Infants' Attentional Responses to Frequency Modulated Sweeps

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COLOMBO, JOHN, and HOROWITZ, FRANCES DEGEN. *Infants' Attentional Responses to Frequency Modulated Sweeps.* CHILD DEVELOPMENT, 1986, **57**, 287–291. In 3 experiments, the attentional responses of 4-month-old infants to frequency-modulated (FM) sweeps corresponding to the frequency range of adult-to-infant and adult-to-adult intonation patterns were assessed. In Experiment 1, infants were observed to discriminate "exaggerated" (i.e., adult-to-infant) FM sweeps from "normal" (i.e., adult-to-adult) FM sweeps in a habituation-dishabituation paradigm but did not selectively attend to one over the other. In Experiment 2, where the same stimuli were used in a paired-comparison paradigm, again no differential attention was observed. In Experiment 3, the most exaggerated sweep was paired against a continuous, monotonic pure tone, but again no difference in salience was observed. These data suggest that the extent of modulation or intonation of an auditory stimulus per se does not constitute a salient cue for infants' attention to sound.

Over the past decade, many investigators have called for a closer analysis of the language-learning environment of the young infant (e.g., Horowitz, 1980). Within the recent rapid proliferation of studies of infant audition (for a comprehensive review, see Aslin, Pisoni, & Jusczyk, 1983), an area of research has emerged to identify those stimulus parameters that best attract the attention of the young infant and that may contribute to early language learning.

Previous studies have shown that young infants will selectively attend to novel and familiar auditory stimuli (Colombo & Bundy, 1983), complex or wide-bandwidth stimuli (e.g., Clarkson & Berg, 1979; Colombo, in press; Trehub & Curran, 1979), and, to some degree, lower frequencies (Appleton, Clifton, & Goldberg, 1975; Colombo & Horowitz, 1985b).

Pitch variability, or frequency modulation, may be another of these parameters. Recent studies show that increased pitch variability (Jacobson, Boersma, Fields, & Olson, 1983) and exaggerated intonation patterns (Fernald & Simon, 1984; Stern, Speiker, & MacKain, 1982) typify adult-to-infant vocalizations. It has been hypothesized that this acoustic property is salient to the young infant (e.g., Fernald & Simon, 1984). Physiological evidence from the auditory cortex (see Pickles, 1981) suggests that FM sweeps are effective in eliciting central pathway activity; the intonation or frequency sweep range of an auditory stimulus may therefore be somewhat analogous to visual parameters whose salience is thought to be determined by the maximizing or optimizing of central neural activity (e.g., Karmel & Maisel, 1975).

In fact, the effect of various intonation patterns on infant attention has been explored in a few studies. Sullivan and Horowitz (1983) tested the salience of rising versus falling intonation contours to 6- and 8-week-old infants

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with a fixation-based choice paradigm and found some selectivity for the rising contour, although both the natural and the synthetic contour samples they used varied along parameters other than the direction of the pitch contour (i.e., the rate and extent of pitch sweep). Two other studies conducted by Fernald (1985; Fernald & Kuhl, 1981) have shown with a head turn–based choice paradigm that 4-month-old infants show some selectivity for speech samples of infant-directed speech or "motherese" (Fernald, 1985). Fernald and Kuhl (1981) have also shown selectivity for the fundamental frequency intonation patterns from the samples used in the Fernald (1985) study.

Aslin et al. (1983) note that the exact factors responsible for this apparent salience (i.e., the extent of intonation and the modulation rate) remain undetermined. We report here the results of three studies on one parameter of adult-to-infant speech, studies in which we have observed no evidence to support the hypothesis that frequency modulation per se constitutes a salient feature of the infant's acoustic environment.

Experiment 1

In the first experiment, we employed an infant-controlled habituation-dishabituation paradigm (Horowitz, 1975) to see whether 4-month-olds would find pure-tone frequency-modulated (FM) sweeps with frequency ranges analogous to "exaggerated" (i.e., adult-to-infant) intonation contours more salient than or discriminable from FM sweeps with ranges approximating "normal" (i.e., adult-to-adult) speech contours.

Method

Subjects.—Thirty 4-month-old infants (range 113–127 days) were recruited by mail and telephone from the suburbs of Kansas City, Missouri. Twenty-four infants successfully completed testing and six were excluded from the final analyses because of equipment failure ($N = 2$) or fussiness ($N = 4$).

Apparatus and stimuli.—An 8 × 8 black-and-white checkerboard served as the visual stimulus. The entire stimulus subtended a visual angle of 22 degrees, and each check subtended 2.75 degrees.[1] The stimulus was rear projected onto a .3 m × .3 m translucent screen centered on a black plywood wall. The wall constituted the front of a 2 m × 1.5 m booth in which testing sessions took place.

The auditory stimuli were two linear FM sweeps generated by a Hewlett-Packard 3250A function generator. An exaggerated sweep cycled from 150 hertz to 550 hertz and then back to 150 hertz over a 1-sec period, while a normal sweep extended from 150 hertz to 275 hertz and back to 150 hertz over the same 1-sec interval. The frequency and temporal parameters were drawn from examples of exaggerated contours in adult-to-infant speech and normal contours in adult-to-adult speech presented in Fernald and Simon (1984). Sweeps were recorded repetitively (i.e., with no intersweep intervals) onto separate tracks of a Teac 3320RS reel-to-reel tape deck and fed through a Teac audio mixer and Sansui amplifier at appropriate times for presentation during the session. Stimuli were presented free field from a Microsonic speaker with peak intensities matched at 70 db.[2]

Procedure and design.—Infants sat on a parent's lap in the booth, facing the translucent screen. The checkerboard was projected onto the screen to begin the session, and auditory stimuli were presented contingent on the infant's looking at the checkerboard. Stimulus

[1] Under the same conditions and procedures of Experiment 1, the checkerboard (without contingent auditory presentation) proves to be a fairly uninteresting stimulus for infants of this age. A sample of 12 4-month-olds habituated to this visual target reached criterion in an average of 6.3 looks (SD = 2.9), accumulating only 33.9 sec (SD = 16.8) in total looking time. The addition of a fixation-contingent auditory stimulus typically doubles the amount of fixation time to habituation and increases the average number of looks by one to four, depending on the sound employed (Colombo & Horowitz, 1985b).

[2] Minor fluctuations in the loudness of auditory stimuli can occur under free-field presentation conditions if head position is not held perfectly constant (such variation is avoided with the use of headphones). Since infants generally do not sit perfectly still during testing sessions, such fluctuations probably occurred in these studies. However, we chose the convenience of free-field presentation in these studies because such fluctuations are small and because the situations in which intonation is proposed to operate are free field (and therefore subject to similar variation). Furthermore, past research suggests that the presentation technique may not affect differential salience, as auditory preferences have been reported both under free-field conditions (Colombo & Horowitz, 1985b; Sullivan & Horowitz, 1983) and with headphone presentation (e.g., Colombo & Bundy, 1981, 1983).

presentation continued as long as the infant maintained the look, and it ceased immediately with a look away. Presentation of the auditory stimulus and recording of fixations was controlled by an observer who monitored corneal reflections from a 5-mm peephole to the side of the screen. For the purposes of the habituation procedure, a "fixation" was defined as beginning with any look of 1 sec or more at the checkerboard and as ending with a 1-sec look away (Colombo & Horowitz, 1985a). Reliability for observers had been established under identical conditions in previous experiments (Colombo & Horowitz, 1985b), with individual fixation records correlating at .97. Observers were made "blind" to auditory presentations by masking music played through headphones.

The procedure included a habituation phase and a test phase. During the habituation phase, one of the auditory stimuli was presented contingent on fixation of the checkerboard until a habituation criterion was reached. The criterion for habituation was two successive fixations at 50% or less of the average of the infants' two peak fixations. During the test phase, an auditory stimulus (the same one for some infants, a different one for others) was presented for four more trials. The design of the experiment was a 2 × 2 factorial (six infants per cell) with the stimulus presented in the habituation phase crossed with the stimulus presented in the test phase. Thus 12 infants were habituated to each of the two stimuli, with half of each group receiving a change of auditory stimulus during the test phase and the other half receiving the same stimulus as during the habituation phase.

Results

If one of the FM sweeps were more salient than the other, then we would expect, on the basis of past research (Colombo & Bundy, 1981, 1983), that some measure within the habituation phase, such as duration of first fixation, total fixation to habituation, or number of fixations to habituation, would vary across groups as a function of the type of sweep presented. However, *t* tests on these measures between the groups receiving the two habituation-phase sweeps revealed no significant differences on any of the measures tested. Respective means and *t* values for the exaggerated (150–550 hertz) and the normal (150–275 hertz) sweeps were 20.3 and 15.6 sec for first fixation, $t(22) = 0.57$, 69.8 and 73.9 sec for total fixation, $t(22) = 0.28$, 6.3 and 7.6 sec for number of fixations, $t(22) = 1.31$, and 27.5 versus 24.8 sec for peak fixation, $t(22) = 0.34$.

Infants' discrimination of the two FM sweeps was assessed by entering the mean of the two habituation-criterion fixations (Pre) and the mean of the four test-phase fixations (Post) into a three-way mixed-design ANOVA along with the factors of Habituation-Phase Stimulus (exaggerated vs. normal sweep) and Group (change vs. control). This analysis yielded a significant Group × Pre/Post interaction, $F(1,68) = 8.3$, $p < .01$, indicating that infants were able to discriminate the two stimuli, as the group receiving a novel test-phase stimulus showed a recovery of fixation (Pre average = 5.7 sec; Post average = 8.0 sec), while the control group continued to habituate (Pre average = 5.6 sec; Post average = 5.0 sec).

Discussion

Despite the fact that infants were clearly able to discriminate between the two FM sweeps, they did not selectively attend to one over the other. We thought it possible, however, that some aspect of our design, such as our use of a between-subject design or our lack of a simultaneous stimulus-stimulus comparison, may have obscured some stimulus effect. We explored this possibility in Experiment 2.

Experiment 2

This experiment was designed to allow for the assessment of infants' preference for the two types of intonation sweeps under paired-comparison conditions (e.g., Colombo & Bundy, 1981; Sullivan & Horowitz, 1983). This procedure allowed infants a simultaneous comparison of the stimuli while at the same time giving us a within-subject measurement.

Method

Subjects.—Twenty-three 4-month-olds (range 113–127 days) were recruited for this experiment as described above, of which 20 completed the session. Three infants were excluded from final analyses because of equipment failure ($N = 1$) or fussiness ($N = 2$).

Apparatus and stimuli.—The auditory stimuli and testing apparatuses were the same for this experiment as for the previous one. However, in this study two identical 8 × 8 checkerboard targets were used. Each target was the same size as the single target from Experiment 1 (which subtended a visual angle of 22 degrees, 2.75 degrees per check). The two checkerboards were positioned side by side, separated by 20 degrees.

Procedure and design.—Infants were seated on their parents' laps. The two checkerboards were presented, and the infants were allowed to accumulate 60 sec of fixation to the targets, with one FM sweep presented contingent on their fixation of one laterally positioned target and the other FM sweep presented contingent on their fixation of the other target. In this way, infants were allowed a simultaneous "choice" between the two available auditory stimuli (e.g., Colombo & Bundy, 1981; Sullivan & Horowitz, 1983). If the infant was looking at the 60-sec point of the accumulation trial, he or she was allowed to finish that look. At that point, the sound/target contingencies were reversed (i.e., exaggerated sweep left/normal sweep right would now became normal sweep left/exaggerated sweep right, and vice versa), and the targets were re-presented for another 60-sec accumulation period. Sullivan and Horowitz (1983) have reported differential salience for auditory stimuli using this accumulated-looking time procedure. This contingency reversal was done to control for any infant lateral bias. Sound/target contingency orders were counterbalanced across subjects.

An observer, blind to stimulus presentation as in Experiment 1, monitored infants' fixations of the two targets via a peephole to the side of one target, recording fixations and presenting stimuli with the same button press. During five sessions, a second observer also recorded fixation durations; the two observers' records for per-target number of fixations and total fixation time correlated at .98 and .97, respectively.

Results

The mean per-session looking times to the exaggerated and normal sweeps were 61.8 and 61.4 sec, respectively; the mean number of looks to the two sweeps was 34.8 and 32.2, respectively. Three-way (contingency order × trial × stimulus) ANOVAs were performed on total looking time and frequency of fixations to the targets, but neither analysis yielded a statistically significant term, all F's$(1,18) < 1.5$.

Discussion

The paired-comparison procedure did not yield any differential attention on the part of infants to the two FM sweeps, thus supporting the results of Experiment 1. Our failure to find any effect for extent of intonation in these first two studies prompted us to test the hypothesis with more extreme examples of the stimulus classes involved.

Experiment 3

In this experiment we tested the salience of our most exaggerated modulated stimulus against a completely monotonic one. This test was conducted because it was possible that the two sweeps used previously were close enough in extent of modulation to be equally interesting to infants. We envisioned this as the most basic test of the hypothesis in question: if a heavily-modulated stimulus could not attract an infant's attention when paired with a stimulus possessing no intonation whatsoever, the possibility that exent of modulation per se is responsible for infants' greater attention to motherese must be revised.

Method

Subjects.—Twenty 4-month-old infants (range 113–127 days) were recruited for this study as described previously. All completed the session.

Stimuli, apparatus, and procedure.—The stimuli, testing conditions, and procedures for Experiment 3 were the same as for Experiment 2, with the exception that a continuous 150 hertz sine wave was substituted for the normal intonation sweep (150–275 hertz) used in the two previous studies. The maximum intensity of the exaggerated (150–550 hertz) sweep, as well as the intensity of the 150 hertz tone, was set at 70 db. As in the other studies, auditory stimuli were presented free field while the infant sat on a parent's lap.

Results and Discussion

Respective means for the FM sweep and sine wave were 63.6 and 61.2 sec for total per-session fixation time and 27.6 and 28.0 for per-session number of fixations. Three-way (contingency order × trial × stimulus) ANOVAs on these variables again yielded no significant differences, all F's$(1,18) < 1.0$.

General Discussion

In the studies we have reported here, the extent of frequency modulation of an auditory stimulus per se was not effective in specially maintaining infants' visual attention. It does not seem reasonable, therefore, to attribute the salience of motherese to young infants to this parameter alone. While the issue of procedural sensitivity may be raised in the context of these negative findings, the visual-fixation paradigms used in this series of studies have been shown in the past to be sensitive to infants' selective attentional responses to auditory stimuli (Colombo, in press; Colombo & Bundy, 1981, 1983; Co-

lombo & Horowitz, 1985b; Sullivan & Horowitz, 1983). Furthermore, infants' attention to stimuli in Experiment 1 was sufficient to allow readily observable discrimination. If the salience of a stimulus parameter is observable only within certain procedural constraints (e.g., specific response windows or visual targets), the parameter cannot be considered to be a powerful one. The consistency of the results across the two techniques and three different stimuli employed in these studies suggests this to be the case. Given the pervasiveness of exaggerated intonation or modulation patterns in adult-to-infant speech, these negative results become all the more interesting.

We have manipulated one of a number of possible stimulus parameters present in adult-to-infant speech. The possibility exists that, within the context of or in combination with other such parameters (e.g., set within logarithmic sweeps or within a more variable stimulus sequence resembling the speech train, as in Fernald & Kuhl, 1981), frequency modulation might serve as an alerting or signaling cue for infants' to attend to speech. The attribution of infant selectivity to such configurations of auditory parameters remains to be more directly investigated. Such a demonstration would raise important issues regarding the ecological validity of studying the acoustic factors of speech in isolation.

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