International Journal of Behavioral Development
2006, 30 (6), 509–516
http://www.sagepublications.com

ijbd

DOI: 10.1177/0165025406071914

Mothers provide differential feedback to infants' prelinguistic sounds

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Few studies have focused on mechanisms of developmental change during the prelinguistic period. The lack of focus on early vocal development is surprising given that maternal responsiveness to infants during the first two years has been found to influence later language development. In addition, in a variety of species, social feedback is essential for vocal development. Previous research demonstrated that maternal feedback to prelinguistic vocalizations influenced the production of more developmentally advanced vocalizations, suggesting that effects of maternal responsiveness on vocal development may start during the prelinguistic phase; however, because mothers were instructed how and when to respond to their infants' vocalizations, the timing and type of typical maternal feedback is unknown. In the present study, we analyzed unstructured play sessions for 10 mother–infant dyads to explore the relationship between prelinguistic vocal production and maternal responsiveness. Mothers responded contingently to prelinguistic vocalizations over 70% of the time. Mothers responded with more vocal responses compared to interactive responses (e.g., gazes, smiling, physical contact). Investigation of specific types of vocal responses revealed that mothers responded mainly with acknowledgments to both vowel-like sounds and consonant–vowel clusters. Mothers also showed differential responding to vocalizations that varied in quality. Mothers responded with play vocalizations to vowel-like vocalizations significantly more than to consonant–vowel clusters, whereas they responded with imitations to consonant–vowel clusters more than to vowel-like sounds. Mothers, therefore, appeared to regulate their contingent feedback relative to the speech-like quality of infants' vocalizations which may provide relevant stimulation to guide communicative development.

Keywords: infant; maternal responsiveness; prelinguistic; social feedback; vocal development

Introduction

Although infants spend the first year producing a wide range of prelinguistic vocalizations that have the infraphonological qualities of adult speech (Oller, 2000), few studies have focused on possible social mechanisms of vocal development. Behavioral responses of social partners can encourage the production of particular vocalizations, but such influences on vocal development likely have not been focused on because vocal production is considered to be related to internal maturational programs not subject to environmental influence (Bloom, 1993; Kent, 1981; Lenneberg, 1967). In addition, because babbling traditionally has been presumed to serve as motor practice to produce adult-like sounds, prelinguistic sounds have not been considered functionally important in and of themselves (Kent, 1981; Oller, 2000).

Until recently, the only proposed mechanism of vocal development was imitation (Papousek & Papousek, 1989). Not only can parents imitate various acoustic aspects of their infants' sounds during social interactions (Papousek, 1992), infants can also imitate different acoustic features of adult speech (Kessen et al., 1979; Kuhl & Meltzoff, 1996). While imitation could provide infants with contingent reinforcement of particular sounds (Papousek, 1992), a review of vocal development in other species reveals that imitation plays a limited role in vocal development; rather, social interactions and the responses of conspecifics influence vocal development through the introduction of new sounds and encouragement of improvisation (Snowdon & Hausberger, 1997). Therefore, a more general mechanism grounded in social interactions may also play a role in infant vocal development but the possible influence of social context on prelinguistic vocal development rarely has been explored (Vihman, 1996).

Results of a study by Goldstein, King and West (2003) provide suggestive evidence for the role of parental social interaction in vocal development. In this study, the experimenter instructed mothers when to respond to their infants' vocalizations. Half of the mothers, the contingent group, were told to respond contingently to their infants' vocalizations with non-vocal, social responses such as smiling or touching. The other half of the mothers, the yoked control group, were told to respond based on the response schedules of the mothers in the contingent group. Infants who received social feedback that was contingent on their vocalizations, compared to infants who received feedback independent of when they vocalized, produced more developmentally advanced vocalizations during the manipulation and after maternal responding was no longer being manipulated (Goldstein et al., 2003; see also

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JGL was supported by an NICHD Ruth L. Kirschstein postdoctoral National Research Service Award. MHG was supported by a pre-doctoral NIMH Research Service Award and by the Center for the Integrative Study of Animal Behavior at Indiana University. The work was also supported by NSF grants to MJW and APK. Sarah Cummings, Ryan Craft and Elizabeth Menig assisted with coding. We would like to thank Linda B. Smith for comments on the manuscript.

Bloom, Russell, & Wassenberg, 1987). Hsu, Fogel and Messinger (2001) found similar results in studies of unstructured mother–infant interactions. Infants produced more syllabic, speech-like vocalizations when mothers were smiling and making eye contact with them. Because mothers' responses were non-imitative in these studies, the results indicate that infants are sensitive to other forms of maternal feedback.

The study by Goldstein et al. (2003) demonstrated that the contingency of caregivers' responses to infant vocalizations in naturalistic social interactions influenced infant vocal production in a developmentally meaningful way; however, the study was experimental in that mothers were told when to respond to infant vocalizations (contingently or non-contingently). Furthermore, mothers responded to all types of vocalizations independent of their quality. If maternal responsiveness serves as a mechanism for vocal development, one thing that needs to be determined is whether caregivers provide consistent, predictable responses to infants' vocalizations during naturally occurring interactions.

Locke (1996) suggested that prelinguistic sounds, in addition to social interactions that accompany vocal production such as turn-taking and joint attention, could elicit proximate responses from caregivers that influence communicative development. Through parents' responses, infants will learn the association between the production of certain sounds and subsequent interactions with caregivers. In addition, parents' input during social interactions and early conversation are thought to scaffold language learning by providing information about activities and objects that are the focus of the infants' attention (Bruner, 1977; Tomasello, 1992). A review of comparative research in avian and primate species indicates a similar mechanism. Immature vocalizations and proximate responses to them form the foundation for communicative development. Vocalizations elicit social interactions from conspecifics and social feedback to immature vocalizations is a systemic influence on vocal development (King, West, & Goldstein, 2005; Marler & Nelson, 1993; Snowdon & Hausberger, 1997; West & King, 1988). The current study seeks to document how mothers respond to their infants' vocalizations during naturalistic social interactions to determine whether mothers show specificity in their responses to different vocal types, thereby providing structured feedback through social interactions.

Adults' sensitivity to differences in prelinguistic vocalizations suggests the possibility that adults may respond differentially to such sounds (but see Hsu & Fogel, 2003). Many studies of adult perception of infant vocalizations indicate that adults distinguish them in a way that tracks their salient features. Adults first perceptually distinguish different cries and the emotional content of non-vegetative vocalizations (cries: Green, Jones, & Gustafson, 1987; quasi-voiced vocalizations: Papousek, 1989; Papousek, 1992). As vowel-like vocalizations become differentiated between 3–5 months, adults show a preference for fully voiced, "syllabic" vocalizations (Bloom, D'Odorico, & Beaumont, 1993; Bloom & Lo, 1990), compared to "vocalic" sounds that are shorter in duration, less melodically complex and have more nasal resonance (Hsu, Fogel, & Cooper, 2000; Masataka & Bloom, 1994). Furthermore, adults see infants as "really talking" and more intentionally communicative when they produce "syllabic" sounds (Beaumont & Bloom, 1993). Between 7–11 months, parents classify vocalizations with distinct acoustic features as emotive or communicative (Papaeliou, Minadakis, & Cavouras, 2002). Furthermore, mothers are able to categorize vocalizations of even unfamiliar infants consistently (Goldstein & West, 1999). Finally, when infants begin to produce their first well-formed consonant–vowel sounds, canonical syllables, parents can readily identify these vocalizations (Oller, Eilers, & Basinger, 2001).

Given that caregivers perceive different vocal types, they may function to elicit different proximal responses, which is necessary if maternal responsiveness plays a role in vocal development. Studies of maternal responsiveness during social interactions indicate that mothers show a wide variety of consistent responses to infants' vocal and social behaviors (e.g., Bornstein et al., 1992; Tamis-LeMonda, Bornstein, & Baumwell, 2001), which influence later language development. In these studies, because all "non-distress" prelinguistic vocalizations were grouped together, it was unclear whether maternal responses to vocalizations were the same regardless of the type of vocalization the infant produced.

The specificity of maternal responses to prelinguistic vocalizations that vary in speech quality typically have been conducted during the first few months of life or have looked at maternal responsiveness to distress vs. nondistress vocalizations through the first year. Few studies have looked at maternal responsiveness to nondistress vocalizations that vary in speech quality during the second half of the first year, a time at which infants are developing a full range of prelinguistic sounds, including speech-like canonical syllables (Oller, 2000). Given the findings of Goldstein et al. (2003), who identified the importance of contingent responding and the production of advanced vocal types in infants aged 6–10 months old, one purpose of this study was to determine the frequency and type of contingent responses of mothers to infant vocalizations during naturally occurring social interactions. In addition, because of the importance of maternal responsiveness to language development, the second purpose of the study was to determine the linguistic variation in mothers' vocal responses relative to infant vocalizations that differ in speech quality. Vocal exchanges were examined during naturally occurring social interactions between mothers and infants aged 6–10 months, to determine the specificity of maternal responses to prelinguistic vocalizations.

Method

Procedure

Participants had been in a study conducted by Goldstein et al. (2003). Participants were recruited from birth announcements in the local newspaper. They were first contacted by letter and then by telephone and invited to participate. Of the 30 mother–infant dyads that had participated in the Goldstein et al. study, data were coded and analyzed for 10 of them in the present study. These dyads were selected based on infants' vocal repertoire size and their total amount of vocal production during the session. Infants had to meet the following two criteria for inclusion in the study to ensure that each infant had enough vocalizations to allow for categorization of different maternal responses to them (see Coding below): 1) infants had to produce a minimum number of vocalizations equal to one standard deviation below the mean, and 2) of the infants who produced a large enough number of vocalizations to be included, those who produced at least four of each of the following prelinguistic vocalizations were selected: vocalizations with quasi- and fully-resonant nuclei, marginal and canonical syllables. Some infants also produced reduplicated babble, but this was not required for inclusion in analysis. Infants produced an average of 50.2 ± 8 vocalizations in the ten minutes of interaction that were coded.

The ten dyads whose data were analyzed for this study included six mother–daughter pairs and four mother–son pairs (mean = 8 months, 27 days; range = 7 months, 24 days to 10 months, 9 days). Nine of these dyads were Caucasian and one was Hispanic. Socioeconomic information was obtained for six of the ten mothers. Their mean SES status based on the Hollingshead four-factor index was 37.9 ($SD = 18.8$). Four of the infants were firstborn, while the remainder had at least one older sibling (range 1–3). All infants were full-term with no known developmental delays and all had normal hearing, based on hearing screenings done at birth.

In the Goldstein et al. (2003) study, mothers and infants participated in two, half-hour unstructured play sessions in a large playroom (4.5 × 3.2m) on consecutive days. Mothers were instructed to play with any of the toys available in the playroom as they would at home. The first day served as a familiarization session. The second day's play session was the focus of the Goldstein et al. study, but the first ten minutes consisted of unstructured free play. These first ten minutes of the second day's play session were coded for this study. Behavioral interactions were recorded using one of three remote-controlled wall-mounted cameras (SONY TR-100 handycam) routed through a video mixer (Videonics MX-1, Focus Enhancements) to allow for selection of the best camera angle. High-quality audio recordings were made using a wireless microphone (FMR-150, Telex Communications) sewn into overalls worn by the infant.

Coding

Infant vocalizations were coded based on their infraphonological properties (see Goldstein et al., 2003; Oller, 2000). Vocalizations were coded in the following categories:

1 quasi-resonant vocalizations lacking full resonance and formant structure;
2 fully-resonant vowels with full resonance and a clear formant structure;
3 marginal syllables (long consonant–vowel transitions, > 200ms) with either quasi- or fully-resonant nuclei;
4 canonical syllables (rapid CV transition, 25–150ms);
5 reduplicated babble (sequence of repeated canonical syllables); and
6 other (e.g., cry, laugh, vegetative sounds).

Vocalizations that occurred in bouts with perceivable silence in between were coded as separate vocalizations. For the purposes of this study, vowel-like vocalizations were combined ('V', categories 1 and 2) and those that consisted of a consonant and a vowel ('CV', categories 3–5). Bouts of vocalizations with no perceivable silence in between vocal elements ('babbling') were coded as "CV" if they contained at least one CV vocalization, otherwise, they were coded as "V". Our choice of V and CV categories represent less developmentally advanced and more developmentally advanced vocalizations (Oller, 2000). In addition, vowel-like sounds lack the consonantal component of marginal and canonical syllables, which provides a perceptually salient difference between the two categories of vocalizations (Oller et al., 2001).

Behaviors were coded as contingent responses if they occurred within 2 sec of the onset of the infant's vocalization because in coding pilot data, responses typically overlapped or occurred within less than 1 sec of the offset of the vocalization (see also Beebe, Jaffe, Feldstein, Mays, & Alson, 1985; Keller, Lohaus, Voelker, Cappenberg, & Chasiotis, 1999; Schaffer, Collis, & Parsons, 1977). A number of codes were selected to classify the behavior of mothers and infants. Behaviors were divided into five mutually exclusive categories:

1 object-related nonvocal: behaviors involving an object (manipulating, showing, getting a toy, looking at a toy);
2 object-related vocal: any object-related response accompanied by a vocal or verbal response;
3 interactive-nonvocal: face-to-face interaction with the infant involving eye contact and/or physical contact (smiling at, touching, picking up);
4 interactive-vocal: any interactive response accompanied by a vocal or verbal response;
5 vocal/verbal: any vocal or verbal response that occurred in the absence of an object or interactive response.

Maternal vocalizations/verbalizations were further subdivided into the following seven categories: 1) naming; 2) questions; 3) acknowledgments; 4) imitations; 5) attributions; 6) directives; and 7) play vocalizations; (see Table 1 for definitions and examples). Imitations took the form of imitating the sound that the infant made (as closely as possible), and often involved the mother modeling the word that the sound approximated and expanding on it (e. g., if the infant uttered "mmaaaa," the mother would say "Ma-ma. Yes, I am ma-ma."). The first four categories of maternal verbal responses were considered language-expectant because they either provide distinct referential information in a labeling context (naming), verbal modeling of adult speech, or verbal input that provides the framework for conversational exchange (questions, acknowledgments). The last three response categories (directives, attributions and play vocalizations) were considered to be language non-expectant because they do not provide direct feedback about linguistic forms or provide structure that encourages conversational exchange.

The first author and two assistants trained in the coding procedure coded tapes. To calculate interobserver reliability, observers coded 20% of the tapes for the 10 subjects (2 min of each 10 min session). Average interobserver reliability was 85% for maternal responses (Cohen's kappas ranged between 0.73–0.85).

Data analysis

Inspection of maternal response types revealed a non-normal distribution and heterogeneity of variance (Shapiro-Wilks tests, p's < 0.05; Levene's test, p's < 0.05). Therefore, arcsine square root transformations were performed on the dataset prior to analysis. Repeated measures ANOVAs were used throughout, with Tukey's *HSD* used in post-hoc comparisons. To examine individual differences in patterns of maternal responses, both vocal types (V and CV) were summed prior to analyses. Binomial tests, one-sample chi-square analyses and correlations were performed. For binomial and chi-square analyses, chance levels of maternal responses were considered to be equal across all possible response types. Therefore,

Table 1
Definitions and examples of maternal vocal/verbal responses

Maternal response	*Definition*	*Examples*
Naming	Supplying a label for something	"That's Eeyore." "It's a cup."
Questions	Asking the infant a question	"Do you want to play with it?" "Can you clap?"
Acknowledgments	A "filler" comment that is conversational as if the infant is saying something	"Mmm-hmm." "Oh really?"
Imitations	Approximation of an infant vocalization and/or expansion based on the word the infant vocalization sounded like	"Ba-ba." "Ma-ma. Yes, and da-da is working."
Attributions	Attributing some characteristic or value to an object	"It's like the truck at home." "That's your favorite."
Directives	Instruction to the infant to do something	"Look at the doll." "Put the block in the box."
Play vocalizations	Sound effects; singing	"Vroom-vroom."

maternal responses were summed within each dyad and divided by the total number of response categories to obtain an expected value. Statistical analyses were conducted using SPSS version 11 (Chicago, IL, USA). All statistical tests are two-tailed.

Results

Background

Infants produced an average of 34.1 ± 5.4 vowel-like sounds and 12.8 ± 3.0 consonant–vowel sounds. Given the purpose of the study, to determine the contingency and specificity of maternal responses to their infants' vocalizations, analyses focused on the contingency, type and specificity of the 351 maternal responses that were scored to infants' vocal behavior.

Contingency of maternal responses

Mothers responded contingently to vocalizations 73% of the time, significantly more than they remained unresponsive ($t(10) = 3.588$, $p < 0.007$). This finding was consistent when maternal responses to vowel-like and consonant–vowel vocalizations were examined independently (V: $t(10) = 2.4$, $p < 0.05$; CV: $t(10) = 6.4$, $p < 0.001$). Mothers showed differentiated responses to infant vocalizations ($F(4, 36) = 2.956$, $p < 0.04$, $\phi = 0.73$; Fig. 1). Although mothers appeared to respond with vocal responses more than any other type of response, post hoc comparisons showed that mothers only responded

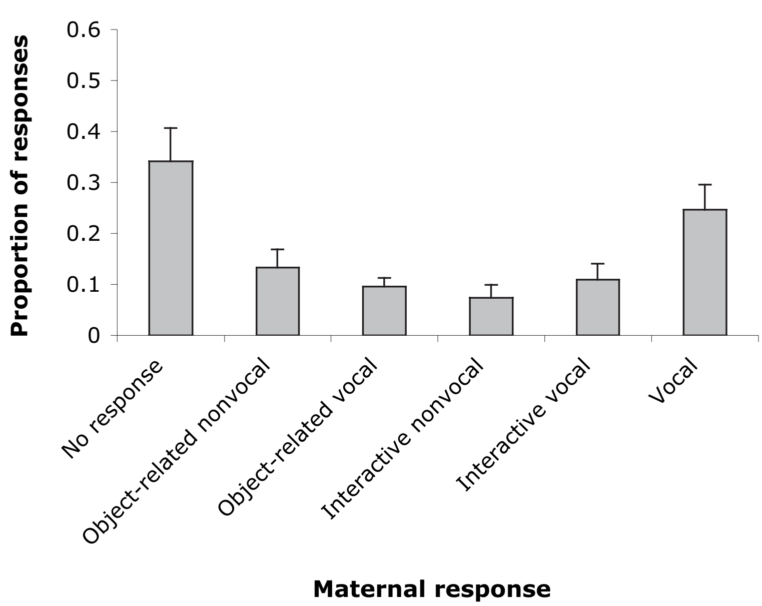

Figure 1. The proportional distribution (mean + SE) of broad maternal responses to infant vocalizations.

with vocal responses significantly more than interactive responses (mean = 0.25 ± 0.05 vs. 0.07 ± 0.03; Tukey's *HSD*, $\alpha = 0.05$).

Binomial tests revealed that six of the ten mothers responded to vocalizations significantly greater than chance (all *p*'s < 0.04). In addition, mothers who were more responsive also responded to a higher proportion of consonant–vowel vocalizations (Pearson $r = .825$, $p < 0.007$).

Broad maternal responses to specific vocal types

Maternal responses differed relative to the type of vocalization the infant produced. There was an interaction between maternal response type and infant vocalization ($F(3, 27) = 3.799$, $p < 0.03$, $\phi = 0.754$; Fig. 2). Post-hoc analyses revealed that mothers were more likely to respond with interactive-vocal responses when infants produced consonant–vowel clusters than when they produced vowel-like sounds (mean = 0.39 ± 0.09 vs. 0.15 ± 0.04; Tukey's *HSD*, $\alpha = 0.05$).

Specific maternal vocal responses to specific vocal types

Given that mothers generally responded mainly with vocal responses to infant vocalizations, the nature of the vocal responses given to each of these vocal types was analyzed. Mothers responded differentially to vowel-like and consonant–vowel vocalizations. An interaction effect was found between vocal type and maternal response ($F(5, 45) = 3.601$, $p < 0.009$, $\phi = 0.889$; Fig. 3).

Comparing different maternal responses to both vocal types revealed that mothers generally responded to their infants' vocalizations mainly with acknowledgments. However, when infants produced vowel-like sounds, mothers produced acknowledgments and play vocalizations with almost equal frequency (0.24 ± 0.06 vs. 0.20 ± 0.04). By contrast, when infants produced consonant–vowel clusters, mothers produced acknowledgments three times as often as the next most frequent category, imitations (0.42 ± 0.09 vs. 0.14 ± 0.06). Inspection of maternal response types across different vocal types revealed significantly different patterns of responsiveness relative to the speech quality of infant vocalizations. When infants produced vowel-like vocalizations, mothers responded almost three times as often with play vocalizations, significantly more than they did when infants produced consonant–vowel clusters (mean proportion = 0.20 ± 0.04 vs. 0.07 ± 0.03; Tukey's *HSD*, $p < 0.05$). By contrast, mothers were more likely to imitate and expand on consonant–vowel vocalizations compared to vowel-like vocalizations. Mothers imitated consonant–vowel vocalizations more than eight times as often as they imitated vowel-like vocalizations (0.14 ± .06 vs. 0.02 ± 0.01, Tukey's *HSD*, $p < 0.05$).

Only seven of the ten mothers had a large enough sample to investigate individual patterns of specific maternal responsiveness. Results of chi-square analyses revealed that six of these seven mothers showed patterns of vocal/verbal responses that differed significantly from chance levels of responding (all *p*'s < 0.05).

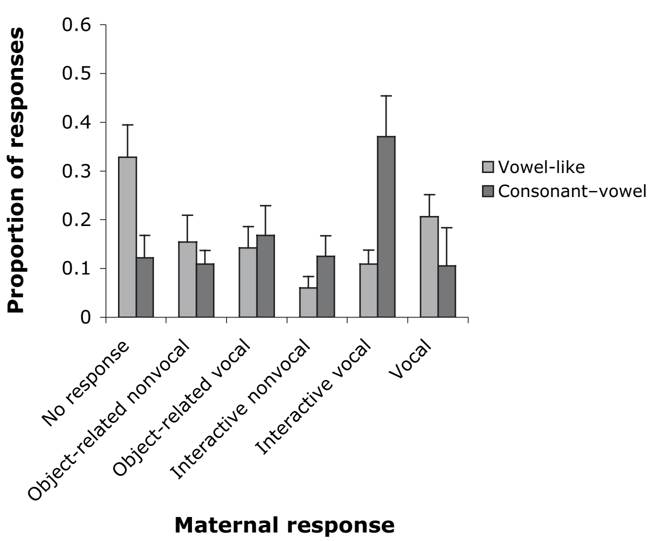

Figure 2. The proportional distribution (mean + SE) of different types of broad maternal responses to infants' vowel-like vocalizations and consonant–vowel syllables.

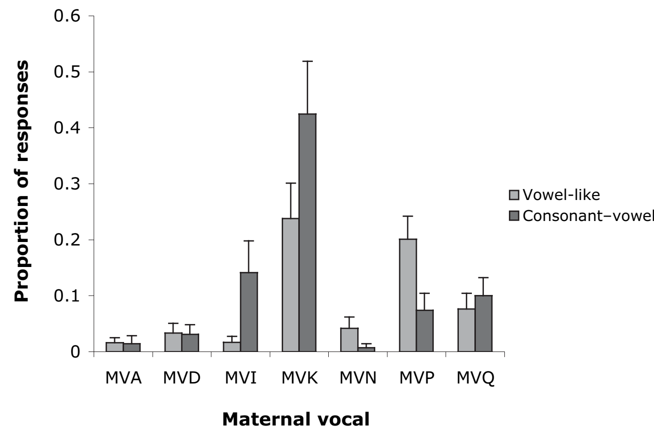

Figure 3. The proportional distribution (mean + SE) of different types of maternal vocal responses to infants' vowel-like vocalization and consonant–vowel syllables. MVA = attribution; MVD = directive; MVI = imitations; MVK = acknowledgments; MVN = naming; MVP = play vocalizations; MVQ = questions.

Language-expectant verbal responses

After combining maternal response categories into those that are language-expectant (questions, naming, acknowledgments, imitations) and those that are language non-expectant (attributions, directives, play vocalizations), analyses demonstrated that mothers differentiated their responses to consonant–vowel, but not vowel-like, vocalizations. Mothers responded to consonant–vowel vocalizations over 75% of the time with language-expectant responses significantly more than they responded with language non-expectant responses (CV: Wilcoxon signed-ranks $T = 2.5$, $n = 10$, $p < 0.02$). By contrast, mothers showed no differences in response types when infants produced vowel-like vocalizations (V: Wilcoxon $T = 14$, $n = 10$, $p > 0.3$; Fig. 4).

Discussion

The results of this study complement those of Goldstein et al. (2003) by demonstrating that mothers naturally provide not only contingent responses to vocalizations, but also responses

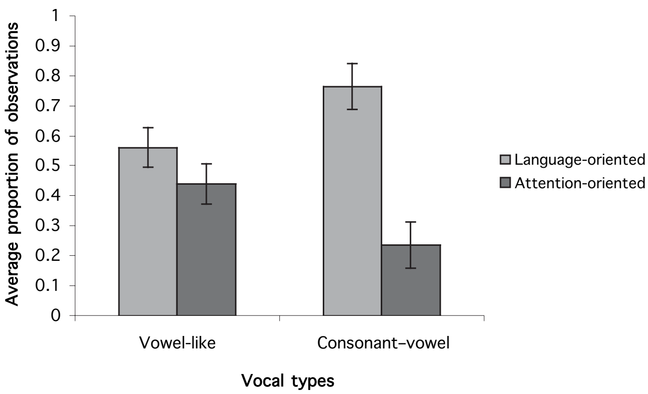

Figure 4. Maternal language-expectant and language non-expectant responses to infants' vowel-like vocalizations and consonant–vowel syllables.

that are specific to particular vocal types. Such differentiation could serve to scaffold vocal development (Bruner, 1977). Mothers provide distinct verbal feedback to vowel-like and consonant–vowel vocalizations, which differ not only in acoustic features, but also reflect different developmental stages of vocal production (Oller, 2000; Stark, 1980). For example, mothers respond with interactive-vocal responses significantly more to consonant–vowel clusters than to vowel-like sounds. Goldstein et al. (2003) found that such interactive, proximate responses resulted in an increase in the production of more developmentally advanced vocalizations. Co-occurring maternal responses, such as interactive-vocal responses, in addition to contingency itself, provide some information to the infant about the "effectance" of infants' vocal production (Locke, 1999). Through differential maternal responding, mothers encourage the use of particular sounds, giving them meaning and framing the interaction.

An examination of specific types of maternal verbal responses reveals mothers' apparent assessment of the information in their infants' vocalizations (cf. Owings & Morton, 1997). Maternal responses, in turn, provide infants with information about the "meaning" of their vocalizations and can influence vocal development. Prior research has shown that particular types of maternal responses, such as imitations and expansions correlate positively with language development (Girolametto, Weitzman, Wiigs, & Pearce, 1999; Tamis-LeMonda et al., 2001), while others, such as directives, have been shown to correlate negatively with language development (Tomasello & Todd, 1983). In this study, vowel-like sounds appeared to be interpreted by mothers as more expressive than consonant–vowel clusters, as indicated by the observations that mothers responded with play vocalizations significantly more to vowel-like sounds. By contrast, mothers responded to consonant–vowel vocalizations with imitations significantly more than they did to vowel-like sounds. The fact that mothers imitated and expanded on more developmentally advanced vocalizations more than vowel-like sounds suggests that the infants' sounds are meaningful to the mother and she encourages the infant to repeat particular sounds (Papousek & Papousek, 1989; Tamis-LeMonda et al., 2001). In addition, mothers tended to respond to vocalizations, particularly consonant–vowel clusters, mainly with acknowledgments (e.g., "oh really?"; "is that so?"), which is the most conversational response type. Mothers responded to vocalizations as if the infant were really saying something, which provides the infant with information that vocalizations can elicit vocal exchange. Therefore, mothers serve as "gatekeepers" of what information is available to be learned through their selective feedback, which can influence the structure of social interactions.

Given the finding that mothers are highly responsive to infant vocalizations during naturally occurring interactions (see also Keller et al., 1999), the question arises as to how consistent, contingent feedback relates to vocal development. To answer this question, it is important to consider that just as language development is embedded in social interactions (Bruner, 1983; Locke, 1993), so is prelinguistic communicative development (cf. Bornstein, 1996; Bullowa, 1979; Reddy, 1999). The parallels drawn between vocal development in humans and birds provide a comparative framework that has thus far proven useful in thinking about general mechanisms of vocal development (Goldstein et al., 2003; Kuhl, 2003). A comparison of observations of birds with those of infants suggests that social interactions involving vocal and non-vocal contingent feedback from others are important for the development of acoustic features of vocalizations.

Similar to Goldstein et al.'s (2003) observation that the quality of infant vocalizations changed in response to social feedback (see also Hsu et al., 2001), vocal development in some bird species shows similar mechanisms (King et al., 2005; Marler & Nelson, 1993; West & King, 1988). Early in development when males are producing immature and variable song, social reinforcement plays a role in shaping vocalizations. In the white-crowned sparrow (*Zonotrichia leucophrys*), for example, males produce a wide variety of song themes prior to producing crystallized song. Males will retain and refine only some of the songs that they sing during the phase of plastic song, a period during which males produce poorly articulated, variably organized elements of crystallized song. This process is mediated through social feedback from neighbors in the form of vocal responses (Marler & Nelson, 1993; Nelson & Marler, 1994). A different form of social feedback, more similar to that seen in the infant vocal development study by Goldstein et al. (2003), plays a role in vocal development of male song in cowbirds (*Molothrus ater*). Non-singing females provide visual feedback to a male's song in the form of a rapid flick of their wing, termed a wing stroke (West & King, 1988). Female wing strokes serve as social reinforcement for effective song and song elements during development when males are producing highly variable immature song. Males tend to repeat and retain songs that have received positive social feedback.

Responses to prelinguistic vocalizations may provide a similar mechanism for prelinguistic vocal development. Consistent, contingent feedback to infant vocalizations has been shown to be related to the achievement of several language milestones in the second year (Nicely, Tamis-LeMonda, & Bornstein, 1999; Rollins, 2003; Tamis-LeMonda et al., 2001). Prior to language, however, infants produce a variety of sounds that are part of a developing communicative system. Between 5 and 10 months, infants begin to produce canonical syllables that reflect acoustic patterns of adult-like speech and are easily recognized by parents (Oller, 2000; Oller et al., 2001). As infant vocalizations become increasingly differentiated in the second half of the first year of life (Oller, 2000), they serve as a springboard for more variable interactions and the infant may, in fact, "guide" maternal responsiveness (see West & Rheingold, 1978). In turn, differentiated maternal responsiveness relative to the speech quality of infant vocalizations may influence vocal development. Recent investigations support the suggestion that contingent positive social feedback to infants' vocalizations influences and may advance prelinguistic vocal production (Goldstein et al., 2003; Hsu et al., 2001; see also Routh, 1969).

The results of the current study, in combination with those of Hsu and Fogel (2003), suggest that the development of maternal responses mirrors changes in acoustic components in infant vocalizations. During the first six months of life, infants begin to differentiate sounds in terms of their resonance and place of articulation (Hsu et al., 2000; Masataka & Bloom, 1994). These sounds appear to be differentiated by adults, given the fact that adults' attribution of characteristics, such as attractiveness, sociability and intentionality, varies with the speech quality of the vocalizations (Beaumont & Bloom, 1993; Bloom & Lo, 1990; Bloom et al., 1993). Nonetheless, in contrast to our findings in the current study, Hsu and Fogel (2003) found that mothers do not respond differentially to these sounds. Hsu and Fogel (2003) suggested that mothers may perceptually differentiate these sounds, but they may not interpret different meaning in these sounds based on the acoustic characteristics used for classification by observers; rather, "meaning" is interpreted through melodic tones of vocalizations, which are salient features of vocalizations in the first months of life (Hsu et al., 2001). The results from the present study suggest that parents may shift from ascribing meaning to melodic tones to ascribing meaning to sounds based on their articulated quality during the second half of the first year of life. This shift is possibly because babbling and early speech share acoustic features (Nathani & Oller, 2001) and consonant–vowel clusters are readily identified by adults as speech-like (Oller, 1980; Oller et al., 2001).

One limitation of the present study is that it focused exclusively on the responses of mothers to infants' vocalizations to try to determine a specific mechanistic component of vocal feedback that might influence vocal development, without considering the responses of infants, in turn, to mothers' responses. Although this study simplified mother–infant interaction to look at the specificity of maternal verbal responses, we are not suggesting that infant vocal development is based on mere stimulus-response associations. Mother–infant interactions clearly are multidimensional and involve many more variables that can influence the dynamics of the interaction and vocal development itself. Many studies have shown that the evolution of dyadic interactions involves the mutual influence of mother and infant behavior; each partner influences the actions of the next in many different facets of mother–infant interaction (Cohn & Tronick, 1988; Papousek & Papousek, 1989; Trevarthen, Kokkinaki, & Fiamenghi, 1999). Aside from such bi-directional influences within particular domains, Hsu and Fogel (2003) point out that the change process that is involved in ongoing social interaction contributes to infants' learning about meaning and content (see also Keller & Scholmerich, 1987). The specific content of maternal responses and how they accommodate the infants' attentional focus (cf. Bornstein et al., 1992; Rollins, 2003) are extremely important, given the role of joint attention on further language development (e.g., Tomasello & Farrar, 1986).

The results of the current study and comparative work in birds suggest that immature vocalizations should be considered to play a role in communicative and vocal development, rather than merely representing stages of vocal development. Regardless of intentionality on the part of the infant to communicate, vocalizations, because they elicit social responses, can become communicative for the infant and used in more specific ways (Locke, 1993). In addition to specific maternal responses providing the infant with structured feedback, vocalizations can also guide the structure of interactions as they can become predictive of ensuing interactions (cf. West & Rheingold, 1978). Infants may learn that vocalizations elicit responses and thus may begin to use vocalizations as bids for social interaction (see also Bornstein et al., 1992; Hsu & Fogel, 2003). These immediate consequences served by babbling are important not only for learning language, per se, but also for the behaviors and interactions that foster communicative development such as turn-taking and joint attention (Locke, 1996; Locke, 1999). Given that mothers and infants both play a role in the dynamics of an interaction, it is also important to consider the way that interactions "unfold" in real time, dependent not only on past experience, but also the moment-to-moment action or reaction of each participant. Future research should focus on the role of vocalizations that vary in speech quality in structuring the dynamics of mother–infant interactions by considering a continuous interactional exchange.

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