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Infant non-distress vocalization during mother-infant face-to-face interaction: Factors associated with quantitative and qualitative differences☆

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Abstract

This study investigated the associations of the quantity and quality of infant nondistress vocalization with maternal and infant social actions (smiling and gazing) during dyadic interaction. Thirteen infants and their mothers were observed weekly in a face-to-face interaction situation from 4 to 24 weeks. Results showed that the quantity (rate per minute) and quality (speech-likeness) of infant nondistress vocalization changed systematically with maternal smiling and gazing as well as with the infants' own smiling and gazing. Infants produced more speech-like syllabic sounds when their mothers were smiling, when they were looking at their mothers' faces, and when the infants themselves were smiling. Follow-up analysis revealed that the amount of infant speech-like syllabic sound was highest during Duchenne smiling (cheek-raise smiling), which is thought to be more emotionally positive than non-Duchenne smiling (smiling without cheek-raise). Sequential analysis further indicated that infants were more likely to produce speech-like syllabic sounds, following the onset of their smiling and gazing at mother and their mothers' smiling as compared to nonspeech-like

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vocalic sounds. These coordinative associations found within the child and between the dyad suggest that the speech quality of nondistress vocalization may be an index of positivity in dyadic face-to-face interactions during early infancy. © 2001 Elsevier Science Inc. All rights reserved.

Keywords: Infant nondistress vocalization; Smiling; Gazing; Mother-infant interaction

1. Introduction

Infants smile, vocalize, and alternate their gaze toward and away from their mothers during early face-to-face interaction (Brazelton, Koslowski, & Main, 1974). Recent findings have further documented that infant communicative behavior in different modalities such as vocalization, gaze, facial expression, body movements, and hand gestures show coordinated patterns during social interaction (e.g., Fogel & Hannan, 1985; Legerstee, Corter, & Kienapple, 1990; Masataka, 1995; Weinberg & Tronick, 1994; Yale et al., 1999). Individual social actions are coherently organized within the child in relation to specific interactive contexts reflecting the infant's internal state (Weinberg & Tronick, 1994). Empirical examination of the coordination of social actions within the child, nevertheless, has mostly focused on the co-occurrence of facial expression with other modalities such as gaze. Relatively fewer studies have investigated the coordination of infant vocalization with various communicative modalities (Malatesta, 1981; Yale et al., 1999), which primarily focused on the coordination of hedonic tones in facial and vocal signals. It was found that while negative vocalizations (fussy and cry) tend to co-occur with negative facial expressions (sad and anger), nondistress vocalization (neutral and positive) are more likely to co-occur with positive facial expression (joy) (Weinberg & Tronick, 1994; Yale, Messinger, Cobo-Lewis, Oller, & Eilers, 1999). Yet, close investigations of the question such as whether the quantity and quality of infant nondistress vocalization change systematically with infant smiling and gazing has not been done. Thus, the first goal of the present study is to unravel the specific coordinative associations between the quantity and quality of infant nondistress vocalization and other social actions such as smiling and gazing within the child.

One of the functions of vocalizations by animals and adults is to serve as the symptom of internal affective state (Scherer, 1992). Available evidence indicates that this may also be the case with vocalizations uttered by infants (see Barr, Hopkins, & Green, 2000). Vocalizations such as cry and laughter are often used by parents as the barometers of their infants' affective state (Papousek, 1992). When in an inactive-alert state, the nondistress vocalizations produced by infants tend to be infrequent, brief, and low intensity, whereas in an active-alert state they tend to exhibit vocalizations that are perceived as more relaxed and with vowel quality (Papousek, 1992). Nondistress vocalizations are also thought of as emotional concomitants of cognitive recognition and mastery (McCall, 1972; Zelazo, 1972). Infants between 8 and 18 weeks old were more likely to vocalize and smile simultaneously when processing simple nonsocial stimuli (Shultz & Zigler, 1970).

Oller (2000) posits that infant nondistress vocalization is not associated with a particular social function, meaning, or usage, nevertheless, sociality is one of its inherent features. Also, together with gazing and smiling, infant nondistress vocalization is conceptualized as a component in the constellation of expressive behavior indexing positive emotional states (Malatesta, 1981). To our knowledge, no study has closely inspected the coordinative pattern between nondistress vocalization and infant smiling during social interaction. This information will enhance our understanding about the role of the quantity and quality of nondistress vocalization in indexing young infants' experience and expression of positive emotional states.

According to previous research (Ekman & Friesen, 1982), different types of smiles are observed with adults. In particular, Duchenne smiles, in which the muscle around eye area contracts raising the cheek, are not only associated with adults' self-report of enjoyment but also observers' ratings of positivity in smiles (Ekman, Davidson, & Friesen, 1990; Frank, Ekman, & Friesen, 1993). Duchenne smiles are also observed in infancy during parent-infant play interaction. During the first 6 months, Duchenne smiles (lip corner raise plus high cheek raise) tend to emerge from non-Duchenne smiles (lip corner raise only, with no cheek raise) (Messinger, Fogel, & Dickson, 1999). Dechenne smiling occurs more frequently during early trails of climax phase of a tickle game (actual physical contact with infant) at 6- and 12-month of age (Fogel at al., 2000). Furthermore, Duchenne smiles are more likely than non-Duchenne smiles to occur when mothers smile at infants and when infants gaze at their mothers during the first 6 months (Messinger et al., 1999). When greeting mothers after a brief separation, 10-month-olds are more likely to exhibit Duchenne smiles. In contrast, when approached by a stranger, these infants are more likely to display non-Duchenne smiles (Fox & Davidson, 1988). Finally, in a study with 12-month-old infants, Duchenne smiles are more likely than non-Duchenne smiles during mother-infant object play and father-infant book reading (Dickson, Walker, & Fogel, 1997). Taken together, the above review suggests that there are different types of smiles in infancy, and these distinct types of smiles may be qualitatively different, indexing different kinds of enjoyment (Fogel et al., 2000). Assuming infant internal affective state is reflected in and externalized by the coordination of various communicative modalities within the child, there may be a reliable and consistent association between infant nondistress vocalization and different types of smiles. In the present study, we explore the coordinative associations of the quantity and quality of nondistress vocalization with different types of infant smiling.

In addition to smiling, eye contact with a social partner is another critical ingredient of the production of infant vocalization (Bloom, 1990). Gustafson and Green (1991) reported an increase in the number of infants showing coordination between cry vocalization and gaze at mother during the 2nd half of the first year. In conditioning experiments, 3-month-olds utter more nondistress vocalizations when they maintain eye contact with the adult partner than when the partner's eyes are invisible (Bloom, 1974). Kaye and Fogel (1980) further confirmed this finding in a naturalistic study of mother-infant communication. When gazing at their mothers' face, infants are more likely to utter nondistress vocalizations at 12 and 26 weeks of age (but not at 6 weeks). Other longitudinal studies also indicated that the occurrence of nondistress vocalization during eye contact with parent steadily increases over the first 4 months during face-to-face interaction (Keller & Scholmerich, 1987; van Beek, Hopkins, & Hoeksma, 1994). However, when objects are involved in mother-infant interaction, the coordination between vocalization and gazing does not become evident until 10 months of age (D'Odorico & Cassibba, 1995). It appears that the strength of the coordination between the occurrence of infant nondistress vocalization and gazing at mother increases during the first year. Nevertheless, it is unclear whether visual attention to social partner is associated with the qualitative difference in infant nondistress vocalization.

During face-to-face interaction, mothers deliver a package of patterned social actions including vocal, facial, and touch actions (Beebe & Gerstman, 1984; Koester, Papousek, & Papousek, 1989). Conditioning studies demonstrated that adults' simultaneous looking, smiling, touching, and vocalizing evoke infants' nondistress vocalization (Poulson & Nunes, 1988; Rheingold, Gewirtz, & Ross, 1959; Weisberg, 1963). Available evidence further suggests that the coordination between social actions in early infancy is not limited to within the child or within the mother; the coordinative patterning is also found between the dyad. For example, research on the occurrence timing of infant vocalization in relation to that of maternal vocalization during naturalistic social interactions suggests two systematic patterns: coaction and alternation (Stern, Jaffe, Beebe, & Bennett, 1975). A coaction (or overlapping) pattern is when mother and infant vocalize simultaneously, which is found to be the predominant mode of mother-infant vocal communication before 3 or 4 months of age. Later, an alternating (or turn-taking) pattern, in which infant and mother engage in a conversation-like communication as in adult-adult interaction, replaces the former one (Jasnow & Feldstein, 1986; Ginsburg & Kilbourne, 1988; Stern et al., 1975; Stevenson, Ver Hoeve, Roach, & Leavitt, 1986). Experimental studies also demonstrated that both the quantity and quality of infant nondistress vocalization change systematically with the temporal, acoustic, and verbal characteristics of adult partners' vocalization (see Bloom, 1990). The verbal component, turn-taking sequence, and contingency in verbal responses by adults increase the ratio of speech-like to nonspeech-like vocalizations emitted by three-month-old infants (Bloom, 1988; Bloom, Russell, & Wassenberg, 1987; Masataka, 1993). Legerstee (1991) reported that young infants produce significantly more speech-like sounds when they engage in a social interaction with an adult as compared to interacting with inanimate objects during the first 6 months. They also utter more nonspeech-like vocalic sounds when interacting with an unresponsive adult partner as compared to interacting with a responsive one.

Taken together, the above studies suggest that the quantity and quality of infant vocalization are associated with overall features of the social context. However, after extensive review of the literature, Vihman (1996) concluded that before the babbling period "The role of social context in facilitating advances in vocal production is intriguing but unresolved. . ." (p. 118). Understanding of the coordination of infant nondistress vocalization with individual maternal social actions such as smiling and gazing may reveal the effects of individual maternal social actions on the occurrence and quality of nondistress vocalization.

Maternal smiling is positively correlated with the frequency and mean duration of infant nondistress vocalization (Millar, 1988). Infants as young as 6 weeks of age are more likely to produce nondistress vocalization when their mothers are facially expressive (with smiles or exaggerated expressions) (Kaye & Fogel, 1980). Infants utter significantly fewer nondistress vocalizations when mothers simulate a depressed mood or pose a still-face as compared to when mothers interact with them spontaneously (Field, 1984; Weinberg & Tronick, 1994). These studies provide grounds for hypothesizing that the occurrences and quality of infant nondistress vocalization are coordinated with the individual social actions of their partner. Coordinative patterning of infant nondistress vocalization with maternal smiling and gazing also suggests that nondistress vocalization is associated with the infant's positive emotional experience and expression during dyadic interaction. Therefore, the second goal of the present study is to provide observations of the coordinative relations between infant nondistress vocalization and maternal smiling and gazing during face-to-face interaction.

The main purpose of this study was to determine whether the quantity and quality of infant nondistress vocalization are differentially associated with infants' own smiling and gazing as well as with their mothers' smiling and gazing. This information would enhance our understanding and fill the gap in the existing literature regarding the role of individual infant and maternal social actions in infant vocal production as well as the linkage between infant nondistress vocalization and positive emotional experience and expression in early infancy. We hypothesized that the quantity and quality of infant nondistress vocalizations uttered during face-to face interaction would change systematically with their own smiling and gazing as well maternal smiling and gazing. Specifically, we hypothesized that the increased occurrence (i.e., rate per minute) and the more speech quality (i.e., speech-likeness) of infant nondistress vocalizations would be contemporaneously associated with and temporally coordinated with smiling and gazing displayed by infant and mothers. Associations between infant nondistress vocalization and different types of infant smiling would also be investigated. Due to the lack of previous research, no specific hypothesis was formulated.

2. Method

2.1 Participants

All research participants were recruited from a university community in the Midwestern United States by letters through birth announcements in the local newspaper. Mothers and their infants were invited to participate in a 2-year longitudinal study on the development of mother-infant communication (for details see Nwokah, Hsu, Dobrowolska, & Fogel, 1994). The data for the present study were from 13 singleton infants and their mothers, who remained in the study during the first six months after the birth of their infants. Of the 13 dyads, 12 were Caucasians and one was African American. All the infants were full-term, had no major birth complications, came from intact families, and passed a hearing test at six months. Six of the infants were first-born and eight were male. Nine of the mothers had their bachelor degrees, 2 had some college education, and 2 had their high school diplomas.

2.2 Procedure

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). Mothers were instructed to play with their infants as they normally would at home in different conditions. Only the face-to-face interaction data from the lap conditions during the first six months were analyzed for the current study (also see Hsu, Fogel, & Cooper, 2000; Hsu & Fogel, 2001).[1] Mothers were seated on a straight-back chair with the baby in their laps with no toys available. Most of the sessions lasted approximately 5 min, with the exception of when the infant became too fussy to continue (9 out of a total of 210 sessions). The average duration of the sessions was 287 s (range = 80–300). 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 positioned to focus on the mother's upper body with a frontal view of the mother's face and with the infant visible. The second camera was focused on the infant's face and body. The third camera was used as a backup camera to get the best view of the mother's and/or the infant's face. The outputs from the two cameras with 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 (Shure 575SB) hung from the ceiling about 12 inches from the mother's head transmitted the audio signals to an amplifier (Shure M267) for recording.

2.3 Infant non-distress vocalization

The on- and off-set times of a nondistress (or nonvegetative) vocalization were coded from the video. A vocalization was identified as a discrete sound occurring within one respiration cycle. Two separate sounds were recorded, if the sound was segmented by a perceivable silence. Following previous studies (e.g., Stark, 1978; Oller, Eilers, Steffens, Lynch, & Urbano, 1994), vegetative sounds (such as wheezes, sneezes, coughs, hiccups, and clicking sounds), effort sounds (such as grunts), and negative vocalizations (subjectively perceived as negative in hedonic tone, such as whimpering, fusses, and cries) were excluded. A total of 168 infant laughs were identified across all infants and sessions. Due to the small sample size and differential contribution,[2] infant laughter was excluded from the data analysis. No babbling (i.e., sequences of consonant-like and vowel-like sound; MacNeilage & Davis, 1992) was observed in the collected samples.

After each of the nondistress vocalization was identified, its quality was evaluated and categorized according to Bloom's (Bloom, 1988; Bloom, Russell, & Wassenberg, 1987) definitions. Based on 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 classifies infant nondistress vocalizations into syllabic and vocalic sounds. *Syllabic sounds* are vocalizations that tend to be uttered in the anterior area of the mouth, containing greater oral resonance, and perceived as more relaxed and speech-like. *Vocalic sounds* are vocalizations that tend to be produced in the posterior area of the mouth, containing greater nasal resonance and lacking oral projection, and perceived as more forced and less speech-like. Sixteen percentage of the sessions (34 sessions) were randomly selected from each dyad and coded by an independent coder for the reliability testing of sound quality. An agreement between two coders was counted when they identified and classified a vocalization the same way within a maximum lag time of 2 s. The vast majority of lag times between coders for the matches were less than 0.5 s. The percentage of agreement between the two coders was 85% and Kappa was 0.80.

2.4. Maternal and infant smiling

In separate coding passes, the infant's and the mother's faces were coded second-by-second using the Facial Action Coding System (FACS; Ekman & Friesen, 1978) by certified coders who were conversant in the application of this coding system to infants.[3] FACS is an anatomically based facial coding system. The coding is done by the identification of particular muscular contractions or facial action units (AUs). Smiling facial expression is identified by the presence of lip corner raising (AU12) which is produced by the action of the zygomatic muscle. The coding criteria for lip corner raising include: (1) raising of the lip corners, (2) raising of the infraorbital triangle which makes the cheeks more distinguished, and (3) deepening of the nasolabial furrow between the nose and the cheeks.

In this study, cheek raising (AU6) produced by the contraction of the muscle around the eye area (orbicularis oculi, pars lateralis) was coded independently for infants. Therefore, two types of infant smiles were differentiated in the present study – Duchenne (both AU12 and AU6 involved) and non-Duchenne (only AU12 involved) smiles. Approximately 15% of the total sessions were coded for infant smiling reliability. Using a 2-sec time window for coding of the onset of facial actions, percentages of agreement for lip corner and cheek raises were both 79%. The average lag times between coders were less than 0.5 s. The reliability based on the amount of time spent in each action (total duration) was also calculated. Total duration was used as the basis of the reliability analyses of facial actions because it formed the basis of the substantive analyses. The total durations of infant facial actions coded by two independent coders who agreed that the same action was occurring at the exact time were used to derive time in agreement – lip corner raising was 89% agreement and Kappa 0.77; cheek raising 87% agreement and Kappa 0.63. Because of obstructions on mothers' face by hair and/or glasses, it was not possible to code the cheek raising (AU6) of mothers.[4] Maternal smiling, therefore, was identified only by the presence and absence of lip corner raising (AU12). The reliability for lip corner raising was 87% and Kappa 0.75.

2.5. Maternal and infant gaze

The continuous coding of the on- and off-set times of gazing at or away from the partner's face was performed separately for mothers and infants. While all gaze changes were coded for infants, gaze changes for mothers were recorded when they lasted for at least 1.5 seconds.[5] Intercoder reliability was calculated based on 15% of sessions selected at random. The same method of calculating reliability for facial actions was used for the computing reliabilities for gaze. Cohen's Kappas were 0.82 and 0.70 and percentage of agreement was 96% and 90% for maternal and infant gaze coding, respectively.

2.6 Data aggregation and analysis

Due to the low and variable occurrence of infant nondistress vocalization (Bloom, 1990), this study adopted an intensive repeated-measures design, in which a smaller number of infants were observed frequently (i.e., weekly) in a social context of mother-infant face-to-face interaction. To reduce sampling zeros and to derive more reliable estimates of infant nondistress vocalization, the weekly sessions were collapsed into five monthly age intervals: (1) 2nd month: 4 to 8 weeks, (2) 3rd month: 9 to 12 weeks, (3) 4th month: 13 to 16 weeks, (4) 5th month: 17 to 20 weeks, and (5) 6th month: 21 to 24 weeks.

To identify whether different types of infant nondistress vocalizations are associated with infant smiling and gazing as well as maternal smiling and gazing, the occurrences of infant syllabic and vocalic sounds were computed separately in each session for the following four time periods: (1) infants were Duchenne smiling, non-Duchenne smiling, and not smiling, (2) infants were gazing at and away from their mothers, (3) mothers were smiling or not smiling, and (4) mothers were gazing at or away from their infants. Because of variations in the durations of these time periods, the occurrence of infant nondistress vocalization was expressed as rate per minute (e.g., the total number of infant vocalization occurring during infant gazing at mother/the total duration of infant gazing at mother).

To test the sequential dependencies of infant nondistress vocalization with infant smiling and gazing as well as maternal smiling and gazing, the time series of infant nondistress vocalization was merged with each of the time series of maternal and infant social actions separately. Using nondistress vocalization as the target event, contingency tables were formulated, in which the frequency of infant syllabic and vocalic sounds occurring at time_t preceded by infant smiling, infant gazing, maternal smiling, and maternal gazing at time_{t-1} was tabulated separately. Conditional probabilities of syllabic and vocalic sounds preceded by each of these social actions were then computed for each infant. Yule's Q statistics were also calculated separately for each infant, measuring the extent to which a conditional probability is significantly different from its expected simple probability. 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 association between syllabic sound and maternal and infant smiling or gazing relative to that of vocalic sound. After Yule's Q statistics were derived for each infant, one-way t tests were then performed to demonstrate whether the Q scores were significantly different from zero (i.e., no sequential association). Number of infants showing effects in the expected direction (i.e., Yule's $Q > 0$) was also tallied. Significance was then computed for proportions (out of 13) by using binomial tests to indicate the strength of effects.

3. Results

3.1. Descriptive statistics

A total of 1,692 nondistress infant vocalizations were sampled across all 13 infants over the course of the first six months. Descriptive statistics by the monthly age-intervals are shown in Table 1. Overall, sixty-one percentage of these vocalizations were speech-like syllabic vocalizations. Mothers smiled about 1/3 of the play session, but they looked at their infants almost constantly. In contrast, infants smiled and gazed much less than did their mothers. Infants displayed approximately the same amount of Duchenne and non-Duchenne smiles during the first 4 months, but exhibited more Duchenne smiles with high cheek-raise

Table 1
Descriptive statistics of infant and maternal social actions

Infant and Maternal Actions	Monthly Age Intervals				
	2 Months Mean (SD)	3 Months Mean (SD)	4 Months Mean (SD)	5 Months Mean (SD)	6 Months Mean (SD)
Infant Vocalization (Rate per Minute)					
Syllabic Sound	0.72 (1.34)	1.08 (1.02)	1.19 (1.19)	1.18 (1.69)	0.92 (0.98)
Vocalic Sound	0.56 (0.50)	0.83 (0.69)	0.93 (0.84)	0.54 (0.50)	0.40 (0.30)
Infant Smiling (% of Session)					
Duchenne Smiles	2.37 (2.12)	5.46 (6.65)	6.33 (6.44)	6.22 (5.78)	7.94 (6.69)
Non-Duchenne Smiles	2.58 (2.78)	4.81 (3.84)	6.18 (4.44)	9.11 (5.99)	10.92 (6.53)
Infant Gazing at Mother (% of Session)	41.91 (20.65)	35.35 (22.76)	31.21 (22.07)	23.17 (14.36)	16.07 (8.54)
Maternal Smiling (% of Session)	29.09 (12.49)	32.66 (16.98)	36.94 (12.56)	38.16 (14.78)	37.61 (17.45)
Maternal Gazing at Infant (% of Session)	88.83 (9.43)	85.85 (10.08)	90.97 (9.12)	91.07 (8.17)	85.24 (13.85)

Note. Proportions were calculated over the total duration of weekly sessions.

during the later sessions of the first six months. Detailed reports for this sample on the development of infant nondistress vocalization (Hsu et al., 2000), smiling (Messinger et al., 1999), and gazing (Fogel et al., 1999) during the first six months in the context of mother-infant face-to-face interaction can be find elsewhere and are not repeated here.

3.2. Comptenperous associations between non-distress vocalization and individual social actions

Four sets of repeated-measures of analysis of variance were performed separately to detect the association between infant nondistress vocalization varying in speech quality with each individual social action that is within the child, including infant smiling and gazing, and between the dyad, including maternal smiling and gazing, across the first 6 months.

3.3 Infant smiling

A 2 (Infant Vocalization: syllabic vs. vocalic) x 3 (Infant Smiling: Duchenne, non-Duchenne, and no smiles) x 5 (Monthly Age Interval) repeated-measures analysis of variance with the rate per minute of infant nondistress vocalization as the dependent variable was conducted[6] (see Table 2 for descriptive statistics). Significant main effects for Infant Vocalization, $F(1,10)=6.53$, $p < .03$, and Infant Smiling were found, $F(2,20)=4.88$, $p < .02$. The two-way interaction of Infant Vocalization x Infant Smiling approached significance, $F(2,20)=2.72$, $p < .09$. Results from the follow-up analyses showed that there was no significant difference in the rate of nonspeech-like vocalic sound during the time period infants displayed different types of smiles. However, a trend analysis demonstrated that with speech-like syllabic sounds, there was a significant linear pattern during the time periods

Table 2
Rate per minute of infant non-distress vocalization by infant smiling and gazing

Infant Social Actions	Monthly Age Intervals				
	2 Months Mean (SD)	3 Months Mean (SD)	4 Months Mean (SD)	5 Months Mean (SD)	6 Months Mean (SD)
Smiling					
Syllabic Sounds					
Duchenne Smiles	5.24 (9.15)	3.12 (3.35)	3.87 (5.12)	3.11 (4.35)	1.71 (2.66)
Non-Duchenne Smiles	1.47 (2.55)	2.05 (2.23)	2.46 (2.50)	2.31 (3.89)	2.17 (1.94)
No Smile	1.35 (2.81)	1.33 (1.48)	1.76 (2.43)	1.56 (2.70)	0.86 (0.68)
Vocalic Sounds					
Duchenne Smiles	0.20 (0.45)	1.46 (1.74)	3.11 (4.35)	0.91 (1.64)	0.67 (0.81)
Non-Duchenne Smiles	1.13 (1.70)	1.89 (2.85)	2.31 (3.89)	0.44 (0.76)	0.59 (0.94)
No Smile	1.38 (1.39)	1.16 (0.99)	1.56 (2.70)	0.83 (1.01)	0.48 (0.27)
Gazing					
Syllabic Sounds					
Gazing at Mother	1.09 (2.15)	1.67 (1.57)	2.30 (2.79)	2.23 (2.82)	1.23 (1.36)
Gazing Away	0.14 (0.13)	0.66 (1.01)	0.55 (0.62)	0.93 (1.27)	0.86 (1.11)
Vocalic Sounds					
Gazing at Mother	0.57 (0.64)	0.91 (1.05)	1.29 (1.85)	0.52 (0.43)	0.59 (0.72)
Gazing Away	0.50 (0.39)	0.55 (0.58)	0.59 (0.37)	0.54 (0.54)	0.39 (0.34)

infants exhibited different types of smiling, $F(1,10)=9.15$, $p < .02$. Infants vocalized speech-like syllabic sounds most frequently during the time period when they smiled with Duchenne smiles (high cheek and lip corner raised), followed by non-Duchenne smiles (only lip corner raised), and the least with no smiling expressions. No significant main effect for and interaction effect involving Monthly Age Interval was found.

3.4. Infant gazing

A 2 (Infant Vocalization: syllabic vs. vocalic) x 2 (Infant Gazing: gazing at mother vs. gazing away) x 5 (Monthly Age Interval) repeated-measures analysis of variance with the rate per minute of infant nondistress vocalization as the dependent variable was performed (see Table 2 for descriptive statistics). Significant main effects for Infant Vocalization, $F(1,10)=8.06$, $p < .02$, and Infant Gazing, $F(1,10)=9.08$, $p < .02$, were found. The two-way interaction of Infant Vocalization x Infant Gazing was also significant, $F(1,10)=10.62$, $p < .01$. Follow-up analyses revealed that infants produced significantly more speech-like syllabic than vocalic sounds during the time period when the infants were gazing at their mothers, but they produced similar amounts of speech-like syllabic and vocalic sounds during the time period when the infants were not gazing at their mothers. No significant main effect for and interaction effect involving Monthly Age Interval was found.

In summary, the results suggested that there was no significant developmental change in the occurrence of infant nondistress vocalizations during the time periods when they displayed different types of smiling and when they were gazing toward or away from their mother's face. Furthermore, the rate of speech-like syllabic sounds changed with different types of infant smiling and gazing direction of the infant. Infant vocalized speech-like

Table 3
Rate per minute of infant non-distress vocalization by maternal smiling and gazing

Maternal Social Actions	Monthly Age Intervals				
	2 Months Mean (SD)	3 Months Mean (SD)	4 Months Mean (SD)	5 Months Mean (SD)	6 Months Mean (SD)
Smiling					
Syllabic Sounds					
Smiling at Infant	1.30 (2.40)	1.54 (1.54)	1.73 (1.46)	1.73 (2.09)	1.20 (1.11)
Not Smiling at Infant	0.54 (1.14)	0.68 (0.57)	0.86 (0.96)	0.75 (1.36)	0.72 (0.67)
Vocalic Sounds					
Smiling at Infant	0.56 (0.66)	1.19 (1.11)	1.47 (1.81)	0.54 (0.38)	0.38 (0.26)
Not Smiling at Infant	0.59 (0.51)	0.68 (0.61)	0.67 (0.53)	0.58 (0.67)	0.40 (0.32)
Gazing					
Syllabic Sounds					
Gazing at Infant	0.90 (1.87)	1.17 (1.11)	1.28 (1.28)	1.24 (1.68)	1.01 (0.99)
Not Gazing at Infant	0.05 (0.18)	0.47 (1.30)	0.29 (0.48)	0.74 (2.41)	0.64 (1.19)
Vocalic Sounds					
Gazing at Infant	0.54 (0.52)	0.89 (0.80)	1.03 (1.05)	0.52 (0.43)	0.41 (0.28)
Not Gazing at Infant	0.64 (1.25)	0.72 (1.04)	0.23 (0.53)	0.72 (1.48)	0.20 (0.50)

syllabic sounds more frequently during the time period they smiled, particularly with Duchenne smiles, and when they looked at their mothers. The hypothesis that the increased quantity in and the speech quality of infant nondistress vocalization would be associated with other social actions within the child such as smiling and gazing was supported.

3.5. Maternal smiling

A 2 (Infant Vocalization: syllabic vs. vocalic) x 2 (Maternal Smiling: smiling vs. not smiling) x 5 (Monthly Age Interval) repeated-measures analysis of variance with the rate per minute of infant nondistress vocalization as the dependent variable was performed (see Table 3 for descriptive statistics). The results indicated significant main effects for Infant Vocalization, $F(1,10)=5.08$, $p < .05$, and Maternal Smiling, $F(1,10)=26.26$, $p < .001$, and a significant interaction effect for Infant Vocalization x Maternal Smiling, $F(1,10)=6.41$, $p < .03$. Follow-up analyses revealed that infants produced significantly more speech-like syllabic than vocalic sounds during the time period when their mothers were smiling, but there was no difference in the occurrence of infant speech-like syllabic and vocalic sounds during the time period when the mothers were not smiling. There was no significant main effect for and interaction effect involving Monthly Age Interval.

3.6. Maternal gazing

A 2 (Infant Vocalization: syllabic vs. vocalic) x 2 (Maternal Gazing: gazing at infant vs. gazing away) x 5 (Monthly Age Interval) repeated-measures analysis of variance with the rate per minute of infant nondistress vocalization as the dependent variable was conducted (see Table 3 for descriptive statistics). The results demonstrated a significant main effect for

Maternal Gazing, $F(1,10)=10.80$, $p < .01$. Infant nondistress vocalization occurred more frequently when mothers were looking at their infants. The two-way interaction between Infant Vocalization and Maternal Gazing approached significance, $F(1,10)=4.74$, $p < .06$. Follow-up analyses revealed no significant difference in the occurrences of syllabic and vocalic sounds during the time period when mothers were gazing at or away from their infants. There was also no significant main effect for and interaction effect involving Monthly Age Interval.

Taken together, the results suggested that there was no significant developmental change in the associations of the occurrence and quality of infant nondistress vocalization with maternal smiling and gazing. Moreover, the rate of speech-like syllabic sounds changed with maternal smiling but not gazing direction. Infants uttered speech-like syllabic sounds more frequently during the time period when their mothers were smiling than not smiling. The hypothesis that the increased quantity in infant nondistress vocalization would be associated with maternal social actions between the dyad such as smiling and gazing was supported, whereas the association of the speech quality of infant nondistress vocalization with maternal social actions was only partially supported.

3.7. Temporal coordinations between non-distress vocalization and individual social actions

Sequential analysis was applied to reveal the temporal coordination between the speech quality of a subsequent infant nondistress vocalization and an antecedent infant smiling, infant gazing, maternal smiling, and maternal gazing, respectively. It was hypothesized that infants would be more likely to produce speech-like syllabic than nonspeech-like vocalic sound followed by infant smiling and gazing as well as maternal smiling and gazing. Since there was no developmental change in the associations of infant nondistress vocalization with smiling and gazing exhibited by infant and mother, the data were aggregated across all sessions for each infant separately.

3.8. Infant smiling

A 2 (Infant Vocalization at $time_t$: syllabic and vocalic sounds) x 3 (Infant Smiling at $time_{t-1}$: Duchenne smile, non-Duchenne smile, and no smile) contingency table was formulated for each infant. To calculate the magnitude of the temporal coordination between infant nondistress vocalization and different types of infant smiling, the 2×3 table was decomposed into two 2 (syllabic vs. vocalic sound) x 2 (Duchenne smiling vs. no smiling and non-Duchenne smiling vs. no smiling) tables. Yule's Q was computed for each table in which no smiling served as the 'baseline' for comparison. Results showed that both Duchenne, $t(12)=2.58$, $p < .03$, and non-Duchenne, $t(12)=2.89$, $p < .02$, smiling were more likely to precede speech-like syllabic sounds in comparison to nonspeech-like vocalic sounds. Furthermore, there was no significant difference in the sequential associations of syllabic sounds with Duchenne and non-Duchenne smiles as compared to those of vocalic sounds, $t(12)=0.03$, $p > .10$. See Table 4 for the descriptive statistics of conditional probabilities and Yule's Q statistics across all infants.

Table 4
Conditional probabilities and Yule's Q of infant non-distress vocalization followed by infant and maternal social actions

Antecedent Infant and Maternal Social Action at $Time_{t-1}$	Conditional Probabilities of Syllabic Sound Occurring at $Time_t$	Conditional Probabilities of a Vocalic Sound Occurring at $Time_t$	Yule's Q	# of Infants (Yule's Q > 0)
	Mean (SD)	Mean (SD)	Mean (SD)	
Infant Smiling	.37 (.16)	.22 (.16)	0.38 (0.37)***[a]	11***[b]
Duchenne Smiles	.18 (.13)	.13 (.10)	0.36 (0.50)*	11***
Non-Duchenne Smiles	.16 (.09)	.09 (.09)	0.35 (0.44)*	11***
Infant Gazing at Mother	.49 (.22)	.37 (.26)	0.34 (0.35)***	10*
Maternal Smiling	.56 (.17)	.41 (.17)	0.30 (0.27)***	13***
Maternal Gazing at Infant	.94 (.10)	.91 (.08)	0.32 (0.59)	9

$p < .05$ **$p < .01$ ***$p < .001$
[a] Significance was calculated using one-way t-tests.
[b] Significance was calculated using binomial tests.

3.9. Infant gazing

A 2 (Infant Vocalization at $time_t$: syllabic and vocalic sounds) x 2 (Infant Gazing at $time_{t-1}$: gazing at mother and gazing away) contingency table was formulated separately for each infant. Results showed that the infants were more likely to utter syllabic as compared to vocalic sounds after they gazed at their mothers, $t(12)=3.45$, $p < .01$. See Table 4 for the descriptive statistics of conditional probabilities and Yule's Q statistics across all infants.

Taken together, the results suggested that there were significant contingent temporal coordinations between the antecedent infant smiling as well as gaze direction and the speech quality of a subsequent infant nondistress vocalization. As compared to nonspeech-like vocalic sounds, speech-like syllabic sounds were more likely to occur not only after the infants gazed at their mothers but also after they smiled. The hypothesis that there would be temporal coordination between the quality of infant nondistress vocalization with other social actions within the child such as smiling and gazing was supported.

3.10. Maternal smiling

A 2 (Infant Vocalization at $time_t$: syllabic and vocalic sounds) x 2 (Maternal Smiling at $time_{t-1}$: smiling and no smiling) contingency table was formulated separately for each dyad. Results showed that maternal smiling was more likely to precede infant syllabic than vocalic sounds, $t(12)=3.93$, $p < .002$. The descriptive statistics of conditional probabilities and Yule's Q statistics across all infants are shown in Table 4.

3.11. Maternal gazing

A 2 (Infant Vocalization at $time_t$: syllabic and vocalic sounds) x 2 (Maternal Gazing at $time_{t-1}$: gazing at and away from infant) contingency table was formulated separately for each dyad. Results revealed that the difference between the temporal contingency of maternal gazing preceding syllabic and vocalic sounds approached significance, $t(12)=2.0$, $p <$ .07. See Table 4 for the descriptive statistics of conditional probabilities and Yule's Q statistics across all infants.

Together, these findings further demonstrated that the speech quality of infant nondistress vocalization changed systematically with maternal smiling but not maternal gazing. The occurrence of infant nondistress vocalizations with more speech quality was more likely to be preceded by maternal smiling, but not maternal gazing. The hypothesis that there would be temporal coordination between the quality of infant nondistress vocalization with maternal social actions between the dyad was partially supported.

4. Discussion

This study explored the coordinative associations of infant nondistress vocalization with other social actions both within the child and between the mother-infant dyad. Specifically, the present study examined the contemporaneous associations and temporal coordination of the quantity (i.e., rate per minute) and quality (i.e., speech-likeness) of infant nondistress vocalization with infants' own smiling and gazing as well as maternal smiling and gazing during face-to-face interaction. Results showed that the infants were more likely to produce nondistress vocalizations, particularly, speech-like syllabic sounds, when they were smiling, when they were gazing at their mothers, and when their mothers were smiling. Moreover, the quality and quantity of infant nondistress vocalizations also changed with different types of infant smiling. Speech-like syllabic sounds were more likely to occur during infants' Duchenne smiles (with high cheek raise) as compared to non-Duchenne smiles (without high cheek raise). In comparison to vocalic nonspeech-like sounds, speech-like syllabic sounds were also more likely to be preceded by infant smiling (both Duchenne and non-Duchenne smiles), maternal smiling, infant gazing at mother, but not maternal gazing. These results provided the initial evidence that the speech quality of infant nondistress vocalization may be an index of positive emotion, possibly, a more intense level of joy, in face-to-face interaction during the first six months of life.

4.1. Coordinative associations within the child

Vocalization has been suggested to be a part of a coherently organized pattern of behaviors that reflect infants' underlying affective state (Legerstee et al., 1990; Weinberg & Tronick, 1994). Nondistress vocalization together with positive facial expressions are thought to formulate the expressive configuration indexing positive emotional states (Malatesta, 1981). On the basis of an activation model, Ewy (1988) proposed that infant vocalization is an energy expensive task, which is more likely to occur when infants' arousal is activated, or when infants are smiling and gazing at mother. In the present study, the quantity and quality of infant nondistress vocalizations were found to be differentially associated with different types of infant smiles: Duchenne (lip corner raise plus high cheek raise) and non-Duchenne (lip corner raise only) smiles. Infants uttered more speech-like syllabic sounds during Duchenne than non-Duchenne smiles. Since Duchenne smiles have been suggested to indicate a more intense level of joy (Messinger et al., 1999), it is plausible that this heightened emotional arousal directly contributes to vocal articulation and phonation in infants. The mediation role of physiological arousal between smile types and vocal quality, however, needs to be further supported by objective physiological measures.

Mechanisms other than physiological arousal may provide alternative explanations for the differential patterns found in the associations between infant nondistress vocalization and smiling. Studies on adults showed that a number of characteristics of vocalization are related to facial actions of smiling. For example, acoustic analyses demonstrated that smiling consistently raises the fundamental and formant frequencies of adults' vocalizations (Tartter, 1980). It has been speculated that the facial movements involved in smiling have a tensing effect on laryngeal action. As a result, the vocal tract is changed from its neutral position – the vocal tract is shortened and its opening is enlarged (Tartter, 1980; Tartter & Braun, 1994). Modifications in the positioning and size of vocal tract due to facial movements related to smiling may explain why infants exhibited more speech-like syllabic sounds after the onset of smiling.

Duchenne smiles involve high cheek raises while non-Duchenne smiles do not. Therefore, the higher level of laryngeal tension may also result from the greater number of facial movements involved in Duchenne smiles than those of non-Duchenne smiles, which may shape the vocal tract in an optimal condition for the production of speech-like syllabic sounds. Nevertheless, we also found that Duchenne and non-Duchenne smiles were equal likely to precede speech-like syllabic sounds. One plausible explanation for this finding is that other facial movements may also be involved during Duchenne and non-Duchenne smiling. For example, mouth opening is usually involved in infants' smiling (Abe & Izard, 1999; Messinger et al., 1999), and Duchenne smiles typically involve higher levels of intensity in lip corner raise (i.e., wider lip stretch; Segal et al., 1995). The magnitude of lip raise and the involvement of jaw opening (which are not considered in the present study) that are associated with infant smiling may have also affected the level of muscle-tension in vocal production apparatus, which in turn, affect the speech quality of vocalization.

Eye contact with an adult partner has been suggested as the catalyst in eliciting 3-month-olds' nondistress vocalization (Bloom, 1974). The previous finding that increase in the quantity of infant nondistress vocalization results from infants' attention to their mothers' face during social interaction was replicated in the current study (Kaye & Fogel, 1980; van Beek et al., 1994). We further demonstrated that infant gazing at mother's face has an effect on the speech quality of infant nondistress vocalization. Affective arousal appears to be the underlying mechanism mediating the coordinative association between the speech quality of nondistress vocalization and infant gazing direction. Infants are more likely to smile when they are attending to their mothers' face (Kaye & Fogel, 1980; Messinger et al., 1999; van Beek et al., 1994). They also use gaze aversion as a regulatory strategy to reduce heightened positive arousal (Stifter & Moyer, 1991). Based on the arousal mediation hypothesis, infants' gazing and smiling may signify an optimal range of arousal during mother-infant face-to-face interaction (Field, 1981; Fogel, 1982), which may be critical for infants to exhibit speech-like nondistress vocalization. Alternative interpretations involving cognitive and neural processes are also plausible. For example, visual recognition and discrimination of maternal face and facial expressions in infancy are found to be associated with brain electrical activity indexed by event-related potentials (de Haan & Nelson, 1997; Nelson & de Haan, 1996). Also, a study examining the patterns of brain electrical activity during social interaction in infancy revealed that the absence and presence of cry vocalization during the expression of negative facial signs are associated with the asymmetries in brain activity (Fox & Davidson, 1988). Together, these findings suggest that vocal production in early infancy may also have underlying cognitive and neural bases.

The systematic associations of infant smiling and gazing with speech-like syllabic sounds suggest that it is not the mere presence but the speech quality of nondistress vocalization reflecting infants' emotional state. The speech quality of infant nondistress vocalization may reflect the positivity in young infants' emotional experience and expression during social interaction. Infant gazing, smiling, and nondistress vocalizations have been speculated to form an emotional envelope or contour, which typically entails successive episodes of build-up, maximum tension, and release phases, or fluctuates in the form of activation-peak-deactivation (see Fogel et al., 1997; Rochat, Querido, & Striano, 1999; Stern, 1999). There is some evidence that infant vocalizations are likely to be embedded in an episodic event of facial expression (Yale et al., 1999). However, the delineation of occurrences of infant nondistress vocalization, particularly, speech-like syllabic sounds, during the peak of emotional buildups needs to be confirmed by further analysis.

4.2. Coordinative associations between the dyad

Newborn infants show a visual preference for their mother's face (Field, Cohen, Garcia, & Greenberg, 1984; Walton, Bower, & Bower, 1992). By 5 months of age, infants are able to detect, discriminate, and recognize happy facial and vocal expressions from other expressions in both nonsocial contexts and social interactions (e.g., Caron, Caron, & MacLean 1988; D'Entremont & Muir, 1999; Haviland & Lelwica, 1987). When exposed to video stimuli, 7-month-old infants prefer to look at positive expressions of happy and interest as compared to negative expressions of anger and sadness (Soken & Pick, 1999). Earlier reports that infants produce more vocalization when their mothers are smiling at them during face-to-face interaction in the first 6 months of age (Kaye & Fogel, 1980; van Beek et al., 1994) were replicated in the current study. We further demonstrated that a higher rate of speech-like nondistress vocalization occurred when mothers were smiling during face-to-face interaction, and speech-like syllabic sounds were more likely to occur after the onset of maternal smiling. Coregulation (Fogel, 1993) or mutual regulation (Gianino & Tronick, 1988) in mother-infant communication may explain the linkage between maternal smiling and the speech quality of infant nondistress vocalization. Maternal smiling signifies a pleasant interaction. This positive emotional experience may be shared by the infant resulting in a heightened positive arousal, which, in turn, elicits the production of more speech-like vocalization. This interpretation is consistent with the finding that infants are more likely to smile when their mothers are smiling (Kaye & Fogel, 1980). The findings that infants exhibit nondistress vocalization with more speech quality following their mothers' smiling also provided further support to our suggestion that the speech quality of infant nondistress vocalization may reflect the positivity in their emotional experience.

An asymmetrical pattern in the duration of maternal and infant gazing is typical during face-to-face interaction. Mothers are more attentive to their infants than vice versa (Messer & Vietze, 1984; Slee, 1984). In fact, mothers look at their infants' face almost constantly (71–87% of the session) in a face-to-face situation (Kaye & Fogel, 1980; Messer & Vietze, 1984; Slee, 1984). Even though exposure to direct gaze may be associated with arousal changes (cf. Kleinke, 1986), the constant visual attention or monitoring by mothers may habituate or desensitize infants' reactivity, which may result in insufficient arousal to elicit speech-like vocalization. Mutual gazing, which is typically associated with reciprocal social engagement between mother and infant, may be a more sensitive proxy of infant arousal and/or sociality than the unidirectional maternal gazing. Of course, the information processing of mother's face and expression during mutual gazing may also be associated with the underlying cognitive and neural processes related to infant vocal production.

Maternal interactive behaviors are typically constituted by multiple modalities and delivered in a package, including spontaneous smiling, gazing, vocalizing, and touching (Beebe & Gerstman, 1984; Koester, Papousek, & Papousek, 1989). Systematic changes in the occurrence and quality of infant nondistress vocalization with maternal smiling and gazing may be due to other concurrent maternal behaviors such as vocalization and touch, or an accumulated effect of multiple interactive actions. Maternal vocalization, for example, has been demonstrated to have an effect on infant vocalization. Experimental and naturalistic studies showed that prelinguistic infants imitate the phonetic and prosodic structure in their mothers' speech (Kuhl & Meltzoff, 1996; Kugiumutzakis, 1993; Masataka, 1992; Papousek & Papousek, 1989). Bloom (1988, 1990) asserts that infants are predisposed to show a social selectivity to adults' baby-directed vocal registry. Infants alter the quality of their vocalizations and become more speech-like through a process of vocal contagion, which is an innate tendency of infants "to imitate, not specific sounds but, sounds making" (Bloom, 1988, p. 478). In the present study, the effects of maternal gazing on the quantity of infant nondistress vocalization as well as the effects of maternal smiling on the quantity and speech quality of nondistress vocalization, however, cannot be teased apart from the vocal modality. In future studies, the isolation and manipulation of maternal gaze, voice, and touch as well as the valence and intensity of facial expressions would reveal the optimal condition for infant nondistress vocalization with more speech quality to occur.

Given the small sample size and observational nature of this study, the generalizability of the results from the current study may be limited. Some of the insignificant findings could also be attributed to low statistical power in detecting differences with small effect sizes. Future studies with larger sample sizes and applications of experimental design with objective psychophysiological measures may be able to discern the mechanisms underlie the coordinative associations of infant nondistress vocalization with individual social actions both within the child and between the dyad. We have suggested a relational approach to early vocal development in a social context, which argues that infant vocal development may not be solely explained by what arises from within-the-child, but also by what emerges from mother-infant interaction (Hsu & Fogel, 2001). The development of prelinguistic nondistress vocalization is highly connected to the cocreated processes between an infant and its caregiver during social communication. On the basis of the current study, we would further suggest that nondistress vocalization emerges from coordinatively configured maternal and infant social actions, and that the speech quality of nondistress vocalization arises from reciprocated emotional positivity between the mother-infant dyad.

Notes

1. Our previous reports focused on the changing relations between the melodic complexity and speech quality of infant nondistress vocalization and the associations of the quantity and quality of infant nondistress vocalization with the moment-to-moment changes in the dyadic patterns of mother-infant communication.
2. Of the 13 infants, 4 infants never laughed, and 2 infants contributed to approximately half of the total number of laughs coded.
3. The Baby Facial Action Coding System (Baby FACS; Oster & Rosenstein, in press) was not available when the coding was taking place. However, a copy of the preprint of the baby FACS was requested from the authors and used as a guide to the application of FACS to infants in coding facial movements. To date, there is not and has never been a certifying test available for the Baby FACS.
4. In adults, the major criterion for identifying high cheek raising is crow's feet wrinkles on the outer corners of the eyes. Unfortunately, these areas on the mothers' faces were often obscured by their hair and by the frames of their glasses.
5. Mothers made frequent fleeting glances to different parts of their infant's body. They also often glimpsed at the direction where the infant was looking at without maintaining a joint focus of attention with their infant. These brief glances typically lasted less than 0.2 s. The precise onset and offset times were not easily determined. Our experience was consistent with Kleinke's (1986) report that low reliability in gaze coding occurs when the time interval required is less than 1 s. To enhance the reliability in coding, a minimum of 1.5-sec was decided as the definition as a steady gaze for mothers. This decision was also consistent with Kleinke's differentiation between gaze and glance and between gaze duration and glance duration. When coding infant gaze, we found that rapid changes in visual attention were rare. It has been documented that the mean latency of gaze shift and the minimum reaction time to visual stimulus is longer than 1 sec before 6 months of age. The latency of gaze shift decreases from approximately 1.4 secs at 3 months to 0.5–0.6 secs after 6 months (Rothbart, Posner, & Boylan, 1990). In addition, when tested in a visual expectation paradigm, the minimum reaction time of infants between 2 to 12 months of age is 1.33 s (Canfield, Smith, Brezsnyak, & Snow, 1997).
6. Because the observations for two infants did not begin until they were 9 weeks of age, as a result of case-wise deletion, the sample size for the repeated-measures ANOVAs was 11 instead of 13.

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