Adult Perception of Emotion Intensity in Human Infant Cries: Effects of Infant Age and Cry Acoustics

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Leger, Daniel W.; Thompson, Ross A.; Merritt, Jacqueline A.; and Benz, Joseph J. *Adult Perception of Emotion Intensity in Human Infant Cries: Effects of Infant Age and Cry Acoustics*. Child Development, 1996, **67**, 3238–3249. The relation between adult perception of emotion intensity in the cries of 1- and 6-month-old infants and the acoustic characteristics of the cries was examined. In the first study, adults who were inexperienced in child care rated 40 cries on 3 emotion intensity scales: anger, fear, and distress. The cries of 6-month-olds were rated as being significantly more intense. Different acoustic variables accounted for emotion intensity ratings for the 2 infant ages. Peak amplitude and noisiness of the cry predicted adult judgments of intensity ratings of 1-month-olds' cries; a measure of amplitude ratio (in 2 frequency bands) was the best predictor of intensity ratings of 6-month-olds' cries. In the second study, parents of infants rated the same cries on the same scales. They also rated the older infants' cries as being more intense. The 2 adult groups did not differ on their ratings, and a regression equation derived from one adult group predicted the other adult group's rating of the same infant age better than it predicted its own ratings for the other infant age. Infant age, and its associated acoustic features, seems to be a more important determinant of adults' perception of emotion intensity than are such adult characteristics as gender or infant-care experience.

Adults report perceiving emotion in the cries of infants. For instance, several research groups have obtained adult responses to infant cry recordings using semantic differential ratings or ratings on emotion intensity scales, and have found that adult ratings vary systematically according to cry characteristics (e.g., Adachi, Murai, Okada, & Nihei, 1985; Brennan & Kirkland, 1982; Green, Jones, & Gustafson, 1987; Gustafson & Green, 1989; Zeskind, Klein, & Marshall, 1992; Zeskind & Marshall, 1988). Others have used autonomic responsivity as an analogous response measure, with similar results (see reviews by Boukydis, 1985; Lester, 1984; Lester & Boukydis, 1992; Murray, 1985). Although subject attributes such as gender and infant care experience influence these measures, overall the effects are quite reliable and consistent: adults exhibit considerable agreement regarding the emotional intensity of infant cries (Gustafson & Green, 1989).

Some attempts have been made to identify the acoustic features that may contribute to adults' cry perceptions. For example, Green et al. (1987) played 30-day-olds' cry pulses (i.e., single expirations) to adults. Multidimensional scaling was conducted on pairwise comparisons of 12 different pulses. They concluded that cry duration, signal-to-noise ratio, and the linear trend in peak frequency contributed to dissimilarity judgments made by the subjects. Zeskind and Marshall (1988) examined the role of fundamental frequency in mothers' attributions of emotionality in the newborn cry. Four measures of fundamental frequency were correlated with mean ratings of 1-sec pain cries on four semantic differential scales. In a multiple regression analysis, mean funda-

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mental frequency was the only variable to enter the equation for three of the scales (urgency, distress, and arousal).

The search for salient acoustic variables has been complicated by differences in cry-eliciting stimuli, duration of the cry stimulus, age of the infant, and measurement and choice of acoustic variables. Cry recordings have been made from infants who were snapped on the heel with a rubber band (e.g., Zeskind & Huntington, 1984), just before a feeding (e.g., Zeskind, Parker-Price, & Barr, 1993), or in a variety of naturally occuring circumstances (this study). Cry playback stimuli range in duration from single cry pulses, which typically last about 1 sec, to bouts of crying lasting 15 sec or more. Although most cry playback stimuli have come from 1-month-old infants, some have been recorded as early as 1 or 2 days or as late as 6 months. Finally, the choice of acoustic variables has influenced results. For instance, some claims that fundamental frequency is the most important acoustic determinant of adults' perception of cries may be overstated because variables from other acoustic domains, such as duration and intensity, often are not included (Gustafson & Green, 1989).

The purpose of the present study was to examine the perception of emotion intensity in infant cries as a function of infant age. Infant cries change with age, due partly to maturation of the vocal apparatus and its neural control systems, and partly to the increasing psychological sophistication of the infant (Golub & Corwin, 1985; Lester & Boukydis, 1992; Lieberman, 1984; Prescott, 1975, 1980). During the first year, for example, growth in the emotional repertoire and changes in cognitive and prelinguistic development alter the expressive functions of the cry as an instrumental, emotional, and communicative signal (Gustafson & Green, 1991; Thompson & Leger, in press). Moreover, physical maturation alters the acoustic properties of the cry. For example, developmental changes in the musculature of the rib cage lead to a reduction in the respiratory rate during crying (Langlois, Baken, & Wilder, 1980); consequently, the duration of respiratory cycles increases with age (Wilder & Baken, 1978). According to studies by Fairbanks (1942), Prescott (1975), and Sheppard and Lane (1968), the fundamental frequency of cries shows a slight increase with age. Finally, Gardosik, Ross, and Singh (1980) reported decreases in the first and second formant frequencies with increasing gestational age. Other than these findings, little work has been devoted to describing the developmental course of infant cry characteristics (Zeskind, 1985). If infant cries change acoustically with age, and if perception of cries is linked with some of these acoustic variables, we predict that the perception of infant cries of two different ages (1 and 6 months) will differ. In these two studies, we identify the acoustic variables that are correlated with adult ratings of cries at each age, and show that different acoustic features are correlated with adult perceptions of emotion intensity at each age. We focus on cry pulses (single, uninterrupted expirations), which are the elemental units of the cry from which adults frequently make judgments about the intensity and nature of the baby's distress (see Green et al., 1987).

Further, we examine whether variations in adult experience with infants has an effect on ratings of emotional intensity. Subject variables such as gender (Frodi, Lamb, Leavitt, & Donovan, 1978; Zeskind, Sale, Maio, Huntington, & Weiseman, 1985) and infant care experience (Adachi et al., 1985; Green et al., 1987) have previously been shown to affect adult ratings of infant cries. For example, Green et al. (1987) played back single cry pulses to male and female parents and nonparents to determine the relation between gender and experience on cry perception. Although all groups rated cries very similarly, there were some subtle differences in the acoustic features that correlated with their perceptual ratings which the authors suggested may have been due to differences in experience with infants. Therefore, an important purpose of our work was to elucidate the role of gender and prior caregiving experience on adults' cry perceptions in developmental context.

Study 1: Cry Perception by Inexperienced Adults

Method

Subjects.—Subjects consisted of 30 students (18 female, 12 male), predominantly white, from middle-class backgrounds, enrolled in an introductory psychology course at a Midwestern university, for whom participation in research was a course requirement. Their mean age was 21.4 years (range = 16 to 32 years). Infant care experience was assessed using a self-report, 7-point scale with 1 indicating no experience with infants and 7 indicating a great deal of experience, either as a parent or, for example, through employment in a day-care setting. In advertising the study, we asked that parents and those with employment involving infant care not participate. Most subjects reported having little or no experience with infants (M = 2.9, SD = 1.9).

Cry stimuli.—Subjects listened to recordings of spontaneous infant cries that had been recorded in the infants' homes during all-day, naturalistic recording sessions. Recording commenced whenever crying began or seemed imminent. We analyzed only those cries that were recorded from the outset. Recordings were made with a Uher 4200 Report Monitor tape recorder at 19 cm/sec tape speed using a Sennheiser ME-40 microphone. The 20 infants (10 1-month-olds and 10 6-month-olds) produced 250 cry bout recordings. We chose 40 cry pulses (defined as single, uninterrupted expiratory vocalizations) from the recordings, with the requirement that two pulses come from each of the 20 infants. Our stimuli did not include "fusses," which are of much lower amplitude and shorter duration than cry pulses. Although infant cries typically consist of several or many pulses, it is clear that adults make judgments about infant emotional intensity before hearing several pulses. During our perception trials, changes in adults' facial expressions are readily observed well before the pulse is completed. Relating these judgments to pulse acoustic features is therefore important, although higher-level features of the cry, such as pulse rate and pause patterns, also influence adult perception (Zeskind et al., 1993).

The two pulses from each infant were obtained by first randomly selecting one of the infant's cry bouts, and then by randomly selecting a 5-sec block from the first 45 sec of the bout. If the block contained more than one pulse, one was randomly chosen. The second pulse came from a different bout. Cry pulses having background noise that may have interfered with listeners' evaluations were discarded. We made no effort to standardize the physiological state of the crying infants, preferring instead to let our stimuli represent the full range of crying infant states. This seems most ecologically valid because it best represents the circumstances in which cry perception normally occurs.

The pulses were re-recorded onto a playback tape in random order, with 5 sec of silence between pulses. Two playback tapes were created using different random orderings of the pulses.

Procedure.—Subjects initially listened to six different cry pulses to acquaint them with the stimuli and rating procedure. These pulses were selected from a pilot study of 32 other pulses and included three from each age. Two had received consistently high emotion intensity ratings, two had consistently low ratings, and two were rated at about the middle of the scale. Subjects were not given feedback on their ratings of the practice pulses. Following the practice, subjects silently rated the intensity of each of the 40 pulses on one of the following emotion intensity scales: anger, fear, or distress. Each subject rated on only one scale. The 7-point scales ranged from 1 (none of the emotion) to 7 (a great deal of the emotion). We had each subject rate on only one scale in order to avoid the possibility that subjects' ideas about the relations among the scales would contaminate the results. Subsequent work in our laboratory revealed no appreciable difference in ratings between subjects who rated on only one scale and subjects who rated all three.

Ten subjects rated on each scale (three males and seven females rated on the anger scale, four males and six females rated on the fear scale, and five males and five females rated on the distress scale). Five subjects typically participated in each playback session. Subjects were unaware of the age of the infant who produced the pulse and were not informed that two ages were represented.

Cry stimuli were played back with the Uher 4200 recorder through a Realistic SA-150 stereo amplifier and two Realistic Minimus-7W speakers. Subjects sat about 3 m from the speakers. Playback volume was set at a level approximating that of a typical crying infant.

Acoustic analyses.—The cry pulses were analyzed on a Personal Acoustics Laboratory (PAL) system (Davis, 1986a, 1986b), a microcomputer-based system that digitizes sounds and performs various acoustic operations on the digital data. From the PAL outputs, 51 acoustic variables were measured or computed for each pulse, as defined in Table 1. There is no generally agreed upon set of acoustic variables that should be included in studies of infant cries. This set represents the time, intensity, and frequency domains of acoustic stimuli, and includes acoustic variables that are affected by respiratory, laryngeal, and vocal tract characteristics of the crying infant (Lester & Boukydis, 1992).

TABLE 1

ACOUSTIC VARIABLES MEASURED ON EACH OF THE 40 INFANT CRY PULSES

Variable	# Measures	Description
Duration	1	Total duration of the cry pulse (in seconds).
Peak amplitude	15	The highest amplitude occurring in each 2-kHz band between 0 and 10 kHz. Peak amplitudes were measured at the beginning, middle, and end of the pulse (12.5 ms from the beginning and 12.5 ms from the end).
Peak amplitude ratios	6	These variables express the amount of energy present in one energy band relative to another band at one point in the cry. Larger values indicate relatively more energy in the lower frequency bands. They were computed by dividing the peak amplitude in the 0–2 kHz band by the peak amplitude in the 4–6 kHz band and the 6–8 kHz band. This was done at the beginning, middle, and end of the pulse.
Fundamental frequency	1	Fundamental frequency (in Hz) was measured by counting the consistent peak patterns on a 12.5 ms time series waveform display centered on the middle of the pulse.
Peak frequency	3	The frequency (in kHz) of the highest amplitude point at the beginning, middle, and end of the cry.
Frequency change	3	Computed from the peak frequency data, these variables express the amount of change in frequency (in kHz) from beginning to middle, middle to end, and beginning to end of the pulse.
Formant frequency	9	Formant frequencies reflect the resonant characteristics of the vocal tract. The high points of the first, second, and third curve on a formant frequency display were considered to be the central frequencies of the first three formants (in kHz). Formants were measured at the beginning, middle, and end of the cry pulse.
Formant amplitudes	9	The amplitudes (in db) of the three formant frequency peaks. These were also taken at the beginning, middle, and the end of the cry pulse.
Noise	4	Noise is the degree to which a cry pulse lacks tonal structure. Noise was measured by counting the number of amplitude peaks on a frequency-by-intensity plot that were at least 20 db greater than the adjacent frequencies. The noisier the cry, the fewer such peaks. The number of peaks was multipled by -1 so that larger values indicate a greater amount of noise. Noise was measured at the beginning, middle, and end of the cry. Total noise is the sum of the three individual values.

Furthermore, the early, middle, and late portions of the cry pulse are represented, in case different parts of the cry are attended to differently by adults. We had previously factor-analyzed these acoustic variables using a large sample of pulses drawn from the same set of recordings. Nine factors emerged, and the variable with the highest factor loading score was chosen to represent that factor in the present study. These variables are listed in Table 2, along with mean values for the two infant ages and the results of age-difference tests.

Results

Ratings as a function of infant age and emotion.—There was a significant difference in the intensity ratings of cry pulses as a function of infant age (see Fig. 1). A 3 (emotion) $\times$ 2 (infant age) split-plot factorial ANOVA revealed a significant difference in ratings for the two infant ages, with the 6-month-olds' cries rated as being more intense than the 1-month-olds' cries, $F(1, 27) = 22.44$, $p < .01$. Anger, fear, and distress ratings did not differ significantly, $F(2, 27) = 3.30$, $p > .05$, and there was no significant

TABLE 2

VARIABLES USED IN MULTIPLE REGRESSION ANALYSES

VARIABLE NAME	MEAN (SD) 1 Month	MEAN (SD) 6 Months	p Level
Fundamental frequency (Hz)	384.8 (79.2)	520.0 (269.6)	<.05
Noise (middle)	−7.2 (5.9)	−5.6 (5.3)	N.S.
Pulse duration (sec)	1.3 (.5)	1.8 (.9)	<.05
Peak frequency change (kHz) (beginning to end)	.3 (2.1)	−.04 (2.0)	N.S.
Peak amplitude ratio (0–2 kHz/4–6 kHz) (beginning)	1.2 (.2)	1.2 (.2)	N.S.
Peak amplitude (0–2 kHz) (dB) (end)	67.3 (9.6)	63.9 (6.1)	N.S.
Peak amplitude (2–4 kHz) (dB) (beginning)	66.4 (7.6)	56.0 (6.0)	<.001
Formant amplitude (dB) (second formant, middle)	77.3 (7.3)	71.3 (9.7)	<.05
Formant frequency (kHz) (third formant, beginning)	4.8 (.9)	5.2 (.9)	N.S.

NOTE.—Significance is based on ANOVA (df = 1, 38).

interaction between infant age and emotion intensity ratings, $F(2, 27) = 0.032$, $p > .05$.

Subject gender, which had been suggested in previous research to have some bearing on the perception of infant cries (Green et al., 1987), did not account for differences in subjects' mean intensity ratings of anger, fear, or distress. Male and female subjects' ratings of the three emotions did not differ significantly, $F(1, 24) = 0.027$, $p > .05$, nor was there a significant interaction between subject gender and emotion, $F(2, 24) = 0.561$, $p > .05$, as evaluated by a 2

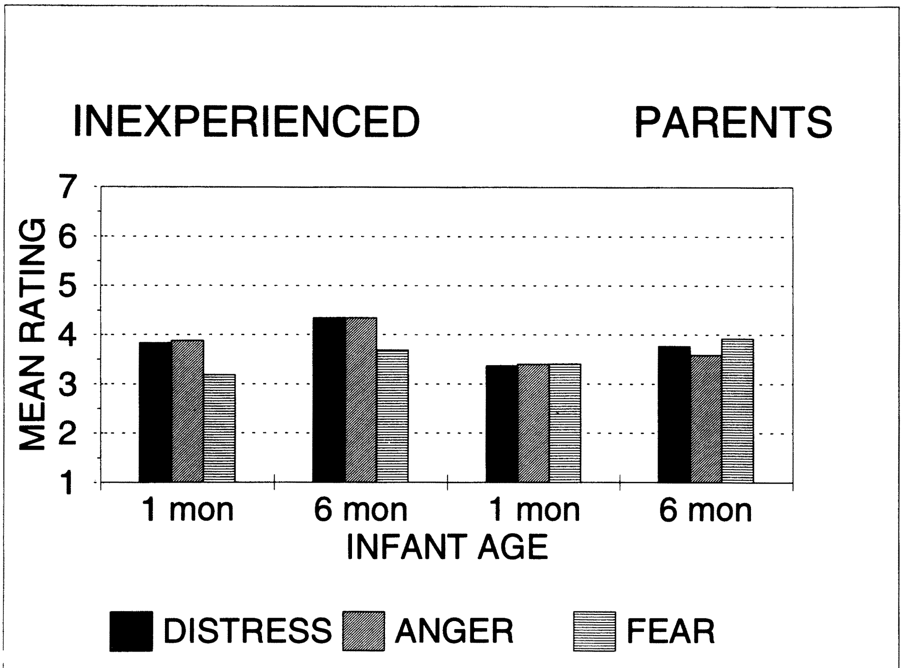

FIG. 1.—Mean cry pulse ratings by adults inexperienced in child care (left) and by parents (right) as a function of infant age and rated emotion.

TABLE 3

CORRELATIONS BETWEEN CRY PULSE ACOUSTIC VARIABLES AND INEXPERIENCED ADULTS' RATINGS OF EMOTION IN TWO INFANT AGE GROUPS

Acoustic Variable	1 Month	6 Months	Difference (z Test)
Fundamental frequency (Hz)	−.358	−.259	.32
Noise (middle)	.639**	−.316	3.16**
Pulse duration (sec)	−.049	.462*	1.60
Peak frequency change (kHz)	−.005	.090	.28
Peak amplitude ratio	−.228	−.689**	1.79*
Peak amplitude (0–2 kHz) (dB)	−.015	−.113	.29
Peak amplitude (2–4 kHz) (dB)	.577**	−.144	2.34**
Formant amplitude (dB)	.389	.438	.17
Formant frequency (kHz)	.596**	.198	1.41

*$p < .05$.
**$p < .01$.

(gender) × 3 (emotion) ANOVA on subjects' mean ratings.

Ratings on the three scales were very similar as judged by the correlations among them. For the 1-month ratings, the correlations were: distress-anger, $r = .794$; distress-fear, $r = .764$; and anger-fear, $r = .780$. For the 6-month ratings, the correlations were: distress-anger, $r = .927$; distress-fear, $r = .848$; and anger-fear, $r = .883$. Because of these strong correlations, we computed a combined emotion intensity score for each pulse by averaging across all three scales. These scores were used in all subsequent analyses.

Acoustic correlates of emotionality ratings.—What acoustic features might be responsible for adults' ratings of cry emotional intensity? Table 3 lists the correlations between the nine representative acoustic variables and the combined emotion intensity scores for the two infant ages. It also includes the results of tests of differences between the correlations from the two infant ages. Two interesting results appear in this table. First, five variables were correlated significantly with the emotion intensity scores, but no variable was correlated significantly for both infant ages. Second, three of the five variables had significantly different correlations between the two ages, and two of them even had opposite signs. The greatest difference emerged for the noise variable, in which greater levels of noise were positively correlated with emotion intensity ratings for the 1-month cries, but negatively correlated (although not significantly so) with emotion intensity ratings for the 6-month cries. The difference between the two correlations was significant. Other significant differences appeared between the correlations with peak amplitude ratio and peak amplitude in the 2–4 kHz band.

Interpreting these correlations is complicated for two reasons. First, we have no idea whether the adult subjects were indeed influenced by the variables with significant correlations, or by some other variable that we did not measure. Experimental manipulations of cries would be necessary to address this issue. Second, intercorrelations among the acoustic variables make a simple interpretation of their assocation with the criterion variable nearly impossible. To address this second point, we conducted multiple regression analyses as an exploratory step toward understanding the possibility of different variables underlying the perception of cries at two infant ages.

The representative acoustic variables were used as predictors in two multiple regression analyses, one for each infant age, using the combined emotion intensity scores of the cry pulses as the criterion variables. The multiple regression analyses were conducted using the forward method of predictor variable inclusion. The results are summarized in Table 4, which provides the equations and R^2 values associated with each of them.

The multiple regression equations were very effective at accounting for variance in mean intensity ratings of the infant cries. The R^2 values were .631 and .475 for 1-month and 6-month cries, respectively.

How similar are the two regression equations? The 1-month regression equation employed two variables (noise and peak amplitude), but the 6-month equation used only

TABLE 4

MULTIPLE REGRESSION EQUATIONS FOR INEXPERIENCED ADULTS' RATINGS OF EMOTION IN TWO INFANT AGE GROUPS

Infant Age	Equation	R^2	Adj. R^2
1 month	.24019 + .08948 (noise) + .06081 (peak amp)	.631	.582
6 months	8.77826 − 3.80753 (amp ratio)	.475	.437

NOTE.—Predictor variable abbreviations are as follows: Noise = noise at the middle of the pulse, Peak amp = peak amplitude, beginning of pulse (2–4 kHz band), Amp ratio = amplitude ratio, beginning of pulse (0–2 kHz band/4–6 kHz band). Adj. R^2 is a conservative estimate of variance accounted for in the population and takes the number of predictor variables into consideration.

one (peak amplitude ratio). However, because the ratio of cases (cries) to predictor variables was unfavorable, there is a risk that chance could lead to a variable being significant in one data set (infant age) but not in the other data set. If the acoustic variables that entered one equation are related to the acoustic variables in the other equation, then the two equations should be nearly equivalent in their ability to predict adult ratings of cries. We explored this possibility by using the regression equation from one infant age to generate predicted scores for the other infant age. For comparison, we also generated predicted scores for the same infant age from which the equation was derived. Next, the predicted scores were correlated with the actual scores. If a regression equation does a good job of predicting emotion intensity scores, then the correlation coefficient between the actual and predicted scores should be strong and positive.

The correlations between actual scores and scores predicted by equations derived from the same age and from the other age were significantly different. We used the regression equation from the 1-month ratings to generate predicted scores for the 1-month and 6-month cries, and then correlated the predicted and actual scores. The correlations between predicted and actual scores were .794 and .228, for 1-month and 6-month, respectively, and these correlations were significantly different, $z = 2.37$, $p < .01$, as assessed by the procedure described by Meng, Rosenthal, and Rubin (1992). Likewise, when we used the regression equation from the 6-month ratings to generate predicted scores for both age groups, the correlations between predicted and actual scores were −.407 and .689 for 1-month and 6-month cries, respectively, and these correlations were significantly different, $z = 3.34$, $p < .001$. These findings suggest that the differences between regression equations for each age are not superficial; rather, the acoustic variables that account for differences in emotion intensity ratings at one age do not account for differences in emotion intensity ratings at the other age, even among the same subjects listening to the cries randomly arranged on the same tape.

Our regression analyses should be viewed only as a preliminary attempt to understand the processes that might underlie the perception of cries. In the absence of theoretical grounds for forcing the inclusion of certain acoustic variables as predictors, we let the data determine the best (linear) combination of variables for predicting subjects' ratings of cries. This is quite common in exploratory work (Kerlinger & Pedhazur, 1973). We are intrigued by the difference that emerged between the two infant ages, but suggest that our findings only serve as candidate predictor variables for subsequent research.

Study 2: Cry Perception by Parents

Method

Subjects.—Participants in this study were 30 parents (16 mothers, 14 fathers), of comparable racial and socioeconomic status to the first sample, who currently had an infant in the 1-month to 6-month age range. Fifteen of the subjects (eight females and seven males) were first-time parents. The other 15 had more than one child. Names of subjects were drawn from birth announcements in the local newspaper and recruited over the telephone. Each participant was paid $5 for participation and was provided with the option of free child care while participating. These parents were not related to the infants whose cries were used as stimuli.

Stimuli and procedure.—The same cry stimuli and procedures used in Study 1 were used here. Ten subjects rated on each scale (six females and four males rated on the dis-

TABLE 5

CORRELATIONS BETWEEN CRY PULSE ACOUSTIC VARIABLES AND PARENTS' RATINGS OF EMOTION IN TWO INFANT AGE GROUPS

Acoustic Variable	1 Month	6 Months	Difference (z Test)
Fundamental frequency (Hz)	−.464*	−.277	.64
Noise (middle)	.780**	−.331	4.05**
Pulse duration (sec)	−.035	.559*	1.95*
Peak frequency change (kHz)	−.174	−.017	.46
Peak amplitude ratio	−.153	−.667**	1.90*
Peak amplitude (0–2 kHz) (dB)	−.008	−.123	.34
Peak amplitude (2–4 kHz) (dB)	.453*	−.099	1.71*
Formant amplitude (dB)	.355	.411	.19
Formant frequency (kHz)	.418	.277	.47

*$p < .05$.
**$p < .01$.

tress scale, and five males and five females each rated on the fear and anger scales). On average, four subjects rated the cries in each playback session.

Results

Ratings as a function of infant age and emotion.—Ratings of the 20 1-month-old cries and of the 20 6-month-old cries were analyzed with a 3 (emotion) × 2 (infant age) split-plot factorial ANOVA. There was a significant difference between the ratings of the two infant ages, $F(1, 27) = 11.94$, $p < .01$, with the 6-month-olds' cry pulses rated higher in intensity of emotion. Ratings on the three emotions did not differ significantly from each other, $F(2, 27) = 0.13$, $p > .05$, and there was no significant interaction between infant age and emotion, $F(2, 27) = 0.85$, $p > .05$. These data are presented in Figure 1.

Male and female subjects' ratings of the intensity of the three emotions did not differ significantly, $F(1, 24) = 1.412$, $p > .05$, nor was there a significant interaction between subject gender and emotion, $F(2, 24) = 2.436$, $p > .05$, as evaluated by a 2 (gender) × 3 (emotion) ANOVA on subjects' mean ratings. Ratings on the three scales were strongly intercorrelated. For the 1-month ratings, the correlations were: distress-anger, $r = .900$; distress-fear, $r = .825$; and anger-fear, $r = .809$. For the 6-month ratings, the correlations were: distress-anger, $r = .956$; distress-fear, $r = .921$; and anger-fear, $r = .911$. Because of these strong correlations, we averaged the intensity ratings from all three scales to form a combined score for each cry pulse for subsequent analyses.

Acoustic correlates of emotion ratings.—The correlations between the nine acoustic variables and the combined emotion intensity scores are presented in Table 5. A pattern of results that was very similar to Study 1 was obtained. In addition to the three variables that had been identified as having significantly different correlations in Study 1, one other variable (pulse duration) was significantly different between the two infant ages (this variable was nearly significantly different in Study 1). Furthermore, the direction of the correlation differences and the magnitude of the correlations were very similar to those obtained in Study 1.

As before, we conducted multiple regression analyses to obtain a predictive equation for each infant age. The results of these analyses are presented in Table 6. The equations accounted for substantial amounts of variance, with R^2 values of .711 and .444 for 1-month and 6-month data, respectively.

We used the regression equations to predict scores for the same age group and for the other age group. The predicted scores were then correlated with the actual scores to assess the predictive ability of the equation. The results paralleled those of Study 1. The 1-month regression equation generated predicted 1-month scores that correlated with actual scores at $r = .843$, but 6-month predicted scores correlated with actual scores at $r = .153$, a significant difference, $z = 2.70$, $p < .01$. The 6-month regression equation generated predicted 6-month scores that correlated with actual scores at $r = .667$, but 1-month predicted scores correlated with actual scores at $r = -.389$, again a significant difference, $z = 3.13$, $p < .001$.

TABLE 6

MULTIPLE REGRESSION EQUATIONS FOR PARENTS' RATINGS OF EMOTION IN TWO INFANT AGE GROUPS

Infant Age	Equation	R^2	Adj. R^2
1 month	1.32468 + .12744 (noise) + .04504 (peak amp)	.711	.673
6 months	8.766 − 4.09585 (amp ratio)	.444	.405

NOTE.—Predictor variable abbreviations are as follows: Noise = noise at the middle of the pulse, Peak amp = peak amplitude, beginning of pulse (2–4 kHz band), Amp ratio = amplitude ratio, beginning of pulse (0–2 kHz band/4–6 kHz band). Adj. R^2 is a conservative estimate of variance accounted for in the population and takes the number of predictor variables into consideration.

Comparisons of the Two Studies

The parents' ratings of the cry pulses did not differ significantly from those of the inexperienced adults, $F(1, 54) = 2.52$, $p > .05$, nor was there a significant interaction between subject group and emotion, $F(2, 54) = 2.08$, $p > .05$, as judged by a 2 (adult group) × 3 (emotion) factorial ANOVA.

Inspection of the regression equations from both studies (Tables 4 and 6) reveals the similarity that exists within the same age group. The same predictor variables were used in both cases. To test the similarity of the regression equations obtained from the two studies, we used the equations from one group of adult subjects to make predicted scores for the same infant age for the other set of subjects. As before, the predicted scores were correlated with the actual scores to evaluate the similarity of the two data sets. These results, displayed in Table 7, indicate that a regression equation for ratings derived from one group of adult subjects does quite well at predicting the ratings of the other group of subjects for the same infant age. (These comparisons were conducted using the procedures described by Meng et al., 1992, for correlated correlation coefficients.) Recall that all of the regression equations within a subject group failed to predict the same subjects' ratings at the other infant age. Taken together, these data indicate that infant age is a better predictor of adult perception than is the experiential status of the adult perceiver.

Discussion

Adults who listened to 40 infant cry recordings (without knowing the ages of the infants who produced the cries) rated the 6-month-olds' cries higher on each of the three emotion intensity scales than they did the cries of the 1-month-olds. This finding was true of both inexperienced adults and parents of infants. Furthermore, male and female adults rated the cries similarly.

Our data also demonstrate that different types of acoustic variables are correlated

TABLE 7

CORRELATIONS BETWEEN MEAN RATINGS FOR CRIES AND PREDICTED RATINGS DERIVED FROM TWO REGRESSION EQUATIONS

1-MONTH DATA; SOURCE OF RATING	SOURCE OF EQUATION: Inexperienced	SOURCE OF EQUATION: Parents	p LEVEL
Inexperienced	.7943	.7702	N.S.
Parents	.8433	.8178	N.S.

	SOURCE OF EQUATION: Inexperienced	SOURCE OF EQUATION: Parents	p LEVEL
Inexperienced	.6892	.6890	N.S.
Parents	.6663	.6665	N.S.

with adults' ratings of emotion intensity in the cries at two infant ages. Measures of noise and peak amplitude were correlated with adults' ratings of emotion in the 1-month-old infants' cries. In contrast, a measure of amplitude ratio across two frequency bands was correlated with ratings of the 6-month-old infants' cries. Interestingly, fundamental frequency, which has been assigned a place of importance in previous literature on assessments of emotionality (Adachi et al., 1985; Green et al., 1987; Lounsbury & Bates, 1982; Wiesenfeld, Malatesta, & DeLoach, 1981; Zeskind & Lester, 1978; and Zeskind & Marshall, 1988) did not appear in any of our regression equations. This does not mean that fundamental frequency is unimportant (indeed, r values correlating fundamental frequency with adult ratings of emotion intensity ranged from $-.26$ to $-.46$), only that it did not account for enough unique variance to enter an equation. The same argument applies to other variables that were significantly correlated with the rating scale data but that did not enter a regression equation. Regression analysis outcomes are driven by the available variables. Our study, using some acoustic measures not previously employed, may have discovered some variables that shared variance with and masked the contribution of fundamental frequency. Similar conclusions have been reported by Gustafson and Green (1989).

Multiple regression equations were derived for both adult groups for both infant ages. Significantly, the equation derived for one infant age from one group of adult subjects predicted the ratings of the other adult group on the same infant age better than it did the ratings of the same adult subjects for the other infant age. This suggests that ratings of emotion intensity in the cries of infants depend more on the age of the infant than on the characteristics of the adults who listen to those cries. Apparently, as infants mature (psychologically and physiologically) their vocal characteristics change as well (see references in introduction), and adults may use different types of vocal characteristics in evaluating the emotional intensity of crying infants.

Because of the correlational nature of our data, we are unable to tell whether the variables that we have identified as good predictors of adults' perception of emotional intensity are in fact responsible for their perceptions. Only experimental analyses involving manipulations of cry stimuli can unambiguously answer such questions. One possibility is that an acoustic variable that we did not measure drives the perception of emotional intensity in both infant ages. Although it is logically impossible to dismiss this possibility, it seems unlikely given the wide range of acoustic stimuli that we analyzed. A more likely explanation of our findings comes from studies of the perception of emotion in adult speech. The consensus view is that there is no simple relation between acoustic variables and emotion quality and intensity (see Scherer, 1982, 1985, 1986). Anger, for instance, can be expressed by loud, fast speech or by soft, slow speech (accompanied by shifts in other acoustic parameters). If the perception of emotion in infant cries is at all similar to the perception of emotion in adult speech, there are probably multiple acoustic features that are interrelated in complex ways that drive the perceptual process. The probable multidimensional nature of emotional perception should come as no surprise; one of the contributions of our work is the suggestion that the particular set of acoustic features used in cry perception may change with infant age.

The variables that appeared in the regression equations for the two ages were not artifacts of the distributions of scores for those variables. In other words, it might be possible that if the cries of one age group had little variability on a particular acoustic variable, that variable would be unable to explain much variance in the emotion intensity ratings. However, an examination of the coefficients of variation (CV) of the acoustic variables for the two infant ages revealed no support for this hypothesis. The acoustic variables that appeared in the regression equations were not particularly variable, judging from their coefficients of variation. The ranks of the CVs for the variables that appeared in the 1-month equations were 2 and 8 (of 9), and in the 6-month equations the rank was 5 (again, of 9).

There seems to be nothing idiosyncratic about the particular 40 cry pulses used as stimuli in these studies. In a pilot study on inexperienced adults that used a different set of 32 cry pulses from the same body of recordings, the older infants' cries were rated as being significantly more distressed sounding than were younger infants' cries. Further, a study by Hanson (1989) in our lab used a third, independent set of 40 cry pulses and found the same infant age effects in parents and age-matched nonparents. More specifically, parents and nonparents each rated 6-month-olds' cries as emotionally more intense, and correlations between these ratings and the acoustic measures in that study were of comparable magnitude and the same direction as those reported here. Clearly, the findings described here seem to be robust and point to infant age (and its changing acoustic attributes) as being most important to adults' perception of emotional intensity in crying infants. Of course, other sets of data may produce different results. Perhaps our cry sample, which came from infants who were not manipulated by the researchers to experience equivalent cry-inducing conditions, contained a fuller range of variation on some acoustic variables, and on ratings of emotion intensity that are driven by those variables.

The patterns of emotion intensity ratings made by parents did not differ significantly from those of inexperienced adults. This raises an interesting question regarding the role of experience with cries in perceiving emotional intensity. To be sure, no one is truly inexperienced with infant cries: All people (including children) make everyday judgments of cry intensity when overhearing babies, even though they may be inexperienced in infant care. Perhaps we use the same perceptual processing schemes for perceiving emotion intensity in cries that we use for perceiving emotion in adult speech, or even nonhuman sounds (such as growling in dogs). If so, we would expect that experience with infants might just fine-tune a general purpose mechanism.

Because it is reasonable to expect that some adult caregiving activities are related to the perception of cries (Malatesta, 1981), and because perception must relate to cry acoustic characteristics, it follows that acoustic analyses are relevant to understanding caregiving behavior. For instance, noisy cries sound harsh and raspy and receive higher intensity ratings of anger, fear, and distress for the 1-month-olds' cries. If such perceptions were to occur in the natural context of infant care, they might be expected to influence the speed or the nature of the caregiving response (Gustafson & Harris, 1990; Zeskind & Collins, 1987), although more research on this association is needed. Because cry acoustic features may contribute to caregiving activities, we expect that further analyses relating acoustic features with cry perception will play an increasingly important role in studies of infant-parent interaction.

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