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Categorization of Infant-Directed Speech

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Observations of caregiver–infant interactions have consistently revealed that adult caregivers begin talking to infants during the newborn period and continue this form of interaction throughout the infancy period. Caregivers engage in these interactions even though young infants themselves can neither reciprocate with language nor comprehend the language that they hear. The type of language adults produce when talking to infants has been labeled *infant-directed* (ID) speech and is different from the type they use for communicating with other adults on several dimensions, but primarily in its prosodic properties. These rhythmic and melodic modifications in speech to infants have been found in a number of languages, and they are produced by children, adults, parents, and nonparents.

This prevalence of ID speech during interactions with infants has led researchers to question if ID speech serves special functions within these interactions. That is, because young infants cannot understand the complete linguistic content of the signal, perhaps the prosodic or melodic properties of the signal serve functions within early social interactions such as regulating infant behavior and communicating speaker affect and intent. Support for this idea has been provided by observations that adult caregivers produce different patterns of ID speech prosody in different interactive or pragmatic contexts—for example, comforting a distressed infant versus eliciting the attention of an infant during play. However, if these ID speech patterns are to serve the functions that have been proposed, it is important that infants be capable of categorizing ID utterances. Infants must detect the acoustic properties that are regularly present in ID

utterances produced within one pragmatic context despite acoustic differences across exemplars. Our recent research examined the development of infants' categorization of ID speech, focusing on 4- and 6-month-old infants' categorization of comforting and approving ID utterances.

Our goals for this chapter are threefold. First, we review the evidence in the literature that documents the types of caregiver ID speech to which young infants are exposed, the evidence that infants respond differently to ID speech than to *adult-directed* (AD) speech, and the evidence that infants respond differently to ID speech produced in different interactive contexts. We also discuss the hypotheses that ID speech may function to regulate infant affect and communicate speaker affect and intent to young infants. Second, we review our research that investigated if 4- and 6-month-old infants categorize ID speech produced to convey different communicative intents, specifically, comforting and approving ID utterances. Finally, we discuss hypotheses for explaining the developmental effect revealed by our data as well as the potential significance of infants' ID speech categorization. We conclude by considering the implications of ID speech categorization for infants' social–cognitive development and their developing understanding of vocal communicative intent.

INFANTS' ID SPEECH EXPERIENCE AND ID SPEECH RESPONSIVENESS

ID speech is produced by adults—parents and nonparents alike (Jacobson, Boersma, Fields, & Olson, 1983)—and by children (Sachs & Devin, 1976) speaking to infants. ID speech is distinguished from typical AD speech primarily on the basis of its distinctive prosody. *Prosody* refers to the melodic quality of speech that is imparted by the rise and fall of pitch, modulation of amplitude, and stress and rhythm patterns. ID speech is higher in average frequency, contains more variable pitch excursions, and is slower in tempo than AD speech (Fernald & Kuhl, 1987; Fernald et al., 1989). ID speech has been documented in interactions with infants ranging in age from newborn through 12 months of life and beyond (Fernald & Simon, 1984; Jacobson et al., 1983; Stern, Spieker, Barnett, & MacKain, 1983). What is interesting about these observations is that during much of the first year of life, infants do not understand the linguistic content of the speech they hear.

Both the use of ID speech and prosodic differences between ID and AD speech have been documented in a number of different languages, including French, German, Italian, Mandarin Chinese, and English (Fernald et al., 1989; Grieser & Kuhl, 1988; Papousek, 1992). Because ID speech occurs

in a number of cultures and linguistic environments, researchers have questioned whether ID speech serves any particular functions for prelinguistic infants.

Several researchers have suggested that the prosody of ID speech might aid language acquisition by providing cues to syntactic structure. Evidence for such a role of ID speech prosody is provided by research that has demonstrated that pauses between phrases and clauses facilitate infants' parsing of the speech stream (Hirsh-Pasek et al., 1987; Jusczyk, Kemler Nelson, et al., 1992), that syllable stress patterns facilitate segmentation (Echols, 1996), and that pitch and sentence position are used to highlight individual words (Fernald & Mazzie, 1991). One model, proposed by Fernald (1992), posits that there are multiple functions of ID speech and that ID speech tends to serve different functions for infants of differing ages across the first year of life. During the later months of the first year and beyond, ID speech prosody may facilitate infants' detection of linguistic structure by highlighting syntactic structure (see Morgan & Demuth, 1996). However, during the first months of life, ID speech prosody may serve functions that are nonlinguistic in nature, such as regulation of infant behavior and affect and communication of the caregiver's emotion to the infant.

In this chapter, we focus on the characteristics of ID speech prosody that do not facilitate detection of linguistic structure per se, but that may have social and/or prelinguistic functions such as regulating infant behavior and arousal or conveying caregiver emotion and intent. One potential function of ID speech is regulation of attention and arousal during the first months of life. Evidence for this hypothesis is provided by the finding that ID speech is much more effective than AD speech at maintaining the attention of 1-, 4- and 9-month-old infants (Cooper & Aslin, 1990; Fernald, 1985; Pegg, Werker, & McLeod, 1992). Some recent evidence suggests that 4-month-olds might also find ID speech more arousing than AD speech (Kaplan, Goldstein, Huckeby, & Cooper, 1995; Kaplan, Goldstein, Huckeby, Owren, & Cooper, 1995). Behaviors indicative of positive affect (e.g., smiling and cooing), also occur more frequently in 4- to 5.5-month-old English-hearing infants in response to English ID speech (Werker & McLeod, 1989) and Cantonese ID speech (Werker, Pegg, & McLeod, 1994) than in response to AD speech.

A second function hypothesized for speech directed to younger infants is that it communicates the speaker's affect and consequently provides information about the communicative intent of the speaker (Fernald, 1992). Consistent with this hypothesis is evidence that adult-directed speech varies acoustically as a function of speaker affect and that these varying acoustic properties are perceived by adults as reflecting different emo-

tional states of the speaker. Acoustic analyses of adult speech produced in different emotional states have shown that there are distinctive acoustic speech qualities produced when speakers experience fear, anger, joy, and sadness (Scherer, 1986). Additionally, adult listeners' attribution of emotional arousal varies continuously with the frequency range of the voice independent of verbal content and speaker identity (Ladd, Silverman, Tolkmitt, Bergmann, & Scherer, 1985). Studies with infants have also shown that different acoustic properties elicit certain emotional responses from infants. Low-frequency acoustic stimuli soothe infants (Birns, Blank, Bridger, & Escalona, 1965), whereas high-frequency stimuli arouse them (Hutt, Hutt, Lenard, Bernuth, & Muntejewerff, 1968).

Additional evidence consistent with the hypothesis that ID speech may function to communicate speaker affect to infants is provided by observations that caregivers from many language environments vary ID-speech prosody as a function of interactive context, for example, playing, feeding, and/or comforting (Fernald et al., 1989; Grieser & Kuhl, 1988). Specifically, ID utterances produced in different contexts or directed to infants in different affective states have characteristic frequency contours, frequency variation, rhythm, and intensity (Fernald & Simon, 1984). Acoustic analyses of ID speech typically examine average fundamental frequency (F_0), which is correlated with vibration rate and size of the vocal cords, modulation or range of $F_{0,}$ and the shape of F_0 contours across individual utterances. These analyses have revealed that comforting utterances are characterized by falling frequency contours (Papousek, Papousek, & Bornstein, 1985; Stern, Spieker, & MacKain, 1982), lower mean F_0 (Fernald, 1989), and lower F_0 variability (Katz, Cohn, & Moore, 1996; Papousek, Papousek, & Symmes, 1991) relative to approving utterances. Approving utterances, in addition to having higher mean F_0 and F_0 variability than comforting utterances, are longer in duration (Fernald, 1989) and are characterized as wave-shaped (Katz et al., 1996). Utterances produced with the intention of attracting infants' attention are characterized by rising frequency contours, whereas those produced with the intention of maintaining infant attention have frequency contours that are bell-shaped (Stern et al., 1982).

Stronger evidence that ID speech has the potential to communicate speaker affect to infants is provided by studies demonstrating that young infants exhibit appropriate responses to approving and disapproving ID utterances. Fernald (1993) reported that 5-month-olds showed more behaviors indicative of positive affect in response to approving ID speech than in response to prohibiting ID speech and that they showed more behaviors indicative of negative affect in response to prohibiting ID speech than in response to approving ID speech. Similarly, Papousek, Bornstein, Nuzzo, Papousek, and Symmes (1990) found that 4-month-olds

fixated a visual stimulus longer in order to hear prototypical approving nonlinguistic ID contours than prototypical disapproving nonlinguistic ID contours. In these studies, infants were most likely responding to acoustic properties that varied as a function of communicative intent and that are characteristic of utterances conveying these particular intents.

Adults modify their speech as a function of an infant's behaviors and affective state as well as their own affective state and intent. Thus, experiences with caregiver speech provide opportunities for infants to associate certain ID speech prosody patterns with their caregivers' behaviors and emotions. In addition, these interactions provide opportunities for infants to associate their own emotions with their caregivers' ID speech patterns. Consequently, several researchers have suggested that ID utterances may serve as the first vocal communicative signals for prelinguistic infants and may acquire the function of contextual reference for young infants (Fernald, 1992; Papousek, 1992; Stern et al., 1982).

In order for these ID utterances to most effectively serve as communicative signals, however, infants must first be capable of categorizing them. Because any two utterances produced with similar communicative intent (e.g., to comfort the infant) typically vary in verbal content as well as on prosodic dimensions such as mean F_0 and frequency range, categorization of the utterances is essential for perceiving the similarity of their communicative intents, and hence for perceiving them as meaningfully different from utterances with different communicative intents. Categorization is dependent on ignoring detectable physical properties that are not shared across the exemplars from within a single ID utterance class, and that are irrelevant for their assignment to a category. Categorization also requires detecting the properties of exemplars that are characteristic of a single ID utterance class. For example, in order for infants to categorize and subsequently respond appropriately to the communicative intent of a comforting utterance, infants must ignore varying and/or irrelevant verbal content and variations in overall frequency range and mean F_0, and instead attend to the lower-frequency, falling frequency contours that characterize all comforting utterances. Data addressing if and when infants categorize ID utterances are important to consider in the ongoing debate about the proposed function of ID speech as communicating speaker affect and intent. Infants' categorization of ID speech would provide an important piece of evidence in this debate, because this ability would indicate that infants have perceptual processing skills that are important for and may be necessary for their comprehension of ID utterances as meaningful signals. In order to address this issue, we conducted a series of experiments examining 4- and 6-month-olds' categorization of approving and comforting ID utterances. This research is discussed in the following section.

ID SPEECH CATEGORIZATION RESEARCH

Seven experiments investigating infants' categorization of ID speech are described in this chapter. First, however, a brief overview of the specific manipulations conducted in each experiment, as well as a review of the general procedure used in all the experiments, is detailed in this section. The first two experiments examined 6-month-old infants' ability to categorize approving and comforting ID utterances. In these experiments, each ID speech stimulus that infants heard was produced by a different female. Experiment 1 tested infants' categorization of low-pass filtered ID speech, and Experiment 2 examined infants' categorization of natural, unfiltered ID speech. The next three experiments examined 4-month-old infants' categorization of the same ID speech stimuli. Experiments 3 and 5 tested 4-month-olds' categorization of low-pass filtered and unfiltered ID speech stimuli, respectively. Experiment 4 was a control study that assessed whether the experimental method used in this research was appropriate for assessing 4-month-olds' response recovery to a novel stimulus following a series of familiarization trials. Finally, we conducted two additional experiments using a different set of ID speech stimuli that were all produced by one female. The purpose of this change in stimuli was to decrease the variability across stimuli introduced by the speaker-specific differences that characterized the stimuli used in Experiments 1 through 5. Again, 4-month-old (Experiment 6) and 6-month-old (Experiment 7) infants' categorization of comforting and approving ID speech stimuli was assessed.

General Procedure and Design

Speech Stimuli. ID utterances produced by caregivers in approving and comforting contexts were presented as stimuli for three reasons: these classes of utterances are frequently produced in caregiver–infant interactions containing ID speech (Fernald, 1992); these two utterance classes have been shown to be quantitatively discriminable on several variables, including F_0 and frequency contour (Fernald, 1992; Katz, Cohn, & Moore, 1996; Papousek et al., 1991); and utterances of these types were not expected to be aversive to the infants.

The first five experiments discussed used speech stimuli analyzed and described in Katz, Cohn, and Moore (1996). These stimuli were maternal utterances to 4-month-old infants produced in approving or comforting contexts. Utterances were obtained during a laboratory visit in which mother and infant were outfitted with wireless microphones and were recorded during a structured set of interactions. Approving interactions

required the mother to indicate approval when her infant reached for and grasped a red ring. Comforting interactions required the mother to speak to her infant as if he or she were distressed. From these stimuli, we selected eight approving utterances and eight comforting utterances, each spoken by a different person. The mean F_0 of approving utterances was significantly higher than the mean F_0 of comforting utterances (Mann-Whitney $U = 1$, $p < .01$), and the F_0 variability of approving utterances was significantly greater than the F_0 variability of comforting utterances (Mann-Whitney $U = 13$, $p < .05$). These differences between comforting and approving ID utterances are typical of the prosodic distinctions that have been previously reported in the literature (Fernald et al., 1989). Additionally, a combination of mean F_0 and F_0 variability distinguished the set of approving utterances from the set of comforting utterances; five of eight comforting utterances were below the median value on both F_0 and F_0 variability measures (binomial $p = .0231$), and five of eight approving utterances were above the median value on both measures (binomial $p = .0231$). These analyses reveal that differences between ID utterance classes on either F_0, F_0 variability, or both, were available in the stimuli to support infants' discrimination and categorization. The speech stimuli presented in Experiments 6 and 7 are described later in the section detailing those studies.

Design and Procedure. A modification of an infant-controlled, familiarization-test procedure (Ferland & Mendelson, 1989) was used in all experiments. In this procedure, an infant's fixations of a visual display are reinforced with contingent presentation of an auditory stimulus, effectively giving the infant control over the presentation of the stimuli. By looking at the display, the infant can initiate playback of the auditory stimulus; by looking away, the infant can terminate it. Because availability of the auditory stimulus depends on their visual behavior, fixation of the display can then be used as an index of interest in the auditory stimulus.

Each infant experienced at least seven familiarization trials followed by at least one test trial; trials eliciting less than 2 s of fixation were repeated (see Moore, Spence, & Katz, 1997 for more details). Infants heard a *different* randomly selected utterance in each trial (unless a trial elicited less than 2 s of fixation, in which case the utterance heard during that trial could be repeated in a later trial). Infants were randomly assigned to one of four groups, with boys and girls equally distributed across these conditions. Half of the infants initially heard seven different comforting utterances, one during each familiarization trial; the other half heard seven different approving utterances during these trials. Half of the infants within each of these two groups were controls who subsequently heard a randomly chosen novel stimulus from the familiar category during a test trial; the

rest were experimental infants who heard a randomly chosen novel stimulus from the novel category following familiarization. Visual fixation of the visual displays on the computer monitors was used as the index of attention to the auditory stimulus. If, as we hypothesized, infants are able to categorize ID speech utterances, following familiarization with stimuli from one category, we should see recovery of response (in this case, fixation) to novel stimuli from the unfamiliar class but *not* to novel stimuli from the familiar class.

Each infant was assessed while seated in a caregiver's lap in a dimly lighted testing room. The infant was seated approximately 1 m in front of two computer monitor screens, each of which was surrounded by a black curtain. The experimenter unobtrusively observed the infant through a small hole in the curtain (above and centered between the monitors) and a video camera recorded the infant's behavior through a second hole (centered below the monitors). Caregivers and the experimenter were fitted with headphones through which played a loud, continuous audiotape recording of simultaneous presentations of four randomly chosen experimental stimuli. This recording prevented either adult from hearing or determining which specific utterance or type of utterance the infant heard on any given trial.

To capture the infant's attention and begin each trial, a string of minilights centered between the monitors was flashed on and off. Once the infant fixated the lights, the lights were extinguished and visual stimuli were presented on the monitors. Each monitor displayed identical images of three black and white random checkerboards (Karmel, 1969) on a gray background. During a trial, the color values of the squares changed, so that black squares could become white and vice versa. These color changes made the checkerboards appear to flash and served the purpose of increasing infants' attention to the displays (see Moore et al., 1997, for a detailed description of the visual stimuli). Identical visual stimuli were presented on the two monitors because pilot research had demonstrated that infant attention was more effectively maintained throughout the task when two monitors rather than one were used. These stimuli were displayed continuously until the end of the trial, which occurred either 30 s after the onset of the trial, or when the infant looked away from the stimuli for 2.5 consecutive seconds, whichever came first. Intertrial intervals were typically less than 3 s. These checkerboard stimuli were presented during familiarization trials as well as the test trial.

Whenever an infant was judged by the experimenter to have begun fixating either one of the monitors, a randomly chosen speech stimulus from the predetermined category was played through a speaker (located between the two computer screens at the infant's midline). As long as the infant continued to fixate a monitor, the utterance was heard. Any time

the end of the utterance was reached, it was replayed from the beginning after a 1-s pause. Whenever the infant was judged to have terminated fixation of the monitors (or at the end of 30 s), the playback of the utterance ended. If, before the end of the trial, the infant refixated either one of the visual displays, the utterance was replayed from the beginning. Total duration of looking at the monitors was recorded on-line during each trial by a trained experimenter. Inter-rater reliability of experimenters was .98 (phi coefficient computed on two experimenters' interval-by-interval records of infant's fixation behavior).

The primary dependent variable of interest was fixation or looking time (s) at the visual displays during specific trials. Each infant's data were divided into three trial blocks. Block 1 consisted of average fixation data from trials 1 and 2, block 2 consisted of average fixation data from trials 6 and 7 (the final two familiarization trials), and block 3 consisted of fixation data from trial 8 (the test trial). Because complete habituation rarely occurred across seven trials, but we thought it necessary to ensure that infants exhibited some looking decrement across familiarization, 6-month-old infants' data were included in subsequent data analyses only if their looking decreased by a minimum of 5% from block 1 to block 2 (see Moore et al., 1997 for a discussion of the process by which this criterion was selected). A more stringent decrement criterion of 25% was set for 4-month-olds to afford them conditions that maximized recovery on the test trial.

In all studies except Experiment 1A, infants' response recovery to novel ID utterances was tested using a mixed ANOVA in which familiarization class (approval and comfort) and group (experimental and control) served as between-subjects factors, and block (2 and 3) was the repeated factor. We have consistently found no effects of familiarization class. For Experiment 1A, a mixed ANOVA of familiarization class (approval and comfort) and block (2 and 3) was performed. Our conclusions regarding infants' categorization were based on the criteria that a significant interaction of group and block was necessary, in conjunction with either significant group differences in test trial (block 3) fixation, or a significant increase in average fixation from block 2 to block 3 for the experimental group but not for the control group.

Six-Month-Olds' Categorization of ID Speech

Experiment 1: Six-Month-Old Infants' Categorization of Low-Pass Filtered ID Speech. We decided to begin by testing 6-month-old infants' categorization of ID utterances because infants in this age range have been shown to categorize a number of different types of stimuli (Bornstein, 1984; Cohen & Strauss, 1979; Miller, Younger, & Morse, 1982; Younger & Cohen, 1986).

Approving and comforting ID utterances that were low-pass filtered at 650 Hz (98 dB/octave attenuation) were presented to 6-month-old infants in Experiment 1 (Moore et al., 1997). This filtering manipulation preserved the prosodic features of the stimuli, such as F_0 contour, rhythm, and amplitude modulation, but attenuated cues that signal phonetic distinctions so that the linguistic content of the utterances was not identifiable by adult listeners (see footnote in Moore et al., 1997 for a description of this assessment). Inasmuch as prosodic differences distinguish ID speech utterances produced in different interactive contexts and ID speech prosody is salient for infants, then it seemed likely that infants would be capable of using prosodic information to categorize approving and comforting utterances. If infants are able to categorize ID speech stimuli using prosodic information, then after the response decrement characteristic of familiarization, we should see recovery of response to novel stimuli from the unfamiliar class of utterances but *not* to novel stimuli from the familiar class of utterances.

Consistent with our hypothesis, 6-month-olds who heard a stimulus from a novel category on the test trial increased looking from the final familiarization trials to the test trial, whereas infants tested with a novel stimulus from a familiar category did not (Moore et al., 1997). As illustrated in Fig. 7.1, after infants steadily decreased looking in response to a series of seven approving stimuli, they increased looking on the test trial

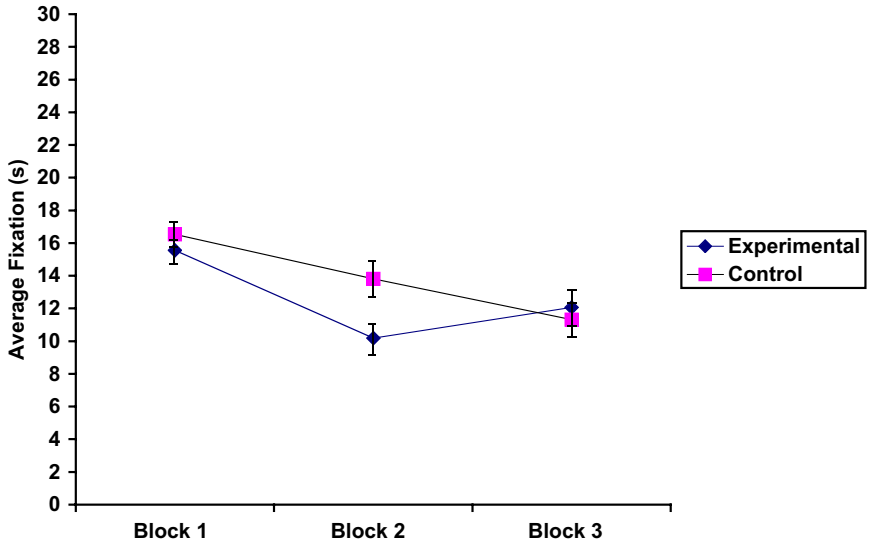

FIG. 7.1. Experiment 1. Average fixation (s) (means and standard errors) of 6-month-old infants presented low-pass filtered ID speech for each trial block. Experimental infants increased fixation from block 2 (last 2 familiarization trials) to block 3 (test trial), whereas control infants did not.

when a comforting stimulus was presented. In contrast, infants who were familiarized with the same series of approving stimuli but tested with a novel approving stimulus did not increase looking on the test trial. The same looking patterns were found for infants familiarized with either comforting or approving stimuli.

Experiment 1A: Six-Month-Olds' Discrimination of Same-Category ID Speech. In Experiment 1A, we used comparable methods and stimuli to establish that similar stimuli *within* each class were in fact discriminable from one another, which is a necessary condition for categorization (Ferland & Mendelson, 1989; Olson & Sherman, 1983). From the 16 stimuli used in Experiment 1, we selected a pair of comforting and a pair of approving stimuli, such that the exemplars constituting a pair had similar frequency contours, durations, and F_0 characteristics. Each infant first heard one of the speech stimuli in each of seven familiarization trials, and subsequently heard the other (novel) stimulus from the same category during a test trial. Infants recovered fixation from the end of familiarization (block 2) to test (block 3), indicating that they were able to discriminate between very similar stimuli chosen from within a single class of utterances. Thus, although infants in Experiment 1 were able to discriminate between a variety of comforting utterances and a variety of approving utterances, they *disregarded the discriminable differences* among stimuli from within classes, treating all instances from a class similarly. Taken together, the results of these studies suggest that 6-month-old infants are able to categorize comforting and approving ID speech stimuli using only prosodic cues.

Experiment 2: Six-Month-Old Infants' Categorization of Unfiltered ID Speech. We next tested if 6-month-olds categorize *unfiltered* approving and comforting ID utterances (Moore & Spence, 1996; Spence & Moore, submitted). The low-pass filtered utterances used in Experiments 1 and 1A did not contain the higher frequencies that infants normally hear in ID speech. In order to test directly if infants categorize *naturalistic* ID utterances, 6-month-olds' categorization of *unfiltered* ID stimuli was examined in this experiment. Relative to low-pass filtered stimuli, unfiltered stimuli contain higher frequencies that signal phonetic distinctions and convey linguistic content to adults. We expected the presence of this additional acoustic information to have one of three possible effects on the infants' categorization. First, the prosodic properties that distinguish comforting and approving utterances—those that likely supported categorization in Experiment 1—may have been relatively more obscure within the context of this additional acoustic information. Thus, the presence of this additional information could have interfered with the infants' categorization of the unfiltered utterances. Alternatively, 6-month-olds could have catego-

rized the unfiltered ID speech stimuli just as readily as they categorized the low-pass filtered stimuli, inasmuch as the prosodic properties that subserved categorization in Experiment 1 still characterized the stimuli presented in the current experiment. Finally, the high-frequency acoustic information in the unfiltered stimuli could have provided additional cues for the infants that actually *facilitated* their categorization.

In this experiment, we tested 6-month-old infants' categorization of unfiltered versions of the comforting and approving ID utterances presented in Experiment 1. If infants categorize the unfiltered ID utterances, they should respond just like the infants studied in Experiment 1. Specifically, infants in the experimental group should recover fixation on hearing a test stimulus from the novel category, whereas control infants should not recover responding on hearing a novel test stimulus from the familiar category.

As shown in Fig. 7.2, the two groups again produced different fixation patterns across trial blocks 2 and 3; experimental infants increased looking from the end of familiarization to test, whereas the control infants did not. Together, the results of these first two experiments indicate that 6-month-old infants categorize exemplars of comforting and approving ID utterances. In particular, they categorize both low-pass filtered ID utterances, for which prosodic properties are salient, and unfiltered ID utterances, which

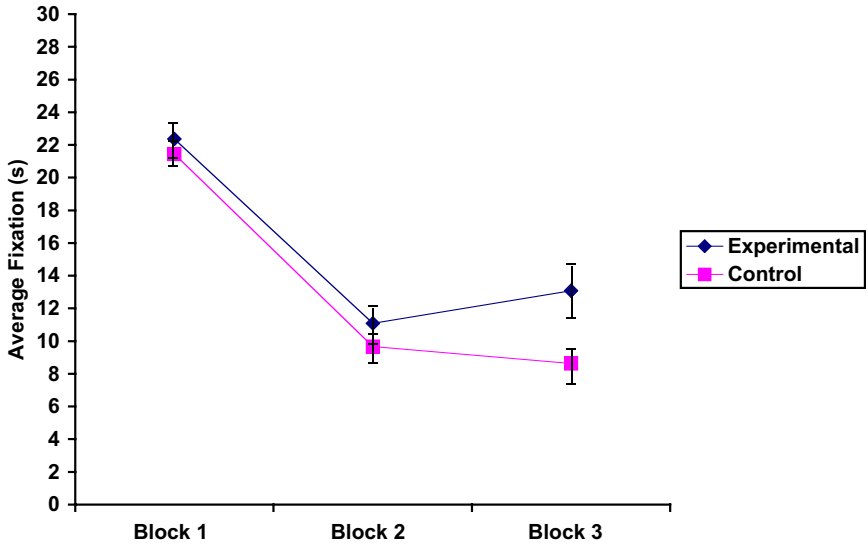

FIG. 7.2. Experiment 2. Average fixation (s) (means and standard errors) of 6-month-old infants presented unfiltered ID speech for each trial block. Experimental infants increased fixation from block 2 (last 2 familiarization trials) to block 3 (test trial), whereas control infants did not.

contain both prosodic and segmental information. Additionally, inasmuch as the two classes of ID utterances presented to these infants are both associated with caregiver intent to evoke positive affect, these results reveal that infants can discriminate utterance categories that have similar affective valence. As discussed in more detail later in the General Discussion, our demonstrations that infants can categorize ID speech suggest that by 6 months of age, they might be learning that caregivers' ID utterances, produced in distinct contexts and characterized by different sets of acoustic properties, signify different communicative intents. Thus, these results provide particularly important support for assertions that ID speech may serve as the first vocal communication of meaningful information (Fernald, 1992; Papousek, 1992; Stern et al., 1982).

Four-Month-Olds' Categorization of ID Speech

Six-month-old infants recovered responding to an ID speech stimulus from a novel category both when the stimuli conveyed only the prosodic properties of the utterance (i.e., when they were low-pass filtered) as well as when they conveyed both prosodic and phonetic information (i.e., when they were unfiltered). In order to explore the developmental trajectory of this ability, we subsequently tested 4-month-old infants' categorization using the same procedure and stimuli used in the studies with 6-month-olds.

Experiment 3: Four-Month-Old Infants' Categorization of Low-Pass Filtered ID Speech. Four-month-olds, like 6-month-olds, have been exposed to and are attentive to ID speech, and they prefer ID to AD speech (Cooper & Aslin, 1994; Cooper, Abraham, Berman, & Staska, 1997). Similarly, the utterances directed at 4-month-olds by caregivers in different pragmatic contexts (and/or in the presence of different infant states) have the characteristic prosodic properties discussed earlier (Fernald & Simon, 1984; Papousek, Papousek, & Haekel, 1987; Stern et al., 1982). However, whether or not 4 months of experience with contextualized ID speech is enough to support infants' categorization of utterances from different ID speech classes is unknown, but an empirical question. Although 4-month-old infants readily discriminate ID and AD speech (Cooper & Aslin, 1990; Fernald & Kuhl, 1987), discrimination of exemplars from different classes of ID speech requires detection of physical differences that are much subtler than those distinguishing ID and AD speech. Consequently, discrimination of utterances from different ID classes presents a more difficult task than discrimination of AD and ID utterances. Categorization would presumably be even more difficult for 4-month-old infants.

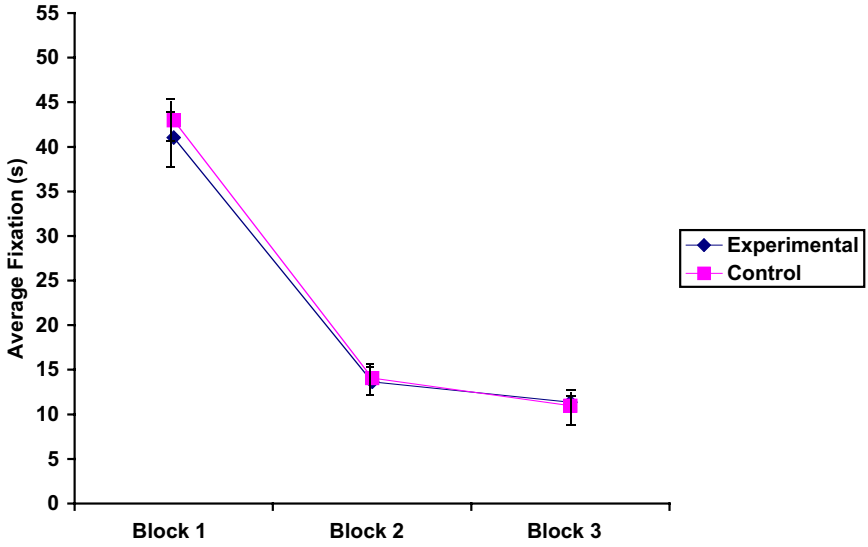

FIG. 7.3. Experiment 3. Average fixation (s) (means and standard errors) of 4-month-old infants presented low-pass filtered ID speech for each trial block. Neither group increased fixation from block 2 (familiarization) to block 3 (test).

We first examined 4-month-olds' categorization of low-pass filtered ID utterances (Spence, Moore, & Longest, 1995) both because speech prosody is very salient for infants at this age and because prosodic properties are particularly salient in low-pass filtered speech. The design, procedure, and stimuli were identical to those used in our work with 6-month-olds, with the exception that longer trials were used with 4-month-olds in order to provide them with sufficient familiarization time (Colombo & Mitchell, 1990). For all experiments with 4-month-olds, a trial ended when stimuli had been presented for a total of 60 s (rather than 30 s) or when the infant looked away from the visual stimuli for 2.5 consecutive s. As in Experiments 1 and 2, control and experimental-group infants were tested—following familiarization—with an ID speech stimulus from the familiar or novel category, respectively.

Neither group of infants recovered responding on the test trial. As seen in Fig. 7.3, the response patterns of the control and experimental groups did not differ. Most importantly, infants tested with a stimulus from the unfamiliar category did not increase looking in response to that stimulus.

Experiment 4: Assessment of the Ability of Our Experimental Method to Induce Response Recovery in 4-Month-Olds. The results of Experiment 3, in conjunction with a very high attrition rate for 4-month-olds, caused us to question whether the experimental method used in this research was ap-

propriate for this younger age group. Specifically, we hypothesized that failure to recover responding on the test trial could have occurred if the infants were fatigued by the end of the session. The longer familiarization times given 4-month-olds might have contributed to such fatigue or lack of interest in the auditory stimuli so that they were no longer attentive by the end of the session. This concern was addressed with an experiment in which we tested if 4-month-olds would recover responding on the test trial if the auditory stimulus presented was more discrepant than novel ID speech. As in the previous experiments, infants heard either approving or comforting ID utterances during familiarization. Then on the test trial, they heard an 8-s segment of instrumental music played by a full orchestra. We reasoned that if, during the test trial, infants failed to recover responding to a highly discrepant musical stimulus, this would imply that the infants in Experiment 3 were fatigued by the end of familiarization and incapable of demonstrating a novelty response. However, if infants increased their fixation of the visual stimuli in response to hearing music on the test trial, then this result would strengthen our confidence that the infants' failure in Experiment 3 to recover to a stimulus from an unfamiliar ID class means that they did not categorize the stimuli with which they had been familiarized.

Infants' response recovery on the test trial was assessed as in the other experiments. As can be seen in Fig. 7.4, the experimental group increased

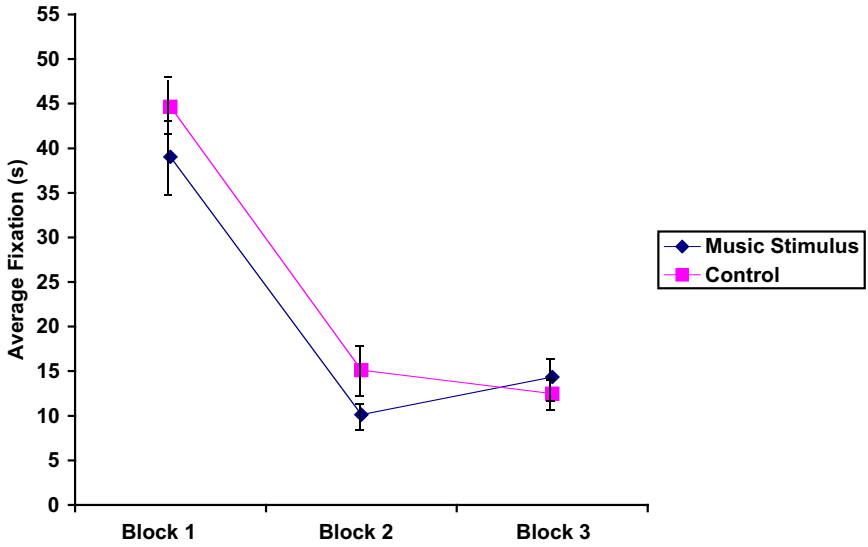

FIG. 7.4. Experiment 4. Average fixation (s) (means and standard errors) of 4-month-old infants tested with music following ID speech familiarization. Infants tested with music increased fixation from block 2 (familiarization) to block 3 (test) whereas control infants tested with a same-category ID stimulus did not.

looking from block 2 to block 3, whereas the control group did not. That 4-month-olds tested with a musical stimulus recovered looking following familiarization with a series of ID utterances indicates that the procedure used in Experiment 3 is capable of revealing young infants' discrimination of auditory stimuli. It also implies that the experimental-group infants in Experiment 3 failed to recover responding on the test trial not because they were fatigued or bored to inaction, but rather because they did not discriminate between the approving and comforting ID utterances.

Experiment 5: Four-Month-Olds' Categorization of Unfiltered ID Speech. We next examined 4-month-olds' categorization of unfiltered ID utterances (Spence & Moore, submitted). Although we did not find that 6-month-olds differentially processed filtered and unfiltered ID utterances, it is possible that younger infants might only be capable of categorizing ID speech stimuli if they are highly similar to those they hear in their naturalistic environment. Infants were tested with unfiltered versions of the comforting and approving stimuli presented in Experiment 3. Again, 4-month-olds failed to recover responding to the ID speech stimuli that were presented on the test trials. As shown in Fig. 7.5, neither experimental nor control infants increased attention on the test trial in response to presentation of the novel stimuli.

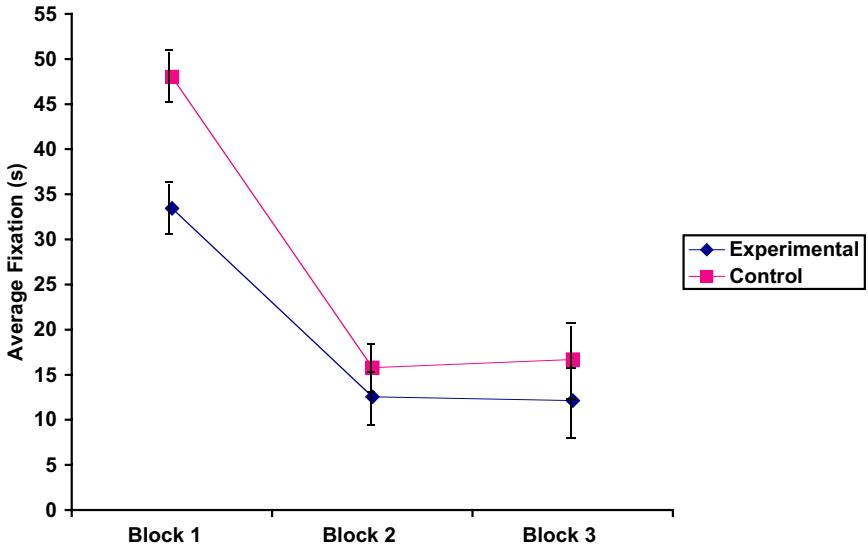

FIG. 7.5. Experiment 5. Average fixation (s) (means and standard errors) of 4-month-old infants presented unfiltered ID speech for each trial block. Neither group increased fixation from block 2 (familiarization) to block 3 (test).

Our evidence that 4-month-old infants fail to categorize ID speech adds to a growing body of conflicting data on infants' auditory categorization skills. For example, infants under 4 months of age have been shown to be able to categorize both phonetically different syllables despite speaker variation (Jusczyk, Pisoni, & Mullennix, 1992), and different vowels produced with irrelevant variation in frequency contour (Kuhl & Miller, 1982) and voice gender (Marean, Werner, & Kuhl, 1992). In contrast, 1- to 4-month-olds do not categorize falling and monotone synthesized frequency contours despite irrelevant variation in vowel identity (Kuhl & Miller, 1982). These results, which were produced within a variety of experimental paradigms and using a variety of auditory stimuli, imply that the ability to demonstrate auditory categorization in young infants depends on both the experimental method used as well as on the nature and complexity of the stimuli presented in the task. These observations led us to ask: If the ID speech stimuli were changed so as to decrease the complexity of the stimulus set, would 4-month-olds then categorize approving and comforting utterances?

Four- and Six-Month-Old Infants' Categorization of ID Speech With Reduced Interstimulus Variability

Experiments 6 & 7: Four- and 6-Month-Olds' Categorization of ID Speech Produced by One Female. The stimulus set presented to infants in all the research presented thus far consisted of eight ID utterances, each produced by a different female. In order to categorize these stimuli, it was necessary for infants to attend to the properties that characterize ID utterances expressed in a given context (e.g., comforting) while ignoring properties that are irrelevant for inclusion in the pragmatic category. Included among these irrelevant properties are variations in physical attributes such as F_0 and tempo, as well as variations in phonetic content and variations that characterize individual speakers' voices. Studies of adults' speech perception have shown that performance on a variety of tasks is influenced by speaker variability (Pisoni, 1993). For example, adults have longer latencies for identifying words produced by multiple speakers compared with words produced by a single speaker (Mullennix, Pisoni, & Martin, 1989). Identification of words presented amidst noise is also less accurate when the words are spoken by multiple speakers rather than by only one speaker (Mullennix et al., 1989). Speaker variability also appears to interfere with infants' encoding and retention of speech: 2-month-old infants can remember a word for a 2-min interval if it is spoken by one person during familiarization, but they do not remember the word if multiple people produce it during familiarization (Jusczyk, Pisoni, & Mullennix, 1992).

Similarly, infants also require more time to habituate to or encode a familiarization word when it is produced by multiple speakers as opposed to a single speaker (Jusczyk, Kemler Nelson, et al., 1992).

Given this literature on the effects of speaker variability on both adults' and infants' speech perception, we hypothesized that young infants may have more difficulty categorizing comforting and approving ID utterances when the stimuli are produced by multiple speakers than when similar utterances are produced by a single speaker. We tested this hypothesis by examining 4-month-olds' categorization of various approving and comforting utterances produced by a single female (Wambacq, Spence, & Marchman, 1998).

The ID speech stimuli used in this study were produced by one female saying a variety of things to her 6-month-old infant. The stimuli were gathered in procedures similar to those used by Katz et al. (1996). Utterances were classified as comforting when (a) the utterance was produced as a response to the infant's distress, and (b) the content of the utterance indicated the mother's intent to comfort her baby. Utterances were classified as approvals when (a) the utterance was a praising reaction to the infant's behavior, and (b) the content of the utterance indicated that the mother was approving of her infant's behavior. In keeping with descriptions of comforting and approving ID utterances found in the ID speech literature (Fernald, 1992; Katz et al., 1996), our single-speaker comforting stimuli had a lower mean F_0 (Mann Whitney $U = 6$, $p = .006$), and F_0 variability (Mann Whitney $U = 8$, $p = .012$) than our single-speaker approving stimuli. These acoustic characteristics also accord well with the acoustic characteristics of the multiple-speaker utterances we used in Experiments 1 through 5 (Moore et al., 1997).

Four-month-old infants were familiarized with low-pass filtered versions of either comforting or approving ID speech stimuli, each of which was unique, but all of which were produced by one female speaker. The stimulus presented during the test trial was also produced by the same speaker, and was either a novel stimulus from the unfamiliar category (experimental group) or a novel stimulus from the familiar category (control group). The procedure and analyses were otherwise identical to those used for Experiments 1 through 5.

The results are shown in Fig. 7.6. Infants' fixation patterns failed to meet the criteria established for categorization (i.e., interaction of block and group). More specifically, experimental infants did not significantly increase fixation on the test trial when an exemplar from the novel category was presented, nor did group differences occur for test trial (block 3) fixation.

Four-month-olds failed to recover responding to an ID utterance from a novel category even though the set of utterances used in the current study

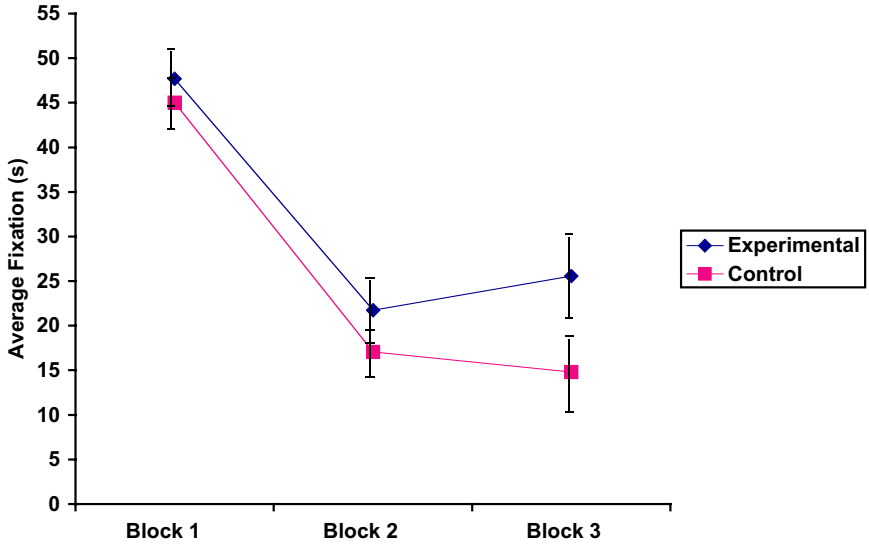

FIG. 7.6. Experiment 6. Average fixation (s) (means and standard errors) of 4-month-old infants presented single-speaker low-pass filtered ID speech. Neither group increased fixation from block 2 (familiarization) to block 3 (test).

was considerably less variable than the set of utterances produced by multiple speakers. However, this null effect might also reflect characteristics of the stimulus set. Although the acoustic attributes of this stimulus set were characteristic of those reported in the literature, the mean F_0 of the speaker was relatively high in frequency (*M* approval = 428 Hz, *M* comfort = 302 Hz) compared to the mean F_0 of the multiple-speaker stimuli used in Experiments 1 through 5 (*M* approval = 361 Hz, *M* comfort = 225 Hz). Given this possibly important difference and the fact that we had not previously studied the ability of older infants to categorize ID speech produced by a single speaker, we conducted a final experiment in which these same stimuli were presented to 6-month-old infants.

Six-month-old infants did provide evidence of categorization of the single-speaker stimuli. Specifically, experimental infants significantly increased fixation from familiarization to test, as illustrated in Fig. 7.7. In contrast, control infants did not increase fixation when presented with a novel exemplar from the familiar category. Thus, 6-month-olds categorized the ID speech stimuli produced by a single speaker. Apparently, the 4-month-olds did not fail to categorize these stimuli because of a property or properties inherent to the stimuli. Rather, 4-month-olds' failure to categorize the single-speaker stimuli mirrored their failure to categorize the multiple-speaker stimuli. This failure was presumably influenced

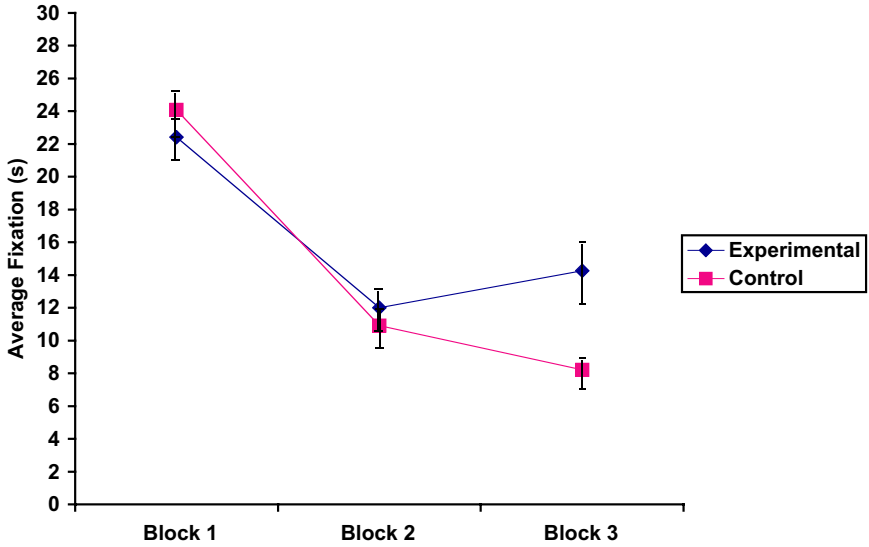

FIG. 7.7. Experiment 7. Average fixation (s) (means and standard errors) of 6-month-old infants presented single-speaker low-pass filtered ID speech. Experimental infants increased fixation from block 2 (last 2 familiarization trials) to block 3 (test trial), whereas control infants did not.

by the same factors that influenced their failure on each of the other tasks reported in this chapter.

GENERAL DISCUSSION AND IMPLICATIONS

These results reveal age-related changes in infants' categorization of ID speech from 4 to 6 months of age. Six-month-olds categorized filtered and unfiltered utterances produced by multiple speakers as well as filtered utterances produced by a single speaker. In contrast, four-month-olds invariably failed to categorize ID speech exemplars from the two classes. They failed to recover responding to an exemplar from the novel category regardless of whether the stimuli were filtered or unfiltered and regardless of whether the stimuli were complex (produced by different speakers) or simplified (produced by one speaker). Is this developmental difference consistent with other findings in the categorization literature? The answer to this question depends, in part, on the type of category the 6-month-olds in our studies are taken to be forming.

The ID utterance categories formed by the 6-month-olds in our studies most closely resemble sensory conceptual equivalence categories (Bornstein, 1984). These types of categories are formed when infants directly

perceive similar physical stimulus attributes—or relations between attributes—across exemplars from one category, even though the exemplars are highly variable on a number of other physical attributes. Infants' categorization of the gender of faces (Cornell, 1974; Fagan, 1979) and facial expressions (Nelson, Morse, & Leavitt, 1979) are cited by Bornstein (1984) as examples of sensory conceptual equivalence categorization, because to form these categories, infants must abstract the relations among the physical attributes that characterize the varying exemplars constituting these categories. Similarly, the categories formed by the 6-month-olds in our studies were sensory conceptual equivalence categories; the ID utterances within each category varied on a number of category-irrelevant attributes (e.g., linguistic content, frequency contour, rhythm, and speaker-specific characteristics such as timbre and speaking rate). However, in spite of this irrelevant variability, 6-month-olds—but not 4-month-olds—detected the co-occurring prosodic properties that characterize the exemplars within each category. Thus, our findings *are* consistent with other findings in the categorization literature; from 4 to 7 months of age, infants have been shown to be increasingly capable of abstracting relations among stimulus attributes (Caron & Caron, 1981), and of processing more complex stimuli (Cohen, 1998; Cohen & Strauss, 1979; Younger & Cohen, 1986).

Hypotheses for Developmental Differences and Future Research Directions

Our studies consistently found that 4-month-olds fail to recover responding to novel-category exemplars. Given the difficulties of interpreting null results, we must emphasize that we cannot be sure that 4-month-olds are completely incapable of categorizing ID speech. Nevertheless, only 6-month-olds—not 4-month-olds—were able to provide evidence of categorization in the specific conditions that characterized our test. Additionally, 4-month-olds did recover responding to music following familiarization with ID speech, suggesting that the experimental procedure we used is capable of detecting discrimination of some contrasts by 4-month-olds. Thus, although 4-month-olds might be capable of categorizing some ID utterances in certain (as yet unspecified) ideal circumstances, our data clearly indicate that their ID speech categorization skills are not yet comparable to those evidenced by slightly older infants. These data suggest that infants' categorization of ID speech changes as a function of age. This developmental difference in ID speech categorization cannot reflect a general deficit in 4-month-olds' categorization, inasmuch as 4-month-old and younger infants do indeed categorize some types of auditory as well as visual stimuli (Eimas & Quinn, 1994; Kuhl & Miller, 1982; Marean, Werner,

& Kuhl, 1992). Therefore, in an effort to explain this phenomenon, we have generated several hypotheses about factors that might mediate such a change.

The developmental difference we observed in ID speech categorization could be due to differences between 4- and 6-month-olds that are not specific to experience with ID speech but that nonetheless influence normal infant functioning (Gottlieb, 1991). Changes in neural structure and/or function that are not dependent on specific ID speech experience but that occur via reciprocal interactions among components of the hierarchical developmental system—ranging from the level of the genes to the level of experience— potentially contribute to the development of categorization (Gottlieb, 1991). Unfortunately, however, we cannot yet offer any more specific hypotheses bearing on this potential source of change.

Infants' specific experiences with ID speech presumably also contribute to the developmental difference we observed in ID speech categorization. More specifically, 6-month-olds' experiences with ID speech may differ qualitatively and/or quantitatively from 4-month-olds' experiences with ID speech. For example, 4-month-olds may not have had sufficient experience with ID speech to be able to categorize ID utterances from two different classes. Their daily experiences might also involve exposure to different distributions of ID utterance types than those to which older infants are typically exposed. It is possible, for example, that infants' exposure to comforting ID speech remains constant or even decreases between 4 and 6 months, whereas their exposure to approving utterances increases across this period due to changes in infants' behavioral and social repertoires (e.g., increased grasping and vocalization). Although we know of no evidence for this hypothesized change in the distribution of ID speech types across this age range, such differences could impact infants' ability to categorize utterances from two different ID speech classes.

Another hypothesis is that 4-month-olds failed to categorize due to the nature of the stimuli presented. Two suggestions relevant to this hypothesis are described now. First, 4-month-old infants may have failed to distinguish the two categories because the acoustic attributes that characterized the categories tested were not sufficiently distinct from one another. In both our multiple- and single-speaker studies reported here, there was considerable acoustic variability among exemplars within each of the two ID speech categories. In addition, there was overlap in the mean F_0 and F_0-variability distributions associated with each category. Although our 6-month-olds' categorization of ID speech was not impeded by the naturally variable, overlapping distributions of the two categories, 4-month-olds' categorization might have been. Second, 4-month-olds may have failed to categorize because the complexity of the ID speech stimuli taxed their information-processing capacity (Cohen, 1998). This suggestion is

consistent with previous findings that older infants are more likely than younger infants to categorize stimuli with multiple components or features (Younger & Cohen, 1986). For infants to categorize the ID utterances used in this research, they had to detect the similarities between exemplars within a category while ignoring irrelevant differences between them. Although our experiments with single-speaker stimuli were conducted to address this issue, the ID stimuli used in these experiments still were quite variable and complex (insofar as they were characterized by a number of acoustic dimensions). Given that our stimuli were representative of naturalistic ID utterances, 4-month-olds might have difficulty categorizing the highly variable and complex ID utterances normally heard in their natural environments.

Yet another possibility is that younger infants might require a human facial stimulus to support their categorization of ID utterances (Lewkowicz, 1996; Walker-Andrews & Lennon, 1991). Support for this hypothesis is provided by research demonstrating that 5-month-olds discriminate happy, angry, and sad vocal expressions in the presence of a facial stimulus, but not when the available visual stimulus is a checkerboard (Walker-Andrews & Lennon, 1991). Four-month-old infants may have failed to categorize ID speech in our studies because a facial stimulus was not available to provide them with a needed social context. Without such a context, infants may not have perceived the auditory stimuli as ID speech, or they may not have attended to the "affective quality of the voice" (p. 140), as Walker-Andrews and Lennon (1991) suggested when trying to explain their results. Why, then, were our 6-month-old participants able to categorize the ID utterances without the context provided by a face? Perhaps as infants develop, they become less reliant on contextual cues for ID speech categorization. This idea is consistent with numerous demonstrations that younger children sometimes require greater contextual support than older children to perform successfully on a variety of tasks (for discussion, see Bjorklund, 1995).

Finally, the developmental difference we observed might reflect the fact that both approving and comforting ID utterances are produced by caregivers in an effort to evoke positive affective responses from infants. It is possible that younger infants may be able to categorize ID utterances, but only if they convey contrasting affect. This possibility is supported by the findings of previous studies that have shown that 4- and 5-month-olds can discriminate vocal stimuli with contrasting affect (e.g., approving vs. disapproving, or sad vs. happy utterances; Fernald, 1993; Papousek et al., 1990; Walker-Andrews, 1997). Thus, infants' ID speech categories may initially be broad—containing exemplars produced in a variety of pragmatic contexts but that all possess the same affective valence (e.g., approving and comforting utterances)—and only subsequently become narrower, ex-

clusively containing exemplars produced within particular pragmatic contexts (e.g., approving utterances). Such a progression would be consistent with evidence that perceptual differentiation of finer and subtler details increases as a function of increasing experience with specific perceptual events (Gibson, 1969). To explore this possibility, we plan to test the breadth of 4-month-olds' ID speech categories using another procedure that may be more sensitive to the discriminative and categorization abilities of younger infants, the Observer-based Psychoacoustic Procedure (OPP) (Werner & Marean, 1991). This procedure insures that infants discriminate the task-relevant features of the stimuli and tests their transfer of this discrimination to novel but categorically similar exemplars.

Implications for Infants' Developing Communicative and Social–Cognitive Skills

Much more research is necessary in order to understand the developmental differences discovered in our research. However, our current results do suggest that 6-month-olds, but not 4-month-olds, can categorize naturalistic, variable ID speech. We think that categorization of ID speech may play a significant role in infants' communicative development. Several researchers have argued that ID speech may communicate speaker affect and intent. Fernald (1992) suggested that ID speech might begin to serve this function toward the end of the first year. Infants' perceptual categorization of ID speech, which occurs at about 6 months of age, may be essential for their processing of ID communicative intent later in the first year, for the following reason. For infants to respond appropriately to vocalizations produced with differing communicative intents, they must categorize the utterances, recognizing and attending to those acoustic attributes that are characteristic of utterances produced within a given pragmatic context while simultaneously disregarding those acoustic attributes that are irrelevant for correct categorization. At a minimum, in the absence of such categorization, the functional meaning of utterances would be lost. Infants would be equally likely to produce appropriate and inappropriate responses to utterances, reacting differently to utterances intended to produce identical responses and similarly to utterances intended to produce different responses.

Our data do not allow us to address whether 6-month-old infants might actually process the communicative intent of ID speech. (They do, however, suggest that younger infants cannot access this information). Inasmuch as 6-month-olds categorize ID speech, it is possible that infants begin processing ID communicative intent in naturalistic interactions during the second half of the first year. If infants do process ID communicative

intent, this ability most likely develops from their association of particular patterns of ID speech with other parental and contextual stimuli, including their own affective and/or behavioral state. As detailed next, the opportunity to associate specific feelings and/or behaviors with the perception of specific ID utterances might facilitate infants' detection of correspondences between forms and functions of utterances.

Infants probably learn to associate particular ID sound patterns with particular classes of interactive contexts by being repeatedly exposed to these sound patterns in these contexts. As we described earlier, caregivers modify the forms of ID speech they produce as a function of infants' behaviors and affective state, providing infants with opportunities to associate sound patterns with different contexts. This association is likely enhanced by the fact that ID speech is one component of multimodal, interactive experiences that infants and their caregivers share. Specifically, caregiver facial expressions, gestures, tactile and kinesthetic stimulation, and ID speech all covary as a function of context. This configuration of covarying cues should facilitate infants' initial association of particular ID utterances with particular interactional contexts.

Another set of stimuli that may influence infants' association of prosody with context is the set of vocalization behaviors infants hear themselves produce. Infants produce vocalizations that vary as a function of social-interactive context and infant state (D'Odorico & Franco, 1991; Legerstee, 1991). For example, infants ranging from 4 to 8 months of age have been found to produce vocalizations characterized by rising melodic patterns and high pitch when engaged in social interaction with, and when looking at, an adult. This pattern is not observed when infants are engaged in object manipulation (D'Odorico & Franco, 1991). Caregivers also frequently mirror infants' vocalizations and facial expressions (Papousek et al., 1985; Rochat & Striano, 1999; Trevarthen, 1979), providing additional response-contingent experiences for infants (Gergely & Watson, 1999). Thus, the vocalizations infants hear themselves produce, as well as those they hear others produce, are both correlated with their own affective and/or behavioral states.

Finally, to the extent that caregivers' ID vocalizations—which are often produced specifically to regulate infant affect and arousal—are effective in modulating infants' behaviors and/or states, then changes in these behaviors and/or states occur as a consequence of hearing ID sound patterns. Thus, the contingencies that typically exist between ID utterances, infants' and caregivers' affective and behavioral states, and other contextual variables could together provide a means by which infants could begin to associate ID speech forms with functions.

Learning that different sound patterns communicate distinctive meanings is an important component in the development of comprehension.

Quite a few researchers have argued that consistent relations between prosodic patterns and communicative functions may provide infants their first experiences with sound-meaning correspondences (Fernald, 1984; Flax, Lahey, Harris, & Boothroyd, 1991; Lewis, 1936; McRoberts, Fernald, & Moses, in press; Stern et al., 1982). Specifically, Lewis (1936) proposed that form–function correspondences that are conveyed by the intonation of ID speech provide a foundation for the infant's later comprehension of words. There are no data available to support the validity of this proposal. However, if this continuity hypothesis is correct, then ID categorization would be quite important for the development of comprehension. Because categorization allows infants to detect classes of ID speech, it affects infants' initial learning about prosody–function pairings. Failure to categorize utterances would result in infants' matching individual prosodic forms with functions, rather than classes of forms with functions. Mismatching of form–function relations would also occur, leading infants to respond inappropriately to ID utterances. An associative process such as that just discussed, in conjunction with categorization processes like those observed in our research, could provide a mechanism by which infants could form associations among classes of forms, functions, and contexts. Infants' processing of vocal communicative intent may also be relevant for their later-developing knowledge that people are intentional agents, organisms who perform behaviors in order to reach specific goals (Tomasello, 1995). A major theme in current developmental literature is that infants' developing understanding of intentionality is important for skills in cognitive, social, and linguistic domains, and is a precursor to the appearance of a "theory of mind," that is, young children's understanding that people's actions are influenced both by desires (emotions) and beliefs (thoughts; Wellman, 1993). Behaviors such as social referencing, joint engagement, imitation, and the use of communicative gestures, all begin between 9 and 12 months of age and are believed by Tomasello and colleagues to reflect an emerging social-cognitive understanding of persons as intentional agents (Carpenter, Nagell, & Tomasello, 1998). Other researchers adopt a more conservative stance, arguing instead that these behaviors form the foundation for an understanding of human intentional activity that develops sometime after 18 months of age (Moore, 1998; Wellman, 1993; for discussion of other views and relevant abilities see Rochat, 1999).

ID speech categorization may be an earlier-appearing *perceptual* ability that, like these other behaviors, may contribute to infants' developing understanding that humans are intentional agents. Although most of the research examining infants' knowledge of others as intentional agents has studied infants' understanding of persons' actions (Carpenter et al., 1998), it is also likely that vocalizations that are either directed toward specific

persons or produced in specific situations also serve as cues that humans are intentional beings. There is evidence, for example, that pragmatic intent conveyed by adults' vocalizations, performed in conjunction with specific actions on objects, affects 14- to 18-month-olds' interpretations of those actions as accidental or intentional. Specifically, infants are more likely to imitate actions on objects when the adult model performs those actions in conjunction with the expression "there!" rather than "woops!" (Carpenter, Akhtar, & Tomasello, 1998). These results suggest that the pragmatic intent of a person's vocalizations influences infants' perceptions of the goal-directedness of that individual's actions. Similarly, for infants in the later months of the first year, categorization of ID speech may influence their perception of object-directedness of actions, which is thought to be a precursor to understanding that actions are goal-directed (Wellman, 1993). Additionally, the association of specific classes of vocalizations with specific actions may facilitate infants' knowledge that utterances are produced by people to obtain specific goals. If infants fail to detect the perceptual similarities across different utterances of the same type, then this failure to categorize could be expected to interfere with their ability to link specific types of utterances with specific actions. To the extent that categorization is involved in this process, then it would contribute to infants' knowledge that vocalizations provide information about a speaker's intentions and emotions (Wellman, 1993). If processing and comprehension of vocal communicative intent contribute to or are indicative of competencies constituting an understanding of intentionality and/or a later-developing "theory of mind," then data on the phenomena we have been studying will likely be of interest to those reading and writing the literature in these areas.

Our conjectures about the possible relation between ID speech categorization and the development of infants' comprehension skills or processing of communicative intent are speculative, inasmuch as we know of no data that address the nature of these relations or the mechanisms underlying their development. Our goal here has been to evoke further discussion and research in this area. We have described a set of experiments that, taken together, suggest that infants categorize approving and comforting ID speech at 6 months of age, but not at 4 months of age. The developmental effect observed warrants further investigation to learn which factors contribute to this change in infants' processing. Additionally, these data contribute to our knowledge of young infants' perception of and responsiveness to ID speech. Finally, they represent an important step toward the goal of evaluating assertions that one function of ID speech may be to communicate speaker affect and intent. One function of categorization per se is that it allows individuals to more efficiently process information in their environments (Bruner, Olver, & Greenfield, 1967). We have

suggested that infants' categorization of ID speech may facilitate processing of communicative intent, which in turn has implications for the development of communicative and social-cognitive abilities.

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