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Categorization of Infant-Directed Speech: Development From 4 to 6 Months

ABSTRACT: *To extend a previous finding that 6-month-old infants categorized low-pass filtered infant-directed (ID) utterances, we examined a) 6-month-old infants' categorization of more naturalistic, unfiltered ID utterances and b) the developmental progression of ID-speech categorization. In Experiment 1, 6-month-olds heard seven different unfiltered tokens from one class of ID utterance (approving or comforting), followed by a novel token from either the same or an unfamiliar category. Infants recovered, responding only to the unfamiliar category token, suggesting that they categorized naturalistic ID utterances. Four-month-olds' categorization of filtered and unfiltered versions of the ID utterances was assessed in Experiments 2 and 4. Four-month-olds did not recover, responding to a test token from an unfamiliar class, suggesting that they did not categorize either filtered or unfiltered ID utterances. Experiment 3 demonstrated that 4-month-old infants' failure to categorize did not result from their inability to complete the procedure. These results suggest that infants' processing of ID speech changes from 4 to 6 months of age.* © 2003 Wiley Periodicals, Inc. Dev Psychobiol 42: 97–109, 2003.

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Adults from many different language communities modify the acoustic properties of their speech to infants as a function of the different social-communicative or pragmatic contexts in which they interact with their infants (e.g., comforting, playing, feeding, etc.) (Fernald Taeschner, Dunn, Papousek, Boysson-Bardies, & Fukui, 1989; Grieser & Kuhl, 1988). Specifically, infant-directed (ID) utterances produced by caregivers in different contexts or in the presence of different infant states have characteristic prosodic or intonational properties (i.e., variations in frequency, rhythm, and intensity) (Fernald & Simon, 1984). For example, utterances produced by caregivers to comfort distressed infants tend to have

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 utterances expressing approval. (F_0 refers to fundamental frequency, which is correlated with our psychological perception of pitch.) Approving utterances, which have higher mean F_0 and F_0 variability than comforting utterances, are also longer in duration (Fernald, 1989) and are characterized as wave-shaped (Katz et al., 1996).

Because infants consistently experience different ID utterance types in different contexts, several researchers have suggested that these utterance types may acquire the function of contextual reference and serve as the first vocal communicative signals (Fernald, 1992; Papousek, 1992; Stern et al., 1982). Each of these types of ID utterance patterns is produced during interactive episodes in which the caregiver's intent is similar; for example, falling, low-frequency utterances are typically produced to soothe fussy or distressed infants. Additionally, these ID utterance patterns are typically repeated within a single episode given the repetitive nature of ID speech (Fernald

& Simon, 1984; Papousek et al., 1985). The repetition of these patterns both within and across similar interactive episodes may provide infants with opportunities to extract the characteristic and correlated prosodic attributes that are produced in each context and to form associations between these attributes and contexts (Papousek, Bornstein, Nuzzo, Papousek, & Symmes, 1990).

However, in order for these ID utterances to serve as communicative signals, infants must be able to categorize them. That is, infants must be able to detect the characteristic attributes of ID speech produced in a given type of interactive context, despite the variety of different utterances produced within that context. For example, they must detect the similarities among comforting utterances that are physically different on a variety of attributes (including attributes such as tempo and linguistic content) but that are produced in similar contexts and so are likely to communicate the same comforting intent on the part of the speaker. Once infants recognize the characteristic properties of different ID-speech categories, then these properties could potentially communicate the speaker's emotion and/or intent.

In research reported by Moore, Spence, and Katz (1997), 6-month-old infants categorized approving and comforting ID utterances that were low-pass filtered at 650 Hz. Low-pass filtered stimuli were presented because speech prosody, which attracts infants' attention to ID speech (Fernald & Kuhl, 1987; Papousek et al., 1990), is quite salient in low-pass filtered speech, and because these attributes were expected to be particularly important for infants' categorization of ID utterances. The research reported here was designed to extend the investigation of infants' ID-speech categorization by addressing two issues. First, we tested if 6-month-olds categorize unfiltered approving and comforting ID utterances. We thought it necessary to ask this question because the physical properties of the filtered utterances presented in our previous research differ from those of the unfiltered ID speech that infants hear during natural social interactions. Low-pass filtering attenuates frequencies above the specified cutoff frequency; the 650-Hz cutoff used in Moore et al. (1997) effectively removed much of the high-frequency information that conveys phonetic distinctions. Additionally, adults' perception of low-pass filtered speech is that it is ''muffled'' and sounds unnatural compared to unfiltered speech. A demonstration that 6-month-old infants can categorize unfiltered utterances would provide evidence that they can detect similarities across different exemplars that are naturally produced in similar contexts.

The second goal of this research was to investigate if younger, 4-month-old infants also categorize ID utterances; testing younger infants allowed us to examine the developmental trajectory of infants' ID utterance categorization skills. Infants under 4 months of age are particularly attentive to ID speech (Cooper & Aslin, 1990) and hear ID utterances produced by caregivers in different interactional contexts (Papousek, Papousek, & Haekel, 1987; Stern et al., 1982). These experiences provide opportunities for associating a variety of exemplars from each category with a particular interactional context. However, we do not know if the quantity or the quality of ID speech experienced during an infant's first 3–4 postnatal months provides a sufficient foundation to support categorization of ID speech. Experiment 2 tested 4-month-olds' categorization of the same low-pass filtered utterances that were presented to 6-month-olds in Moore et al. (1997). Experiment 3 examined if the procedure used in these experiments was indeed suitable for assessing 4-month-olds' recovery to a novel auditory stimulus following familiarization with multiple exemplars. Finally, Experiment 4 tested 4-month-olds' categorization of unfiltered, more naturalistic ID utterances, using the same unfiltered stimuli presented to 6-month-olds in Experiment 1.

EXPERIMENT 1

Our previous research demonstrated that 6-month-old infants categorized 650 Hz low-pass filtered approving and comforting ID utterances (Moore et al., 1997). Using an infant-controlled familiarization-test procedure, these infants were familiarized with a set of 650 Hz low-pass filtered ID utterances that had been produced by a variety of mothers in either comforting or approving contexts. After hearing seven different tokens of one type of utterance, infants were tested with either a novel ID utterance from the same category (control group) or an ID utterance from a novel category (experimental group). During familiarization, attention to a visual display (which was taken as an index of interest in the auditory stimulus) decreased across trials for both groups. Comparison of responding during the last two familiarization trials with responding on the test trial revealed that experimental-group infants, but not control group infants, increased their attention when presented a novel test stimulus. An additional experiment demonstrated that 6-month-olds could discriminate closely matched exemplars from within each category. These two sets of findings together indicate that 6-month-olds were indeed categorizing these utterances, since they ignored discriminable differences between tokens within each class but they discriminated stimuli from the different classes.

The low-pass filtering manipulation used by Moore et al. (1997) preserved prosodic features of the stimuli such as F_0 contour, rhythm, and amplitude modulation, but it 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). We filtered the utterances to evaluate the possibility that the prosodic properties of ID speech alone provide sufficient acoustic information for infants to categorize ID utterances. However, while filtering allowed us to test this hypothesis, it generated stimuli that lacked the higher frequencies that infants normally hear during their exposure to ID speech. In order to directly address the question of whether infants categorize naturalistic ID utterances, 6-month-olds' categorization of unfiltered ID stimuli was examined in this experiment.

One prediction of infants' performance in this task is that they may have more difficulty categorizing unfiltered than low-pass filtered ID utterances. Relative to filtered stimuli, unfiltered stimuli contain additional (higher) frequencies that signal phonemic distinctions and linguistic content to adults. Consequently, the prosodic properties that distinguish comforting and approving utterances may be somewhat obscured within the context of this additional acoustic information. A second prediction is that 6-month-olds may categorize unfiltered ID-speech samples just as readily as they categorized low-pass filtered ID-speech samples. This prediction is based on the fact that the acoustic properties that subserved categorization of filtered ID utterances also are present in the unfiltered versions of these utterances. Since these properties are present in both the filtered and unfiltered ID samples, then infants' categorization may not be affected by the presence of the higher frequencies in the unfiltered samples. A third potential outcome is that infants might more easily process and thus categorize unfiltered ID utterances than low-pass filtered ones. One index of this would be if infants exhibited a larger novelty effect to between-category changes for the unfiltered relative to the filtered stimuli. Infants might be expected to process unfiltered ID speech more efficiently than low-pass filtered ID speech, owing to their increased familiarity with the former. Additionally, the presence of the higher frequency information in the unfiltered stimuli may facilitate infants' processing of ID utterances. Since infants' pitch perception is related to the number of harmonics in a signal (Clarkson, Martin, & Miciek, 1996), then these wider-bandwidth stimuli may provide additional acoustic cues supporting infants' discrimination of ID speech tokens from different categories.

In Experiment 1, we tested 6-month-old infants' categorization of unfiltered versions of the comforting and approving ID utterances presented by Moore et al. (1997). The data collected were compared with the results of our previous study (Moore et al., 1997). If the presence of the higher frequencies interferes with infants' processing of unfiltered ID stimuli, then infants should not categorize

unfiltered utterances. However, if infants can categorize the unfiltered ID utterances, the results should reflect a similar pattern of responding as reported in Moore et al. (1997). Specifically, infants in the experimental group should recover fixation upon hearing a test stimulus from the novel category, while control infants should not recover responding upon hearing a novel test stimulus from the familiar category. If 6-month-olds more easily categorize unfiltered than low-pass filtered utterances, then they may exhibit greater recovery to between-category changes than the infants tested with low-pass filtered ID speech.

SUBJECTS AND METHODS

Participants

The participants were 42 healthy 6-month-old infants, half male and half female, ranging in age from 5 months, 18 days to 6 months, 18 days (mean age = 6 months, 3 days). Half of the infants were tested by one experimenter in a laboratory in California, while the other half were tested by one experimenter in an identical laboratory in Texas; we believe this approach strengthened the external validity of this research. All infants were from primarily English-speaking households and were screened for a family history of seizure disorder (because flashing visual stimuli were presented). A caregiver brought each infant to the laboratory, was present with the infant throughout the procedure, and provided informed consent for the infant's participation. Thirty-three additional infants were tested but did not contribute data to the analyzed data set due to failure to meet the criterion decrement described below ($n = 17$), inattention to the procedure ($n = 10$), fussiness ($n = 4$), session interruption ($n = 1$), or equipment failure ($n = 1$).

Equipment

The procedure was controlled by custom software that was run on IBM PC-clone computers. The software assigned subjects to groups, chose and presented both auditory and visual stimuli, timed trials, collected and stored looking-time data received from an experimenter-operated joystick, and rejected trials defined to have elicited insufficient looking. The auditory stimuli, digitized and stored on the computer, were output through a Realistic speaker (with an 8.5-inch woofer and a 5.5-inch tweeter) centered between two high-resolution computer monitors. The speaker produced sound stimuli that averaged approximately 60.5 dB as measured with a Scott (type 451) A-weighted sound level meter at the infant's ears.

Speech Samples

The present investigation used speech samples of maternal utterances to 4-month-old infants. These utterances were produced during interactions that elicited approving or comforting verbalizations from the mothers (Katz et al., 1996). Eight

approving utterances and 8 comforting utterances, each spoken by a different person, constituted the stimulus set for these experiments. The mean F_0 of approving utterances ($M = 399.96$, $SD = 79.57$) was significantly higher than the mean F_0 of comforting utterances ($M = 221.04$, $SD = 31.20$), Mann-Whitney $U = 1$, $p < .01$, and the F_0 variability of approving utterances ($M = 88.67$, $SD = 81.26$) was significantly greater than the F_0 variability of comforting utterances ($M = 32.83$, $SD = 19.51$), Mann-Whitney $U = 13$, $p < .05$. These differences are typical of prosodic distinctions between comforting and approving ID utterances (Fernald et al., 1989). Additionally, five of eight comforting utterances were below the median value on both F_0 and F_0 variability measures, binomial $p = .0231$, while five of eight approving utterances were above the median value on both measures, binomial $p = .0231$. The average durations of the two classes of stimuli did not differ; the mean duration of comforting utterances was 1.43 s ($SD = .48$), while the mean duration of approving utterances was 1.50 s ($SD = .37$). 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 stimuli in the two classes also differed in frequency contour, as has frequently been reported in the literature (Katz et al., 1996; Papousek et al., 1985). As shown in Figure 1, frequency contours of typical approvals were bell-shaped, while typical comforting utterances consisted of falling contours.

Visual Stimuli

The visual stimuli were presented on two high-resolution computer monitors. The monitor screens and the space between the screens subtended 14.25 and 23.50 degrees of visual arc, respectively. The images on the two monitors were identical; each monitor displayed an image of three black and white random checkerboards (Karmel, 1969) on a gray background. During a trial, the luminance values of the squares changed, so that black squares could become white and vice versa. These 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 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.

Procedure

The design and procedures were the same as those used and described in Moore et al. (1997). An infant-controlled familiarization procedure was used in which subjects experienced at least seven familiarization trials followed by at least one test trial. Trials eliciting less than 2 s of fixation were repeated. Subjects heard a different 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). Presentation order of the auditory stimuli was randomly determined, with the condition that each utterance was to be heard only once (when heard for more than 2 s).
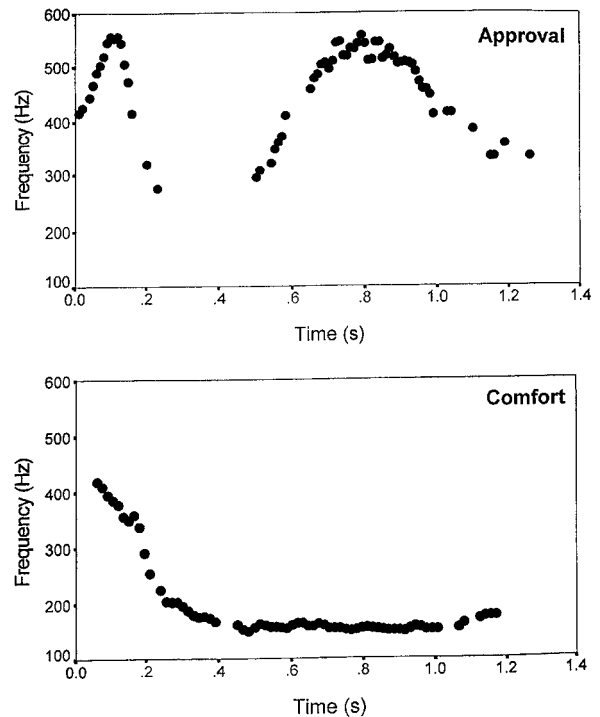
FIGURE 1 Frequency contours of two stimuli that are representative of the ID stimulus classes.

Infants were randomly assigned to one of four groups, with boys and girls equally distributed across these conditions. Half of the subjects initially heard seven different comforting utterances, one during each familiarization trial and the other half heard seven different approving utterances during these trials. Half of the subjects within each of these two groups were control subjects who subsequently heard a randomly chosen novel token from the familiar category during a test trial; the rest were experimental subjects who heard a randomly chosen novel token from the novel category during the test trial following familiarization.

Each infant was tested 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 that were 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 were instructed to refrain from interfering with the infant's perception of the stimuli, and they were fitted with headphones so that they could not systematically influence the behavior of the infants with respect to the auditory stimuli. Throughout the procedure, caregivers heard a loud, continuous audiotape recording of simultaneous presentations of four randomly chosen experimental stimuli. This recording prevented caregivers from being able to determine which utterance or type of utterance the infant was hearing on any given trial.

To capture the infant's attention and begin each trial, a string of mini-lights centered between the monitors was flashed on and off. Once the infant fixated the lights, the lights were extinguished and the visual stimuli were presented. 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 both monitors for 2.5 consecutive seconds, whichever came first. Inter-trial intervals were typically less than 3 s.

Whenever an infant was judged to have begun fixating either one of the monitors, a randomly chosen speech token from the pre-determined category was played through the speaker. As long as the infant continued to fixate either monitor or to shift fixations between monitors without looking away, the utterance was heard; looking away caused the utterances to stop playing. If, at any point before the end of the trial, the infant re-fixated one of the visual displays after looking away for less than 2.5 s, the utterance was re-played from the beginning (as it was if the end of the utterance was reached while the infant was still looking at the monitors).

Total duration of looking at the monitors was recorded on-line during each trial by one of two different experimenters trained to record infants' fixations. Inter-rater reliability of experimenters from the two different laboratories was calculated on-line to be .98. The experimenters wore headphones that delivered the same auditory mask heard by the caregivers; these sounds allowed the experimenters to remain deaf to the auditory stimulus available to the infant in any given trial. The duration of fixation during each trial was stored in a data file, along with information regarding the subject and the stimulus heard during the trial.

RESULTS AND DISCUSSION

The primary dependent variable of interest was total duration of looking (TDL) at the visual displays during specific trials. Each infant's data were divided into three trial blocks. Block 1 consisted of averaged TDL data from trials 1 and 2, block 2 consisted of averaged TDL data from trials 6 and 7 (the final two familiarization trials), and block 3 consisted of TDL data from trial 8 (the test trial). As in our previous research (Moore et al., 1997), we established an a priori criterion for acceptable decrement of fixation during familiarization. Infants were required to decrease looking by a minimum of 5% from block 1 to block 2 in order for their data to be included in the subsequent data analyses. Seventeen infants failed to meet this decrement criterion. An outlier analysis was then conducted on the TDLs for blocks 2 and 3 for each infant meeting the 5% decrement criterion, since extreme fixation times during these blocks in either direction (e.g., high or low) could bias the results. This analysis revealed that six infants produced mean fixation times greater than two standard deviations from the mean for

either block 2 or 3; data from these infants were not included in subsequent analyses.

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. A main effect of group resulted, $F(1, 38) = 5.22$, $p = .028$, such that the experimental group looked for a longer duration than the control group. Of importance for our hypothesis, this effect was qualified by a significant interaction of block and group, $F(1, 38) = 4.55$, $p = .039$; the means and standard errors are shown in Figure 2. TDL scores for each group changed in opposite directions across blocks 2 and 3, as revealed by a two-sample t-test comparing difference scores (TDL3 − TDL2) for the control and experimental groups, two-tailed $t(37) = -2.27$, $p = .029$. The mean TDL difference for experimental infants was 1.99 ($SE = 1.05$), reflecting an increase in fixation from block 2 to block 3, while the mean TDL difference for control infants was −2.17 ($SE = 1.51$), indicating a decrease in fixation across these blocks. Moreover, 15 of the 22 experimental infants increased looking from block 2 to block 3 (binomial $p < .05$), while 14 of 20 control subjects decreased responding across these blocks (binomial $p < .05$).

In order to compare infants' categorization of low-pass filtered and unfiltered ID utterances, the data from this experiment ($n = 42$) and the data from the study of low-pass filtered utterances ($n = 48$) (Moore et al., 1997) were entered into a single analysis (see Table 1 for mean TDL values from Moore et al., 1997). A mixed-design ANOVA was conducted in which group (experimental and control), spectral composition (filtered and unfiltered), and familiarization class (approval and comfort) were the between-subjects measures and block (2 and 3) was the repeated measure. A significant interaction of block and group was revealed, $F(1, 82) = 12.88$, $p = .0006$, resulting from
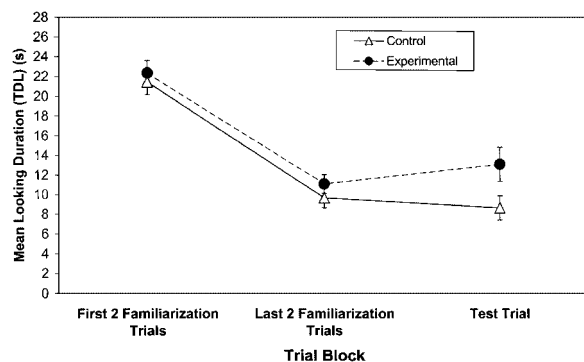
FIGURE 2 Experiment 1: Mean looking duration (TDL) (and standard errors) for 6-month-old infants familiarized and tested with unfiltered ID utterances.

Table 1. Experiment 1: Looking Duration (or TDL in s) for 6-Month-Old Infants Presented Unfiltered and Low-Pass Filtered ID Utterances

	Trial Block		
	First 2 Familiarization Trials	Last 2 Familiarization Trials	Test Trial
Unfiltered stimuli			
Group			
Control (n = 20)	21.45 (1.28)	9.67 (1.02)	8.63 (1.23)
Experimental (n = 22)	22.36 (1.25)	11.09 (0.97)	13.09 (1.74)
Low-Pass filtered stimuli (Moore et al., 1997)			
Group			
Control (n = 24)	16.53 (0.62)	13.81 (1.01)	11.31 (1.09)
Experimental (n = 24)	15.55 (0.73)	10.18 (0.86)	12.07 (1.15)

Note: Values are expressed as mean (*SE*).

different patterns of responding across blocks for the two groups. Again, a two-sample t-test comparing the difference scores in TDL across blocks 2 and 3 for infants in the control and experimental groups resulted in a significant effect, $t(79) = -3.74$, $p = .0003$; TDL for the experimental group increased from block 2 to block 3 (*M* difference = 1.945, *SE* = .95), while TDL for the control group decreased (*M* difference = −2.35, *SE* = .65).

An interaction of group and spectral composition also resulted, $F(1, 82) = 6.06$, $p = .0159$. Independent of block, control infants looked less than experimental infants when presented unfiltered stimuli (*M* unfiltered control = 8.58, *SE* = 1.48; *M* unfiltered experimental = 12.10, *SE* = 1.36) but not when presented filtered stimuli (*M* filtered control = 12.56, *SE* = 1.05; *M* filtered experimental = 11.12, *SE* = 1.01). We traced the source of this effect to block 2, in which unfiltered control subjects looked less than subjects in the other three groups. Because control and experimental infants were treated identically through blocks 1 and 2, there is no logical explanation for these shorter looking times in block 2 for the unfiltered control group. As a result, we believe that the interaction of group and spectral composition should be considered uninterpretable.

The interaction that would have indicated that 6-month-olds differentially categorized filtered and unfiltered ID utterances did not appear; there was no three-way interaction of block, spectral composition, and group. As can be seen in Table 1, experimental-group infants increased looking from block 2 to block 3 when presented either filtered or unfiltered ID utterances. In contrast, control-group infants decreased looking from block 2 to block 3 for both filtered and unfiltered utterances. These results reveal that 6-month-old infants categorized both unfiltered and filtered ID utterances and suggest that the additional acoustic information available in the unfiltered

utterances did not impede or facilitate infants' categorization of these utterances.

EXPERIMENT 2

We investigated the developmental trajectory of categorization of ID speech by assessing the performance of 4-month-old infants using the same task and low-pass filtered stimuli that we previously presented to 6-month-old infants (Moore et al., 1997). By 4 months of age, infants have been exposed to and are attentive to ID speech. For example, mothers begin producing ID speech to their infants in the newborn period (Fernald & Simon, 1984) and infants prefer ID over adult-directed (AD) speech in the first days following birth as well as at 1 and 4 months of age (Cooper, Abraham, Berman, & Staska, 1997; Cooper & Aslin, 1990, 1994; Pegg, Werker, & McLeod, 1992). Additionally, the utterances directed to 4-month-olds by caregivers in different pragmatic contexts or in the presence of different infant states have the characteristic prosodic properties discussed above (Fernald & Simon, 1984; Papousek et al., 1987; Stern et al., 1982). These findings suggest that infants as young as 4 months of age have heard ID speech in different pragmatic contexts, which provides experiences that may contribute to categorization of ID utterances.

ID and AD speech are easily discriminated by 4-month-old infants (Cooper & Aslin, 1994). However, discrimination of exemplars from different pragmatic classes of ID speech requires detection of physical differences that are much subtler than those distinguishing ID and AD speech. There is some evidence that 4- and 5-month-olds discriminate single exemplars from pragmatic categories that are characterized by different acoustic properties and that also convey distinctly different

emotional valences. For example, 4-month-old infants discriminate single exemplars of approving and disapproving ID utterances (Papousek et al., 1990) and 5-month-olds have different emotional reactions to approving and prohibiting ID speech (Fernald, 1993). Infants' discrimination of ID utterances from pragmatic classes that are less acoustically or emotionally distinctive has not been examined but would presumably be more difficult for young infants than categorization of more dissimilar utterances. However, 4-month-olds in the laboratory might even categorize ID utterances from these less distinct categories if they have had sufficient experience with ID speech and if they detect the relevant properties of ID utterances without the support of a natural context.

Previous research has provided conflicting results concerning young infants' auditory categorization skills. Infants under 4 months of age categorized vowels produced with irrelevant variation in frequency contour (Kuhl & Miller, 1982) and voice gender (Marean, Werner, & Kuhl, 1992); they also categorized phonetically different syllables despite speaker variation (Jusczyk, Pisoni, & Mullennix, 1992). However, 1- to 4-month-olds did not categorize falling and monotone synthesized frequency contours despite irrelevant variation in vowel identity (Kuhl & Miller, 1982). These results imply that demonstrations of young infants' auditory categorization are dependent on the stimuli presented and the experimental procedures used. Thus, it is not possible to predict if young infants will categorize in the current study, since the ID speech tokens that constitute our stimulus set have never been presented to infants as young as 4 months of age.

Experiment 2 examined 4-month-old infants' categorization of low-pass filtered ID utterances produced by caregivers in approving or comforting interactional contexts. We chose to begin our investigation of 4-month-olds by presenting them low-pass filtered stimuli since 1) the prosody that is characteristic of ID speech is preserved, and rather salient, in low-pass filtered speech (discussed in the Introduction) and 2) our investigation of 6-month-olds' ID-speech categorization began with the presentation of filtered stimuli (Moore et al., 1997). As in Experiment 1, control and experimental infants in the current study were each familiarized with a set of seven different ID utterances from one category (comfort or approval) contingent on fixation of a visual stimulus. If infants detect the properties shared by individual category members, then fixation times should decrease across familiarization trials for both groups. In contrast, if experimental infants recover fixation when tested with an utterance from an unfamiliar category, whereas control group infants exhibit no increase in fixation when tested with a novel utterance from the familiar category, we will conclude that we have obtained evidence that 4-month-olds can categorize these stimuli.

METHOD

Participants

The participants were 48 healthy, full-term infants (24 males and 24 females) between 3 months, 4 days and 4 months, 7 days of age (mean age = 3 months, 24 days). Forty-three additional infants were tested but did not contribute data to the final analysis due to failure to meet the looking decrement criterion described below ($n = 10$), inattention to the procedure ($n = 9$), fussiness ($n = 21$), session interruption ($n = 1$), or experimenter/equipment error ($n = 2$).

Stimuli, Design, and Procedure

The auditory stimuli consisted of the low-pass filtered versions of the eight approving and eight comforting ID utterances presented to infants by Moore et al. (1997) and in Experiment 1. The stimuli were low-pass filtered at 650 Hz with −98 dB/octave attenuation. This effectively removed the linguistic content of the utterances (as described in Moore et al., 1997) but preserved prosodic characteristics such as frequency contour and rhythm.

The design and procedure were identical to that described in Experiment 1 except that trials were allowed to continue longer in order to provide these younger infants with the increased familiarization time appropriate for their age (Colombo & Mitchell, 1990). Studies using fixed-trial familiarization paradigms have shown that the amount of time necessary for familiarization decreases with age (Horowitz, Paden, Bhana, Aitchison, & Self, 1972; Wetherford & Cohen, 1973) and that habituation decrements decrease with age (Cohen, 1969; Fantz, 1964). Additionally, infants are less likely to provide evidence of habituation and recovery in fixed-trial procedures than in procedures for which the number of trials is infant-controlled (Lewis, 1969). Given these considerations, we decided to first run pilot sessions using 30 s trials, the trial length used in our work with 6-month-olds. The data from these sessions revealed that the 4-month-olds neither decreased looking across familiarization trials, nor recovered fixation on the test trials. Consequently, we increased the trial length to 60 s; this provided the younger infants with adequate opportunity to exhibit some decrement of looking across familiarization trials as well as to recover responding on the test trial. Thus, in Experiment 2, a trial ended when stimuli had been presented for a total of 60 s or when the infant looked away from the visual stimuli for 2.5 consecutive seconds.

RESULTS AND DISCUSSION

As in Experiment 1, each infant's average TDL for each of three trial blocks was computed and served as the dependent measure in subsequent analyses. We first analyzed the data using the 5% decrement criterion used in both Experiment 1 and Moore et al. (1997). This analysis revealed no evidence of categorization. We then analyzed the data using a 25% decrement criterion for the following reasons. In the studies with 6-month-olds, infants were given a fixed number of familiarization trials

rather than a variable number of familiarization trials under the infant's control. It was necessary to use the same procedure and stimulus set for 4- and 6-month-old infants to allow for cross-age comparisons, so 4-month-olds also were presented seven familiarization trials each. The fixed-trials procedure, unlike the infant-controlled procedure, however, leaves open the possibility that an infant will arrive at a test trial before achieving complete habituation. Consequently, the 25% decrement criterion was used to give us confidence that the 4-month-old infants were habituated, thereby giving them maximal opportunity to provide evidence of categorization. Ten infants failed to meet this criterion. An outlier analysis (identical to that conducted in Experiment 1) revealed that seven infants produced extreme fixation times for either block 2 or 3; their data were excluded from further analysis. The analysis reported here was conducted on the remaining sample of 41 infants.

The critical comparison for testing if infants categorized the stimuli was conducted with 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. A significant main effect of block resulted, $F(1, 37) = 4.21$, $p = .0474$, such that infants looked longer in block 2 ($M = 13.85$, $SE = 1.84$) than in block 3 ($M = 11.16$, $SE = 2.00$). All other effects failed to reach statistical significance, including the interaction between block and condition that would have supported the conclusion that the 4-month-olds were categorizing the utterances ($F(1, 37) = .20$, $p = .6538$; see Figure 3 for the mean TDL scores for the two groups in each block).

These data provide no evidence that experimental infants discriminated the test tokens representing one pragmatic category from the set representing the other pragmatic category. However, these findings could also have resulted from infant fatigue and/or inattention rather than from an inability to discriminate tokens from the two

stimulus classes. Experiment 3 was conducted to ensure that 4-month-olds can effectively complete the procedure used in this series of studies.
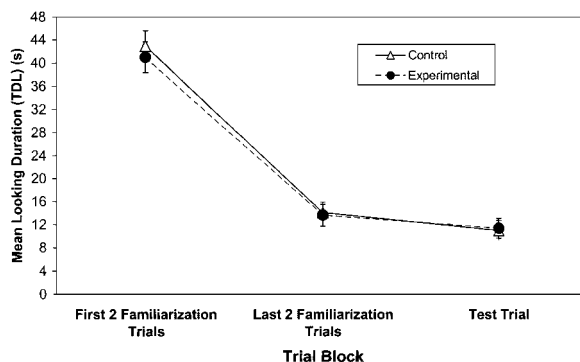
EXPERIMENT 3

The attrition rate in Experiment 2 was higher than that found in our previous research with 6-month-old infants (Moore et al., 1997). This observation, which suggested that it was difficult to maintain infants in quiet, alert states throughout the session, led us to be concerned that the procedure used might not be suitable for detecting categorization by 4-month-olds. This concern was compounded by the fact that we had increased the length of trials from the 30-s trial length used in Moore et al. (1997) to 60 s. These longer sessions may have fatigued the infants so that they were unlikely to recover on the test trial.

These concerns were addressed with the following experiment in which we tested if 4-month-olds would recover responding on the test trial to instrumental music, a more discrepant auditory stimulus than novel ID speech. If, during the test trial, infants fail to recover fixation to visual stimuli accompanied by music, this would suggest that infants in Experiment 2 might have been fatigued by the end of familiarization and incapable of demonstrating a novelty response. However, if infants increase fixation to visual stimuli accompanied by music following familiarization with ID speech stimuli, this would suggest that 4-month-olds can recover fixation, even after relatively long familiarization periods. Such a finding would therefore strengthen our confidence that infants in Experiment 2 did not categorize the filtered approving and comforting ID utterances presented in that study.

SUBJECTS AND METHODS

The participants were 31 healthy, full-term infants (16 males and 15 females) between 3 months, 14 days and 4 months, 2 days of age (mean age = 3 months, 23 days). Subjects were recruited as in Experiments 1 and 2. Thirty-six additional infants were tested but did not contribute data to the analyzed data set due to inattention to the procedure ($n = 10$), fussiness ($n = 13$), experimenter/equipment error ($n = 2$), or failure to meet the 25% looking decrement criterion also used in Experiment 2 ($n = 11$). Half the infants were randomly assigned to a group that heard seven different filtered comfort utterances during the familiarization trials; the other half of the infants heard seven different filtered approval utterances during these trials. Subsequently, half of the subjects within each of these two groups (control subjects) heard a novel token from the familiar category during a test trial; the rest (experimental subjects) heard a sample of instrumental music during the test trial.

FIGURE 3 Experiment 2: Mean looking duration (TDL) (and standard errors) for 4-month-old infants familiarized and tested with low-pass filtered ID utterances.

Stimuli and Procedure

The 650-Hz low-pass filtered comforting and approving utterances presented in Experiment 2 served as the familiarization stimuli for all Experiment 3 infants and as the test stimuli for infants in the control group. On the test trial, experimental-group infants were presented a lively 8-s sample of 650-Hz low-pass filtered instrumental music played by a full orchestra. The experimental procedure was otherwise identical to that described in Experiment 2.

RESULTS AND DISCUSSION

Each infant's average TDL for each block was computed as in Experiments 1 and 2 and served as the dependent measure in subsequent analyses. Infants' response recovery on the test trial was assessed 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) served as the repeated factor. The interaction of block and condition was significant, $F(1, 27) = 4.45, p = .044$; the mean TDLs and standard errors for each group in each block are shown in Figure 4. A two-sample t-test that compared difference scores of the two groups across blocks 2 and 3 (TDL3 - TDL2) revealed that experimental infants increased looking from block 2 to 3, while control infants did not; two-tailed t (29) = 2.041, $p = .05$. Experimental group infants increased fixation from familiarization (block 2) to the test trial (block 3) ($M = 4.20, SE = 2.28$), while control infants decreased fixation ($M = -2.65, SE = 2.47$). Additionally, 12 of the 16 experimental infants increased looking from block 2 to block 3 (binomial $p = .0278$), while 10 of 15 control subjects decreased responding across these blocks (binomial $p = .0916$).

The 4-month-old infants familiarized with a series of ID utterances increased looking when tested with a musical stimulus. This result indicates that this procedure
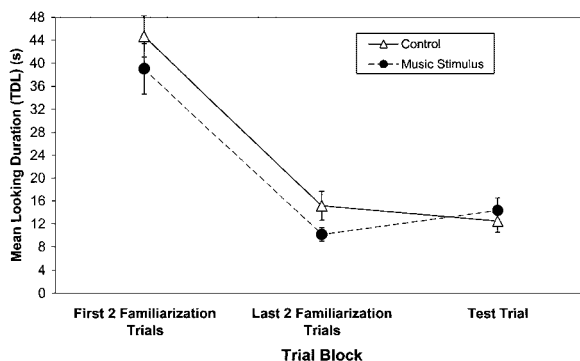
FIGURE 4 Experiment 3: Mean looking duration (TDL) (and standard errors) for 4-month-old infants familiarized with ID utterances and tested with music or a within-category ID utterance (control).

is capable of revealing young infants' discrimination of auditory stimuli. It also suggests that experimental-group infants in Experiment 2 failed to recover responding on the test trial because they did not discriminate the novel category (test) utterance from the multiple utterances in the familiarization category, not that they failed to recover because of fatigue. Given this finding, we then examined 4-month-olds' categorization of unfiltered ID utterances.

EXPERIMENT 4

The final experiment in this series assessed 4-month-olds' categorization of unfiltered ID utterances. Although 6-month-old infants categorized both low-pass filtered and unfiltered ID utterances, 4-month-olds did not categorize low-pass filtered ID speech. It is possible that 4-month-olds may have more difficulty than 6-month-olds in processing low-pass filtered speech because filtered speech is so discrepant from speech they have experienced during the postnatal developmental period. Interestingly, the low-pass filtered ID utterances used in these studies were described by adult listeners (Moore et al., 1997) as sounding "strange" and non-speechlike. Perhaps 4-month-olds would benefit from the presence of the higher frequency information in the unfiltered stimuli. Since aspects of infants' auditory perception are related to the number of harmonics in a signal (Clarkson, Martin, and Miciek, 1996), wider-bandwidth ID speech tokens may provide acoustic cues needed by younger infants to discriminate ID speech tokens from different categories. Given these considerations, 4-month-olds might more easily process and categorize unfiltered ID speech than low-pass filtered ID speech. In order to examine this possibility, 4-month-old infants were tested with unfiltered ID stimuli.

SUBJECTS AND METHODS

Participants

The participants were 46 healthy, full-term infants (23 males, 23 females) between 3 months, 15 days to 4 months, 6 days (mean age = 3 months, 28 days). Twenty-five additional infants were tested but did not contribute data to the final analysis due to failure to meet our pre-established 25% looking decrement criterion ($n = 12$), inattention or fussiness ($n = 9$), or experimenter/equipment error ($n = 4$).

Stimuli, Design, and Procedure

The auditory stimuli consisted of the unfiltered versions of the ID utterances presented to 6-month-olds in Experiment 1. The design and procedure were identical to those used in Experiment 2, which was conducted with 4-month-olds. Infants were presented a new ID utterance during each of seven

familiarization trials. Each trial ended either after 60 s or when the infant looked away from the visual stimuli for 2.5 consecutive seconds. In the test trial following familiarization, either a novel stimulus from the familiarization category or a stimulus from the novel category was presented contingent on infant fixation of the visual stimulus.

RESULTS AND DISCUSSION

Each infant's average TDL for each block was computed as in Experiments 1, 2, and 3, and served as the dependent measure in subsequent analyses. An outlier analysis revealed that seven infants produced extreme fixation times for either block 2 or 3; their data were excluded from further analysis. The analysis reported here was conducted on the remaining sample of 39 infants.

Again, a mixed ANOVA was conducted to test if infants categorized the stimuli. Familiarization class (approval and comfort) and group (experimental and control) served as between-subjects factors, and block (2 and 3) was the repeated factor. The means and standard errors for each group in each block are illustrated in Figure 5. An interaction of familiarization stimulus and group resulted, $F(1, 35) = 5.371$, $p = .026$. This effect resulted because control group infants who were presented approving utterances ($M = 15.42$; $SE = 1.68$) had larger averaged TDL scores across blocks 2 and 3 than did experimental infants presented approving utterances ($M = 8.47$; $SE = 1.26$; $t (17) = 3.31$). There is no logical explanation for control infants looking longer than experimental infants across both blocks 2 and 3; this interaction is uninterpretable. No other effects reached statistical significance (all $ps > .05$), including the interaction of group and block that would have provided evidence for categorization of the utterances ($F (1, 35) = 1.77$, $p = .191$). Because we thought it possible that the failure to find significant effects for the 4-month-old infants could

have resulted from a lack of statistical power, and because we had performed a comparable analysis on the data produced by 6-month-olds, we performed a mixed ANOVA in which spectral composition (filtered and unfiltered), group (experimental and control), and familiarization class (approval and comfort) were the between-subjects measures and block (2 and 3) was the repeated measure. Again, no significant effects were found; most importantly, there was no significant interaction of block and group ($F(1, 72) = 1.76$, $p = .19$).

GENERAL DISCUSSION

The series of studies reported here provides new information concerning young infants' categorization of ID speech. Experiment 1 allows us to compare 6-month-old infants' categorization of filtered and unfiltered ID utterances, while the experiments testing 4-month-olds allow us to compare the performance of these infants with that of the 6-month-olds. Taken together, the results of Experiment 1 and Moore et al. (1997) indicate that by 6 months of age, infants can categorize ID utterances (i.e., they can detect similarities across discriminably different utterances produced in similar contexts) as well as discriminate utterances produced in different contexts. With regards to discrimination, the results of Experiment 1 contribute to the few studies that have examined infants' differential responsiveness to exemplars from different categories of ID speech. For example, there have been several demonstrations that young infants exhibit different responses to ID utterances intended to elicit contrasting affect. 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 et al. (1990) found that 4-month-olds preferred prototypical approving non-linguistic ID contours to prototypical disapproving non-linguistic ID contours. Our results indicate that 6-month-olds also can discriminate approving and comforting ID utterances. Since these types of ID utterances are both associated with caregiver intent to evoke positive affect, the difference between them is probably much subtler than that between approving and disapproving utterances. Nonetheless, our results suggest that six-month-old infants can discriminate them.

With regards to categorization, Experiment 1 demonstrated that 6-month-old infants can categorize unfiltered ID utterances, utterances that are more similar to natural linguistic stimuli than are the low-pass filtered stimuli categorized by infants in Moore et al. (1997). This result indicates that infants detect properties that characterize
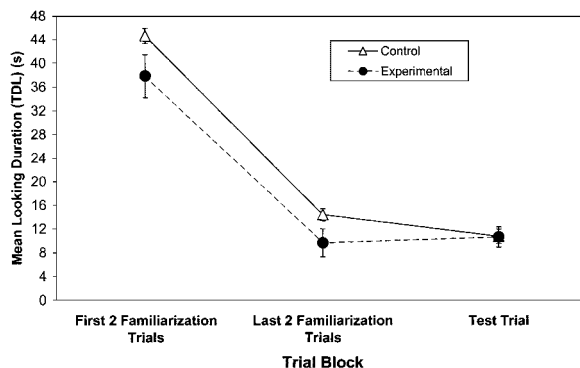
FIGURE 5 Experiment 4: Mean looking duration (TDL) (and standard errors) for 4-month-old infants familiarized and tested with unfiltered ID utterances.

these pragmatic classes of ID utterance. Because two utterances produced with the same communicative intent (e.g., to comfort the baby) are liable to vary in verbal content as well as on various prosodic dimensions such as mean F_0 and frequency range, categorization of the utterances is a prerequisite ability for perceiving the similarity of their communicative intents, and hence for perceiving them as meaningfully different than utterances with different communicative intents. Our data demonstrating ID-speech categorization provide particularly important support for assertions that ID speech may serve as the first verbal communication of meaningful information (Fernald, 1992; Papousek, 1992; Stern et al., 1982). We emphasize, however, that our data do not provide any direct indication that 6-month-old infants perceive the communicative intent of these two classes of ID utterance.

The data presented in Experiments 2 and 4 provide no evidence that 4-month-olds categorized the approving and comforting ID utterances. These younger infants failed to recover responding when a test stimulus from a different category of ID utterance was presented, although in Experiment 3 they did recover responding to music (a highly discrepant stimulus) following familiarization with ID utterances. Thus, the results of the studies presented here, combined with those from Moore et al. (1997), reveal a developmental progression from 4 to 6 months of age for infants' categorization of ID speech. 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. However, for the specific conditions that characterized our test, only 6-month-olds, not 4-month-olds, were able to provide evidence of categorization.

These findings of age differences in performance on this task are consistent with other categorization data showing that from 4 to 7 months of age, infants become increasingly capable of processing complex stimuli (Cohen & Strauss, 1979), abstracting relations among stimulus attributes (Caron & Caron, 1981), and detecting similarities among less prototypical exemplars (Younger & Gotlieb, 1988). Categorization of the ID speech stimuli in this study required infants to detect the similarities across utterances in frequency contour, mean F_0, and F_0 range, while ignoring irrelevant variation in absolute frequency characteristics, phonetic composition, and talker characteristics. Bornstein (1984) has argued that the level of categorization involved in tasks such as this involves detection of co-occurring relations among attributes. This form of categorization, referred to as sensory conceptual equivalence categorization (Bornstein, 1984), is more difficult for young infants than categorization requiring detection of only one attribute in the face of variations in other attributes. Given that the exemplars within each of the two ID speech categories used in this

research were characterized by considerable acoustic variability, and that the mean F_0 and F_0-variability distributions characterizing the two categories overlapped, it is perhaps not surprising that 4-month-olds failed to categorize the ID utterances whereas 6-month-olds succeeded. The complex, highly variable stimuli used in this research may have strained 4-month-olds' information processing capacity (Cohen, 1998), a hypothesis supported by previous findings that younger infants are less likely than older ones to categorize stimuli with multiple components or features (Younger & Cohen, 1986). Additional research using less variable ID-speech stimuli would be necessary to determine if 4-month-olds are capable of ID utterance categorization under any circumstances.

In addition to the acoustic similarity of the approving and comforting speech tokens, stimuli from both classes were produced with the intent to communicate and elicit positive affect from infants. Although previous research has shown that 4- and 5-month-olds discriminate exemplars from contrasting affective categories (Fernald, 1993; Papousek et al., 1990), our findings indicate that 4-month-olds cannot discriminate ID speech stimuli from approving and comforting classes, which are similar in their affective valence. These findings suggest that young infants may initially only discriminate ID utterances that differ in affective valence but that they may later make finer discriminations among utterances that are more similar in affective quality. In other words, development of ID-utterance categorization may proceed such that infants initially form categories that are quite broad in nature, for example, young infants might group together all high-frequency utterances that are produced with positive affect, and later make more subtle differentiations among ID utterances that fall within this larger class (e.g., between comforting and approving utterances). Studies are currently underway in our laboratories to address this possibility.

We do not yet know what specific experiences mediate the developmental changes in ID speech categorization that we observed. These changes may reflect a variety of factors including increased ID speech experience and/or changes in the nature of ID speech experience (for additional discussion on this issue (see Spence & Moore, 2002). As infants rapidly expand their behavioral repertoires and become more actively engaged in social exchanges between 4 and 6 months of age (Fogel, 1997), the ID speech they hear may also change. For example, as infants begin reaching, grasping, and vocalizing, parents may speak more to their infants. Additionally, contingent relationships between caregiver speech and infant behavior may become more obvious to the infant who is producing a greater number of overt behaviors likely to generate a response from the caregiver. If an infant

becomes aware of the contingency between her own behavior and her parents' ID speech, this could facilitate her interest in and attention to ID speech. Increased attention to ID speech, either alone or coupled with increased exposure to ID speech, may in turn facilitate detection of the specific acoustic properties that characterize ID utterances produced in specific pragmatic contexts.

The development of infants' categorization of ID utterances is a prerequisite for responding to utterances as meaningful communicative signals. An important accomplishment in the development of language comprehension is learning that different sound patterns communicate distinctive meanings. If infants learn that different classes of ID utterances communicate distinctive messages, then categorization of ID speech plays an important role in infants' developing social and communicative competence.

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