

## Social Regulatory Effects of Infant Nondistress Vocalization on Maternal Behavior

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This study investigated the social regulatory function of infant nondistress vocalization in modulating maternal response. Thirteen infants and their mothers were observed weekly in a face-to-face interaction situation from 4 to 24 weeks. After the occurrences and the speech quality of infant nondistress vocalization were identified, maternal contingent responses to these vocalizations were also coded. Each responsive action was further classified by the change processes involved. Results showed that it was the occurrence of infant nondistress vocalization rather than its speech quality that regulated maternal verbal response concurrently and that infant nondistress vocalization was more likely to be synchronized with maternal facial expression and touch than with head movements. Developmentally, significant individual differences were found in the linear growth patterns of overall maternal response and within the individual modalities when responding to speechlike vocalizations.

Infant nondistress (noncry) vocalization is believed to be the precursor to later speech development. Fine-tuned maternal response to infant vocalization is positively related to language development (Beckwith & Rodning, 1996; Murray, Johnson, & Peters, 1990). In a recent investigation of language acquisition, Tamis-LeMonda, Bornstein, and Baumwell (2001) further reported that even though infants' vocalization is predictive of their achievement of language milestones, the contributions of maternal responsiveness to infant vocalization are over and above infants' contributions. This result indicates that language development needs to be examined in the context of contingent and responsive mother–infant vocal interchange. It also implicates the need for a relational conceptualization of the complementary link between infant vocal signals and maternal responding. Infants' vocalizations may serve as social signals to regulate maternal responsive actions, and the nature of maternal contingent response may reflect mothers' active assessments of the information encoded in the vocal signals (cf. Owings & Morton, 1997, 1998). Thus, the present study was an attempt to investigate (a) the social function of infant nondistress vocalizations varying in speech quality in

regulating maternal verbal and nonverbal responsive actions and (b) the nature of maternal contingent response.

### Infant Vocalization as a Social Signal

Scherer (1988, 1992) proposed that vocalizations by animals and adult humans serve three distinct functions: (a) as symptoms, which reflect the phenomenological experience and express the underlying motivational–affective state of the vocalizer; (b) as symbols, which represent the contextual information of the situation in which the vocalizations are produced; and (c) as social signals, which exert social influences and elicit actions from others. Evidence from infancy research suggests that prelinguistic vocalizations, particularly cries, by human infants serve these same functions (Barr, Hopkins, & Green, 2000). In the absence of accompanying facial displays and contextual information, adults of different genders and parental statuses accurately differentiated infant cry, comfort, discomfort, and joy sounds (Papousek, 1989). Caregivers have also been shown to utilize infant vocal signals as barometers for determining the infant's readiness to interact and for adjusting the amount and type of their own behavioral responses (Papousek, 1989). Empirical studies on infant cry vocalizations provide clear support for the argument that infant vocalizations exert an influence on others' behaviors. For example, cry sounds varying in pitch level were found to elicit different types of behaviors from caregivers in a child-care setting (Zeskind & Collins, 1987). Parents are also more likely to respond to infants' distress vocalizations with rhythmical physical stimulation, caregiving behaviors, and soothing vocalizations at a lower pitch (Keller & Scholmerich, 1987). Although substantial work has been done to examine the effects of infant cry vocalizations, relatively little is known about the social function of nondistress vocalizations.

Approximately 35% to 50% of nondistress vocalizations are ignored by mothers, in contrast to 15% of cry sounds (Bornstein & Tamis-LeMonda, 1989; Green & Gustafson, 1997). Oller (2000)

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posited that sociality is one of the inherent features of infant nondistress vocalization, yet there is no particular social function, meaning, or usage associated with it. Nevertheless, there is some evidence refuting his contention. Compared with visual regard, infant nondistress vocalization has been found to be more salient in regulating maternal actions (Bornstein et al., 1992). Mothers respond to nondistress vocalizations with brief pauses (to listen), vocal imitation, and high-pitched vocalizations with rising melodies (Bornstein et al., 1992; Keller & Scholmerich, 1987; Papousek, 1995), which are distinctly different from their responses to physiological and cry sounds, as described earlier. It appears that hedonic tones in infant vocalization (i.e., distress vs. nondistress) regulate parental responsive actions. Yet little is known about whether other characteristics of infant nondistress vocalization, such as speech quality, differentially regulate maternal response.

Speech quality (i.e., segmental sound quality) is one of the primary characteristics of early nondistress vocalization. Oller (1986; Oller & Lynch, 1992) suggested that the speech quality of vocalizations in early infancy is judged by the degree to which they approximate the infrastructural characteristics of adult speech. On the basis of the resonance pattern (oral or nasal), sound location (anterior or posterior area of the mouth), and perceived effort in sound making (relaxed or forced), Bloom (1988, 1989, 1993) classified infant nondistress vocalizations into syllabic and vocalic sounds. Compared with vocalic sounds, syllabic sounds are vocalizations with more speechlike quality.

Adults tend to favor speechlike sounds. Infants who produce nondistress vocalizations with speechlike quality are perceived as more attractive, friendly, and sociable than are infants who exhibit nonspeechlike sounds (Beaumont & Bloom, 1993; Bloom & Lo, 1990). Adults also attribute more positive emotionality to infants who utter syllabic sounds than to infants who produce vocalic sounds (Scott, Moore, & Bloom, 2001). Legerstee (1991) demonstrated that infants are more likely to utter vocalizations with speechlike quality when interacting with their mothers than when interacting with a stranger and when interacting with a person rather than an inanimate object. A recent study further revealed that both the quantity and the quality of infant nondistress vocalizations are systematically associated with the moment-to-moment dynamics of mother–infant communication (Hsu & Fogel, 2001). Infants are more likely to produce nondistress vocalizations, particularly speechlike sounds, when they and their mothers are mutually engaged in social interaction. Despite the fact that the speech quality of infant nondistress vocalizations changes with the social context, it is not known whether mothers respond differentially to infant nondistress vocalizations varying in speech quality. Our first goal in the present study was to explore maternal verbal and nonverbal responses to infant speechlike and nonspeechlike vocalizations.

### Maternal Response to Infant Signals

The supporting role of maternal contingent response in the development of infant affect, attachment, attention, cognition, language, and play behavior is well documented (e.g., Blehar, Lieberman, & Ainsworth, 1977; Bornstein & Tamis-LeMonda, 1989, 1997; Nicely, Tamis-LeMonda, & Bornstein, 1999; Tamis-LeMonda et al., 2001). In this study, we investigated individual

differences in maternal verbal and nonverbal responses to infant nondistress vocalizations varying in speech quality. Mothers deliver a package of vocal, facial, and touch actions in response to infant social signals during face-to-face interaction (Beebe & Gerstman, 1984; Koester, Papousek, & Papousek, 1989). Because maternal infant-directed speech is characterized by synchrony and redundancy across multiple sensory modalities (Gogate, Bahrick, & Watson, 2000), we further explored the multimodal nature of maternal contingent response to infant nondistress vocalization; specifically, we investigated individual differences in the synchronization of maternal verbal actions with nonverbal actions.

Maternal responsiveness has been conceptualized as a multidimensional construct encompassing far more than the mere overall temporal contingency between maternal actions and infant signals (Bornstein et al., 1992; Nicely, Tamis-LeMonda, & Grolnick, 1999; Tamis-LeMonda et al., 2001). Maternal response varies according to (a) the type of infant signals or activities mothers respond to (e.g., infant visual regard or nondistress vocalization), (b) the content of the maternal response (e.g., smiling at the infant or providing caregiving), and (c) the coherence (i.e., matching) between the infant signal and the maternal response in terms of their valence (i.e., positive or negative) and gradient features (e.g., intensity and tempo). These different dimensions of maternal responsiveness show specific associations with infant developmental outcomes. For example, higher levels of maternal responsiveness to infant attention to objects are associated with infants' environment-exploration activities, whereas higher levels of maternal responsiveness to infant social initiations are linked to infant social looks and bids (Bornstein et al., 1992). A maternal matching response to infant affective expression is more predictive of later infant expressivity and language development than is a nonmatching response (Nicely, Tamis-LeMonda, & Bornstein, 1999; Nicely, Tamis-LeMonda, & Grolnick, 1999). In the present study, we explored a new dimension of maternal responsiveness, namely, the change process involved in a maternal responsive action.

A maternal response to infant social signals is typically defined as the mother's exhibition of a new action that was not present prior to the infant's signal. A mother is considered to be responsive to an infant's cry, for example, if she picks up the infant immediately after the infant utters a cry vocalization. As a result, maternal response elicited by infant social signals is limited to the change process of addition—the addition of one or more new actions to the existing maternal behavioral repertoire. Mothers also modify the characteristics of their ongoing actions, such as their intensity, rhythm, or form, in response to infant social signals. Furthermore, mothers may eliminate some ongoing actions from their behavioral configurations when responding to infant signals. Therefore, the multidimensional nature of the construct of maternal responsiveness should take into consideration change processes in maternal actions, such as addition, deletion, and modification. In a study by Keller and Scholmerich (1987) investigating maternal response to various types of infant vocalization, a maternal action was credited as responsive when a new act was performed, an ongoing behavior was eliminated, or an adjustment was made in an ongoing behavior's form, location, or timing. However, the change processes involved in maternal response were not inspected in their study. Change processes in maternal responsive actions may reflect maternal assessments of infant vocal signals. Therefore, it is plausible that different types of change process

occur systematically in maternal verbal and nonverbal responsive actions. A closer examination of the change processes involved in maternal responsive actions would not only highlight the dynamics of organization and reorganization in the configuration of maternal actions but also further unravel the social regulatory function of infant nondistress vocalization.

### Developmental Changes in Maternal Response

Significant developmental changes are found in infant and maternal individual behaviors during the first months of life (Belsky, Gilstrap, & Rovine, 1984). However, research findings on the individual stability (assessed by correlation coefficients) and the developmental continuity (evaluated by group means) of maternal response have been mixed. Individual differences in maternal responsiveness to infant crying remain stable during the first 6 months (Bell & Ainsworth, 1972). Individual differences in maternal responsiveness to infant affective expressions are also moderately stable over time even after the contributions of infants are controlled for (Nicely, Tamis-LeMonda, & Bornstein, 1999). However, there is no individual stability in maternal response to overall infant behaviors and to infant nondistress vocalization (Belsky, Taylor, & Rovine, 1984; Bornstein & Tamis-LeMonda, 1989). Furthermore, no evidence has been found for significant developmental changes in maternal contingent response to infant smiling and to overall infant social signals in early infancy (Belsky, Gilstrap, & Rovine, 1984; Symons & Moran, 1994). On the other hand, different growth trajectories have been found for infant syllabic and vocalic vocalizations in the context of mother–infant face-to-face interaction (Hsu & Fogel, 2001). It is not clear whether maternal verbal and nonverbal responses to infant speechlike–syllabic and nonspeechlike–vocalic vocalizations would also show different developmental trajectories across the first 6 months.

Studies on maternal responsiveness typically use a population study design, in which data are collected on large samples and target behaviors are observed infrequently. With this type of study design, information on central tendencies such as group means is obtained and analyzed. However, little is learned about whether and when individual differences arise over time. Because nondistress vocalizations uttered by young infants are short in duration and low and variable in frequency (Bloom, 1990), a unique study design is needed for the investigation of developmental changes in maternal response to infant nondistress vocalization. A microgenetic design is a person-oriented (as opposed to a variable-oriented) approach to the understanding of developmental changes, one in which intensive observations with a smaller number of mother–infant dyads are necessary to keep track of their growth trajectories over time (Lavelli, Pantoja, Hsu, Messinger, & Fogel, in press). Therefore, in the present study, intensive weekly observations were conducted to investigate the developmental pattern of maternal verbal and nonverbal responses to infant nondistress vocalizations across the first 6 months.

In summary, the literature review suggests that maternal responsiveness (a) is multidimensional in nature and characterized by synchrony and redundancy across different behavioral modalities, (b) demonstrates significant individual differences, and (c) reveals developmental changes in some behavioral modalities. Our purpose in the present investigation was to better understand the social

regulatory effects of infant nondistress vocalization on maternal contingent response and the nature of maternal verbal and nonverbal responsive actions. Although mothers are sensitive and responsive to the valence (i.e., positive or negative) of infant vocalization, little is known about whether mothers are equally sensitive and responsive to infant nondistress vocalizations varying in speech quality. Therefore, we first investigated whether it is the occurrence or the speech quality of infant nondistress vocalizations that elicits differential maternal verbal and nonverbal responsive actions. Because of the mixed results previously found with regard to individual stability and developmental continuity in maternal responsiveness, in this study we investigated individual differences and developmental changes in overall maternal responsiveness to infant nondistress vocalization across different behavioral modalities as well as specific responsiveness within each behavioral modality. Because synchrony and redundancy are characteristics of maternal interactive behaviors, we further examined whether verbal and nonverbal actions co-occur in maternal response and whether there are individual differences in this synchronization. Finally, to further unravel the multidimensional nature of maternal responsiveness, we addressed the question of whether different types of change process such as addition (adding an action), deletion (eliminating an action), or modification (altering the rhythm, intensity, or form of an action) occur systematically in maternal verbal and nonverbal responsive actions.

### Method

#### *Participants*

Thirteen mother–infant dyads participated in a 2-year longitudinal study on the development of mother–infant communication. Twelve of these mother–infant dyads were Caucasian, and 1 was African American. Six of the infants were firstborn, and 8 were male. Nine of the mothers had bachelor's degrees. About half of the mothers were employed full time when first recruited. Infants and their mothers were videotaped weekly in a laboratory playroom beginning when the infants were between 4 and 9 weeks of age ( $M = 5.3$  weeks). During the first 6 months of visits, the face-to-face interactions between mothers and infants were videotaped for 5 min and analyzed for the current study. Only about 6% of the total sessions (13 out of 210) lasted less than 5 min. The average session duration was 287 s (range = 80–300 s). The average number of sessions collected from each dyad was 16 (range = 9–20).

Three remote-controlled cameras were used to videotape the play sessions. One camera was focused on the mother's upper body to obtain a frontal view of the mother with the infant visible. The second camera was focused on the infant's face and body. The third camera served as a backup and was used to get the best view of the mother and/or the infant. The outputs from the two cameras that had the best views of the mother and the infant were passed through a special-effects generator to produce a split-screen image with a timer superimposed on the screen. A microphone (Model 575SB, Shure Inc., Niles IL) that was hung from the ceiling about 12 in. (30.5 cm) from the mother's head transmitted the audio signals to an amplifier (Shure Model M267) for recording.

#### *Infant Nondistress Vocalizations*

The on- and offset times of a nondistress vocalization were coded from the video. If there was a perceivable silence in a long bout of vocalization, two separate sounds were recorded. Following previous studies (e.g., Oller, Eilers, Steffens, Lynch, & Urbano, 1994; Stark, 1978), we excluded vegetative sounds (e.g., sneezes, coughs, and hiccups), effort sounds (e.g.,

grunts), negative vocalizations (e.g., fusses and cries), and laughs. After each nondistress vocalization was identified, its speech quality was evaluated and categorized according to Bloom's (Bloom, Russell, & Wassenberg, 1987) classification system: (a) *Syllabic vocalizations* are sounds uttered in the anterior area of the mouth that contain greater oral resonance and are perceived as more relaxed and speechlike. (b) *Vocalic vocalizations* are sounds produced in the posterior area of the mouth that contain greater nasal resonance and lack oral projection and are perceived as more forced and less speechlike. A total of 1,692 vocalizations, 61% syllabic and 39% vocalic, were sampled across all 13 infants over the course of the first 6 months. Maternal responses to a total of 1,669 nondistress vocalizations were further analyzed. Missing data were due, in most cases, to the obstruction of the mothers' faces (e.g., by hair). A second coder independently coded 16% of the total sessions for reliability. We considered coders to be in agreement if their identifications of the onset and offset of an infant vocalization were within a 2-s time window; the percentage of agreement between the two coders was 85%, and kappa was .80.

### Maternal Responsive Actions

To determine the contingency and contiguity of maternal responsive actions, the coder located each previously identified infant nondistress vocalization and viewed the video episode from 5 s before the onset of the vocalization to 5 s after the offset of the vocalization. It has been reported that maternal response to infant nondistress vocalization occurs predominantly after the offset of vocalization (Bornstein et al., 1992). Consequently, maternal actions were deemed to be responsive when they occurred within 1 s after the offset of infant vocalization (Keller, Lohaus, Voelker, Cappenberg, & Chasiotis, 1999; Malatesta, Culver, Tesman, & Shepard, 1989; Nicely, Tamis-LeMonda, & Bornstein, 1999).

Maternal responsive actions in four different behavioral modalities, including maternal vocalization/verbalization, facial expression, touch, and head movement, were coded in separate passes (see definitions in Table 1). Within each behavioral modality and for each identified infant nondistress vocalization, an absence of maternal response was coded if the coder observed no change in the mother's ongoing behavioral action, that is, if

the mother simply did not appear to acknowledge the occurrence of the infant nondistress vocalization. If the mother exhibited a new action, eliminated an ongoing action, or made a change in the form, intensity, rhythm, and timing of her previous action as evidenced by the contiguity and contingency within a behavioral modality, a response was credited. Approximately 18% of the sessions were coded by an independent coder, and the agreements between the two coders in classifying the absence or presence of responsive action through maternal vocalizations/verbalizations, facial expressions, touch, and head movements were 79.0%, 73.3%, 80.2%, and 95.4%, respectively.

### Change Processes in Maternal Response

Guided by Keller and Scholmerich's (1987) coding strategy, we further classified the change process involved in maternal responses within each behavioral modality into one of the following three categories:

1. *Deletion*—the mother terminated her action upon hearing the vocalization. For example, a mother was smiling at her infant before the onset of vocalization, and upon hearing the vocalization, she stopped smiling and did not resume smiling within 1 s after the offset of the infant nondistress vocalization.

2. *Addition*—the mother performed a new action after the onset of infant vocalization. For example, a mother was smiling at her infant quietly, and immediately after hearing the infant's vocalization, she started laughing (addition of vocal component<sup>1</sup> without a change in the intensity of positive facial expression<sup>2</sup>). Another example was that of a mother who was vocalizing to the baby and who, upon hearing the baby's vocalization, started nodding her head exaggeratedly as she was talking.

3. *Modification*—the rhythm, intensity, and/or form of an ongoing maternal vocalization/verbalization, facial expression, touch, or head movement were changed, or a new part of the infant's body was stimulated after the onset of infant vocalization. For example, a mother halted her verbalization briefly during her infant's vocalization but resumed her verbalization immediately after the offset of infant vocalization. Another mother was talking to her infant, and after hearing the infant's vocalization, she imitated the sound. Another example was a mother who was bouncing the infant and who, after hearing the vocalization, started tapping on the infant's mouth area.

These three change processes are mutually exclusive. For each given nondistress vocalization, only one change process was assigned to a maternal response in each behavioral modality. The agreements between the two coders for the change processes in maternal vocalizations/verbalizations, facial expressions, touch, and head movements were 72.5%, 65.0%, 74.6%, and 74.8%, respectively.

Table 1  
Definitions and Examples of Coding Categories for Maternal Responsive Actions

Modality of maternal response	Definition and examples
Vocal/verbal	The first utterance with or without lexical content, such as a vocal sound (e.g., a laugh or "goo"), a word (e.g., "Yes."), a phrase (e.g., "Good girl."), or a sentence (e.g., "You are funny!") vocalized by the mother
Nonverbal	
Facial expression	The mother displayed a smile (i.e., facial movement involving the action of the zygomatic major around the mouth) or a mock surprised face (i.e., raised eyebrows, widened eyes, and mouth open with a jaw drop).
Touch	Maternal touch actions mediating sensations through the receptors of temperature and/or equilibrium were identified, including vestibular actions (e.g., rocking and bouncing), kinesthetic movements (e.g., bicycling exercise of infant's legs and "so big" movements with arms), and tactile contacts (e.g., caressing, massaging, and tickling).
Head movements	Exaggerated head bobbing, shaking, and/or nodding.

## Results

### Do Infant Nondistress Vocalizations Varying in Speech Quality Elicit Differential Maternal Responses?

To investigate whether mothers responded to syllabic and vocalic vocalizations differentially, we performed three separate data

<sup>1</sup> Even though maternal laughter is typically accompanied by positive facial expressions, it is primarily a vocal action with unique acoustic properties (Nwokah, Hsu, Davies, & Fogel, 1999).

<sup>2</sup> In Ekman and Friesen's (1978) Facial Action Coding System, the intensity of smiles is determined by the contraction of the zygomatic major muscle, which raises the lip corners. It is likely that the occurrence of maternal laughter indicates a higher intensity of positive emotional experience. However, to date, there is no empirical evidence suggesting that the intensity of smiling with co-occurring vocal actions of laughter is higher than the intensity of smiling without laughter.

analyses, including analyses of maternal response across modalities and within individual modalities as well as an analysis of the types of change process involved in maternal response. Because some infants made relatively few nondistress vocalizations, the frequency of maternal responsive actions was tallied separately for each mother–infant dyad across all sessions.

*Maternal response across modalities.* The numbers of behavioral actions performed by mothers across different behavioral modalities were tallied and aggregated separately for each type of vocalization and each dyad.<sup>3</sup> A paired *t* test was then performed to compare the numbers of behavioral modalities involved in the maternal responses to the two types of vocalization. Results demonstrated that mothers used similar numbers of behavioral modalities when responding to infant speechlike–syllabic ( $M = 1.57$ ,  $SD = 0.12$ ) and nonspeechlike–vocalic ( $M = 1.65$ ,  $SD = 0.18$ ) vocalizations,  $t(12) = 1.85$ , *ns*. Overall, infant nondistress vocalizations, regardless of their speech quality, elicited more than one modality of maternal responsive action.

*Maternal response within individual modalities.* To further examine whether mothers responded differentially to infant nondistress vocalizations with different speech quality within a modality, we performed separate 2 (vocalization type: syllabic vs. vocalic)  $\times$  2 (maternal response: yes vs. no) chi-square tests for each dyad and for each modality. Because the statistical analysis was performed separately for each dyad, an adjusted significance level of .004 (= .05/13) instead of .05 was used as the cutoff value to prevent inflation in Type I error. Results revealed that only 1 out of 13 mothers showed significantly more vocal/verbal responses to speechlike–syllabic than to nonspeechlike–vocalic vocalizations,  $\chi^2(1) = 11.0$ ,  $p < .001$ , and that only 1 mother was significantly more likely to display facial expressions in response to syllabic vocalizations,  $\chi^2(1) = 18.7$ ,  $p < .001$ . None of the mothers showed significant differences in their touch and head movements when responding to infant vocalizations varying in speech quality.

*Types of change process.* To examine whether the types of change process involved in maternal responsive actions differed systematically with the speech quality of infant nondistress vocalizations, we performed separate 2 (vocalization type: syllabic vs. vocalic)  $\times$  3 (change process: deletion, addition, or modification) chi-square tests for each modality and each dyad. Results indicated that only 1 out of 13 mothers exhibited a preference in responding to infant syllabic vocalizations by modifying her vocal/verbal actions,  $\chi^2(2) = 12.73$ ,  $p = .002$ . None of the mothers showed a preference in how they changed their facial expressions, touch, and head movements when responding to infant syllabic and vocalic vocalizations.

### *Are There Individual Differences and Developmental Changes in Maternal Response?*

To reveal individual differences and developmental changes in maternal responsive actions, we separately analyzed the overall rate of maternal response, the rate of maternal response within individual modalities, and maternal preference for using verbal and nonverbal responsive actions.

*Overall rate of maternal response.* Linear and curvilinear patterns of the developmental change in the overall rate of maternal response to infant nondistress vocalization (indexed by the percentage of infant vocalizations responded to by the mother) were

examined with a growth-curve-modeling multilevel analysis. Growth curves were modeled as a polynomial function of infant age (in weeks) by using MLn software (Woodhouse, 1996). The emergence of individual differences in the developmental trajectories was indicated by the deviation of individual curves from the average developmental trend. The significance of individual differences was tested with a likelihood ratio. To further explore the relation between infant vocal development and individual differences in maternal response, we also performed additional analysis. First, growth curve modeling was performed separately for the rates per minute of syllabic and vocalic vocalizations in order to examine their developmental trajectories. Second, rates of infant syllabic and vocalic vocalizations were added separately as covariates in the model to reveal whether between-individual differences in maternal response would be accounted for by variations in the rate of infant vocalization, as would be indicated by an improvement in the fit of the model.

Results showed that there were significant individual differences in the linear growth pattern (intercept = 86.48; slope = 0.15) of the overall maternal response to infant syllabic vocalizations across the weekly sessions,  $\Delta\chi^2(2) = 9.39$ ,  $p < .01$  (see Figure 1a). The growth patterns of increase, decrease, and no change were detected. Five mothers showed a trend toward increase, 4 mothers demonstrated a pattern of decrease, and 4 mothers displayed no change in the overall rate of response. Growth curve modeling further revealed that there were no significant linear or curvilinear growth patterns in the overall rate of maternal response to infant vocalic vocalizations. Similarly, no linear or curvilinear developmental pattern was detected in the trajectories of infant syllabic and vocalic vocalizations. However, the addition of rate of syllabic vocalization in the growth model improved the fit of the model for overall maternal response, suggesting that variations in infant syllabic vocalization (estimated coefficient = 7.15) contributed to developmental changes in the overall maternal response,  $\Delta\chi^2(1) = 21.12$ ,  $p < .001$ .

To further demonstrate individual differences in maternal responsiveness, we evaluated the overall maternal response to infant nondistress vocalization to determine whether it occurred at a level greater than chance. The frequencies of infant nondistress vocalizations responded to by mothers (irrespective of behavioral modality) were tallied separately for each dyad and collapsed across weekly sessions. A separate binomial test was then performed for

<sup>3</sup> To examine the possible effect of infant age on the number of behavioral modalities used by mothers in their responses, we first collapsed weekly sessions into five monthly age intervals: (a) 2nd month, 4–8 weeks; (b) 3rd month, 9–12 weeks; (c) 4th month, 13–16 weeks; (d) 5th month, 17–20 weeks; and (e) 6th month, 21–24 weeks. A 2 (vocalization type)  $\times$  5 (monthly age interval) repeated measures analysis of variance (ANOVA) was then performed. Because the observations for 2 infants did not begin until they were 9 weeks of age, as a result of casewise deletion, the sample size for the repeated measures ANOVA was 11 instead of 13. Results showed that there were no significant differences among the five monthly age intervals,  $F(4, 40) = 1.16$ ,  $p > .10$ , and between the two types of vocalization,  $F(1, 10) = 0.03$ ,  $p > .10$ . Also, no significant Vocalization Type  $\times$  Monthly Age Interval interaction was found,  $F(4, 40) = 1.02$ ,  $p > .10$ . These findings suggested that the number of behavioral modalities used by mothers when responding to infant nondistress vocalizations did not show developmental changes during the first 6 months.

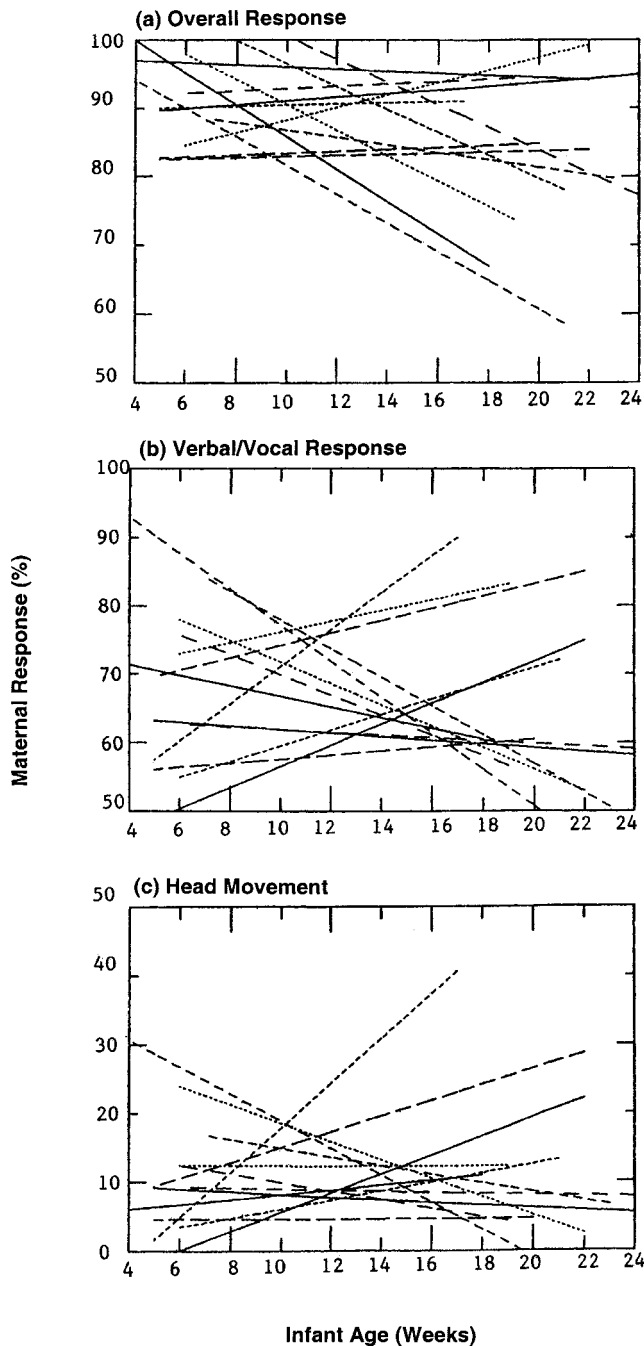


Figure 1. Modeled individual developmental trajectories of rates of maternal response (%) to infant syllabic vocalization: (a) overall response across modalities, (b) vocalizations/verbalizations, and (c) head movements.

each dyad to determine whether the overall maternal response to infant nondistress vocalization was greater than the 50% chance level. Because a binary classification was used to code maternal response (respond vs. not respond), the chance level of 50% was chosen. Results revealed that despite individual differences (range = 62.3%–90.4%), the overall response rate of all 13 moth-

ers was significantly greater than chance responding. Across all behavioral modalities, mothers responded consistently to infant nondistress vocalizations approximately 80% of the time, on average (see Table 2 for details).

*Maternal response within individual modalities.* To examine whether there were individual differences in the developmental trajectories of maternal verbal and nonverbal response rates, we performed a separate growth curve analysis for each individual modality. With regard to infant syllabic vocalizations, there were significant individual differences in the linear growth patterns of response rates of maternal vocalizations/verbalizations (intercept = 83.92; slope =  $-0.12$ ),  $\Delta\chi^2(2) = 14.01$ ,  $p < .001$  (see Figure 1b), and head movements (intercept = 19.6; slope =  $-0.67$ ),  $\Delta\chi^2(2) = 12.19$ ,  $p < .01$  (see Figure 1c). Again, the growth curves demonstrated three different developmental patterns: increase, decrease, and no change. With respect to maternal vocal/verbal responses to infant syllabic vocalizations, 5 mothers showed a pattern of increase, 5 mothers displayed a trend toward a decrease, and 3 mothers demonstrated no change across weekly sessions. With regard to maternal responding to infant syllabic vocalizations with head movements, 6 mothers increased their rates across weekly sessions, 3 mothers showed a trend toward a decrease, and 4 mothers revealed no change. Furthermore, the addition of rate of infant syllabic vocalizations to the growth model improved the fit of the model for maternal vocal/verbal responses,  $\Delta\chi^2(1) = 5.96$ ,  $p < .02$ , but not head movements,  $\Delta\chi^2(1) = 2.75$ , *ns*. Thus, variations in infant syllabic vocalizations (estimated coefficient = 5.69) contributed to developmental changes in maternal vocal/verbal responses. However, no significant linear or curvilinear developmental trends were found for maternal facial expressions and touch in response to infant syllabic vocalizations. Moreover, no significant linear or curvilinear growth patterns were found in any of the rates of individual maternal responsive actions to infant vocalic vocalizations.

To further demonstrate individual differences in maternal response to infant nondistress vocalizations within individual modalities, we evaluated maternal responsiveness to determine whether it occurred at a level greater than chance. Separate binomial tests were performed for each dyad and for each modality, with weekly sessions aggregated. Results revealed that 9 out of 13 mothers responded vocally or verbally at more than a 50% chance level, whereas 12, 10, and 13 mothers responded with facial expressions, touch, and head movements, respectively, at significantly less than a 50% chance level (see Table 2 for details).

*Maternal response across behavioral modalities.* To examine maternal preference for behavioral actions in response to infant nondistress vocalizations, we calculated the percentage of infant nondistress vocalizations responded to with each of the four different behavioral modalities of maternal actions separately for each dyad (see Table 2 for details). A 2 (vocalization type)  $\times$  4 (behavioral modality)  $\times$  5 (monthly age interval) repeated measures ANOVA with the percentage of maternal response as the dependent variable was performed first. Results showed that there were no significant differences among the five monthly age intervals,  $F(4, 40) = 1.05$ , or between the two types of vocalization,  $F(1, 10) = 0.02$ , nor were any of the interaction effects involving vocalization type and/or monthly age interval significant. Because no significant effects of infant age and types of vocalization were found, the data were then further collapsed across weeks and

Table 2  
*Frequencies (and Percentages) of Infant Nondistress Vocalizations and Maternal Responsive Actions*

Dyad	Overall maternal response	Maternal responsive actions within individual modalities				Total frequency of infant nondistress vocalizations
		Vocalizations/verbalizations	Facial expressions	Touch	Head movements	
1	148 (77.9)*	139 (73.2)*	48 (25.3)*	54 (28.4)*	3 (1.6)*	190
2	47 (67.1)*	47 (67.1)	6 (8.6)*	22 (31.4)*	1 (1.4)*	70
3	59 (77.6)*	54 (71.1)*	3 (3.9)*	27 (35.5)	7 (9.2)*	76
4	150 (82.3)*	138 (76.2)*	55 (30.4)*	62 (34.3)*	12 (6.6)*	181
5	104 (79.4)*	92 (70.2)*	18 (13.7)*	28 (21.4)*	26 (19.8)*	131
6	122 (88.4)*	115 (83.3)*	29 (21.0)*	38 (27.5)*	19 (13.8)*	138
7	216 (90.4)*	204 (85.4)*	46 (19.2)*	69 (28.8)*	25 (10.5)*	239
8	220 (85.3)*	158 (61.2)*	70 (27.1)*	97 (37.6)*	51 (19.8)*	258
9	14 (77.8)*	14 (77.8)	2 (11.1)*	7 (38.9)	1 (5.6)*	18
10	66 (62.3)*	57 (53.8)	12 (11.3)*	12 (11.3)*	8 (7.5)*	106
11	146 (92.4)*	144 (91.1)*	42 (26.6)*	7 (4.4)*	14 (8.9)*	158
12	55 (84.6)*	51 (78.5)*	21 (32.3)	21 (32.3)	1 (1.5)*	65
13	28 (71.8)*	24 (61.5)	9 (23.1)*	10 (25.6)*	5 (12.8)*	39
<i>M</i>	105.8 (79.8)	95.2 (73.1)	27.8 (19.5)	34.9 (27.5)	13.3 (14.3)	
<i>SD</i>	67.8 (8.9)	58.7 (10.6)	22.3 (9.0)	27.8 (10.1)	9.2 (6.2)	

\*  $p < .004$ .

between vocalization types. A repeated measures one-way ANOVA was performed to compare the differences among the four behavioral modalities. Results revealed that mothers showed a preference in using behavioral modalities in their responses,  $F(3, 36) = 119.7, p < .001, \eta = .91$ . The percentage of maternal vocal/verbal responses was significantly higher than the percentages of responses involving touch, facial expressions, or head movements,  $ts(12) = 10.77-17.68, ps < .001$ . Although there was no difference between the percentages of maternal responses involving touch or facial expressions, the percentages of maternal responses involving touch or facial expressions were significantly higher than the percentage of maternal responses involving head movements,  $ts(12) = 3.08-5.31, ps < .01$ .

#### *Do Maternal Verbal and Nonverbal Responsive Actions Co-Occur in Synchrony?*

Maternal responsiveness to infant social signals is multimodal in nature. To further understand individual differences in the extent to which mothers used one or more than one behavioral modality in their responses, we compared unimodal versus multimodal responses and also assessed the likelihood of a verbal response occurring with a nonverbal response. Even though there were significant individual differences in the developmental trajectories of overall maternal response and specific responses to syllabic (but not vocalic) vocalizations, maternal responsive actions to syllabic and vocalic vocalizations were combined in all further analyses. This decision was made on the basis of three observations: (a) the low frequencies of maternal responses when we examined unimodal and multimodal responsive actions separately; (b) the lack of systematic differences in maternal response to the speech quality of infant nondistress vocalization in terms of whether mothers responded or not, the number of their responsive actions, and the types of change process involved in their responses, as demonstrated by the results of the first research question; and (c) the lack of differences in maternal individual responsive actions in different modalities when responding to syllabic and vocalic vocalizations, as revealed in the analysis described above.

*Unimodal versus multimodal maternal response.* On the basis of the behavioral modalities involved, each maternal response was categorized as unimodal or multimodal. The frequency of each type of response was tallied separately for each session and for each dyad. A unimodal response included verbal responses only (mother responded with verbalization/vocalization) or nonverbal responses only (mother responded with facial expressions, touch, and/or head movements), whereas a multimodal response included a combination of a verbalization/vocalization with one or more of the nonverbal actions.

Separate one-way chi-square tests were performed to compare the frequency distributions of these three patterns of maternal response for each dyad. Results revealed that 10 out of 13 mothers showed a preferential pattern in their responses. They preferred to respond with either a unimodal verbal action or a multimodal response consisting of verbal and nonverbal actions,  $\chi^2s(2, Ns = 15-220) = 0.53-76.37, ps = .0001-.47$  (see Table 3 for details).

*Co-occurrence of verbal responses with nonverbal responses.* To further examine whether a maternal vocalization/verbalization was systematically synchronized with a nonverbal action, we calculated the conditional probability of a maternal nonverbal action given a maternal verbal action separately for each nonverbal modality and for each dyad. Following Bakeman and Robinson's (1997) suggestion, we computed Yule's  $Q$  to measure the extent to which a conditional probability is significantly different from its expected simple probability. Yule's  $Q$  statistics were also calculated separately for each modality and each dyad. See Table 4 for conditional probabilities and  $Q$  scores. Yule's  $Q$  is a simple transformation of the odds ratio, which ranges from  $-1$  to  $+1$  (see Bakeman, McArthur, & Quera, 1996; Bakeman & Robinson, 1997). The magnitude of Yule's  $Q$  indicates the strength of co-occurrence associations between verbal response and maternal touch, facial expressions, and head movements, respectively. After Yule's  $Q$  statistics were derived for each dyad, one-way  $t$  tests were then performed to demonstrate whether the  $Q$  scores were significantly different from zero (i.e., no co-occurrence association). One-

Table 3  
Frequencies of Unimodal and Multimodal Maternal Responsive Actions

Dyad	Unimodal		Multimodal	$\chi^2(2)$
	Verbal	Nonverbal		
1	69 (46.6)	9 (6.1)	70 (47.3)	49.47*
2	21 (44.7)	0 (0.0)	26 (55.3)	0.53
3	23 (39.0)	5 (8.5)	31 (52.5)	18.03*
4	52 (34.7)	12 (8.0)	86 (57.3)	54.88*
5	43 (41.3)	12 (11.5)	49 (47.1)	22.75*
6	50 (41.0)	7 (5.7)	65 (53.3)	44.57*
7	99 (45.8)	12 (5.6)	105 (48.6)	75.25*
8	51 (23.2)	62 (28.2)	107 (48.6)	24.01*
9	6 (42.9)	2 (14.3)	8 (57.1)	5.20
10	37 (56.1)	9 (13.6)	20 (30.3)	18.09*
11	87 (59.6)	2 (1.4)	57 (39.0)	76.37*
12	19 (34.5)	4 (7.3)	32 (58.2)	21.42*
13	7 (25.0)	4 (14.3)	17 (60.7)	9.93
<i>M</i>	43.4 (41.1)	10.7 (9.6)	51.8 (50.4)	
<i>SD</i>	29.0 (10.4)	16.0 (7.2)	33.2 (8.5)	

\*  $p < .004$ .

sample  $t$  tests demonstrated that the  $Q$  scores for maternal vocalization/verbalization co-occurring with facial expression as well as touch were significantly greater than 0,  $ts(12) = 4.71-5.51$ ,  $ps < .001$ , suggesting that the odds of the mothers exhibiting facial expressions and touch in response to infant nondistress vocalizations increased significantly when mothers vocalized/verbalized.

*Do Change Processes Occur Systematically in Maternal Verbal and Nonverbal Responses?*

To examine whether change processes occurred systematically in mothers' responses to infant nondistress vocalizations, we tab-

ulated the frequencies of change processes involved in maternal responsive actions separately for each modality and each dyad. A one-way chi-square test was then performed for each dyad within each modality.

With respect to verbal/vocal responsive actions, 11 out of 13 mothers exhibited a preferential pattern in the change process,  $\chi^2s(2, Ns = 14-204) = 5.2-236.6$ ,  $ps = .001-.32$ . Addition and modification were the two most frequently used change processes in maternal vocal/verbal responses (see Table 5 for details). Only 1 out of 13 mothers showed a preference for using a particular type of change process when responding with a facial expression,  $\chi^2s(2,$

Table 4  
Yule's  $Q$  for Maternal Vocalizations/Verbalizations Co-Occurring With Nonverbal Actions in Response to Infant Nondistress Vocalizations

Dyad	Facial expressions		Touch		Head movements	
	$p^a$	Yule's $Q$	$p$	Yule's $Q$	$p$	Yule's $Q$
1	.39	.88	.34	.51	.02	.37
2	.15	.78	.47	.95	.02	.00
3	.04	-.11	.41	.40	.13	.74
4	.36	.49	.41	.68	.07	-.04
5	.17	.59	.26	.51	.18	-.14
6	.23	.53	.30	.33	.15	.29
7	.21	.47	.29	.06	.11	.35
8	.29	.08	.37	-.05	.22	.20
9	.14	.14	.50	.78	.07	-.24
10	.12	.00	.14	.29	.12	.74
11	.29	.69	.06	.24	.10	.17
12	.41	.62	.37	.56	.02	-.23
13	.42	.82	.25	-.04	.21	.78
<i>M</i>	.25	.46	.32	.40	.11	.23
<i>SD</i>	.12	.33	.12	.31	.07	.36
No. of dyads <sup>b</sup> showing effect (Yule's $Q > 0$ )		11**		11**		8

<sup>a</sup> Conditional probabilities given maternal verbal response. <sup>b</sup> Significance was calculated using binomial tests. \*\*  $p < .001$ .



$N_s = 9-70$ ) = 0.0–28.5,  $ps = .001-1.0$ . Addition was the preferred change process (see Table 5 for details). None of the mothers demonstrated a preference for a specific type of change process in their touch responses,  $\chi^2s(2, N_s = 8-97) = 0.29-14.8$ ,  $ps = .01-.96$ . Finally, none of the mothers showed a preference for a specific type of change process when responding with head movements,  $\chi^2s(2, N_s = 9-51) = 0.0-32.1$ ,  $ps = .01-1.0$ .

### Discussion

The present study explored (a) the social regulatory effects of infant nondistress vocalizations varying in speech quality on maternal response and (b) the nature of maternal verbal and nonverbal responsive actions. We first addressed the question of whether maternal verbal and nonverbal responsive actions are regulated by the occurrence or by the speech quality of infant nondistress vocalizations. To discern developmental continuity and individual stability in maternal responses, we then examined individual differences and developmental changes in the growth trajectories of mothers' overall (across different modalities) and specific (within each individual modality) response rates. Because of the unique characteristics of synchrony and redundancy in maternal social behaviors, we investigated whether maternal verbal and nonverbal responsive actions to infant nondistress vocalizations also co-occur systematically in a synchronized fashion. Finally, to further explore the multidimensional nature of maternal responsiveness, we also inspected the systematic patterning in the change processes of maternal verbal and nonverbal responsive actions such as addition, deletion, and modification.

#### *Infant Nondistress Vocalization Exerted Social Regulatory Effects on Maternal Response*

In the present study, we found that the overall maternal response to the occurrence of infant nondistress vocalizations exceeded chance, which suggested that mothers do not just respond to infant

nondistress vocalizations at random. Furthermore, it was the occurrence rather than the speech quality of infant nondistress vocalizations that elicited maternal response concurrently during mother–infant face-to-face interaction. However, across time, the findings from the developmental trajectories showed a clear differential effect of speech quality on maternal response. The respective concurrent and developmental social regulatory effects of the occurrence and speech quality of infant nondistress vocalizations on maternal response are discussed separately. We first discuss the regulatory effects of the occurrence of infant nondistress vocalizations on concurrent maternal responsive actions or, specifically, the plausible interpretations for the lack of effects of speech quality.

*Concurrent social-regulatory effects of the occurrence of infant nondistress vocalizations.* During spontaneous face-to-face interactions, mothers in this study reacted similarly to infant speechlike–syllabic and nonspeechlike–vocalic sounds in terms of whether they responded or not, the number of their responsive actions, and the types of change process involved in their responses. Both objective and subjective assessments show that infant syllabic and vocalic vocalizations are qualitatively and quantitatively different (e.g., Beaumont & Bloom, 1993; Bloom & Lo, 1990; Masataka & Bloom, 1994; Scott et al., 2001). Papousek (1995) further proposed that parents intuitively respond differentially to different types of infant vocalization. The finding from the present study, however, suggests that this proposal may be limited to the emotional tones of infant vocalizations and cannot be extended to their speech quality. The nonsignificant finding may simply be due to the fact that parents are unable to discriminate syllabic and vocalic vocalizations in spontaneous social interactions during which infants emit a variety of signals in multiple channels simultaneously.

Alternatively, parents may be able to recognize the difference between these two types of vocalization, but they may fail to understand the meaning of the information encoded in these

Table 5  
*Frequency Distributions (and Percentages) of Change Processes Involved in Maternal Verbal and Facial Responses to Infant Nondistress Vocalizations*

Dyad	Vocalizations/verbalizations				Facial expressions			
	Deletion	Addition	Modification	$\chi^2(2)$	Deletion	Addition	Modification	$\chi^2(2)$
1	7 (5.0)	73 (52.2)	59 (42.4)	52.2*	2 (4.2)	32 (66.7)	14 (29.2)	28.5*
2	4 (8.5)	29 (61.7)	14 (29.8)	20.2*	1 (16.7)	0 (0)	5 (83.3)	4.6
3	1 (1.9)	8 (14.8)	45 (83.2)	62.1*	1 (33.3)	1 (33.3)	1 (33.3)	0
4	9 (6.5)	49 (35.5)	80 (58.0)	55.1*	7 (12.7)	23 (41.8)	25 (45.5)	10.6
5	13 (14.1)	21 (22.8)	58 (63.0)	37.6*	2 (11.1)	12 (66.7)	4 (22.2)	9.3
6	11 (9.6)	33 (28.7)	71 (61.7)	48.1*	4 (13.8)	14 (48.3)	11 (37.9)	5.4
7	26 (12.7)	38 (18.6)	140 (68.6)	115.4*	10 (21.7)	21 (45.7)	15 (32.6)	4.0
8	34 (21.5)	56 (35.4)	68 (43.0)	11.3*	15 (21.4)	26 (37.1)	29 (41.4)	4.7
9	6 (42.9)	0 (0)	6 (42.9)	5.2	0 (0)	1 (33.3)	2 (66.7)	0.3
10	12 (21.1)	32 (56.1)	13 (22.8)	13.4*	1 (8.3)	3 (25.0)	8 (66.7)	6.5
11	3 (2.1)	6 (4.2)	135 (93.8)	236.6*	8 (19.0)	13 (31.0)	21 (50.0)	6.1
12	9 (17.6)	9 (17.6)	33 (64.7)	22.6*	5 (23.8)	7 (33.3)	9 (42.9)	1.1
13	2 (8.3)	11 (45.8)	11 (45.8)	6.8	1 (11.1)	3 (33.3)	5 (55.6)	2.7
<i>M</i>	10.5 (13.2)	28.1 (30.3)	56.5 (56.5)		4.4 (15.2)	11.9 (35.6)	11.5 (49.3)	
<i>SD</i>	9.6 (11.0)	21.9 (19.7)	43.6 (19.9)		4.5 (8.9)	10.8 (20.3)	8.9 (22.3)	

\*  $p < .004$ .

sounds and, thus, may respond to them similarly. Scherer (1988) suggested a distinction between *emic* versus *etic* social markers in vocalization, which provide information regarding biological, social, and psychological characteristics of the vocalizer. *Etic* markers are vocal parameters associated with a particular internal state and are easily recognized by the listener, whereas *emic* markers are the vocal features that are associated with the internal state but are not processed by the listener. Infant cries can be considered as encoded with *etic* social markers. Listeners are efficient in processing the information encoded in infant cry sounds, making accurate inferences and attributions of the vocal signal and therefore taking appropriate actions (see Barr et al., 2000). The speech quality of infant nondistress vocalizations, on the other hand, may be an *emic* social marker that is not easily processed by mothers in identifying the current psychological state of their infants; as a result, mothers may fail to respond differentially in their actions.

Nevertheless, it is also plausible that parents' inability to respond differentially to infant nondistress vocalizations varying in speech quality has adaptive value.<sup>4</sup> In order to facilitate interaction with young infants, parents opt to respond to all types of vocal signals in early infancy. As infants become more competent in engaging in social exchanges, parents are then more likely to exhibit discriminatory patterns in their responses, with the intent to encourage more mature forms of vocalization. This argument is consistent with the finding that a maternal smiling response to infant smiling remains the same during the first 6 months (Symons & Moran, 1994). The finding from this study that mothers showed different developmental trajectories in their responses to syllabic but not vocalic vocalizations also provides partial support for this argument (see further discussion below).

Moreover, the melodic contours of infant nondistress vocalization were not considered in the present study, and these may be one of the primary characteristics of infant nondistress vocalization (Hsu, Fogel, & Cooper, 2000) that exerts interpersonal regulatory functions in influencing maternal responsive actions. D'Odorico (1984) reported that melodic patterns found in the vocalizations produced by 4- to 9-month-olds have different meanings. Request sounds, for example, are characterized by flat (level) as well as rising pitch contours, call sounds are more likely to show a rising contour pattern, and discomfort sounds tend to have flat or falling pitch contours. It remains to be determined whether the melodic contours of infant nondistress vocalization serve to regulate maternal behaviors.

*Developmental social-regulatory effects of the speech quality of infant nondistress vocalizations.* When responding to infant syllabic vocalizations, mothers in this study showed evident individual differences in their overall response across modalities and within the individual modalities of vocalization/verbalization and head movement across the first 6 months. Whereas some mothers showed a linear increase over time in their responsive actions, others demonstrated either a pattern of decrease or no developmental changes. No systematic patterns or significant individual differences, however, were found in the growth curves of maternal response to infant vocalic vocalizations.

Growth curve analysis further revealed that the rates of infant syllabic and vocalic vocalizations demonstrated no specific linear or curvilinear developmental trends over the first 6 months. It appears that the developmental trajectories of maternal overall and specific response rates did not mirror infant vocal development.

However, variations in the rate of syllabic vocalizations contributed significantly to the development of individual differences in maternal overall response and vocal/verbal responses. At first glance, the differential effects of speech quality on developmental changes in maternal responsiveness may simply reflect an adaptive function of maternal response to a more mature form of speechlike-syllabic vocalization. Upon closer examination, however, variations in the growth trajectories of maternal responses to syllabic vocalizations further suggest that the relational history of mother-infant interaction may be the major contributing factor to the developmental social-regulatory effects of speech quality on maternal responsiveness (cf. Tarabulsky, Tessier, & Kappas, 1996). One would expect that a mother who repeatedly received no feedback from her infant when she provided contingent responses to syllabic vocalizations would become less responsive over time. In contrast, a mother who was successful in eliciting further responses from her infant when she provided contingent responses to the infant's syllabic vocalizations would be more likely to maintain the same level of responsiveness or become more responsive over time. It thus appears that infant nondistress vocalizations exert concurrent social-regulatory effects on maternal behaviors and that further infant responses to maternal responsive actions are critical in shaping the developmental social-regulatory effects of infant nondistress vocalization on maternal responsiveness. The maternal responsive actions of vocalization/verbalization and head movement may be particularly sensitive to the transactional effects of signal-response coupling in mother-infant interaction. However, this speculation needs to be further examined in future studies.

The diverse linear developmental paths of maternal responses to infant syllabic vocalizations found in this study also provide an explanation for why neither individual stability nor developmental discontinuity in maternal response to infant social signals was found in some previous studies that adopted a snapshot approach to longitudinal design. When some mothers become more or less responsive over time and others remain the same in their response rates, they cancel each other out and fail to reveal either individual stability or developmental change. Our findings demonstrate the importance of adopting a microgenetic, person-oriented approach to the understanding of developmental process that focuses on variability between dyads over time. Collecting data that are dense in time points (e.g., weekly observation) and rich in details (e.g., microanalytic coding) can provide direct observations and valid depictions of developmental processes (Granott & Parziale, 2002; Lavelli et al., in press).

Moreover, individual differences in overall maternal responsiveness are related to infant attachment (Blehar et al., 1977), child compliance (Martin, 1981), language development (Tamis-LeMonda et al., 2001), and cognitive development (Bornstein & Tamis-LeMonda, 1989). A recent study by Jaffe, Beebe, Feldstein, Crown, and Jasnow (2001) further demonstrated a nonlinear relation between mother-infant vocal contingency and later attachment security. A mid-range of vocal coordination between mother and infant at 4 months of age is optimal for a secure attachment. For further understanding of the significance of concurrent and

<sup>4</sup> We thank an anonymous reviewer for suggesting this alternative interpretation.

developmental social-regulatory effects of infant nondistress vocalizations, it would be valuable in future research to examine not only whether and to what extent individual differences in concurrent maternal verbal and nonverbal responsive actions contribute to different areas of developmental outcomes but also how different patterns of developmental trajectories are linked to optimal development.

### *Social Regulatory Effects on Maternal Response Were Modality Specific*

Results from the present study also revealed that infant nondistress vocalizations reliably elicited maternal verbalizations/vocalizations (an average response rate of 73%), whereas maternal nonverbal actions were not consistently regulated by infant nondistress vocalizations (an average response rate below 28%). Although mothers were less likely to respond with facial expressions and touch, they responded with head movements the least. It appears that mothers respond contingently and consistently but preferentially to infant nondistress vocalizations with vocalizations/verbalizations. This result not only replicated previous findings that infant nondistress vocalizations tend to elicit vocal/verbal responses from mothers (Bornstein & Tamis-LeMonda, 1989; Keller & Scholmerich, 1987) but also suggests a modality-specific social regulatory function of infant nondistress vocalization in eliciting maternal vocal/verbal actions, rather than nonverbal responses.

Locke (1996, 2001) argued that the production of nondistress vocalizations is motivated by infants' desire to develop and maintain social relationships with their primary caregivers. Evidence from animal research further suggests that in addition to motivational information, contextual information is encoded in vocal signals. Referential specificity in animal communication refers to a vocal signal that conveys sufficient contextual information about an event (as opposed to motivational information about the internal state of the vocalizer) for receivers to select appropriate responses (Owings & Morton, 1997). The fact that mothers responded to infant nondistress vocalizations in a modality-specific manner indicates the possibility of a referential specificity in infant nondistress vocalization. The production of nondistress vocalizations may reflect not only infants' motivation to continue the interactions, as theorized by Locke (1996, 2001), but also information about the context (e.g., the infant is not hungry or the diaper is not wet) that promotes maternal selection of a verbal response rather than, for example, caregiving actions. Nevertheless, our assumption that the responsive actions by mothers reflect their assessments of the information encoded in infant vocalizations needs to be directly evaluated. Future experimental studies are needed to examine the mediating role of maternal information processing of auditory and visual cues by infants (e.g., abilities to discriminate the speech quality of infant nondistress vocalizations) and associated physiological responding (i.e., cardiac response) in regulating maternal response to infant nondistress vocalization.

The modality-specific function found in the current study, however, may be further moderated by culture. Cross-cultural studies have reported that maternal verbal and nonverbal responses are shaped by cultural background. For example, when responding to infant nondistress vocalizations, American mothers are more likely to use verbal responses than are Gusii mothers in Kenya (Richman,

Miller, & LeVine, 1992). Also, despite the fact that American and Japanese mothers are equally contingent in their responses to infant vocalizations, Japanese mothers are also more likely to respond with nonverbal actions such as leaning close and touching than are their American counterparts (Fogel, Toda, & Kawai, 1988). Cross-cultural studies are needed to reveal the moderating role of culture in the modal specificity of maternal responsive actions.

Findings from previous studies also suggest that certain types of maternal responsiveness are specifically associated with certain child outcomes at specific periods in development (i.e., developmental specificity; Tamis-LeMonda et al., 2001). The modal specificity in maternal responsiveness to infant nondistress vocalizations may add more complexity to the developmental story. One can speculate that certain infant signals are more likely to elicit certain types of maternal responsive actions, which, in turn, are more likely to affect certain areas of child development at certain developmental periods. For example, Bornstein and Tamis-LeMonda (1997) failed to find a predictive association between maternal responsiveness (indexed by the combination of maternal physical and verbal responses) to infant nondistress signals (indexed by a composite measure of social gazing, object exploration, and nondistress vocalization) assessed at 5 months and infant language comprehension measured at 13 months. According to our new theoretical formulation, it is likely that the development of language comprehension in early toddlerhood is specifically associated with maternal vocal/verbal responsiveness, which is reliably elicited by infant nondistress vocalization. This delineation of specificity in the relation between maternal responsiveness and child developmental outcomes, however, needs to be empirically tested.

### *Maternal Verbal Response Was Synchronized With Maternal Nonverbal Response*

Our finding of co-occurrence between verbal and nonverbal actions in maternal response provides support for the contention that maternal verbal actions are characterized by redundancy across multiple behavioral modalities and by synchronization in their tempo and intensity (Gogate et al., 2000). Maternal interactive actions are delivered as a package (Beebe & Gerstman, 1984) with which mothers signal turn-taking to their infants (Mayer & Tronick, 1985). Research on the development of intermodal perception of expressive behaviors has established that infants are sensitive to the correspondence in vocal and facial affective expressions during their first few months. It seems that young infants perceive the affordances of multimodal communication rather than perceiving voices and faces as distinct entities. Multimodal information facilitates young infants' accurate perceptual detection, discrimination, and recognition (cf. Walker-Andrews, 1997). Mothers appear to be sensitive and adaptive to their infants' perceptual development, as demonstrated by our findings that despite individual differences, the majority of mothers preferentially showed a multimodal response in which a verbal action co-occurred with a nonverbal one.

The synchronization of maternal verbal communicative behaviors with nonverbal communicative behaviors may be devised to capture infants' attention and to facilitate their detection of the multimodal relations. It has been speculated that even though

vocalizations by caregivers during face-to-face interactions serve to recruit infant attention, it is the caregiver's facial expression that cues the infant to the emotional content of the voice (D'Entremont & Muir, 1999). Touch is also used by mothers to regulate infant visual attention, vocalization, and emotions. Presumably, contingent changes in tactile stimulation co-occurring with maternal vocalizations/verbalizations would better elicit infant attention, vocalization, and smiling than would maternal vocalizations/verbalizations alone during face-to-face interactions (Stack & Muir, 1992; Pelaez-Nogueras, Field, Hossain & Pickens, 1996). The specific verbal-nonverbal synchronization in maternal response found in this study between maternal vocalizations/verbalizations and facial expressions and touch lends further credence to the maternal adaptation-to-infant-needs hypothesis.

In the present study, we investigated the synchrony of maternal verbal and nonverbal responses with only one type of nonverbal response. Gogate et al. (2000) suggested that "motherese" during mother-infant communication may be trimodal (i.e., showing synchrony in auditory, visual, and tactile stimulation) instead of bimodal in nature. It remains to be determined in future studies whether and how the synchronization among multiple behavioral modalities may vary according to the speech quality of the infant nondistress vocalization, may differ across interactive contexts (e.g., mother and infant mutually vs. unilaterally engaged), and may change with the psychosocial characteristics of the mother (e.g., depression) and the infant (e.g., temperament).

#### *Change Processes Occurred Systematically in Maternal Verbal Response*

The examination of change processes in maternal responses to infant nondistress vocalizations highlights the fact that maternal responsiveness is a dynamic process in which the configuration of maternal verbal and nonverbal actions is organized and reorganized in accordance with infant signals. Infant nondistress vocalizations elicit a change in maternal action, which is conventionally defined as the emergence of a new action and its addition to the existing configuration of maternal behaviors. Besides the change process of addition, we explored two other change processes in this study, namely, deletion (i.e., elimination of actions in the ongoing behavioral configuration) and modification (i.e., adjustment in the rhythm, intensity, timing, and/or form of ongoing behaviors). Our findings suggest that some change processes were more likely to occur in maternal vocal/verbal responsive actions. Specifically, mothers were more likely to add and modify the features and/or content of their vocalizations/verbalizations when responding to infant nondistress vocalizations. Therefore, in addition to considering the target, the content, and the coherence of maternal response, a multidimensional conceptualization of maternal responsiveness may also need to consider change processes.

The relatively high success rate of infant nondistress vocalizations in eliciting modification and addition in maternal vocal/verbal actions provides further evidence that the pattern of mother-infant vocal communication is characterized by protoconversation or turn-taking, as in adult communication (e.g., Bateson, 1975; Beebe, Jaffe, Feldstein, Mays, & Alson, 1985). Our findings also confirmed previous reports that mothers make fine-tuned adjustments in their speech according to infants' behavioral states and interactive patterns (Brousseau, Malcuit, Pomerleau, & Feider,

1996; Sokolov, 1993). Compared with adult-directed speech, infant-directed speech is unique in its prosodic, paralinguistic, and lexical characteristics. Features of "motherese" include high and exaggerated pitch, wide excursions of melodic contour, slow tempo, and long pauses between utterances, which are more effective in engaging, maintaining, and modulating infant attention and arousal (Fernald, 1992). In response to infant nondistress vocalizations, mothers frequently make a contingent change in the form of their baby talk—from an infant-directed speech to sound imitation. Maternal mirroring or matching of infant vocalization has also been suggested to facilitate early communication (Kugiumtzakis, 1993; Papousek & Papousek, 1989). Because prespeech mouth movements in young infants tend to precede the onset of vocalization (Trevvarthen & Marwick, 1986), mothers are also likely to pause in their vocalizations/verbalizations and attentively wait for their infants to vocalize. Immediately after infant vocal production, mothers make referential comments by attributing meanings to these content-free sounds. This maternal verbal response of "thickening thin data" (Kaye, 1979) may also contribute to the reciprocity of early communication.

Addition and modification in contingent maternal vocal/verbal responses to infant nondistress vocalizations appear to suggest that maternal infant-directed speech is not a mere biologically based interactive strategy resulting from evolution (Fernald, 1992) but a product of dynamic mutual adaptation between mother and infant during social interaction. Maternal responsive actions to infant nondistress vocalizations, therefore, are inherently an expression of the dynamics of a dyadic communication system contributed to by both infant and mother. It would be fruitful to conceptualize the social signal function of infant nondistress vocalization from a relational approach in order to further unravel the transactional effects between infant signals and maternal responses over time.

#### *Methodological Issues in Studying Maternal Responsiveness*

The present examination of maternal responsive actions to infant nondistress vocalizations has generated a number of methodological issues that deserve further discussion. Factors such as the selection of the context for data collection (home vs. lab), the operationalization of maternal responsiveness (contingent promptness vs. appropriateness), the selection of the size of the time window between infant signal and maternal response, the confounding effect of co-occurring infant social signals (e.g., gazing and smiling), and the determination of the base rate of maternal response would all affect the results of an investigation on the social regulatory effects of infant nondistress vocalization.

*Home versus laboratory settings.* In this study, an average of 80% of the infant nondistress vocalizations were responded to by mothers verbally or nonverbally, which is higher than the figures of 50%–65% reported in previous studies (Bornstein & Tamis-LeMonda, 1989; Green & Gustafson, 1997). This difference may be due to the fact that data collection in the current study took place in a laboratory situation, whereas in the previous studies it took place in the infants' homes. Mothers are typically instructed to follow their daily routines during home observations. Mothers and their infants may or may not be in close proximity during a 45-min to 2-hr observation. Molar maternal responsive actions such as approaching the infant, picking up the infant, and offering

a toy (as opposed to molecular behaviors such as smiling and head movements) are typically the target behaviors chosen to reflect the regulatory effects of nondistress vocalizations on distal social interactions. As a result, one would expect substantially fewer maternal responses to infant nondistress vocalizations with an average duration of less than 1 s (Hsu et al., 2000) to be observed at home than in a laboratory situation, which is consistent with the finding that mothers are more active and responsive in the laboratory than in the home setting (Belsky, 1980). Despite the constraints on the physical proximity between mothers and infants in laboratory observations, individual differences in maternal response were found in the present study. Therefore, results from this study are meaningful for understanding the social regulatory function of infant nondistress vocalizations when mothers and their infants are engaged in face-to-face communication.

*Responsiveness versus appropriateness of maternal actions.* In previous studies, maternal responsiveness has often been conceptualized as a unitary dimension of sensitive responsiveness that integrates appropriateness (i.e., affection and warmth) and contingency (i.e., timing and promptness). Because the current study focused on maternal contingent response to infant nondistress vocalization, a maternal responsive action was determined solely on the basis of the timing of its occurrence, and it was not necessarily an appropriate action. Even though a stringent 1-s interval was applied to ensure the contingency of maternal behavior, one would expect the maternal response rates reported in this study to be higher than those found in previous studies in which maternal responses were further qualified by their appropriateness. Because contingency and appropriateness are independent dimensions of maternal social behaviors (Keller et al., 1999), and each requires a different behavioral coding strategy at a respective micro- and macro-level, it may be fruitful to separate these two constructs in empirical investigations of maternal responsiveness aimed at elucidating individual differences, developmental changes, and developmental significance.

*Size of time windows between infant signal and maternal response.* The time windows used to determine the contingency of maternal response vary from intervals of 1 s to 30 s. In the present study, a 1-s latency rule was applied to determine changes in both maternal verbal and nonverbal response actions. This may have limited the identification of change processes occurring within nonverbal behavioral modalities. Despite the fact that there is a propensity for mothers to respond to their infants' signals during face-to-face interactions within short intervals of less than 1 s (Keller et al., 1999), it is plausible that the latency of maternal response to infant signals may be different for each individual behavioral modality. Whereas it may take mothers less than 1 s to respond vocally or verbally to infant nondistress vocalizations, it may take several seconds for mothers to respond with facial expressions, touching, and/or head movements. The establishment of optimal contingent latencies for different behavioral modalities would facilitate future research on the change processes involved in the social regulatory function of infant nondistress vocalization.

*Univariate versus multivariate effects of infant social signals on maternal response.* During spontaneous interactions, maternal verbal and nonverbal actions may not be exclusive and specific contingent responses to infant vocal signals. Indeed, infant nondistress vocalization tends to co-occur with infant smiling and gazing at the mother during face-to-face communication (Hsu,

Fogel, & Messinger, 2001) and, therefore, exerts a "multivariate effect" on maternal response. In other words, maternal response may be elicited by infant social signals involving multiple modalities. To determine the "univariate effect" of infant vocalization on maternal responsive actions, experimental manipulations controlling for the occurrence of infant nondistress vocalizations with and without co-occurring eye contact and facial expressions would be necessary. Experimental studies analyzing the univariate and multivariate social regulatory functions of infant vocalization, gaze, and facial expression can be carried out, for example, by assessing maternal responses to video clips in which infant social signals appear in unimodal (e.g., voice alone, gaze alone, face alone) and multimodal (e.g., voice with gaze, voice with face) formats.

*Assessing base rates of maternal actions.* In the present study, when determining whether the likelihood of maternal response was greater than expected, we performed binomial tests with a chance level of 50% because of the application of a dichotomous (i.e., responded or not) maternal response classification. Watson (1979, 1985) suggested a different method of investigating the likelihood of temporal contingency. Three different approaches based on coding methods—namely, time-based, interval-based, and event-based coding—can be used to derive the estimate of expected probability (Moran, Dumas, & Symons, 1992). The time-based approach, which assumes that a given maternal action is randomly distributed in time with respect to a given infant action, has been shown to be more advantageous than the other two in avoiding sampling bias. Therefore, despite the fact that it is extremely time consuming and labor intensive to achieve sufficient reliability, a continuous, real-time coding has been recommended as the best strategy for deriving the expected unconditional probability, or base rate, of a maternal action (Symons, 1992; Symons & Moran, 1994).

In contrast, when examining the change processes involved in maternal responsive actions, it is impossible to derive the expected unconditional probability, which is assumed to be independent of infant actions, in the manner discussed above. This is because a change process of maternal response can only be identified by comparing maternal actions occurring before and after the event of the infant action. In the absence of a target infant action, the change processes of addition, deletion, and/or modification in maternal actions cannot be determined. Nevertheless, it may be informative to examine the contingent signal–response relationship by comparing the differences and similarities in the change processes of maternal responses to infant vocalizations with different emotional tones (e.g., nondistress vocalizations vs. laughing vs. crying) and to infant social signals emitted via different behavioral modalities (e.g., voice vs. gaze vs. face).

In sum, the present study demonstrated that infant nondistress vocalization exerts social regulatory effects on maternal behaviors. This regulatory function of infant nondistress vocalization appears to be modality specific in that it modulates maternal verbal actions concurrently through its occurrence rather than through speech quality. Developmentally, the speech quality of infant nondistress vocalization—in particular, speechlike syllabic vocalization—exerts an effect on maternal response that is revealed by individual differences in growth trajectories. Additions to and modifications of maternal vocal/verbal responses are likely to be synchronized with changes in maternal touch and facial expressions, which suggests that maternal response to infant nondistress vocalization

is multidimensional and multimodal in nature. Locke (1996, 2001) maintained that vocal development is an unintended consequence of infants' developing abilities in recognizing caregivers, interpreting and predicting caregivers' behaviors, and sharing their emotional experience with caregivers. Irrespective of the apparent asymmetry in parent and infant behavioral capacities, we suggest that the social regulatory function of infant nondistress vocalization implicates the dynamic transactional processes of co-regulation and mutual adaptation between the actions of infant signaling and parent responding over time.

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### Call for Nominations

The Publications and Communications (P&C) Board has opened nominations for the editorships of *Comparative Psychology*, *Experimental and Clinical Psychopharmacology*, *Journal of Abnormal Psychology*, *Journal of Counseling Psychology*, and *JEP: Human Perception and Performance* for the years 2006–2011. Meredith J. West, PhD, Warren K. Bickel, PhD, Timothy B. Baker, PhD, Jolida C. Hansen, PhD, and David A. Rosenbaum, PhD, respectively, are the incumbent editors.

Candidates should be members of APA and should be available to start receiving manuscripts in early 2005 to prepare for issues published in 2006. Please note that the P&C Board encourages participation by members of underrepresented groups in the publication process and would particularly welcome such nominees. Self-nominations also are encouraged.

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- *Journal of Counseling Psychology*, Susan H. McDaniel, PhD, and William C. Howell, PhD
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