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AGE-RELATED CHANGE IN JAPANESE MATERNAL INFANT-DIRECTED SPEECH AND INFANT'S VOCAL RESPONSE

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Abstract

We have investigated how maternal infant-directed speech shows age-related change, and which acoustic features of maternal infant-directed speech elicit an infant's vocal response effectively during the prelinguistic period. Voice samples of 50 Japanese mother and infant dyads were recorded during the first 9 months of the infant's life longitudinally. Fundamental frequency (f_0) from the mother's speech and the infant's vocalization during mother-infant interaction were extracted and analyzed using an acoustic analyzer. The acoustical features measured in this study were the mean f_0, f_0-range, and the intonation contour. We found age-related change in the prosodic features of mother's speech. The mothers changed f_0 in their infant-directed speech during months 3-5, and 7-9 postnatally, and they changed f_0-range during months 5-7 postnatally. They showed a falling pattern of intonation contour most frequently during age 3 and 7 months and a rising pattern appeared most frequently at the infant was 9 months old. The infant's response also showed age-related change. Three-month-old infants tended to respond to the maternal speech with any value of f_0 and f_0-range. In contrast, 9-month-old infants tended to respond to the speech with higher f_0, more exaggerated f_0-change, and a rising pattern of intonation contour selectively. The results suggest that the change in acoustic features of maternal speech reflects the infant's perceptual and linguistic development.

Key Words : mother-infant vocal interaction, infant-directed speech, infant, prelinguistic period, acoustic analysis

Introduction

Numerous attempts have been made by psychologists and linguists to show the characteristics and the roles of maternal speech to infants. There are many differences between infant-directed speech and adult-directed speech. When mothers talk to their infants, the melodic and rhythmic qualities of maternal voices are exaggerated (Fernald & Simon, 1984; Fernald, Taeschner, Dunn, Papousek, DeBoysson-Bardies, & Fukui, 1989; Grieser & Kuhl, 1988; Papousek & Hwang, 1991; Shute & Wheldall, 1989). Mothers use higher pitch, a greater pitch range, slower tempo, longer pauses, shorter phrases, higher

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exaggerated pitch contour, and more prosodic repetition compared to their speech to an adult (Bergeson & Trehub, 1999; Fernald & Simon, 1984).

One of the roles played by maternal infant-directed speech is apparently the regulation of arousal and attention in infants (Cooper, Abraham, Berman & Staska, 1997). Mothers try to maintain infants' attention and positive affection by using infant-directed speech which is characteristic phonetically (Bergeson & Trehub, 1999; Trainor, 1996; Trainor, Clark, Huntley, & Adams, 1997). Newborns show preferences for the maternal voice over an unfamiliar female's voice (DeCasper & Fifer, 1980; Fifer & Moon, 1995). Fernald (1985) found that 4-month-old infants chose to listen more often to infant-directed speech than to adult-directed speech. This preference appears to be consistent throughout the first year of life (Fernald & Kuhl, 1987). Infants start to produce utterances in response to maternal speech to them from early in life (Masataka, 1992).

This brings us to the question as to which acoustical features infants pay attention. Niwano & Sugai (2001, 2002) reported the acoustic features of maternal speech and 3-month-old infant's utterance during mother-infant interaction. One of the important findings in the studies is that intonation contour is the most effective means to elicit 3-month-old infant's vocal response in acoustic features of maternal infant-directed speech, and that a 3-month-old infant responds to the maternal speech which is terminated with a falling contour more than other contour types. As Fernald and Simon (1984) pointed out, infants prefer to listen to the intonation contour of maternal speech, and the intonation patterns of maternal infant-directed speech may be perceptually salient to the infant. Powers (2001) reported that infants are sensitive to prosodic features of adult vocalization.

However, few attempts have been made to date to elucidate the age-related change in maternal infant-directed speech. It is known that during the first year after birth, infants show radical developmental change. We should notice that the prosodic features of mother's speech might show change consistently in the prelinguistic period and some changes in maternal infant-directed speech might relate to the development of the infant's communication ability and biological maturation. More noteworthy is that which acoustic features infants respond to might also change according to development. Although Fernald (1992) pointed out that infants have predispositions innately to respond selectively to characteristic features of maternal infant-directed speech, the selection might change through the infant's prelinguistic period. Therefore we need to discover details of normal communicative development occurring within the prelinguistic period and how a mother communicates with her infant. This offers a key to understanding how the ability of communication develops, and it would contribute to early detection and early intervention for the children with a communication disorder.

The purpose of this study was to investigate how maternal infant-directed speech shows age-related change, and to determine which specific acoustic features of maternal speech elicit the infant's vocal response effectively during the first 9 months after birth. In the present study, we focused on three acoustic features: fundamental frequency (f_0), f_0-range, and intonation contour. The reason why we chose these three acoustic features is as follows. First, f_0 is the most salient of the prosodic components in infant-directed speech (Katz, Cohn, & Moore, 2000). Second, one of the characteristics of maternal

speech is exaggerated f_0-range (Katz, Cohn, & Moore, 1996). Third, intonation contour is considered to most define infant-directed speech (Bergeson & Trehub, 1999). We carried out an acoustic analysis and extracted these three acoustic features from the voice samples of mother-infant interaction and analyzed them in detail.

In many previous studies on maternal infant-directed speech, the researchers regarded that f_0-range equaled the difference between the maximum and minimum values of f_0 for each speech, and utilized 'Hz' as an f_0-range unit. However, human perception of f_0-range should be calculated logarithmically in general, so we utilized 'semitone' (12 semitones = 1 octave) in this study. In addition, the sample size has not been an issue in almost all studies on mother-infant vocal interaction. However, a large number of samples are needed to obtain universal data. Thus, our study was conducted on 50 mother-infant dyads in longitudinal samples of infants ranging in age from 3 to 9 months.

Method

Participants

Fifty Japanese mothers and their infants composed the final sample. The infants were firstborn, born in 1998-1999, 25 males and 25 females. All of the mothers were full-time housewives (*M* age at child birth = 29.3 years, *SD* = 4.3 years), primarily drawn from the middle socioeconomic classes and native-born citizens of Japan. The data were collected during home visits when the infants were 3, 5, 7, and 9 months of age. All of the infants were healthy with no history of hearing disorder or infection. An additional 4 infants failed to complete the recording because of excessive crying (2), and little utterance (2).

Procedure

Utterances by the mother-infant dyad were tape-recorded. A high-quality microphone (Sony ECM909) was connected to a portable, audio cassette recorder with automatic gain control circuitry (Sony TCS90) and set on a table in the home. The microphone was set on a table about 1 meter away from both the mother and infant. The mother was instructed to talk to her infant as she normally did at home. Each recording session lasted 15 minutes. Both the mother and the infant were seated on a chair or on the floor facing each other. Then, we sampled 3 consecutive minutes, selecting them so that the vocal interaction of mother and infant included many utterances and the least noise. To compare the mother's infant-directed speech with her adult-directed speech, the conversation between mother and experimenter was also recorded for 5 minutes at home. We sampled the last 3 minutes in the 5-minute recording.

Following Stern, Spieker, & MacKain (1982), a sequence of maternal infant-directed speech which did not include any pause exceeding 0.3 sec was defined as one utterance. All meaningful communicative vocalizations were considered as words, e.g., agreeable sounds such as *ooh*, *aah*, and *mmm*. Whispered and partially whispered utterances, songs, and nonverbal sounds such as kisses, and laughter were excluded. Following Masataka (1992), when an infant vocalized within 3.0 seconds after the end of maternal infant-directed speech, the utterance was counted as a response.

Acoustic analysis

Two skilled coders acoustically analyzed the three-minute speech samples. One of the coders was an author of the present study and the other was blind to the purpose and hypotheses of the present study. Inter-coder concordances: measurement fundamental frequency (f_0), duration of pause, and categorization intonation contour type, were presented with high reliability (.94, .95, .98). For cases in which there was disagreement, the data were excluded. They used Multi Speech 3700 (Kay Elemetrics), which is software for acoustic analysis and allows measurement of f_0, and duration of utterance and pause. Analysis of f_0 was performed with narrow-band analysis (29 Hz) and frequency scale up to 2000 Hz (sampling rate = 10000 Hz).

Dependant Measures

Mean f_0

A mean f_0 is an arithmetic mean of start frequency, end frequency, maximum frequency and minimum frequency of one utterance. Multi Speech 3700 is allowed to computerize statistically a mean f_0 of each utterance, but it was not appropriate in the present study because the mother's utterance was sometimes overlapped by the conversational partner's utterance.

F_0-range

An f_0-range is measured logarithmically as the distance in semitones between f_0-minimum and f_0-maximum for each utterance.

Classification of intonation contour

Previous studies have shown that the typical intonation contour of the infant-directed speech can be classified according to the extent and direction of the f_0 excursion (Fernald & Simon, 1984; Griesern & Kuhl, 1988; Masataka, 1992; Stern, Spieker, Barnett & MacKain, 1983; Stern, Spieker & MacKain, 1982). Five of the most common intonation contours were identified by Stern, Spieker & MacKain (1982): sinusoidal (up-down-up or down-up-down); bell (up-down); bell right (slight up-large down); rise (up); and fall (down). We classified the seven intonation contours of all voiced maternal speech into three groups concentrating on the terminated intonation contour, comparable to those described by Papousek, Papousek, & Haekel (1987). Garnica (1977) noted the function of the terminal contour of sentences uttered by adults when they spoke to children. Sugito (1994) observed that the partner's terminal falling contour gave another partner cue timing for response during adult-adult conversation in Japanese. Therefore, it seems that the terminal contour is the predominant part of the contour compared to the initial or middle part in a whole utterance.

The first group of terminal pitch movement is falling, the second group is rising, and the third group is flat with no shift in the direction of pitch movement. Each of the groups of falling and rising includes three types of contours: The falling group includes (1) unidirectional falling, (2) bell-shaped (up-down) contours, and (3) complex sinusoidal contours with two or more shifts and is terminated with falling. The rising group

includes (1) unidirectional rising, (2) U-shaped (down-up) contours with one shift, and (3) complex sinusoidal contours with two or more shifts, and is terminated with rising. Following the study by Fernald & Simon (1984), a minimum f_0 excursion of 6 semitones/s (12 semitone = 1 octave, which is calculated logarithmically) was a defining characteristic of all contour-types in the present study.

Results

Mean f_0 and f_0-range

The total numbers of mothers' analyzable utterances, overall mean f_0, and average f_0-range every postnatal month of maternal infant-directed speech and maternal adult-directed speech were presented in Table 1. Comparing the mothers' infant-directed speech with their adult-directed speech, all of the features (i.e., number of utterances, overall mean f_0, and average f_0-range) were higher in infant-directed speech than in adult speech. Inter-infant-directed speech, the number of utterances decreases at 5 months, but increases after 7 months. Both of overall mean f_0 and average f_0-range increase from 3 to 9 months of age. To determine the difference of overall mean f_0 and average f_0-range between age groups: the data of 3 months and 5 months, the data of 5 months and 7 months, and the data of 7 months and 9 months, were statistically ana-

TABLE 1 Mean f_0 and mean f_0-excursion of infant-directed speech and adult-directed speech. The numbers in parentheses in the line of mean f_0 and mean f_0-excursion indicate standard deviation.

	Infant-directed speech				Adult-directed speech
Infant's age (month)	3	5	7	9	
Number of utterances	2908	2501	2731	2963	1527
Mean f_0 (Hz)	301 (77)	312 (65)	317 (72)	329 (81)	208 (53)
Mean f_0-range (semitone)	7.2 (5.5)	7.9 (4.3)	8.9 (5.7)	9.6 (6.2)	6.6 (2.4)

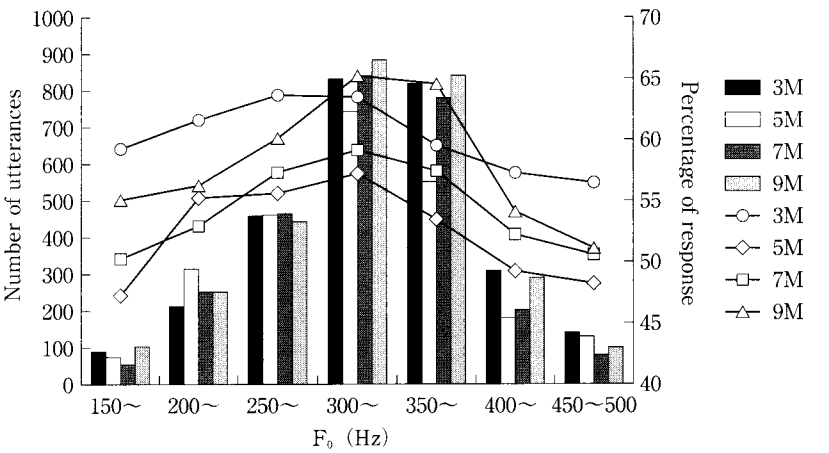

Figure 1 The bar chart indicates the number of maternal infant-directed utterances at each section of every 50 Hz of f_0. The line graph indicates the percentage of infant's vocal response to each f_0 section of maternal infant-directed speech.

lyzed by Student's t test. There were significant differences of average of mean f_0 between 3 and 5 months, and 7 and 9 months (t = 1.66, t = 1.67, all ps < .01, respectively), and average of f_0-range between 5 and 7 months (t = 1.84, p < .01).

Fig. 1 shows the number of maternal infant-directed utterances at each section of every 50 Hz of value of f_0. The utterances that were more than 500 Hz existed in each month group, but they were omitted them from the chart because the number was less than 20. The rate of 5-, 7-, and 9-month-old infant's response to maternal speech highly

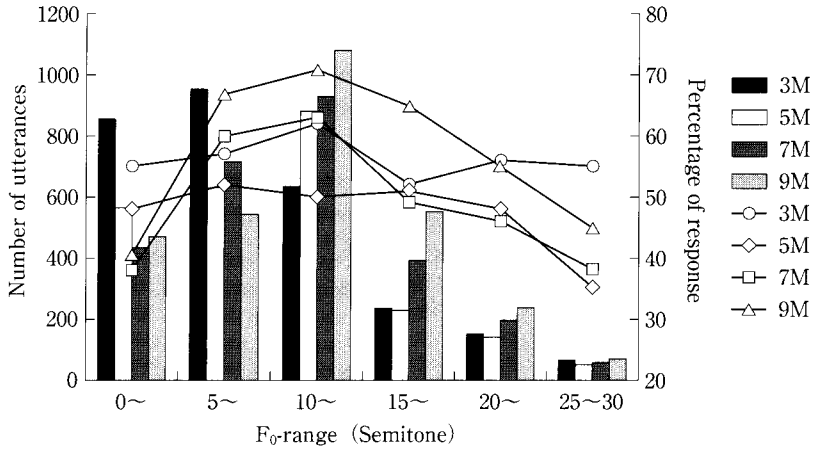

Figure 2 The bar chart indicates the number of maternal infant-directed utterances at each section of every 5 semitones of f_0-range. The line graph indicates the percentage of infant's vocal response to each f_0-range section of maternal infant-directed speech.

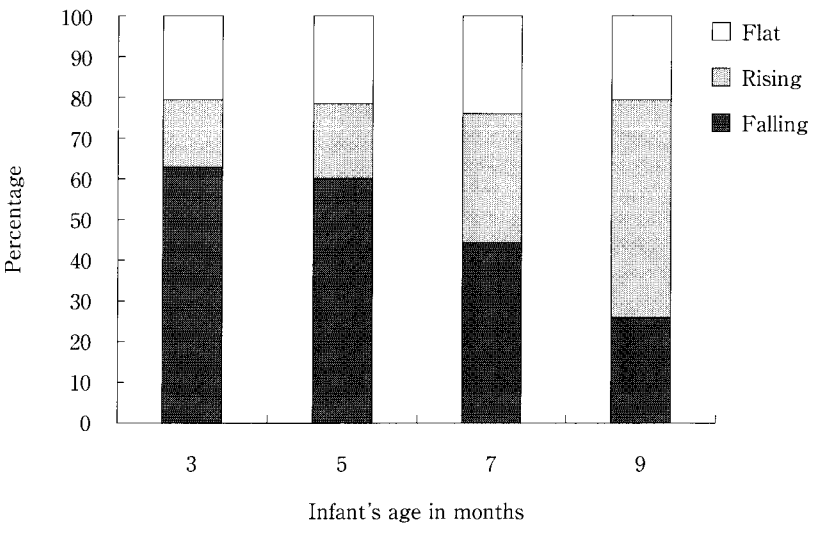

Figure 3 Percentage of appearance of each intonation contour pattern of maternal infant-directed speech according to infant's age.

Figure 4 Percentage of infant's vocal response to each intonation contour pattern of maternal infant-directed speech according to infant's age.

correlated with the number of maternal speech in each 50 Hz section (r = 0.89, r = 0.95, r = 0.95, all ps < .001, respectively).

Fig. 2 shows the percentage of infant's vocal response to each f_0 section of maternal infant-directed speech. The utterances which were more than 30 semitones existed in each month group, but were eliminated them from the chart because the number was less than 20. The rate of 7-month-old infants' response to maternal speech significantly correlates with the number of maternal utterances in each 5-semitone section (r = 0.86, p < .005).

Intonation contour

Fig. 3 shows the rate of appearance of intonation contour patterns of maternal infant-directed speech according to infant's age. The intonation contour pattern that appeared most often in the maternal infant-directed speech was the falling contour from 3 to 7 months, but it decreased steadily. On the other hand, the rising contour increased steadily from 3 to 9 months of age. At 9 months, the rising contour appeared most often.

Fig. 4 shows that the rate of infant vocal response to the maternal speech with each intonation contour pattern. Intra-pattern differences of the rate of infants' response in each month of age were analyzed by the Kruskal Wallis test. There were significant differences among the rate of infants' response to the three patterns of intonation contour uttered by their mothers at 3, 5, 7, and 9 months ($\chi^2(2)$ = 15.21, $\chi^2(2)$ = 13.62, $\chi^2(2)$ = 9.34, $\chi^2(2)$ = 15.81, all ps < .001, respectively). The infants responded to the maternal speech with the falling contour most frequently when they were 3 and 5 months old, then did to the speech with the rising contour most frequently when they were 9 months old.

Discussion

Mean f_0 and f_0-range

Mothers were found to change their mean f_0 and f_0-range when they spoke in terms of the infant age. For 3-month-old infants, the mothers tended to speak with lower mean f_0 and f_0-range, similar to their adult-directed speech. Then the mothers kept on changing the quality of their speech steadily to a higher mean f_0 and expanded f_0-range. However, it seems reasonable to suppose that the rate of the 3-month-old infants' vocal response was not influenced by f_0 value and f_0 range of maternal infant-directed speech. On the other hand, at 7 and 9 months, the infants displayed selective response to the maternal speech with a specific f_0 value and f_0-range. They tended to respond to maternal speech with mean f_0, which was between 300 and 350 Hz, more frequently than other maternal speech of f_0 value. They also tended to respond to the maternal speech with f_0 -range, which was 10 to 15 semitones more than maternal speech with another f_0-range level. The maternal speech with 300-350 Hz and 10-15 semitones frequently evoked the infants' response. Also, such speech was uttered by mothers often. Given that infants tended to respond to the most familiar value of mean f_0 and f_0-range, we can explain why there were significant correlations of the rate of infant's response with the number of maternal utterances in each section of the mean f_0 and f_0-range.

Garnica (1977) found that higher pitch is unique to a social function and that it attracts the child's attention to verbal material directed to him. In the present study, the infants showed age-related change and more response to the maternal speech with higher f_0 and grater f_0-range after 3 months, possibly reinforcing the mothers' habit of speaking with higher f_0 and greater f_0-range. It seems like a newborn infant may have universal sensitivities and may respond to any phonetic variation in speech signals. But after 3 months, infants learn certain specific function of phonetic features and show selective response.

Intonation contour

The intonation contour pattern of maternal infant-directed speech also was changed from 3 to 9 months of age. With each month, there was a significant difference in an infant's response. This means that the discrimination of intonation contours depends on the infant's age.

The infants showed the highest rate of response to maternal infant-directed speech with the falling contour at 3 to 7 months of age, but the response to the falling contour was decreasing; on the contrary, the response to rising contour was increasing and it showed the most frequent response at 9 months. A possible reason why 3- to 7-month-old infants responded to the falling contour more than other contours may be that they had become more familiar with the maternal infant-directed speech terminated with the falling contour than the other contour types because the falling contour occurred most frequently in maternal infant-directed speech. This tendency presumably reflects the appearance of intonation contour in the maternal speech. Most of the maternal nodding and agreeable responses (e.g., hi (yes), so (is that so?), ooh, aah, and mmm) were uttered with the falling contour. According to Sugito (1994), more agreeable responses appear in a Japanese conversation than in may other languages, and they tend to termi-

nate with the falling contour. She pointed out that what a partner responds to is the terminal intonation with the falling contour in Japanese conversation. We suggest that the agreeable response in this case serves to elicit the infant's response.

On the other hand, the rising contour tended to be used as question (e.g., 'Are you having a good time?') or request (e.g., 'Can you pass me the toy?'). Therefore the speech with rising contour might serve to encourage an infant's response, and rising terminals might cue the infants in timing their response. Mothers reportedly use rising contour for encouraging a visual or vocal turn (Fernald & Simon, 1984 : Stern, Spieker, & MacKain, 1982). Papousek, Papousek and Symmes (1991) suggested that mothers seem to mark opening, continuing, and closing interaction using rising or falling contours. As long as infants are not able to control their own communicative turns, mothers establish a framework of turn taking (Kaye, 1979). We suggest that infants learn the function of a rising contour in context through interaction, and their response to the rising contour gradually increases until 9 months. We can be fairly certain that mother's speech facilitates communication learning, and that change in the pattern of maternal speech is a way of adjusting to the infant's developing understanding of the role of intonation contours.

General discussion

Undoubtedly, rich mother-infant interaction is important for an infant's normal development. Vocal interaction between mothers and prelinguistic infants is an important step in the acquisition of communicative skills for infants, and these skills lead eventually to the acquisition of language (Masataka, 1992). It is also important for a mother to interpret what the infant wants to express with vocalization through interaction. The mother's interpretation awakens the infant to a social awareness of his/her own vocalization (Shimura & Imaizumi, 1995). The developmental stage of the infant's vocal response and the infant's biological development deserves closer investigation. Aitken and Trevarthen (1994, 1997) found that the neural system for providing the motivation for intersubjective communication is already formed in the brain of the human fetus. Therefore infants have an innate motivation to communicate. They are thus born to communicate and to learn (Powers, 2001).

Before birth, all the neurons are formed, but head size, brain weight, and thickness of the cerebral cortex continue to grow rapidly in the year after birth. Synapses in the infant brain continue to develop after birth and peak in number between 9 months and 2 years. Metabolic activity in the brain reaches adult levels by 9 to 10 months. Therefore infants show the turning point of language development around 8 or 9 months (Bate, Thal, & Janowsky, 1992), when they start active, spontaneous communication. This accords well with much of the data in the present study. One reason for an immediate sharp increase in response for certain specific acoustic features particularly at 9 months in the present study is that infants then achieve the turning point in the maturation of their neuro network and physiological change.

Another biological maturation is needed for vocal communication. The shape of the human vocal tract seems to have been modified for the demands of speech during the year after birth (Pinker, 1995). When the infant reaches around 5 months, he/she starts to utter canonical babbling. During 3-5 months after birth, the infant's vocal tract

changes physiologically. The larynx slides down and the pharynx extends. It is a modification for the demands of speech. Thus, the quality of an infant's voice changes very much during the pre-linguistic period. The change in the mother's prosodic features might also reflect the infant's anatomical development.

Mother serves a primary function in facilitating the increasing communicative vocalizations and language learning. Mothers and infants influence one another and develop mutually. The mother's use of appropriate infant-directed speech in accord with the infant's developmental level of maturation of the neurons, metabolism and vocal tract is an effective means to facilitate the infant's communication ability.

Conclusion

The present study led us to the following conclusions: (1) Maternal infant-directed speech shows age-related change in the prosodic features during the first 9 months of infant life. (2) Mothers change the f_0 in their speech during months 3-5, and months 7-9 of postnatal life. (3) Mothers change the f_0-range during months 5-7. (4) Mothers produce a falling pattern of intonation contour most frequently during the first 3 to 7 months, and the rising pattern appears most frequently at 9 months. (5) The infant's response also shows age-related change. (6) Three-month-old infants tend to respond to any value of f_0 and f_0-range. (7) Nine-month-old infants tend to respond to higher f_0, and more exaggerated f_0-change. (8) Three- and 5-month-old infants tend to respond to a falling contour more than other contour patterns. (9) Seven- and 9-month-old infants tend to respond to a rising intonation contour more than other contour patterns.

These results suggest that infants learn certain specific functions of phonetic features and show selective response. On the other hand, the change in an infant's response to each maternal infant-directed utterance with different acoustic features depends on the infant's physiological development. We may, therefore, reasonably conclude that mothers modified their use of acoustic features and pattern of intonation contour for the infant's perceptual and linguistic development during the first 9 months.

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