocalizations separately, we found a significant difference in the average number of infants’ object-directed vocalizations for the first 3 months and the last 3 months ($t(11) = -2.405$, $p > .05$), but not for mother-directed vocalizations ($t(11) = -1.732$, $p > .1$), suggesting that infants’ ODV’s and MDV’s did not show similar changes over time. For the ten infants who produced mother-directed vocalizations in both the first month and last month to allow for comparison, infants’ mother-directed vocalizations involved more eye contact with mothers in the last month compared to the first month ($t(9) = 3.29$, $p < .01$).
<table>
<thead>
<tr>
<th></th>
<th>Month 1 Mean (SE) Range</th>
<th>Month 2 Mean (SE) Range</th>
<th>Month 3 Mean (SE) Range</th>
<th>Month 4 Mean (SE) Range</th>
<th>Month 5 Mean (SE) Range</th>
<th>Month 6 Mean (SE) Range</th>
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<tr>
<td>Infants Directed Vocalizing (frequency)</td>
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<tr>
<td>Mother-directed vocalizations</td>
<td>16.3 (4.4) 1–57</td>
<td>13.9 (4.7) 1–48</td>
<td>9.3 (2.3) 0–21</td>
<td>14.8 (3.6) 0–34</td>
<td>21.6 (4.4) 4–47</td>
<td>20.3 (6.0) 0–58</td>
</tr>
<tr>
<td>Undirected vocalizations</td>
<td>11.4 (2.4) 2–34</td>
<td>11.2 (2.9) 0–40</td>
<td>9.08 (2.5) 3–33</td>
<td>14.7 (4.1) 1–54</td>
<td>10.5 (1.7) 1–21</td>
<td>13.0 (3.9) 2–47</td>
</tr>
<tr>
<td>Object-directed vocalizations</td>
<td>29.1 (5.9) 3–78</td>
<td>33.7 (7.3) 9–103</td>
<td>33.3 (5.3) 12–63</td>
<td>48.4 (8.0) 17–122</td>
<td>51.8 (12.1) 11–153</td>
<td>40.8 (8.1) 8–98</td>
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<tr>
<td>Vowel-like vocalizations</td>
<td>33.5 (6.1) 9–88</td>
<td>45.1 (14.4) 10–188</td>
<td>29.7 (5.9) 4–58</td>
<td>32.7 (6.9) 10–78</td>
<td>38.2 (7.6) 7–108</td>
<td>65.3 (17.2) 15–230</td>
</tr>
<tr>
<td>Consonant-vowel vocalizations</td>
<td>23.8 (6.4) 1–70</td>
<td>13.9 (3.0) 0–28</td>
<td>24.0 (4.3) 4–55</td>
<td>46.2 (8.6) 9–107</td>
<td>48.1 (9.5) 6–110</td>
<td>87.7 (25.1) 8–271</td>
</tr>
<tr>
<td>Maternal Responsiveness to Directed Vocalizations (proportion)</td>
<td></td>
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<tr>
<td>Mother-directed vocalizations</td>
<td>.55 (.09) 0–1.0</td>
<td>.68 (.09) 0–1.0</td>
<td>.60 (.08) 0–1.0</td>
<td>.60 (.09) 0–1.0</td>
<td>.61 (.07) 0–.94</td>
<td>.62 (.11) 0–1.0</td>
</tr>
<tr>
<td>Undirected vocalizations</td>
<td>.43 (.10) 0–.86</td>
<td>.31 (.07) 0–.71</td>
<td>.51 (.09) 0–1.0</td>
<td>.39 (.09) 0–.89</td>
<td>.41 (.11) 0–1.0</td>
<td>.37 (.11) 0–1.0</td>
</tr>
<tr>
<td>Object-directed vocalizations</td>
<td>.38 (.06) 0–.73</td>
<td>.46 (.06) 0–.75</td>
<td>.44 (.07) 0–.86</td>
<td>.48 (.07) 0–.77</td>
<td>.48 (.07) 0–.78</td>
<td>.52 (.08) 0–.77</td>
</tr>
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</table>

*Note.* Two play sessions are combined for each month.
Maternal responsiveness

Over the 6 months, mothers responded, on average, to 17–83% of infants’ vocalizations. Although maternal responses were typically sensitive ($M = .71$, $SD = .11$, range = .41–.88, $n = 12$), mothers also ignored vocalizations ($M = .24$, $SD = .12$, range = .03–.51, $n = 12$) and responded redirectively to a small number of vocalizations ($M = .05$, $SD = .04$, range = 0–.14, $n = 12$).

The average proportions of the seven different maternal verbal response types produced per infant per month are presented in Table 2. A repeated measures analysis found significant differences in the proportion of maternal verbal response types, $F(2.302,25.321) = 3.297$, $p < .05$; however, applying Bonferroni corrections in pairwise comparisons yielded no significant pairwise differences. Examination of changes in maternal verbal responses over time, we found a significant increase in the overall proportion of maternal naming responses out of all possible responses ($M_{\text{increase/month}} = .03$, $SD = .01$; $p = .003$; Figure 2). Specifically, mothers produced more object names in response to infant vocalizations directed to objects. There was a significant increase in maternal naming in response to object-directed vocalizations between the first month (at 8 months) and last month (at 14 months) of the study ($t(11) = 4.34$, $p = .001$).

In addition to documenting wide variability across mothers in overall responsiveness, mothers showed differences in responsiveness relative to the directedness of infants’ vocalizations (Table 1 and Figure 3). Visual inspection of the proportion of responses to different infant-directed
vocalizations suggests that most mothers responded proportionally more to mother-directed vocalizations than to object-directed vocalizations. Object-directed vocalizations were by far the most frequent vocalization, but mothers responded to a significantly lower proportion of object-directed vocalizations than mother-directed vocalizations. Repeated measures analysis found significant variation in responsiveness to object-directed,

| TABLE 2 |
| Maternal Specific Vocal Responses |
| Month 1 | Month 2 | Month 3 | Month 4 | Month 5 | Month 6 |
| Mean (SE) | Mean (SE) | Mean (SE) | Mean (SE) | Mean (SE) | Mean (SE) |
| Maternal Vocal Responses (proportion) |
| Acknowledgements | .10 (.028) | .12 (.024) | .12 (.025) | .08 (.014) | .07 (.015) | .07 (.016) |
| Attributions | .04 (.006) | .04 (.009) | .02 (.005) | .03 (.005) | .03 (.006) | .03 (.009) |
| Directives | .05 (.018) | .03 (.013) | .04 (.012) | .04 (.009) | .06 (.013) | .02 (.008) |
| Imitation | .05 (.024) | .05 (.017) | .06 (.017) | .06 (.019) | .06 (.022) | .09 (.029) |
| Naming | .03 (.008) | .05 (.018) | .07 (.020) | .09 (.020) | .07 (.011) | .10 (.018) |
| Play vocalizations | .06 (.024) | .06 (.018) | .06 (.012) | .06 (.011) | .07 (.020) | .06 (.021) |
| Questions | .08 (.019) | .11 (.024) | .10 (.020) | .12 (.020) | .10 (.018) | .10 (.021) |

Note. Two play sessions are combined for each month.

Figure 2  Change in maternal naming responses over time as a proportion of all maternal responses across infants. Figure shows the mean and upper and lower 95% confidence intervals.
mother-directed and undirected vocalizations, $F(2, 22) = 25.043, p < .001, \eta_p^2 = .695$. Maternal responses to infants’ mother-directed vocalizations were significantly greater than responses to object-directed and undirected vocalizations (both $p$’s $\leq .001$). We explore potential effects of responsiveness on changes in directed vocalizations over time in the next section.

**Relationships between maternal responsiveness to infant vocalizations and communication**

Maternal responsiveness was related to changes in vocal usage over the 6-month study. Maternal overall responsiveness correlated with the relative increase in mother-directed vocalizations from the beginning of the study to the end of the study, measured as the difference in proportion of mother-directed vocalizations between the 8-month visit and the 14-month visit ($r = .814, n = 12, p < .002$). When examining month-to-month changes, however, increases in mother-directed vocalizations were not found. A repeated measures analysis of covariance (infants’ mother-directed vocalizations per month as the dependent variable and maternal responsiveness to mother-directed vocalizations as the covariate) did not find a main effect of mother-directed vocalizations $F(5, 50) = 1.094, p > .3$, but there was an interactive effect of mother-directed vocalizations and maternal responsiveness to mother-directed vocalizations, $F(5, 50) = 3.671, p < .008, \eta_p^2 = .269$. This suggests that the difference in mother-directed vocalizations across months is partly dependent on maternal responses to these vocalizations.

![Figure 3](image-url) 

Figure 3  Proportion of infants’ maternal-directed (MDV), object-directed (ODV), and undirected (UDV) vocalizations responded to by mothers.
Given the relationship between mother-directed vocalizations and maternal responsiveness, we next employed a generalized linear mixed model analysis to examine the relationship between previous maternal responding and current vocal behavior of an infant. We used maternal cumulative responding in the previous months’ visits as the explanatory value for infant current vocal production to reflect dynamic influences in mother–infant interactions as opposed to a static variable of overall maternal responsiveness. Results indicate that maternal sensitive responses in the previous month(s), rather than overall response rate, predicted an increase in infants’ mother-directed vocalizations in social interactions in the following month ($\ln[p/(1-p)] = -1.34\times 0.044\times \text{Percent sensitive responses} + 0.00783\times \text{Percent sensitive responses}^2\times \text{Percent sensitive responses}$, $p < .03$; Figure 4). That is, mothers’ responsiveness in month 1 predicted infants’ mother-directed vocalizing in month 2. Months 1 and 2 maternal sensitive responsiveness predicted infants’ mother-directed vocalizing in month 3, etc.

We next examined the relationship between mothers’ specific vocal responses and change in mother-directed vocalizing over time. Using a generalized linear mixed model analyses as above, we found that mothers’ imitation of their infants’ vocalizations in prior months related to an increase in infants’ mother-directed vocalizations in future months ($\ln[p/(1-p)] = -1.328\times 0.047\times \text{Percent imitative responses}$, $p < .04$).

Lastly, there was a significant positive association between maternal responses to mother-directed vocalizations and a relative increase in developmentally advanced consonant–vowel vocalizations from 8 to 14 months.

**Figure 4** The proportion of infant mother-directed vocalizations as a function of maternal responses to directed vocalizations in prior months.
of age \( (r = .58, n = 12, p < .05) \). That is, comparing maternal responses to mother-directed vocalizations across infants, infants who received proportionally more responses to their mother-directed vocalizations, showed a larger increase in developmentally advanced vocalizations from their 8-month visit to their 14-month visit.

**Correlations between maternal responsiveness to infant vocalizations and language measures**

For the nine infants for whom we obtained MCDI scores at 15 months of age, infants who received more maternal sensitive responses overall to their vocalizations scored higher on both vocabulary production and gesture on the MCDI at 15 months (vocabulary production: \( r = .77, n = 9, p < .02 \); gesture: \( r = .84, n = 9, p < .01 \)). We next explored the relationship between maternal responsiveness to infants’ directed vocalizations and language outcomes. When looking specifically at maternal responses to object-directed, mother-directed, and undirected vocalizations separately, we only found two significant negative correlations: maternal responsiveness to undirected vocalizations (UDV’s) was negatively correlated with vocabulary production and gesture production at 15 months of age (vocabulary production: \( r = -.78, n = 9, p < .02 \); gesture: \( r = -.76, p < .02 \)).

**DISCUSSION**

The results of this study suggest that maternal contingent, sensitive responses to infants’ directed vocalizations contribute to the emergence of vocal usage and the shaping of vocal development. By identifying that maternal contingent responses to prelinguistic vocalizations predict developmental change in vocal usage, this is the first study to validate previous experimental research suggesting that social shaping can act as a mechanism of communicative development (e.g., Goldstein & Schwade, 2008). One difference between this study and prior studies is that in this study we examined unstructured mother–infant behavioral interactions over a longer developmental period, providing support for social shaping in naturalistic settings. In addition, we identified the specific behaviors on which social shaping can operate. Rather than a steady overall increase in infant vocalizing and maternal responding, a dynamic relation between infants’ production of directed vocalizations and maternal responses underlies developmental change. Mothers’ sensitive responding to directed vocalizations predicted an increase in infant vocalizations directed to mothers over
time. In addition, we found a specific predictive relationship of prior maternal imitative responses and an increase in mother-directed vocalizations. This is consistent with findings from a recent meta-analysis of studies of the effects of maternal contingent verbal and vocal response on infants’ vocal production. Dunst, Gorman, and Hamby (2010) found that imitative responses, over and above comments and nonverbal responses such as smiling, predicted an increase in infants’ vocal production.

Evidence for a social shaping mechanism operating in communicative development parallels what has been found in songbirds, which are considered model species for human speech development (King, West, & Goldstein, 2005; Kuhl, 2003; Smith, King, & West, 2000; West & King, 1988). Similar to maternal responses to infant vocalizations observed in this study, female cowbirds’ nonvocal feedback (“wingstrokes”) produced contingently to males’ vocalizations resulted in a faster rate of vocal development (Smith et al., 2000; West & King, 1988). Furthermore, the directness of song (i.e., to a social partner) has been shown to be critical to communicative development and reproductive success in several songbird species (reviewed in Gros-Louis, West, & King, 2010). Similarly, earlier in vocal development, mother–infant mutual, coordinated engagement has been shown to be associated with more syllabic vocalizations (longer and more melodically complex), suggesting that interaction influences vocal production (Hsu & Fogel, 2001). The current study found that infants who received more maternal sensitive responses to their directed vocalizations showed a larger relative increase in phonologically advanced consonant-vowel sounds and mother-directed vocalizations. This suggests continuity over development in the role of interaction in eliciting vocalizations and responses that can shape vocal development.

The notion that caregivers can bootstrap infants to more sophisticated communicative behaviors through caregiver responses to vocalizations that are initially “directed” to caregivers or objects coincidentally is not new (cf Bruner, 1983; Collis, 1979; Harding, 1983; Locke, 1996). As infants receive feedback about the effectiveness of their vocalizations, they may increase vocalizations in combination with visual gaze (toward objects or social partners). This results in more advanced communication, in that the infants’ attentional focus can bring functionality and meaning to vocalizations (Golinkoff, 1986; Locke, 1996). Rich descriptive studies of toddler–mother communication indicate that children’s use of eye contact with speech indicates that an utterance is socially intended and directed to specific person (e.g., Bates et al., 1979; Schieffelin, 1983). Results from the current study suggest that these vocal pragmatic abilities may emerge from directed vocalizations and caregiver responsiveness during the prelinguistic period.
A similar role of social responses has been suggested to underlie the transition to communicative gestures out of initially self-directing behaviors (Iverson & Thal, 1998). An important point is that gestures initially influence caregivers’ behavior prior to infants’ intention to do so. It is through caregivers’ interpretation of, and responses to, these gestures that intentional communication can emerge (Carpendale & Carpendale, 2010; Jones & Zimmerman, 2003). Our findings are suggestive of a similar effect of caregiver responses to prelinguistic vocalizations on the development of mother-directed vocalizations.

One caveat that should be noted is that in the current study we specifically explored a possible predictive relationship of maternal responsiveness in prior months on infant behavior. It is likely, however, that infants influence maternal sensitivity over development, although in this study we examined the influence of maternal responsiveness in previous months on infant production of mother-directed vocalizations. Therefore, infants elicit particular caregiver responses, which in turn influence a change in infant behavior, feeding back on caregiver behavior. Prior studies have shown that infant and child characteristics clearly affect caregiver responses. In addition to infant stable characteristics such as child temperament (Crockenberg & Leerkes, 2003) and gender (Weinberg, Tronick, Cohn, & Olson, 1999), infant dynamic behaviors that are continually changing over development also have an effect (Vallotton, 2009). In one of the early studies identifying bidirectional effects between mother and infant behavior, Bell and Ainsworth (1972) documented that infants’ negative affect (crying) at 6 months results in mothers who responded less at 12 months; however, mothers who responded more immediately to infants’ cries at 6 months have infants who cry less at 12 months. In terms of positive communicative behaviors, Hsu and Fogel (2003) found effects of infant nondistress vocalizations on mothers in ongoing interactions (see also Gros-Louis et al., 2006). In addition to vocalizations influencing caregiver responses, infants’ pointing and infant signs are predictive of particular responses from caregivers (Vallotton, 2009). Thus, prelinguistic communicative behaviors differentially influence caregivers in the moment and over time, which should be taken into account in future studies.

Additional results showed that infants’ directed vocalizations, and maternal responses that are sensitive to infants’ attentional focus when they vocalize, are associated with early language measures. Infants who received more sensitive responses to vocalizations produced more words and gestures at 15 months of age. Clearly, we are limited in drawing firm conclusions based on the small sample size. Nonetheless, the findings are consistent with experimental and observational evidence that maternal responses that are related to infants’ attentional focus facilitate language
development (Baumwell et al., 1997; Rollins, 2003; Tamis-LeMonda et al., 2001; Tomasello & Farrar, 1986); however, in the current study, we examined maternal responses to infants’ directed vocalizations exclusively, that is, co-occurring vocal behavior and attentional focus, rather than considering maternal responses to infants’ ongoing nonvocal and/or vocal behaviors (e.g., Tamis-LeMonda et al., 2001). This is important in light of recent findings that suggest that object-directed vocalizations specifically may be an indicator of readiness to learn and are associated with word learning (Goldstein et al., 2010; see also Schieffelin, 1983). Our results extend this finding by identifying that infant object-directed vocalizations and maternal responses potentially interact to influence learning, given that maternal naming responses to infants’ object-directed vocalizations increased over time during a period when infants are learning first words (8–14 months). Responding to infants’ object-directed vocalizations helps infants make the link between the object and the potential label (cf Goldstein et al., 2010), or at the very least, helps infants to understand a potential communicative function of concurrent visual gaze and vocalizations.

A similar relationship between infants’ gestures and maternal responses has been found to facilitate language acquisition (Goldin-Meadow et al., 2007). Infants’ gestures in real-time interactions facilitate communication with caregivers. Infants’ pointing gestures indicate what they are interested in (Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004) and elicit verbal responses from caregivers (Goldin-Meadow et al., 2007; Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2007). Caregiver responses provide descriptions of objects that infants are attending to, “translating” infants’ requests, comments, etc., thus facilitating the acquisition of two-word speech (Goldin-Meadow et al., 2007). The results of the current study suggest that prelinguistic directed vocalizations, which precede pointing but could nonetheless direct adults’ attention (“pointing with the eyes”-Streeck, 2009), may potentially serve the same function.

The results of this study indicate a dynamic process in the development of pragmatic usage of vocalizations and language development facilitated by maternal responses to infants’ directed vocalizations. Thus, the current study and comparative work in songbirds provide direct evidence that a social shaping mechanism can drive communicative development (Kuhl, 2003). Given that we now know that social feedback to vocalizations is an underlying mechanism for developmental change, it is important to identify the potential for social interactions, in addition to characteristics of interactions, with social partners in different social environments. A concept that was developed from research on songbirds is the “social gateway”: different social environments offer different opportunities for
interactions with social partners, which can affect individuals’ behaviors and responses to those behaviors (White, King, Cole, & West, 2002). We propose that the social gateway provides a useful construct for examining how social interactions between infants and social partners (caregivers, parents, siblings) vary across social environments. Interactions and related contingencies in every day contexts may vary considerably with socio-economic status or birth order. For example, children who “inherit” an older sibling have additional models for acquiring speech sounds as compared to first-born children (West, King, & Arberg, 1988). Additionally, different social partners may provide different contingencies.

One limitation of the current study is that we only examined infants’ interactions with their mothers. Preliminary analyses of caregiver responsiveness to prelinguistic vocalizations have documented similar levels, but different types, of maternal and paternal responses to infants’ directed vocalizations (Gros-Louis & Wu, unpublished data). In addition, although we had a diverse sample, we could not examine effects of birth order or SES, which are known to influence language and communicative development (e.g., Fenson et al., 1994; Hoff-Ginsberg, 1998). Thus, a more detailed examination of the social interactions in which social shaping can operate is needed to determine how different social partners influence variability in developmental outcomes. In addition, because the sample size was extremely small, future research should examine social contingencies across contexts and social partners in a larger sample. Data from a broader sample could contribute to the formulation of a model of communicative development that captures the variability in interactions and contingencies present in different social environments.

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