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Consistent Responses of Human Mothers to Prelinguistic Infants: The Effect of Prelinguistic Repertoire Size

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The salience of infants' vocal and visual cues was examined to evaluate the efficacy of prelinguistic vocalizations to guide adult behavior. A videotape, constructed of brief behavioral episodes from 3 infants with different-sized vocal repertoires, was played to 40 mothers of prelinguistic infants. Playback mothers' responses to the episodes were consistent, demonstrating that preverbal behavior elicits comparable reactions across unfamiliar receivers. The audio and video components of the infants' episodes were then recombined. As the vocal repertoire of the stimulus infants increased, changes in the audio component more often led playback mothers to change responses. Thus, playback mothers used vocalizations as cues as the infants' vocal repertoires became larger.

Investigating receivers' responses to infants' vocal behavior is a first step in evaluating the role of social feedback as a mechanism of human vocal learning. Although infant vocalizations can be conditioned by consistent social reinforcement (Rheingold, Gerwitz, & Ross, 1959; Routh, 1969; Weisberg, 1963), noncrying infant sounds have rarely been studied in terms of their functional effects on the responses of social partners. Prelinguistic sounds are often considered to be biologically predetermined (Bloom, 1993), and the development of vocal learning is held to an internal program of physiological and cognitive maturation. However, feedback from companions may provide reliable cues about the consequences of vocalizing and serve as a source of learning for the infant. Data from deaf and hearing-impaired infants (Locke, 1993; Locke & Pearson, 1992; Oller, 1985; Oller & Eilers, 1988; Oller, Eilers, Bull, & Carney, 1985; Stoel-Gammon & Otomo, 1986) show that their babbling is acoustically different from that of hearing infants, which suggests that vocal development relies on the activity of proprioceptive and social feedback. Applying a functional perspective to vocal learning in humans requires that infant sounds be understood not only in terms of their acoustic properties, but also in terms of their ability to regulate and be regulated by social interactions with receivers of the sounds. Although the idea that human vocal learning is influenced by social interaction is not new (e.g., Locke, 1993), few researchers have attempted to determine the degree to which infants' early sounds are actually used by receivers.

Characterizing vocal development by measuring receiver behavior represents a new initiative in communication research. Instead of relying on purely structural representations of sounds (e.g., sonograms), we measured prelinguistic vocalizations in terms of function—their impact on receiver behavior. A focus on the functional significance of vocal precursors has been successfully used by researchers studying vocal learning in animals (Marler & Nelson, 1993; Snowdon & Hausberger, 1997; West, King, & Duff, 1990). Many researchers of communicative development in animals have used playbacks of vocal precursors to conspecifics so that the communicative content of early sounds could be assessed. Results from playback studies of vocal development in avian and primate species suggested that vocal precursors elicit consistent responses from conspecifics (Cheney & Seyfarth, 1990; West & King, 1988). In songbirds, the vocalizations of young male cowbirds (*Molothrus ater*) elicited orientation and wing movements from adult females, and this feedback facilitated the development of more advanced forms of song (West & King, 1988). Young cowbirds thus used social feedback to modify their vocal behavior. Researchers used a functional approach to arrive at these findings, which indicate that conspecifics respond consistently to the early signals of the young.

Some evidence exists supporting the potency of human infants' prelinguistic sounds in guiding adults' responses. Adults have consistently categorized the sounds of 2-month-old infants on the basis of emotional (happy–sad) content (Papousek, 1989). Adults also displayed a preference for 3-month-old infants that produced more fully voiced vocalizations (Beaumont & Bloom, 1993; Bloom, D'Odorico, & Beaumont, 1993; Bloom & Lo, 1990). Mothers imitated their infants' sounds with a high degree of accuracy (Papousek, 1991) and actively did so in their interactions with 2- to 5-month-old infants (Papousek & Papousek, 1989). Parental behavior, then, is influenced by the early vocalizations of infants.

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How sensitive is mothers' behavior to prelinguistic sounds? From the mothers' point of view, what is the relative salience of infants' vocalizations compared with cues derived from their appearance and gestural behavior? To assess mothers' consistency in responding to the prelinguistic vocalizations of infants, we used a playback paradigm. We collected "reference" episodes of prelinguistic behavior from 3 infants. The infants had vocal repertoires of different sizes. We used the acoustic classification system presented in Oller and Lynch (1992) to categorize the infants' sounds. From 1 to 4 months of age (primitive articulation stage), vocal production incorporates articulator movements at the back of the vocal tract, using tongue and epiglottal contact with the soft palate to produce some consonant stops. Combinations of stops with quasi-resonant nuclei produce the first "goo"- and "coo"-type syllables. At 3 to 8 months of age (expansion–exploratory stage), the vocal tract becomes more open and fully resonant sounds are produced. Infants produce marginal syllables, which are slow sequences of consonant–vowel articulation, with long transitions between consonant and vowel. From 5 to 10 months of age (canonical syllable stage), infants begin to produce fully resonant sounds and faster formant transitions, resulting in canonical syllables (e.g., [ba], [da]), which represent a language-general unit of mature vocal production.

The reference episodes captured the differences among the vocal repertoires, but the videotape showed the infants engaged in similar activities. The audio and video components of the infants' reference episodes were digitally separated and permuted to create new combinations of cues. The playback mothers viewed both the reference and the recombined episodes. The mothers responded to each episode by choosing one of four possible action categories, which were defined by lists of behaviors (Table 1). For example, if a mother wanted to respond to an infant by pointing to objects, giving the baby something, or by asking the baby what he or she wanted, she would choose the "I think the baby wants something" category. Maternal perception was examined in two steps. In the first analysis, we examined responses to the reference episodes for consistency. In the second analysis, we examined responses to the recombined episodes for reliance on vocal versus visual cues. Response shifts were calculated between each reference episode and (a) recombined episodes that shared the reference's audio component but differed in video content and (b) recombined episodes that shared the reference's video component but differed in audio content. We compared response shifts due to audio and video manipulations to determine the relative salience of auditory versus visual cues for receivers.

Method

Participants

Forty mothers of infants volunteered as participants. Their infants were in the same age range (9–20 months) as the infants on the stimulus videotape. Six mothers had infants from 9–10 months of age, 19 mothers had 11–15-month-old infants, and 15 mothers had 16–20-month-old infants. The mothers were recruited from birth announcements in the local newspaper. Twenty-one mothers were primiparous, and 17 had additional children (2 mothers did not supply information). Thirty-five mothers spoke English as their native language (5 mothers did not supply information). The sample was predominantly Caucasian and middle-class.

Preparation of Playback Stimulus Tape

We obtained videotaped examples of infant behavior from parent–infant play sessions that were conducted in the Laboratory of Infant Behavior at the University of North Carolina at Chapel Hill. The duration of play sessions ranged from 19 to 41 minutes. Parents were asked to respond naturally to their infants and to play as they would at home.

We used the behavior of the infants' parents to define communicative episodes and to ensure that our stimuli represented a wide range of infant behavior. Parents had to behave within 3 s following a vocalization. To be included on the stimulus tape, infants had to elicit one of three kinds of behavior from their caregivers: giving or showing, naming or acknowledging, or soothing or showing concern. For each infant, an additional episode was used that had not elicited a discernible response. A set of four episodes from each of 3 infants (9, 11.5, and 19 months old) was acquired for the stimulus tape. Each episode was 5 s in duration.

Table 1
Categories and Examples of Responses to the Stimulus Infants

Category	Examples of responses
I think that the baby wants something.	Point to objects Give baby something Ask baby what he or she wants
I think that the baby is commenting on something.	Correct baby ("That's not an X, it's a Y.") Agree with baby ("Yes, that's an X.") Acknowledge baby ("Uh huh.")
I think that the baby is upset or distressed.	Soothe baby Check on baby Pick up baby
I think that the baby is not attempting to communicate.	Ignore baby Continue as if nothing happened

The episodes of the 3 infants were matched for visual characteristics. The infants had the same racial appearance (Caucasian) and did not wear gender-specific clothing. The stimuli were also matched for the activities in which the infants were engaged. Each infant was seen pointing, locomoting, and playing with toys. However, the contexts of the behaviors varied slightly. Two of the four episodes taken from the 9- and 11.5-month-olds showed the infants in a high chair, and two of the episodes showed the infants playing in a large room. All of the episodes from the 19-month-old showed the infant in the playroom.

The stimulus infants varied in the range of their vocalizations. The 1st infant (an 11.5-month-old female) used the same vocal expression, consisting of a fully resonant [ɛ] with no accompanying consonant, throughout the play session. Her small vocal repertoire of vocalizations had the full resonance typical of an infant at the expansion–exploratory stage but with the limited utterance types (fully resonant nuclei) of an infant at the primitive articulation stage. The 2nd infant (a 9-month-old female) used marginal syllables encompassing multiple vowel and consonant types. Her medium vocal repertoire of vocalizations (fully resonant nuclei and marginal syllables) was typical of an infant at the expansion–exploratory stage. The 3rd infant (a 19-month-old male) used a mix of fully resonant nuclei, marginal syllables, canonical syllables, and reduplicated babbling. He also used the most vowel types of the 3 infants. His large repertoire of vocal behavior was typical of the canonical syllable stage. The level of vocal complexity of each infant was represented in the stimulus episodes (Table 2). The episodes thus varied systematically in acoustic complexity across the stimulus infants.

All stimuli were digitally modified so that the infants' parents were removed from view. Thus, the responses of the playback mothers could not be based on either prior knowledge of the infants or on the outcome of the episode. Only the infants' behavior could be used to guide the playback mothers' responses. The audio and video components of the reference episodes were then permuted. Permutations were performed only across episodes from the same infant. Recombining the audio and video created the possibility of visible mismatches between articulatory movements and sounds that could influence participants' perception of the stimuli (McGurk & MacDonald, 1976). To neutralize false auditory perceptions that could be caused by audio–visual recombinations, we froze the last frame of each video episode for an additional 5 s. The vocalization was presented during the freeze-frame. This procedure was performed on all stimuli, including the original reference episodes. The stimulus tape included all audio–video permutations as well as the 12 reference episodes, so that the relative influence of vocal and visual components on subjects' responses could be assessed.

A Macintosh 8100 with a Radius VideoVision Studio video capture card was used to digitize the source videotapes. Video and audio manipulations were accomplished with Adobe Premiere software (1996). Each stimulus was presented twice, with 2-s pauses between repetitions and 7-s interstimulus intervals. The stimulus order was randomized. In addition, the videotape began with four warm-up stimuli to familiarize participants with the task. Including the warm-ups, reference episodes, and permutations, the tape contained 52 segments of infant behavior lasting 10 s each and was 25 min in duration.

Table 2
Vocalizations Used in Reference Episodes

		Vocalization characteristics	
Episode	Behavior of original parent	Acoustic complexity	Duration (s)
	Small vocal repertoire		
1	Gave/showed	FRN	1.16
2	Named/acknowledged	FRN	0.96
3	Soothed/showed concern	FRN	1.81
4	Did not respond	FRN	1.31
	Medium vocal repertoire		
1	Gave/showed	MS	0.81
2	Named/acknowledged	MS	0.95
3	Soothed/showed concern	FRN	1.35
4	Did not respond	MS	0.93
	Large vocal repertoire		
1	Gave/showed	FRN	0.40
2	Named/acknowledged	RD	0.79
3	Soothed/showed concern	FRN	0.72
4	Did not respond	MS	0.56

Note. All vocalizations were produced during parent–infant play sessions. Vocal types follow Oller and Lynch (1992): FRN = fully resonant nucleus; MS = marginal syllable; RD = reduplicated babble. All vocalizations were presented at the same amplitude (55 dB).

Procedure

Playback mothers viewed the stimulus tape on a Panasonic AG-513-A monitor/VHS player. The playback mothers were not acquainted with the infants on the stimulus tapes. We chose to use unfamiliar infants to control for the background knowledge that mothers would bring to samples of their own infants' behavior. The infants' vocalizations were presented at 55 dB. The sounds were measured at the location of a participant's head relative to the speaker, a distance of approximately 70 cm. To familiarize the playback mothers with the videotape, they were first asked to rate the infants' emotional state on a three-category scale (happy or content, neutral, sad or angry). The playback mothers were then asked to watch the tape a second time while indicating their response to the infants using four categories of possible actions. The response categories are shown in Table 1. Participants were asked to pick the category closest to their response and were told that there were no right or wrong answers.

Data Analysis

Because the stimulus infants were characterized by different vocal repertoires, the responses to each infant were analyzed separately. For each reference episode, a chi-square test was used to compare the two categories receiving the highest number of responses. If the modal response to a reference episode did not reach statistical significance, that example and its permutations were dropped from further analyses. Responses to the reference episodes were also compared across parity groups.

The relative influence of vocal versus visual components of the stimuli on maternal behavior was assessed by comparing responses between reference episodes and their permutations. Responses were compared between each reference episode and (a) permutations that shared the reference's audio component but differed in video content, and (b) permutations that shared the reference's video component but differed in audio content (Figure 1). The number of shifts in playback mothers' responses to new categories between a reference episode and each of its audio and video permutations was counted. Thus, there were no correct or incorrect

Video (Activity) \ Audio (Vocalization)	1	2	3	4
1	Reference episode 1	V1,A2	V1, A3	V1, A4
2	V2, A1	Reference episode 2	V2, A3	V2, A4
3	V3, A1	V3, A2	Reference episode 3	V3, A4
4	V4, A1	V4, A2	V4, A3	Reference episode 4

Figure 1. Permutation of the reference episodes. The audio (A) and video (V) components of the infants' four reference episodes were permuted to create new combinations of cues. Data were analyzed by comparing responses between reference episodes and their permutations.

responses to the permuted episodes. For each reference episode, shifts in responding were summed (a) across all the audio permutations and (b) across all the video permutations. This procedure gave us a tally of how many times the playback mothers used a new response category when the audio or video component changed. A chi-square test was then used to assess differences in the number of response shifts due to an audio or video manipulation. Significant numbers of shifts in responses meant that the message in the infants' behavior had changed.

Results

Responses to Reference Episodes

Playback mothers demonstrated a high level of agreement in their responses to the reference episodes of prelinguistic behavior. They converged on the same response category (see Table 1 for category descriptions) when viewing infants in the reference examples. As measured by chi-square tests ($n = 40$, $df = 1$) that compared the two categories receiving the highest number of responses, significant modal responses were obtained for 10 of the 12 episodes. Responses were significant at the $p < .05$ level for 1 episode, at the $p < .01$ level for 3 episodes, and at the $p < .001$ level for 6 episodes. Thus, the brief reference episodes contained unambiguous information for the playback mothers. No differences in responding to the reference episodes were found across parity groups.

Influence of Auditory and Visual Cues

Data on response shifts are reported for permutations of the 10 reference episodes that achieved significant subject agreement. Because the modal responses of both parity groups were identical for 33 (91.6%) of the 36 recombined stimuli, data from both groups were pooled. All four reference episodes from the low-repertoire infant attained significant agreement, so each episode yielded three permutations in both audio and video components (Figure 1). Across the three permutations, each component could cause a total of 120 (40 mothers × 3 permutations) shifts in responses. Three of the reference episodes from both the medium- and large-repertoire infants attained significant agreement. For these infants, each episode's audio and video components yielded two permutations and could cause a total of 80 (40 mothers × 2 permutations) possible shifts.

When the audio and video components of the reference episodes were permuted, playback mothers reliably shifted their responses. Chi-square tests ($df = 1$; low-repertoire $n = 120$, medium-repertoire $n = 80$, large-repertoire $n = 80$) revealed differences in the number of shifts due to audio versus video manipulations (Table 3). When the video components were changed, only the behavior from the small-repertoire infant resulted in increased shifts in playback mothers' responses (Table 3). In contrast, when the audio components were changed, changes to the vocal behavior of both the medium- and large-repertoire infants resulted in more shifts in playback mothers' responses (Table 3). Overall, there was a tendency for increased audio-influenced response shifts as the infants' vocal repertoires became larger.

Discussion

Playback mothers responded consistently to the unmodified episodes of infant behavior. The mothers agreed on responses even though the stimuli were of short duration and of unfamiliar infants. Our examples of prelinguistic infant behavior, then, contained sufficient information to guide playback mothers' reactions toward consensus as to communicative content. The similarity of responses across playback mothers suggests a social mechanism of reliable feedback for infant behavior. Consistent feedback is assumed to occur within mother–offspring dyads, but our study demonstrates the consistency of interactions between mothers and infants that are not their own. Previous work has provided evidence of adults' ability to consistently categorize infant sounds. Papousek (1989) has revealed the consistency with which

Table 3
Number of Shifts in Responses Away From That Given to the Reference Episode

Episode	Number of shifts in responses: Audio changed	Video changed
	Small vocal repertoire	
1	29	63***
2	48	95***
3	75*	47
4	56	59
	Medium vocal repertoire	
1	60**	44
3	56***	24
4	49	50
	Large vocal repertoire	
1	51*	34
2	54***	26
3	59**	38

Note. For all chi-square tests, $df = 1$; small repertoire $n = 120$, medium repertoire $n = 80$, and large repertoire $n = 80$. Methods for computing the chi-square n (the number of possible response shifts for the episodes of each stimulus infant) are given in the text. *$p < .05$. **$p < .01$. ***$p < .001$.

adults rate the emotional state represented by 2-month-old infants' sounds. However, the scale of responses he used in his study was not directly relevant to the development of communicative skills. To explore the connection between receiver responses and a crucial step in vocal learning—associating one's sounds to predictable outcomes—we have examined receiver behavior that is relevant to what the infant would experience.

What proximal cues drive the reliability of mother–infant interactions? The communicative potency of prelinguistic vocalizations was demonstrated by playback mothers' responses to the recombined stimuli. As the vocal repertoire size of the stimulus infants increased, changes in vocalizations resulted in more shifts in playback mothers' responses. Only the behavior from the small-repertoire infant resulted in video-influenced response shifts. When exposed to the 2 infants with larger and more complex repertoires, mothers shifted their responses when the audio component was changed. This is not an age-graded effect, as the small-repertoire infant was 2 months older than the medium-repertoire infant. In addition, the infants were matched for the activities in which they were engaged, so that the visible behaviors of the infants did not systematically vary with increases in repertoire size. Thus, when presented with behavior of sufficient acoustic diversity, the playback mothers' responses were sensitive to changes in prelinguistic sounds.

Given the exploratory nature of the experiment, there are a number of cautionary notes that should be sounded. Although participants had lists of possible response actions, they recorded their responses in terms of only four categories, which could be partially responsible for the observed consistency. Also, because the same mothers responded to all the stimuli, the statistical tests comparing modal responses are not truly independent. More important, the study only used 3 stimulus infants, raising the risk of pseudoreplication. Such a low number of stimulus infants allows for the possibility that responses could be due to characteristics of a particular infant and not to changes in repertoire size. All of these concerns are addressed in playback studies currently being conducted in our lab.

There are probably several acoustic determinants of the observed consistency in maternal responses. Adults have rated 3-month-old infants as being more attractive, likable, and more capable of intentional communication when the infants' vocalizations are more fully voiced or syllabic (Beaumont & Bloom, 1993; Bloom et al., 1993; Bloom & Lo, 1990). Acoustic analyses of syllabic sounds revealed longer duration and less nasal resonance as compared with less fully voiced or vocalic sounds (Masataka & Bloom, 1994). In our study, the infants with larger prelinguistic repertoires used higher proportions of fully voiced sounds, possibly increasing adults' attention to the infants' vocalizations. Prosody has also been found to play a role in adults' perception of infants and young children. Vocalizations that ended in rising pitch contours yielded interpretations of requesting or wanting from adult listeners (D'Odorico, 1984; Flax, Lahey, Harris, & Boothroyd, 1991; Furrow, 1984; Masataka, 1993). We are currently using the playback paradigm to explore further the consequences of acoustic modifications of early sounds on the behavior of receivers.

In light of the influence of vocal precursors on the responses of mothers, babbling must be considered a form of social interaction that may direct the development of later, more complex vocal behavior. The development of vocal skills has usually been studied from a categorical perspective, in which vocal development has been described in stages of increasing acoustic complexity (Oller, 1980, 1985; Oller & Lynch, 1992; Stark, 1979, 1980). These studies were not designed to consider the effects of the social environment on vocal production but rather to map out the species-typical course of development. These acoustic taxonomies cannot by themselves illuminate the building blocks of communicative function.

What is the relationship between the increasing complexity of vocal production over a child's first year and the consistency observed in caregivers' responses to prelinguistic sounds? In our study, the playback mothers had different patterns of reacting to changes in the infant sounds. Though mothers were consistent about shifting their responses when the vocalizations were changed, different mothers shifted to different responses. An individual mother's pattern of responses to prelinguistic sounds may be related to her infant's level of vocal development. The role of receiver experience in response consistency to early sounds has received little attention, especially when compared with the wealth of research on the capabilities of senders. Most studies of adult ratings of infant sounds have failed to find an effect of caregiving experience (Bloom et al., 1993; Papousek, 1989). However, the above research asked adults to either rate infant sounds on scales having to do with emotional content (Papousek, 1989) or rate the infants themselves on attractiveness (Bloom et al., 1993). Measuring real-world behavioral responses to infant sounds may prove to be a more sensitive task. We are presently undertaking a series of playback experiments to investigate the emergence of caregiver response consistency over the first year.

As pointed out by Snow (1988) and Locke (1993), prerequisites for language come from multiple sources such as speech perception and social development. Our understanding of vocal development in avian and primate species has been enriched by an emphasis on the social functions of vocal precursors (Snowdon and Hausberger, 1997; West & King, 1988; West et al., 1990). In the avian work, the consistency in the responses of conspecifics to infant sounds has been shown to be a powerful force influencing the development of more complex communicative behavior. The findings from these studies suggest a strong role of vocal precursors in the acquisition of communicative skills. In contrast, most studies of human vocal development portray vocal precursors only in terms of their resemblance to adult forms of production. Noncrying vocalizations are usually assigned to the categories of practice and play without reference to the reactions of receivers. Our data show the potential importance of the social environment. Such a view challenges the predominant view of human vocal learning, which emphasizes the signals of senders over the responses of receivers (see reviews by Ingram, 1989; Locke, 1993). We propose that receiver behavior allows early sounds to gain functional significance, thus facilitating the development of communicative skills.

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