AN ANALYSIS OF TWO INFANTS’ FIRST CRIES

A Thesis by

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The following faculty members have examined the final copy of this thesis for form and content, and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Arts with a major in Communication Sciences and Disorders.

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ABSTRACT

As part of a larger study, two low-risk primigravida (first pregnancy) women who intended to breastfeed and their newborns were audio- and videotaped in the first two hours after birth. For this pilot study, recordings were analyzed to investigate early infant crying patterns. One mother-infant pair remained in close contact immediately following delivery with short periods of separation. The other mother-infant pair experienced longer periods of separation during the first two hours. Although data are preliminary, the separation cries of the infants were noticeably different perceptually than the cries produced in contact with mother. The separation cries were shorter in duration, with a higher first peak frequency, and a less distinct harmonic structure than those of non-separation cries. Results suggest that a separation distress cry is biologically plausible, both in terms of tension and stress in the newborn’s vocal physiology and because of the newborn’s dependence on the mother. Confirmation and expansion of these findings could serve as a motivating factor in preventing the separation of mothers and newborns immediately after birth.

KEYWORDS: mother-infant interactions; newborn care; skin-to-skin contact; crying behavior; acoustic analysis
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CHAPTER I

REVIEW OF THE LITERATURE

Newborn humans are developmentally immature at birth and rely upon close contact with a nurturing adult (typically the mother) to sustain life. All mammals have behavioral adaptations that serve to keep the adult and newborn together and these adaptations center around touch. The importance of touch in human development, behavior and communication was documented by Montagu (1971) in his pioneering work on tactile experiences and, as a result, the use of sustained (60-90 minutes) skin-to-skin contact between human infants and their mothers immediately after birth has been recommended for some time. This sustained skin-to-skin contact enables mothers and infants to benefit from hormone levels that are optimal for the development of the reciprocal, stereotypic interaction and communication patterns associated with successful breastfeeding outcomes (Anderson, Moore, Hepworth, & Bergman, 2003; Crenshaw, 2007; Kaitz, Lapidot, & Bronner, 1992; Lawrence & Lawrence, 1999). These interaction patterns include the newborn’s use of natural reflexes to crawl to the mother’s breast and latch onto the nipple, olfaction, and the mother’s intuitive assistive movements, touch, and verbalizations (Crenshaw, 2007; Ludington-Hoe et al., 1999; Sheridan, 1999; Varendi, Porter, & Winberg, 1994; Widström & Thingström-Paulsson, 1993). Further, the infant’s touch and suckling behavior has been shown to stimulate the release of oxytocin in the mother, an important hormone in the production of breastmilk (Matthiesen, Ransjo-Arvidson, Nissen, & Uvnäs-Moberg, 2001). Sustained skin-to-skin contact immediately after birth also could possibly reduce the transient forgetfulness and confusion many women experience in the 24 hours following childbirth (Eidelman, Hoffman, & Kaitz, 1993).
To facilitate skin-to-skin contact for mothers and full-term (mature, 37 to 42 weeks gestation) infants who have experienced an uncomplicated vaginal delivery, the naked newborn is placed on the mother’s bare chest immediately following delivery, or as close to delivery as possible, and remains there for at least 60 minutes (Anderson et al., 2003). This immediate postpartum skin-to-skin contact also may be possible and profitable for some pre-term infants (Harrison, Olivet, Cunningham, Bodin, & Hicks, 1996; Miles, Cowan, Glover, Stevenson, & Modi, 2006). The optimal position for the mother is semi-reclined to facilitate reflex activity of the infant (Colson, Meek, & Hawdon, 2008). Although methodological variations exist between studies, separation of term human newborns from skin-to-skin contact with their mothers immediately following birth has been associated with a number of adverse physiological changes for the infant. These adverse changes include increased heart rate, decreased temperature, higher respiratory rate, higher base excess, and lower blood glucose values compared to infants who were held continuously skin-to-skin (Christensson et al., 1992). In a study of infants born via Cesarean section, Erlandsson, Dsilna, Fagerberg, and Christensson (2007) documented that paternal skin-to-skin contact was better than chair-side cot-caring based on infants’ temperature levels, crying time, and pre-feeding activities. Newborn infants with sustained skin-to-skin contact thus expend less effort in adapting to their new environment immediately after birth (Ludington-Hoe et al., 1999). Further, mothers without sustained skin-to-skin contact breastfeed their infants notably shorter (in months) than mothers who have more skin-to-skin contact immediately after birth (Anderson et al., 2003).

The advantages of breastfeeding for mothers and their babies are many and have been well-documented (see studies cited in American Academy of Pediatrics, 2005; Witters-Green, 2003). Breast milk is the optimal source of early nutrition for infants when there are no
contraindications for the mother or infant. Breast milk is readily available, does not have to be purchased, does not require sterilization, and has an analgesic effect on infants (Carbajal, Veerapen, Couderc, Jugie, & Ville, 2003). Breastfed infants generally are healthier than formula-fed infants and significantly less susceptible to many types of pathology, including obesity in childhood and adolescence, allergic diseases, hospitalization for respiratory infections, otitis media, gastrointestinal infections, inflammatory bowel disease, leukemia and diabetes, (American Academy of Pediatrics, 2005; Kramer et al., 2008; Niers, Stasse-Wolthuis, Rombouts, & Rijkers, 2007; Oddy et al., 2004). The duration of breastfeeding has been positively correlated with enhanced cognitive development and level of intelligence in the developing child (Anderson, Johnstone, & Remley, 1999; Kramer et al., 2008). Maternal benefits include reduced risks of ovarian cancer, premenopausal breast cancer and Type II diabetes (American Academy of Pediatrics, 2005). In addition, there are economic benefits to families, society, and the environment (Ball & Wright, 1999). As a result, breastfeeding exclusively for the first four-six months and then to complement the introduction of solid foods until at least 12 months is advocated by the American Academy of Pediatrics (2005), World Health Organization (2002), and the United States Department of Health and Human Services (2000, 2008). While the rate of the initiation of breastfeeding is increasing (Ryan, Wenjun, & Acosta, 2002), many factors continue to prevent its exclusive use with infants for the first six months of life in the United States. One of these factors is the limited implementation of sustained skin-to-skin contact between mothers and infants in the first few hours after birth.

The positive relationship of skin-to-skin contact following birth to successful breastfeeding has been well-documented (American Academy of Pediatrics, 2005). However, routine childbirth practices in many hospitals in the U.S. continue to move the infant to a warmer
or bed immediately following birth (Bartick, Stuebe, Shealy, Walker, & Grummer-Strawn, 2009; U.S. Department of Health and Human Services, 2008). Further, this mother-infant separation frequently is maintained during the first hours of life despite evidence that the mother is the best source of heat for her infant (American Academy of Pediatrics, 2005). This practice may reflect unintended but incorrect nursing perceptions that it is important for an infant to cry immediately after birth to establish lung function and to indicate the infant’s vitality (Apgar, 1953; Christensson, Cabrera, Christensson, Uvnäs-Moberg, & Winberg, 1995).

In their investigations of mother-infant interactions when mothers and infants were together or separated, researchers noted that infants not held skin-to-skin and/or separated from their mothers cried more (Anderson et al., 2003; Christensson et al., 1992; Christensson et al., 1995; Michelsson, Christensson, Rothgänger, & Winberg, 1996). Earlier work by Widström and Thingström-Paulsson (1993) showed that the initiation of a cry caused the infant’s tongue to rise to the palate rather than remain on the floor of the mouth. The lower position of the tongue is critical for an infant to latch onto the nipple efficiently and begin to suckle. Thus, crying behavior prevents effective breastfeeding. Further, Christensson et al. (1995) speculated that the characteristic short pulse cry heard in the separated infants was one of distress as it ceased when infants were re-united with their mothers.

A separation-distress call is a specific sound produced by the newborn that elicits a specific response in the parent. Although a distinct separation-distress call has been identified in other species (e.g., Groer, Hill, Wilkinson, & Stuart, 2002), a specific human separation-distress cry has not been clearly and consistently distinguished from other cries of the human infant. Previous studies have attempted to classify different types of infant cries based on the infants’ physiological state (Goberman & Robb, 1999; Golub & Corwin, 1982) and on their
comfort/discomfort level (Gustafson, Wood, & Green, 2000; Michelsson & Wasz-Höckert, 1980). A review of the infant cry literature reveals only one study in which newborn cries were examined in separated and non-separated conditions (Michelsson et al., 1996). These investigators found differences in the number of pain, hunger, and separation cries but did not document significant acoustic differences in the duration or melody contour of the cries for the two groups of infants. Their study was compromised because the infant cries were recorded on an analog tape recorder, limiting both the quality of the recording signal and the validity of quantitative measurement of the signals.

By capturing infant cries in relationship to mother-infant interactions during the first two hours after birth, and using high quality digital recordings, it may be possible to identify and characterize the unique separation distress cry which has been hypothesized (Christensson et al., 1995; Goberman & Robb, 1999; Gustafson et al., 2000; Michelsson et al., 1996). Such a separation distress cry could serve as an additional motivating factor to argue against the separation of mothers and infants immediately after birth. The purpose of the current pilot study was to analyze and compare the initial cry sequence of two newborn infants under conditions of sustained and not sustained skin-to-skin contact. The specific research question was: Is there a difference in the initial cry sequence of two newborn infants when they are, and are not, separated from skin-to-skin contact with their mothers?
CHAPTER 2

METHODOLOGY

The following sections describe the participants, procedures, and data analyses in this pilot study.

Participants

The participants were two male newborn infants (Infant 1 and Infant 2). These infants were full term and born to women who were pregnant for the first time. The mothers were 32 and 27 years of age, respectively. Each infant experienced an uncomplicated delivery. Infant 1 weighed 6 lbs 15 oz and Infant 2 weighed 7 lbs 7 oz. Both infants were born at the same urban hospital. Demographic data are provided in Table 1.

TABLE 1

DEMOGRAPHIC DATA FOR INFANT 1 AND INFANT 2

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Infant 1</th>
<th>Infant 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Birth</td>
<td>9/18/09</td>
<td>10/01/09</td>
</tr>
<tr>
<td>Sex</td>
<td>Male</td>
<td>Male</td>
</tr>
<tr>
<td>Gestational Age</td>
<td>37 weeks</td>
<td>39 weeks</td>
</tr>
<tr>
<td>Weight</td>
<td>6 lbs 15 oz</td>
<td>7 lbs 7 oz</td>
</tr>
<tr>
<td>APGAR scores (out of 10) at 1 and 5 minutes</td>
<td>8, 9</td>
<td>9, 9</td>
</tr>
<tr>
<td>Mother’s Age</td>
<td>32</td>
<td>27</td>
</tr>
<tr>
<td>Time spent with mother in the two hours after birth</td>
<td>1 hr. 53 min.</td>
<td>1 hr. 20 min.</td>
</tr>
<tr>
<td>Time spent separated from mother in the two hours after birth</td>
<td>7 min.</td>
<td>40 min.</td>
</tr>
</tbody>
</table>
Procedures

Institutional Review Board (IRB) approval was obtained from Wichita State University and the Wesley Medical Center. The mothers of the infants were recruited from prenatal childbirth classes within eight weeks of their estimated due date. When recruited, these expectant mothers confirmed they intended to breastfeed their infants.

Each mother provided written informed consent for audio- and videotaping of her and her infant in the two hours following birth. Each mother also agreed to provide demographic information, pertinent pregnancy history, labor-delivery-postpartum medical data from her medical chart, and to notify the physician involved with the study (Dr. Powers) when she went to the hospital for delivery.

In the delivery room, a microphone and digital audio recorder were placed in a standardized location on each mother’s bed prior to the birth of the infant. A videographer (an experienced nurse) also filmed each mother and infant for the first two hours after birth using a high-quality video recorder with a built-in microphone. Although born at the same medical center, the two mother-infant pairs were treated differently in the delivery room. One infant remained with his mother for sustained skin-to-skin contact with the exception of seven minutes. The other infant was separated from his mother for a total of 40 minutes and then wrapped and placed next to mother.

The cry data were downloaded from the audio and video-recorders for acoustic analysis. This analysis was completed by two students who were not directly involved with the study. The two students underwent a period of training to familiarize them with the necessary measurements. Details of the acoustic analysis are provided in the next section.
Data Collection and Analysis

The goal of this pilot study was to identify differences in the initial cry sequence of one full-term infant who experienced essentially sustained skin-to-skin contact with his mother compared to the initial cry sequence of one full-term infant who was separated from his mother. Because the digital recorder and the microphone from the video recorder were recording the same signal, the cries on the digital audio recording could be linked to specific events in the video signal. In this way, it was possible to see whether a cry occurred during the separation condition or the non-separated condition. Each cry then could be coded appropriately. The total number of cry signals during the 120-minute post partum period was counted for each infant. Quantitative data on the onset time, duration (in seconds or milliseconds), intensity (in decibels), and other spectral characteristics (e.g., fundamental frequency) of each infant’s initial cry sequence were analyzed but are presented descriptively due to the small number of infants in this pilot study.

Independent variable: Conditions of being separated or not separated from mother

The independent variable for this study was separatedness between the infants and their respective mothers. There were two conditions: the infant was in direct contact with the mother (Condition 1) or the infant was separated from the mother (Condition 2). The two conditions were conceptually identically for both infants, but operationally different. For Infant 1, the non-separated condition was defined by direct skin-to-skin contact with the mother; the separated condition involved the infant’s being removed from this skin-to-skin contact by a nurse. Infant 2 also remained on the mother during the non-separated condition but there was no skin-to-skin contact due to the blankets that enveloped the infant; for the separated condition, Infant 2 was in a different place in the delivery room than the mother.
Selection of cry segments

For both Infant 1 and Infant 2, the cry segments selected for analysis were chosen from the portion of the digital audio signal occurring within the first 40 minutes of birth. Infant 1’s cry segments were derived from the first 15 minutes of the recording; Infant 2’s cry segments occurred within minutes 20 through 40. It was not possible to use any cry segments from earlier in Infant 2’s audio recording because of the presence of ambient noise in the delivery room and because the infant was initially too far away from the digital audio recorder.

Classification of cry segments into conditions

Two complementary methods were used to classify each cry segment as belonging in the non-separated condition or the separated condition. First, a log was available that recorded when each infant was with its mother. Related to a project independent of this current study, this log had been created using a video recording of each infant’s delivery. The time markers of the log were compared to the time markers of the digital audio recording containing the cry segments. Second, the digital audio recording contained confirmatory clues regarding the infants’ placement that supported the information provided by the time code. For example, in Infant 1’s recording, the beginning of the separated condition is delineated when a delivery-room nurse reports that she will clean the infant, requiring her to lift the infant away from the mother. The end of the separated condition is marked when the nurse states that she is returning the infant under a blanket on the mother. Both infants had 53 cry segments available for analysis. For Infant 1, 24 cry segments were classified as non-separated, and 29 as separated. Infant 2 had 33 cry segments that were in the non-separated condition and 20 in the separated condition.

Dependent variables: Cry measures
Five acoustic measures of each cry segment were selected as dependent variables for this study: the frequency of the first spectral peak, the duration of the cry segment, the intensity of the first spectral peak, the mean root-mean-square (RMS) intensity of the cry segment, and the standard deviation of the RMS intensity. The five cry measures and their respective definitions are listed in Table 2.

**TABLE 2**

DEFINITIONS OF THE FIVE ACOUSTIC MEASURES OF EACH CRY SEGMENT

<table>
<thead>
<tr>
<th>Cry measure</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>First peak frequency</td>
<td>Frequency of first spectral peak of cry segment from initial point to end point, measured in Hertz and serving as a proxy for fundamental frequency</td>
</tr>
<tr>
<td>Cry duration</td>
<td>Duration of cry segment from initial point to end point, measured in milliseconds</td>
</tr>
<tr>
<td>Intensity of first spectral peak</td>
<td>Intensity of first spectral peak of cry segment from initial point to end point, measured in decibels</td>
</tr>
<tr>
<td>Mean RMS intensity</td>
<td>Mean root-mean-square intensity of cry segment from initial point to end point, measured in volts</td>
</tr>
<tr>
<td>SD RMS intensity</td>
<td>Standard deviation of root-mean-square intensity of cry segment from initial point to end point, measured in volts and representing the overall variability of intensity</td>
</tr>
</tbody>
</table>

*Note. SD = standard deviation.*
An important point needs to be made regarding the inclusion of the frequency of the first spectral peak. Because the delivery rooms were so noisy, it was neither practical nor appropriate to measure the fundamental frequency of each cry segment using pitch analysis techniques. An alternative technique was required to derive an estimate of the main vibratory cycle of the infants’ respective vocal folds. Because the digital recorder captured the audio signal at such a high sampling rate (44.1 kHz), the decision was made to calculate a long-term average spectrum on the cry segments for analysis. This type of spectral analysis provides an average of important frequency features in a signal. These features include the frequency and intensity of the first spectral peak, which for this study was used as a proxy for fundamental frequency and a correlate with vocal fold tension (Goberman & Robb, 1999).

It is also critical to emphasize the three intensity-related measures are highly sensitive to ambient noise. This was particularly true for the cry segments associated with the separated condition for Infant 2.

Identification and coding of cry measures

Coding software

The software program used to identify and code the cry measures was TF32 ("Time-Frequency Analysis for 32-bit Windows") (Milenkovic, 2000). The TF32 program can be used to visualize an audio signal (presented as a waveform). The user can access algorithms built into the software to measure acoustic features of a signal, including frequency, intensity, and duration.

Selection of appropriate cry segment measurements

The complete digital audio signal was viewed in TF32 and the time positions of cry sequences (defined as more than one cry segment in close succession) and isolated cry segments were labeled for future reference. The cry segments identified during this labeling procedure
were copied and made into individual cry segment audio files. Each of these individual cry segment files was then loaded back into TF32 and the five cry measures were calculated and coded using one of three TF32 features or “tools,” which are listed in Table 2.

The duration measure was coded using a label that was applied directly to the waveform. The duration was the length (in milliseconds) between the initial point of the cry segment and the end point. The duration measure was not influenced by the presence of ambient noise in the delivery room—including crosstalk from others in the recording field.

The other four measures, which involved acoustic frequency and intensity information in the signal, were sensitive to ambient noise. In cases in which a portion of the cry segment was overlaid by noise, only the noise-free portion of that cry segment was selected for analysis. The frequency and intensity of the first spectral peak were calculated by a three-step process: (1) the TF32 spectrum function was applied to the cry segment waveform, (2) the long-term average spectrum option was selected, and (3) the first spectral peak was identified and saved for coding. Because of the frequency resolution of the spectrum, the first spectral peak frequencies across all of the cry segments of both infants were categorized into four frequencies, from lowest to highest: 375 Hz, 469 Hz, 563 Hz, and 656 Hz. The mean and standard deviation of the root-mean-square intensity of each cry segment was identified by using a TF32 feature that calculates an overall intensity trace for a waveform; these measures also were saved for coding.

Statistical Analyses

The cry segments of Infant 1 and Infant 2, respectively, were different from each other in terms of delivery room setting, ambient noise level, and position of the infant in both the non-separated and separated conditions. For that reason, it was not appropriate to run an analysis comparing the infants against each other. All of the statistical analyses were limited to
comparing each infant’s cry segments in the non-separated condition to that same infant’s cry segments in the separated condition.

Frequency of the first spectral peak

Given the categorical nature of the first peak frequency cry measure, it was not appropriate to use a $t$ test to compare the values of that measure in the non-separated condition with those of the separated condition. Instead, chi-square tests for independence for each infant were completed to determine whether the frequencies of the first spectral peaks were distributed differently between the non-separated and the separated conditions. The chi-square test of independence is used to determine whether the actual counts (observed frequencies) of one categorical variable are distributed differently across another categorical variable than would be expected by chance (expected frequencies). For this study, a significant chi-square test for independence would suggest that the distribution of peak frequencies for one of the conditions was statistically different than the distribution for the other condition. A non-significant chi-square test would indicate that the frequencies were distributed equally between conditions.

Other cry measures

Each of the other four cry measures was analyzed using an independent-measures $t$ test to determine if the mean value of the measure for the non-separated condition was significantly different than the corresponding mean measure for the separated condition. The cry measures and the statistical test selected for each of them are listed in Table 3.
### TABLE 3
CODING TOOLS AND STATISTICAL ANALYSIS METHODS FOR THE FIVE CRY MEASURES

<table>
<thead>
<tr>
<th>Cry measure</th>
<th>Coding tool</th>
<th>Statistical analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>First peak frequency (Hz)</td>
<td>Spectrum</td>
<td>$\chi^2$ test$^a$</td>
</tr>
<tr>
<td>Cry duration (ms)</td>
<td>Waveform</td>
<td>$t$ test$^b$</td>
</tr>
<tr>
<td>Intensity of first peak frequency (dB)</td>
<td>Spectrum</td>
<td>$t$ test$^b$</td>
</tr>
<tr>
<td>Mean RMS intensity (V)</td>
<td>Intensity trace</td>
<td>$t$ test$^b$</td>
</tr>
<tr>
<td>SD RMS intensity (V)</td>
<td>Intensity trace</td>
<td>$t$ test$^b$</td>
</tr>
</tbody>
</table>

*Note. All five cry measures were coded using TF32 software. Hz = Hertz; ms = milliseconds; dB = decibels; RMS = root-mean-square; V = volts; SD = standard deviation.*

$^a$Chi-square test for independence. $^b$Independent-measures $t$ test.
CHAPTER 3
RESULTS

Both infants: Frequency of the first spectral peak

As mentioned previously, chi-square tests for independence for each infant were completed to determine whether the frequencies of the first spectral peaks were distributed differently between the non-separated and the separated conditions. The chi-square test for Infant 1 was significant, $\chi^2(3, n = 53) = 13.75, p = .003$, indicating that the frequency distribution of frequencies within and between conditions was significantly different than what would be expected by chance. Lower frequencies of first spectral peaks were more likely to occur in the non-separated condition; higher frequencies of first spectral peaks were more likely to occur in the separated condition.

The chi-square for Infant 2 also was significant, $\chi^2(3, n = 53) = 8.80, p = .032$. The distribution of peak frequencies was similar to that of Infant 1: lower peak frequencies occurred when the infant was with the mother and higher peak frequencies occurred when the infant and mother were separated.

The results were consistent. For both infants, the non-separated condition showed a higher distribution of lower peak frequencies and the separated condition showed a higher distribution of higher peak frequencies. The distributions of frequencies for both infants, as well as the percentages within frequencies between the two conditions, are presented in Table 4.
TABLE 4
OBSERVED FREQUENCIES OF FIRST SPECTRAL PEAKS BETWEEN CONDITIONS BY INFANT

<table>
<thead>
<tr>
<th>Condition</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>375 Hz</td>
</tr>
<tr>
<td>Infant 1(^{a})</td>
<td></td>
</tr>
<tr>
<td>Non-separated</td>
<td>11 (84.6)</td>
</tr>
<tr>
<td>Separated</td>
<td>2 (15.4)</td>
</tr>
<tr>
<td>Infant 2(^{b})</td>
<td></td>
</tr>
<tr>
<td>Non-separated</td>
<td>10 (83.3)</td>
</tr>
<tr>
<td>Separated</td>
<td>2 (16.7)</td>
</tr>
</tbody>
</table>

Note. Percentages by frequency are in parentheses. Hz = Hertz.

\(^{a}\)\(\chi^2\) (3, \(n = 53\)) = 13.75, \(p = .003\). \(^{b}\)\(\chi^2\) (3, \(n = 53\)) = 8.80, \(p = .032\).

Infant 1: Other cry measures

Based on the results of the independent-measures \(t\) tests, there were significant differences between the non-separated and separated conditions on three of the four other cry measures. Non-separated cry segments were significantly longer than those of the separated condition, \(t(24.6) = 2.31, p = .030\). The intensity of the first spectral peaks in the non-separated condition was significantly lower than that of the separated condition, \(t(51) = -3.48, p = .001\). The standard deviation of the RMS intensity of non-separated cry segments was larger than the corresponding measure for the separated cry segments, \(t(27.5) = 2.85, p = .008\). There was no
significant difference between the two conditions on the measure of mean RMS intensity, \(t(35.5) = 1.17, p = .249\).

In summary, Infant 1’s cry segments were longer in duration, had less intense first peak frequencies, and were more variable in intensity when with the mother than when separated from her. It is also important to note that the standard deviation of the non-separated cry durations (880 ms) was much higher than that of the separated cry durations (183 ms). This suggests that there was more variability in non-separated cry durations. The results are summarized in Table 5.

<table>
<thead>
<tr>
<th>TABLE 5</th>
</tr>
</thead>
</table>

DIFFERENCES BETWEEN CONDITIONS FOR SELECTED CRY MEASURES FOR INFANT 1

<table>
<thead>
<tr>
<th>Cry measure</th>
<th>Non-separated(^a)</th>
<th>Separated(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(M)</td>
<td>(SD)</td>
<td>(M)</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Cry duration (ms)</td>
<td>977          880</td>
<td>555           183</td>
</tr>
<tr>
<td>Intensity of first peak frequency (dB)(^d)</td>
<td>–61.6       2.7</td>
<td>–58.2        4.1</td>
</tr>
<tr>
<td>Mean RMS intensity (V)</td>
<td>1.11       0.50</td>
<td>0.97         0.29</td>
</tr>
<tr>
<td>SD RMS intensity (V)</td>
<td>0.45       0.32</td>
<td>0.26         0.11</td>
</tr>
</tbody>
</table>

Note. ms = milliseconds; dB = decibels; RMS = root-mean-square; V = volts; SD = standard deviation.

\(^a n = 24.\) \(^b n = 29.\) \(^c Decimals represent adjustments following a significant Levene’s test for equality of variances. \(^d Less negative values mean higher intensity.\)
Infant 2: Other cry measures

The independent-measures $t$ tests revealed significant differences between the non-separated and separated conditions on the three cry measures related to intensity. First, the intensity of the first spectral peaks in the non-separated condition was significantly higher than that of the separated condition, $t(24) = 2.94, p = .007$. Second, the mean RMS intensity of non-separated cries was significantly higher than that of separated cries, $t(51) = 4.79, p < .001$. For both of these measures, the direction of the difference was opposite of the results for Infant 1. However, the significant differences for the cry measures related to intensity are due to the fact that Infant 2 was closer to the microphone during the non-separated condition than during the separated condition. This placement confound explains the results, but makes the comparison between conditions unreliable. Finally, the standard deviation of the RMS intensity of non-separated cry segments was larger than the corresponding measure for the separated cry segments, $t(49.9) = 5.71, p < .001$. Whereas the direction of the difference on this measures matches that seen with Infant 1, the placement confound for Infant 2 makes this statistical result questionable.

Regarding the duration measure, non-separated cry segments were over 200 milliseconds longer than separated cry segments, but this difference was not significant, $t(51) = 1.74, p = .087$. The results are summarized in Table 6.
**TABLE 6**

DIFFERENCES BETWEEN CONDITIONS FOR SELECTED CRY MEASURES FOR INFANT

<table>
<thead>
<tr>
<th>Cry measure</th>
<th>Non-separated&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Separated&lt;sup&gt;b&lt;/sup&gt;</th>
<th>df&lt;sup&gt;c&lt;/sup&gt;</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cry duration (ms)</td>
<td>1410 393</td>
<td>1178 574</td>
<td>51</td>
<td>1.74</td>
<td>.087</td>
</tr>
<tr>
<td>Intensity of first peak frequency (dB)&lt;sup&gt;d&lt;/sup&gt;</td>
<td>–62.9 2.6</td>
<td>–66.8 5.6</td>
<td>24.0</td>
<td>2.94</td>
<td>.007</td>
</tr>
<tr>
<td>Mean RMS intensity (V)</td>
<td>0.49 0.17</td>
<td>0.29 0.11</td>
<td>51</td>
<td>4.79</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>SD RMS intensity (V)</td>
<td>0.21 0.09</td>
<td>0.09 0.06</td>
<td>49.9</td>
<td>5.71</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

*Note. s = milliseconds; dB = decibels; RMS = root-mean-square; V = volts; SD = standard deviation.*

<sup>a</sup>n = 33.  <sup>b</sup>n = 20.  <sup>c</sup>Decimals represent adjustments following a significant Levene’s test for equality of variances.  <sup>d</sup>Less negative values mean higher intensity.
The purpose of this pilot study was to record and analyze the initial cries of two full-term healthy infants in two conditions: with mother and separated from mother. Cries were analyzed in terms of their length (duration), pitch (frequency), loudness (intensity), and the variability of these characteristics. The length of time each infant was with mother was documented, but not controlled. Infant 1 was separated for seven minutes; Infant 2 was separated for 40 minutes. When separated from mother, both infants remained in the delivery room. The type of contact in the non-separated condition also was not controlled. Although the accepted hospital protocol encouraged skin-to-skin contact, Infant 2 was wrapped in a blanket when given to and held by mother. Recordings documented that birthing rooms are busy places and captured the comments of many different people, including family members, nurses, doctors, and other medical personnel. Thus, a notable amount of background noise was present throughout the recordings. Despite this ambient noise, the acoustic analyses of the initial cries of Infant 1 and Infant 2 when they were separated from mother and with mother provided support for the existence of a separation distress cry that is characteristically different from a non-separated cry.

Infant 1

The cry segments of Infant 1 were significantly shorter, less variable, and higher in pitch in the separated condition compared to the non-separated condition. This finding supports the earlier speculation of Christensson et al. (1995) that such short bursts of vocalization indicated a distress cry when infants were separated from their mothers. The current study extends the work
of Christensson et al. as it provides a more detailed acoustic analysis of the onset time, duration, and intensity of each cry sequence in each of the conditions.

Results for Infant 1 suggest that even at birth there was significant communication occurring between mother and newborn. Different stimuli (when with mother and when separated from mother) produced different responses as measured by this infant’s cries. When with mother, cries were longer and more variable. This may suggest a more relaxed physiological state in the infant in response to, and readiness for, ongoing touch (skin-to-skin or not) from mother. In contrast, when separated from mother, the shorter and higher pitch cry bursts can be interpreted as reflecting a dramatic change in the infant’s physiological state, characterized by increased tension and stress. This increased tension and stress in the infant’s respiratory and laryngeal musculature resulted in increased air pressure through the vocal mechanism and consequent higher pitch. The increased tension also could suggest that the infant had less control in manipulating his cry under duress. Further, it could explain the rapid audible inhalation documented immediately after each cry segment, additional evidence of this infant’s distress when separated from mother.

It would be logical to expect increased intensity in the cry of an infant under distress when separated from mother. However, there was no statistically significant difference in cry intensity between the separated and non-separated conditions for Infant 1. This finding for Infant 1 can be explained by the amount of background noise documented in the delivery room. Nonetheless, the documented overall differences for this infant’s cries when separated from mother and not separated, support the existence of a discernible distress cry in the separated condition.
Infant 2

The cry segments of Infant 2 were significantly higher in pitch, softer, and less variable in intensity when he was separated from mother. There was no significant difference in the duration of cry segments in the separated and non-separated conditions, although the cry segments in the separated condition were noticeably shorter. The finding of no significant differences for duration could reflect the prolonged time Infant 2 was separated from his mother. The stress experienced by this infant during this prolonged separation may have influenced the duration of cry segments when Infant 2 was reunited with mother. In other words, when reunited with mother, Infant 2 remained stressed for a period of time, i.e., it took a longer period of time to calm him from his separation experience, and this continuing stress was reflected in the duration of cry segments even though he was now held by mother. The decreased intensity of the cry segments in the separated condition was of interest and counterintuitive. This appeared due to the fact that Infant 2 was further away from the microphone during the separated condition than during the non-separated condition. This placement confound explains the results, but makes the comparison between conditions unreliable.

The presence of a separation distress cry in Infant 1 and Infant 2

A comparison of cry segment characteristics for Infant 1 when separated and not separated from mother showed distinct acoustic and temporal differences between the two conditions. These differences in the separated condition were interpreted as indicators of a separation distress cry. A comparison of cry segment characteristics for Infant 2 under the two conditions identified a similar but less distinct pattern, particularly with regard to increased pitch and decreased variability of intensity in the separated condition.
These results suggest that infants communicate through cry behavior immediately after birth, and equally importantly, different stimuli create different cries in newborns. Goberman and Robb (1999) suggested that acoustic differences in infant cries could reveal differences in the amount of stress an infant experiences. Golub and Corwin (1982) and Gustafson et al. (2000) have focused on the vital diagnostic data that may be derived from newborn infant cries. Previous research with older infants (Michelsson & Wasz-Höckert, 1980) has identified differentiated cries in response to hunger, pain, and discomfort.

Results of the current study support the findings of Christensson et al. (1995) and have important implications for mother-neonate interaction immediately after birth. The most primal type of communication infants have is their cry. If the difference in cry segments discovered in this small sample is supported by further research with increased numbers of infants, results will confirm that infants communicate immediately after birth much more than has been previously identified. This would imply that typical newborns can modulate their communicative attempts with parents, particularly the mother, and that communication involves learning that begins immediately after birth.

Communication requires a dyad. One individual must encode and send a message while another individual must receive and decode that message. Mothers kept in close contact with their infants have been found to more easily understand the needs of the infant (Crenshaw, 2007). The use of a distress cry by the neonate when separated from mother is a clear signal to both mother and birthing staff to reunite mother and baby as quickly as possible. Ideally, each mother-infant dyad should experience sustained skin-to-skin contact for a minimum of 90 minutes, until the baby has completed its first feeding (American Academy of Pediatrics, 2005). The importance of sustained skin-to-skin contact for mother and baby and the many positive
effects of sustained skin-to-skin contact following birth have been documented (Anderson et al., 2003; Montagu, 1971) and promoted by the American Academy of Pediatrics (2005). Further, the guidelines established by the Academy document that skin-to-skin contact is the optimal source of heat for the baby and that the non-separated condition should be the norm rather than the reverse.

In the current pilot study, both infants were born in the same hospital. However, the afterbirth protocol that was followed differed notably for both babies. The delivery protocol for Infant 1 largely adhered to the guidelines advocated by the American Academy of Pediatrics (2005). The delivery protocol for Infant 2 did not. If this inconsistency in compliance with best practice is found in other birthing centers, there is a clear need for regular education for delivery staff and expectant mothers regarding the importance of sustained skin-to-skin contact immediately following birth. This education needs to acknowledge the importance of skin-to-skin contact and the newborn infant’s communicative behavior through his or her first cries.

Conclusions
The following conclusions can be drawn from this pilot study:

1. In the two infants studied, there was a distinctly different cry when the infants were separated from mother immediately after birth and this cry appeared to be one of distress. These findings complement existing data that demonstrate the adverse effects of separation on the newborn’s heart rate, body temperature, glucose metabolism, and respiratory rate.

2. To minimize physiological distress, newborn infants need to experience sustained skin-to-skin contact with mother during the first few hours of life.
3. Newborn infants appear able to use differentiated cries to communicate immediately following birth.

4. Physicians and delivery staff may require regular education to comply with the guidelines established by the Academy of Pediatrics regarding sustained skin-to-skin contact following birth.

5. Confirmation and expansion of the findings of this study could serve as a motivating factor in preventing the separation of mothers and newborns immediately after birth.
REFERENCES


