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PERCEPTUAL JUDGMENTS AND ACOUSTIC CHARACTERISTICS OF PAIN CRIES OF NORMAL AND HYPERBILIRUBINEMIC INFANTS

A Thesis

Presented for the

Master of Arts

Degree

The University of Tennessee, Knoxville

Leslie Gwen Petcher

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DEDICATION

This thesis is dedicated to my family, Shelly, Phyllis, Melissa and Glenn, who have spent the last 23 years loving, encouraging, and guiding me. My parents have always stressed the value of a good education, hard work, and believing in myself. If I said "thank you" and "I love you" every day for the rest of my life, it would not be sufficient. I will always be thankful for such a wonderful and loving family, who are also such wonderful friends.

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Appreciation is also extended to the parents and their infants who participated in this study. Their confidence and trust made the work much easier for me.

ABSTRACT

Fourteen full term (36-41 weeks gestational age) normal nursery infants (28-118 hours old) served as subjects in this study. Seven normal infants with low (below 8 mg/dl) serum bilirubin concentration and seven infants with high (above 12 mg/dl) serum bilirubin concentration formed the two groups under investigation.

A pain cry, elicited by a heelstick, was tape recorded while a blood sample was taken. The tape recordings were presented in their entirety to a panel of five nurses from the newborn nursery at The University of Tennessee Medical Center. The nurses rated their perceptions of the infants' cries by using a 1-5 point rating scale. The perceptual parameters included: urgent to not urgent, pleasing to grating, healthy to sick, soothing to arousing, piercing to not piercing, comforting to discomforting, aversive to nonaversive, and distressing to not distressing. An overall profile of the bilirubin infants' cries was seen from the ratings of the nurses. The bilirubin cries were more urgent, grating, sick, arousing, aversive, and distressing than the normal infants' cries. The cries of the bilirubin infants were also rated significantly more piercing than the cries of normal infants. The parameter of piercing was thought to be the parameter most closely related to the acoustic characteristic of pitch.

The 14 mothers of the infants identified the cry of their infant from the cries of two other infants. Seventy-one percent of the mothers identified their infant's cry correctly from the cries of others. No correlation was found between the amount of time the mother had spent with her infant and the ability to correctly identify her infant's cry. It was speculated that the ability to identify cry might be hormonally mediated or the result of some intrauterine imprinting.

The 14 cries were analyzed on both narrow and wide band spectrograms according to: cry latency (msec), 2nd pause (msec), minimum Fo for the first and second cry segments (Hz), peak Fo for the first and second cry segments, (Hz), the presence of continuity in the first and second cry segments, and the presence of furcation in the entire cry signal. The feature of fraction was present in all of the hyperbilirubinemic infant cries, but was not present in any of the normal infant cries. Furcation was identified when a split in the Fo was seen resulting in small branching of the Fo.

Correlations were examined between the physical state of the infant at the time of the recording and the acoustic characteristics. A statistically significant correlation was determined between cry latency and the infants' state of wakefulness.

Based on the results of technical and interactive evaluation of the infants' cries, the utility of cry analysis

might prove to be a powerful tool for early intervention. Cry analysis could be used in the evaluation of subclinical and clinical repercussions of hyperbilirubinemia and other neonatal disorders. Even at a moderate serum bilirubin level (8-12 mg/dl), which traditionally has not been implicated as a cause of overt pathology, infants may experience subacute or subclinical changes that might indicate a need for ongoing evaluation.

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CHAPTER I

INTRODUCTION

The first investigation of the characteristics of infant cry was that reported by Sherman in 1927. This study dealt with the ability of untrained listeners to identify an infant's emotion based on perceptual quality. Since that time investigators have claimed that an infant's health can be estimated by the perceptual quality of the cry. Truby and Lind (1965) indicated that perceptual analyses of infant cry are used by clinicians as "supplementary criteria for the evaluation of neurological function, in general, and specifically of respiratory function." Truby and Lind (1965) further state that purely perceptual approaches to the diagnosis of an infant are not valid and cannot point reliably toward one specific clinical syndrome. Although perceptual information may not be clinically useful alone, when paired with acoustical analysis one can pinpoint the dimensions of the cry which associate perception with that of a sick infant (Lester, 1985).

The spectral and temporal patterns of the neonatal and infant cry have been the subjects of considerable investigation (Fisichelli and Karelitz, 1963; Ringel and Kluppel, 1964; Truby and Lind, 1965; Wasz-Hockert, Lind, Vuorenkoski, Partanen and Valanne, 1968; Sirvio and Michelsson, 1976; Golub and Corwin, 1982; Michelsson,

Jarvenpaa, and Rinne, 1983; Murry, Hoit-Dalgaard, and Gracco, 1983; Lester, 1987). Much of this research has examined the feasibility of infant cry in the differential diagnosis of medical problems. After Lennberg (1967) and Liberman (1967) suggested that cry was at least partially controlled by the central nervous system (CNS), researchers began to examine cry characteristics of infants with various CNS disorders.

The research examining cry characteristics and CNS disorders have included such abnormalities as severe oxygen deficiency at birth (Michelsson, 1971) and hydrocephalus (Wasz-Hockert, Koivisto, Vuorenkoski, Partanen, and Lind, 1968). Vuorenkoski et al. (1976) found that the spectral characteristics of the cry sound could be used to support the diagnosis of a wide range of CNS disorders. In particular, an unusually high pitch cry sound is frequently attributed to an infant with neurologic involvement (Zeskind, 1978, 1982). This high pitch cry has been associated with such neurologic disorders as hydrocephalus, meningitis and cerebral irritability (Illingworth, 1955).

A disorder that is related to CNS function and remains a threat to infants is neonatal hyperbilirubinemia (see Appendix A). Hyperbilirubinemia is considered the most common problem experienced by the full term infant during the neonatal period (Osborn, Reiff, and Bolus, 1984). A complication of hyperbilirubinemia is bilirubin encephalopathy or kernicterus, which is a yellowish staining of the nuclei in the brain

(Frank, Turner, and Merenstein, 1985). A high pitched or shrill cry has sometimes been described as one of the earliest signs of kernicterus in a newborn infant (Wasz-Hockert, Koivisto, Vuorenkoski, Partanean, and Lind, 1971). Wasz-Hockert et al. (1971) described acoustic characteristics found in the cries of infants with hyperbilirubinemia, including latency, duration, minimum pitch, maximum pitch, furcation, and bi-phonation (see Appendix B). However, this study focused strongly on the characteristic of furcation and did not stress the importance of differences in other acoustic characteristics when compared to a normal group of infants.

The serum bilirubin level which may cause medical complications (the concentration in milligrams of bilirubin per deciliter of plasma or serum) is still under investigation. According to Cashore (1983), treatment for physiologic hyperbilirubinemia or jaundice in full term infants does not begin until the bilirubin level exceeds 15 mg/dL. Other investigators have suggested that neurologic effects have been seen when bilirubin levels were lower. Lendhardt et al. (1984) demonstrated changes in the auditory brainstem response (ABR) waveform in some infants whose serum bilirubin concentrations were only 11 mg/dL. Ahlfors (1986) suggested that more thorough investigation was necessary to determine if subtle neurologic injury had occurred in the infants with serum bilirubin concentrations above 11 mg/dL.

Statement of Purpose

Research has shown that infant cry analysis can identify and differentiate known healthy newborn infants from infants who have confirmed CNS or neurologic involvement. The purpose of this study was to investigate perceptual judgement and the acoustic characteristics of the cries of healthy newborn infants and newborn infants with serum bilirubin concentrations of 12.0 mg/dL and above.

The research questions to be tested in this study were:

1. Can a panel of nurses perceptually judge a difference between the cries of normal infants and infants with hyperbilirubinemia using the following parameters?
   a) urgency
   b) pleasing quality
   c) healthy
   d) soothing quality
   e) piercing quality
   f) comforting quality
   g) aversive
   h) distressing
2. Can mothers identify their infant's cry by listening to the cries of a group of infants?
3. Is there an acoustic difference between the cries of normal infants and infants with hyperbilirubinemia using the following acoustic parameters?
   a) latency (msec)
   b) minimum fundamental frequency (Hz)
   c) peak fundamental frequency (Hz)
   d) 2nd pause (msec)

e) occurrence of continuity (present or absent)

f) occurrence of furcation (present or absent)

CHAPTER II

REVIEW OF THE LITERATURE

Crying is a sequence of behaviors all infants exhibit. For the neonate, crying is the primary mode of expressing and communicating basic needs (Lester, 1985). Crying is not only a social behavior, it is an acoustical event that contains information about the function of the central nervous system (Michelsson, Sirvio and Wasz-Hockert, 1977).

The initial research on infant cry investigated the infant's communicative intent and emotional state. Sherman (1927) assessed the ability of graduate students, student nurses, and third year medical students to correctly match the stimulus situation with the cry (i.e., hunger, anger, pain, and fear). The observers attempted to identify the four conditions by specifying the "emotion" they believed they heard. This procedure resulted in the listing of 12 different "emotions." Very little relationship was noted between the judgments and the nature of the stimuli. The role of experience with infant cry was not addressed in Sherman's study. Although the listeners were nurses, they may not have been infant caregivers. While the fact that experience was not controlled for within the listeners, this may have biased the perceptual task.

Wasz-Hockert et al. (1964) attempted to correlate infant vocalizations with cry evoking stimuli. Twenty-four infants

were divided into four groups and their cries were recorded under four different situations: (1) at birth, (2) hunger, (3) pain, and (4) pleasure. The pleasure vocalization was more vegetative noises than a cry. The age of the subjects ranged from birth to 8 months. Eighty nurses listened to the random presentation of the 24 cries (sample length 5.0-17.7 seconds) and correctly identified cry type 67% of the time.

Driscoll and Freudenberg (1978) asked 42 college students to determine how strongly they felt towards the cries of 6 normal infants and 6 Down Syndrome infants. The results of this study indicated that the listeners could discriminate between cries of normal and Down Syndrome infants. The cries of the normal infants, however, were rated as being more unpleasant. The more unpleasant cries were also thought to indicate a need of more immediate attention.

Friedman et al. (1981) asked mothers to use 5 rating scales to rate the cries of "at risk" infants. The mothers rated the moderate at risk infants as having the most urgent cry and males were rated as having more aversive cries than females. Freudenberg et al. (1978) asked women with varied amounts of experience with infants to rate the cries of normal and Down Syndrome neonates. The normal infants were rated as in greater need of attention and having more unpleasant cries than the Down Syndrome infants.

Muller et al. (1974) examined mothers responses to cries of eight infants 3 to 5 months of age. Each mother responded

to the cries of her own infant and infants belonging to the other mothers in the study. Three types of cries were elicited: (1) pain, (2) startle, and (3) hunger. The results of this investigation suggested that mothers cannot successfully match cry samples with cry evoking conditions. Further, no advantage was found when mothers judged cries produced by their own infant. It was interesting to note that mothers had very little difficulty in recognizing which cry samples were produced by their own infant but not the cry evoking stimulus.

Illingworth (1955) and Formby (1967) have suggested that mothers can easily identify their infants cries from the cries of other infants. Illingworth (1955) reports that mothers in a maternity hospital claim they were awakened whenever their own infant cried but did not respond to the crying of other infants. Formby (1967) recorded 31 pain cries from fullterm infants ranging in age from 14-144 hours. When infants were less than 48 hours old, 52% of the mothers correctly identified their own infant's cry. When listening to infants older than 48 hours, 100% of the mothers recognized their own infant's cry.

Murry et al. (1975) also examined the abilities of mothers to correctly identify their infant's cry from the cries of other infants. Eight mothers were asked to identify all of their infant's cries from a total of 768 cries produced by eight infants, ranging in age from 3 to 5 months. The cries

were elicited in one of three ways: (1) pain, (2) startle, and (3) hunger. The mothers correctly identified 91% of their infants' cries. Results of this study also support the premise that experience with the infant enhances the ability to identify the infant cry as her own.

A number of conclusions can be drawn from the results of perceptual investigations of infant cry. First, Muller et al. (1973) concluded that infant cry actually carries very little information regarding emotion for the caregiver and therefore the emotional state of the infant cannot be identified through auditory perception alone. Secondly, mothers do have the ability to correctly identify their infants cry from the cries of other infants; however, it is difficult for mothers to accurately identify the cry eliciting stimulus used to evoke a specific cry (i.e., hunger, pain, fear, etc.) Lastly, the amount of time the mother spends with the infant is a factor for careful consideration. Only mothers with close contact over a certain length of time were able to identify their infant's cry.

Listeners' perceptions and feelings regarding the sound of the infant cry is an important aspect to consider in cry analysis studies (Lester, 1985). Differences in the acoustic characteristics reflect how a person feels about the status of the infant and therefore what kind of immediate care the infant requires. This kind of information can be useful

clinically. Through acoustic analysis one can validate caregiver and parental perceptions.

A second method for investigating infant cry is through acoustic analysis. Auditory analysis of infants' cries have led to an increase in understanding infants' early communication (Karelitz, Karelitz, and Rosenfeld, 1960; Karelitz and Fisichelli, 1962; Wasz-Hockert, 1967; Wasz-Hockert et al., 1963, 1958; Ostwald, Phibbs and Fox, 1968; Lind et al., 1965).

Thoden and Koivisto (1980) investigated the acoustic characteristics of 38 normal healthy full term infants, aged birth to 6 months, in an effort to create normative spectrographic pain cry data. The infants met strict criteria for their inclusion in this study with regard to birth weight, gestational age, and Apgar score. The pain cries were recorded at 1 day, 5 days, 3 months and 6 months of age for a total of 140 cry samples. The pain cry was induced by pinching the infants arm. The following cry features were noted as follows: the mean cry latency periods among different age groups fell between 1.2 and 1.4 seconds. The first cry signal was significantly longer in duration than the second and third cry signals across all age groups. The maximum of peak Fo ranged from 400-2250 Hz for the first cry segment and 400-1850 Hz for the second cry segment, including the shift, across all age groups. Shift is defined as an abrupt upward or downward movement of the fundamental

frequency (Michelsson, 1971). The minimum Fo ranged from 190-770 Hz for the first cry segment and 130-550 Hz for the second cry segment, including the shift, across all age groups. A shift in the cry signal occurred in 14-38% of the cries with no statistically significant differences seen between age groups. The continuity of the cry signal was evaluated, and, across all age groups, the first cry signal was significantly less continuous when compared to the second and third cry signals. The first cry was continuous 32-66% of the time and the second and third cries were continuous 68-92% of the time. Double harmonic breaks occurred quite frequently across all age groups as did vibrato. Glottal roll was seen in 18-30% of the first cry signal at all ages. Some rarely seen cry features (ie. glide, bi-phonation, and furcation) which are usually regarded to be pathological, were rarely seen in this population of infants. Glide was seen in one infant at age 3 months and bi-phonation and furcation were seen in one signal each at 1 and 5 days of life.

Sirvio and Michelsson (1976) found the average cry latency in normal healthy infants to be 1.2 seconds. They also determined that cry latency is a good indicator in evaluating abnormalities in cries of infants with disorders, especially those affecting the central nervous system (CNS). Cry latency tends to increase when abnormalities exist (Wasz-Hockert, 1968). Lester and Zeskind (1978) and Prescott (1975) found the duration of the first three cry segments in normal infants

to range from 2.6-5.2 seconds. This range was found to decrease when abnormalities were present (Ringel and Kluppel (1964).

Kittel and Hecht (1977); and Flatau and Gutzmann (1906) report only the mean of the maximum Fo for the entire cry rather than values reported for each cry segment. Tenold et al. (1974) reports only the median of the maximum Fo as 620 Hz, which does agree with a median value of maximum Fo reported by Thoden and Koivisto. Agreement is also seen when comparing minimum Fo between studies. Wasz-Hockert et al. (1968) report a mean minimum Fo of 410 Hz for infants under 1 month of age. Michelsson (1971) reported a median minimum Fo of 390 Hz.

Wasz-Hockert et al. (1967, 1968, 1971) examined the spectrograms of hunger, pain, and pleasure cries of Down Syndrome infants, infants with brain damage, and infants with hydrocephalus. They reported that the cries do contain certain diagnostically valuable information. Babies with brain damage needed more stimulation to cry than did normal infants. There were longer cry latencies and shorter overall cry lengths demonstrated by the brain damaged infants (Wasz-Hockert, 1968). Wasz-Hockert (1968) also found that "defective" infants cried more, not less, as they got older.

High pitched, "shrill" cries have often been associated with diseases involving the brain. With advances in cry research, it has been shown that pitch is not the only

indicator of pathology in infants. Michelsson (1971) studied 310 newborn infants and found that the cry of the underweight full term infants closely resembled the cries of normal birth weight full term infants. Michelsson et al. (1983) concluded that gestational age of an infant should be taken into consideration in cry analysis. Michelsson et al. (1971) also states that when infants reach 38 weeks gestational age, their cries become very similar to the cries of full term infants.

Lester (1976) compared the cries of 12 normal and 12 malnourished infants. He found the malnourished infants had a longer first cry segment, higher overall pitch, lower amplitude, more arrhythmias, and longer latency between cry segments. These findings are similar to those infants with brain defects.

The features of bi-phonation, glide and furcation are thought to be found mainly in the cries of abnormal infants. The cries of infants with asphyxia and meningitis exhibit bi-phonation and glide (Michelsson, 1971; Michelsson et al., 1977; Juntunen et al., 1978).

Acoustic features of the cries of 45 newborns with hyperbilirubinemia were studied (Wasz-Hockert et al., 1971). The most abnormal segment of each cry was selected for analysis. The mean of the maximum Fo was 2120 Hz, where the mean of the minimum Fo was 960 Hz. A common descriptor used when discussing the cries of hyperbilirubinemic infants is a "high pitched" cry. Bi-phonation occurred in 49% of the cries

and furcation in 42%. Furcation has been evident only in the cries of infants with hyperbilirubinemia.

When investigating hyperbilirubinemia, it is unclear at what level or concentration of serum bilirubin causes change in the infant to occur. Vohr et al. (1988) studied two groups of hyperbilirubinemic infants, those with serum bilirubin concentrations <8mg/dl (low) and those infants with serum bilirubin concentrations 10-12 mg/dl (moderate). The results showed that the auditory brainstem response of infants in the moderate group had significantly longer overall latencies and interpeak latencies. Although these differences were statistically significant, they may not be clinically significant. Results of the acoustic cry analysis revealed the moderate group had greater percent phonation and greater variability in the first formant then did infants in the low bilirubin group. Increased variability of the Fo has also been documented by Wasz-Hockert (1971) in infants with hyperbilirubinemia. Various differences can be noted between the subjects in the Vohr et al. (1988) and Wasz-Hockert (1971) studies: (1) the range of bilirubin concentration of Vohr's subjects was 10-12 mg/dl while the subjects of Wasz-Hockert had a mean bilirubin concentration of 16.3 mg/dl; and (2) Wasz-Hockert evaluated the presence of furcation and Vohr did not. Overall, a complete evaluation of acoustic characteristics present in the cries of infants with hyperbilirubinemia does not exist.

Because changes have been seen in the acoustic characteristics of the cry and the ABR when only moderate bilirubin concentrations were present, it is crucial to determine a level at which serum bilirubin becomes dangerous and in need of medical intervention. Vohr et al. (1988) discusses the possible relationship between moderate bilirubin levels and changes in the ABR and acoustic characteristics of the infant cry. This, however, was only speculation and was not documented through thorough acoustic analysis of other acoustic characteristics in the infant. Although it has been shown that changes occur in the brainstem function of infants with hyperbilirubinemia (Vohr et al., 1988; Ahlfors, 1986; Wennberg et al., 1982; and Perlman et al., 1983), it is not yet possible, with the information from studies to date, to identify a critical level of bilirubin concentration which cause changes in the infant cry.

CHAPTER III

METHODS

Subjects

Fourteen full-term (36-41 weeks gestational age), normal nursery infants 28 to 118 hours old, served as subjects in this study. All subjects were patients in the Newborn Nursery at the University of Tennessee Medical Center, Knoxville. The subjects met the following selection criteria: pregnancy uncomplicated, delivery uncomplicated, birth weight normal for gestational age, absence of congenital anomalies, and initially normal newborn screening physical examination. Seven normal infants with low serum bilirubin concentration (below 8 mg/dl) and seven infants with high serum bilirubin concentration (12 mg/dl and above) formed two subject groups. Table 1 includes the bilirubin concentration, state of wakefulness, age at test in hours, gestational age, and birth weight for each of the infants. The mean state of wakefulness for the normal group was 3.14 and a mean of 1.70 was found for the bilirubin group. The mean gestational age for each group was quite similar: 39.4 for the normal group and 38.6 for the bilirubin group. The mean birth weight for each group was also quite close: 3318 grams for the normal group and 3233 grams for the bilirubin group. Although these groups were not matched for gestational age and birth weight, the mean values were similar.

Table 1. Subject Profiles of Bilirubin Concentration, State of Wakefulness, Age at Test in Hours, Gestational Age, and Birth Weight.

	SUB	PHOTO-TX.	BILI (MG/DL)	STATE	AGE IN HOURS	GA WKS	BW GR
NORMAL GROUP	1	--	7.1	5	39	37	3324
	2	--	6.4	5	44	41	3279
	3	--	6.0	2	28.5	40	3827
	4	--	7.3	4	42.5	39	3019
	5	--	6.8	1	37	37	2910
	6	--	7.2	1	47.5	41	3522
	7	--	6.2	4	45	41	3345
		$\bar{X}$ =	6.71	3.14	40.5	39.4	3318
		RANGE =	6.0-7.3	1-5	28.5-47.5	37-41	2910-3827
BILIRUBIN GROUP	8	++	13.5	1	34	40	3440
	9	++	12.1	1	46	36	2590
	10	++	14.3	1	69	36	224
	11	++	11.8	3	103	39	3523
	12	++	12.2	1	43.5	40	3510
	13	++	13.4	3	59	40	3714
	14	++	11.6	2	35	39	3610
		$\bar{X}$ =	12.7	1.70	55.6	38.6	3233
		RANGE =	11.6-14.3	1-3	34-103	36-40	2247-3714

Bilirubin Determination Method

Blood samples for the determination of bilirubin levels from each infant, at time intervals set by the physician, were taken to accurately monitor the infant's condition. The bilirubin determination method used by the University of Tennessee Medical Center laboratory is the Jendrassik-Grof Bilirubin Test, a reagent system which measures total bilirubin in serum or plasma. This qualitative method determines the bilirubin levels in serum on the basis of the ability of the bilirubin to couple with the stabilized diazonium salt of 24-dichloroaniline, forming azobilirubin.

Collection of Samples

The entire pain cry of each infant was tape recorded while a blood sample was taken by a laboratory technician at the hospital. One recording from each infant is considered sufficient because Ringel and Kluppel (1964) determined that specific acoustic characteristics of a single infant's cry are stable and indicative of crying over the time sampled for an individual neonate. Each infant, within its crib, was taken to a quiet room and placed in the supine position with one foot well exposed for the heelstick and blood test. The tape recording apparatus was then placed in the crib with the infant, as shown in Figure 1.

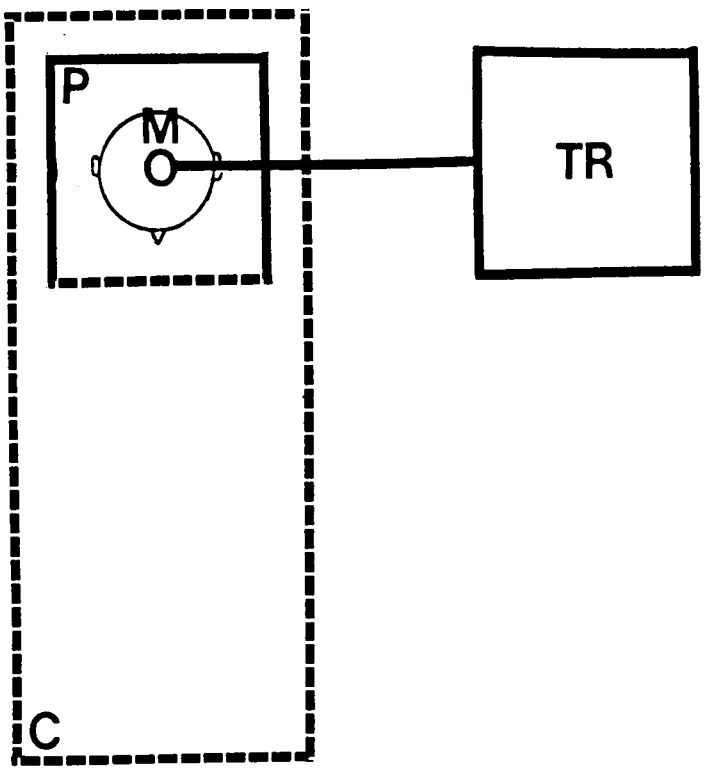


Figure 1: Block diagram of recording apparatus.

Key: M=Microphone
TR=Tape Recorder
C=Crib
P=Plexiglass Box
TR=Tape Recorder

The stimulus used to induce the pain cry was a "heelstick." The word "now" was announced by the investigator at the time the infant received the heelstick. The infant's pain cry and the word "now" were recorded on a Pioneer reel-to-reel tape recorder (model RT-1011L) through a Unisphere I Dynamic microphone (model 5655D) at 12 inches from the infant's mouth. The investigator stood 24 inches from the microphone. The microphone was mounted on the plexiglass box, thereby maintaining a constant recording distance from the infant and the investigator. The pain cry has been reported as the most stable cry of infants because it is the most intense cry produced (Ringel and Kluppel, 1964; Truby and Lind, 1965; Michelsson, 1980.)

The behavioral state of each infant was determined by the investigator immediately before the blood sample and tape recording were obtained. The five possible behavioral states used were determined by Prechtl (1974) and are described in Appendix C. Prechtl found these states to be easy to determine from each infant. The state of wakefulness of the infant at the time of the tape recording is important because differences in the cry latency occur if the stimulus is applied while the child is deeply asleep or awake (Michelsson, 1980). The states of the infants' wakefulness ranged from 1-5 with a mean of 3.14 for the normal infant group and a mean of 1.7 for the hyperbilirubinemic group.

Perceptual Training and Judgments

A panel of five nurses (two registered nurses, two licensed practical nurses, and one nurse practitioner), who were full time staff in the Newborn Nursery, judged the 15 infant cries on eight 1-5 point rating scales proposed by Zeskind and Lester (1978). (Appendix D). The eight parameters include urgency, pleasing, healthy, soothing, piercing, comforting, aversiveness, and distressing. The 1-5 point scale was constructed with 1 being the most positive of the continuum and 5 being the most negative. The 14 cries were played in a random order (Pioneer, model RT-1011L). Care was taken to provide adequate time for all nurses to make their judgments. One of the 14 infant cries was randomly selected and played a second time to evaluate the reliability of the nurses judgments. Thus, the panel judged a total of 15 cries.

The panel of nurses were trained in the use of the perceptual rating scales. Two infants' cries from the pilot study were used for the listeners. The panel was considered to be trained when the nurses felt comfortable using the rating scales. The actual form of the rating scales each nurse was given (one for each infant cry presented) appears in Appendix D.

Mother's Infant Identification

The 14 mothers of the 14 infants attempted to identify their infant's cry. Each mother was presented with three tape recorded 10 second infant pain cry samples through Koss (model K/6A) headphones. The three cries included: (1) a healthy newborn infant pain cry, (2) the pain cry of an infant with an elevated serum bilirubin level, and (3) the mother's own infant. The three cries were presented in a random order. Each mother selected one of the three cries as their infant's cry. Prior to the parental identification, each mother was interviewed using the five questions in Appendix E to determine the mother's familiarity with her infant's cry.

Acoustic Analysis of Infant Cry Samples

The 14 infant cries were analyzed with a DSP Sona-Graph 5500 (Kay Elemetrics Corp.). A wide band spectrogram was used to analyze cry latency and duration of second pause in milliseconds (msec). A narrow band spectrogram was used to analyze minimum Fo and peak Fo in Hz. The presence or absence of cry continuity in the first and second cry segments and the presence of furcation was determined by auditory and visual inspection of the wide band and narrow band spectrographs.

Calibration

A 20 second 1000 Hz calibration tone was tape recorded and monitored with a Data Precision frequency counter (model 5740)

throughout the experiment. The frequency remained constant at 1000 Hz. This insured accurate recordings of frequency and duration.

CHAPTER IV

RESULTS

Analysis of Perceptual Data

Reliability. To evaluate the reliability of the panel of nurses, one infant's cry was presented to the panel twice. The nurses' average responses and percent agreement of the two recordings are presented in Table 2. The percent agreement was high. Five of the parameters had 100% agreement, one parameter each had 96%, 95%, and 91% agreement. One parameter had a percent agreement of 77%. The judgments were considered reliable for the study.

Experimental questions. Means and standard deviations for the nurse's perceptual judgments for the normal and bilirubin groups are presented in Table 3. The normal infants had better ratings (lower mean score) than the bilirubin group with the exception of parameter 3.

Multivariant analyses of variance were performed to determine if statistically significant differences existed among the nurses' judgments of eight perceptual parameters when listening to the cries of the two groups of infants. The nurses' judgments of piercing quality were significantly different for the cries of the normal healthy infants and the infants with hyperbilirubinemia. The perceptual parameter of

Table 2. Nurse's Mean Perceptual Judgments For the Infant's Cry Recording Presented Twice. Using 1-5 Point Rating Scales and Eight Perceptual Parameters. P1=Urgency. P2=Pleasing. P3=Healthy. P4=Soothing. P5=Piercing. P6=Comforting. P7=Aversiveness. P8=Distressing. 1=Most Positive. 5=Least Positive.

PRESENTATION NUMBER	P1	P2	P3	P4	P5	P6	P7	P8
15 A	4.4	4.2	2.0	4.4	4.6	4.4	4.4	4.2
15 B	4.4	4.2	2.6	4.4	4.4	4.0	4.4	4.0
DIFFERENCE	0.0	0.0	-0.6	0.0	+0.2	+0.4	0.0	+0.2
PERCENT AGREEMENT	100%	100%	77%	100%	96%	91%	100%	95%

Table 3. Means and Standard Deviations For The Nurse's Perceptual Judgments of The 15 Infant Cry Recordings Using 1-5 Point Rating Scales and Eight Perceptual Parameters Between Normal and Hyperbilirubinemic Infants. P1=Urgency. P2=Pleasing. P3=Healthy. P4=Soothing. P5=Piercing. P6=Comforting. P7=Aversiveness. P8=Distressing. 1.0=Most Positive. 5.0=Least Positive.

	N		P1	P2	P3	P4	P5	P6	P7	P8
NORMAL GROUP	7	$\bar{X}$ =	3.31	3.57	2.42	3.74	3.08	3.51	3.11	3.14
		SD =	0.90	0.52	0.24	0.42	0.52	0.48	0.64	0.48
		RANGE =	1-5	2-5	1-4	1-5	1-5	2-5	1-5	2-5
BILIRUBIN GROUP	7	$\bar{X}$ =	3.72	3.87	2.40	4.02	3.82	3.80	3.75	3.52
		SD =	0.69	0.43	0.30	0.24	0.57	0.40	0.63	0.46
		RANGE =	1-5	2-5	1-4	2-5	1-5	1-5	1-5	1-5

piercing was statistically significant at the 0.05 alpha level (F=6.73). F values for the eight perceptual parameters are presented in Table 4. No statistically significant differences existed among nurses' judgments of the remaining seven perceptual parameters.

The results of these tests for significance provided an affirmative answer to research question 1. There was a statistically significant difference between groups when nurses judged the piercing quality of cries recorded from normal and hyperbilirubinemic infants.

Mother's Identification of Infants

The ability of mothers to correctly identify their infant's cry from the cries of two other infant's was 71.4%. This percent value is well above the calculated level of chance. Mothers who identified another infant's cry as that of her own always selected the cry of an infant similar in nature to her own infant (i.e., healthy or hyperbilirubinemic).

The responses to individual items on the mother's questionnaire (Appendix E) were not statistically analyzed; however, the results of the mother's ability to identify her infant's cry from the cries of other infants was statistically treated. A contingency coefficient (C) was determined to examine a correlation between mother's ability to correctly identify her infant's cry and the number of hours the mother

Table 4. F values of Eight Perceptual Parameters (P1=urgency, P2=pleasing, P3=healthy, P4=soothing, P5=piercing, P6=comforting, P7=aversiveness, and P8=distressing) for Normal and Hyperbilirubinemic Infants.

PERCEPTUAL PARAMETER	F VALUE	dF	P < 0.05
P1	1.00	1	0.33
P2	1.50	1	0.24
P3	0.04	1	0.84
P4	2.52	1	0.13
P5	6.73	1	0.02
P6	1.55	1	0.23
P7	3.68	1	0.07
P8	2.42	1	0.11

had spent with her infant since birth. The calculated Chi squared (X^2) value of 0.949 and a C value of 0.25. To determine whether an observed C differs significantly from chance, a X^2 was calculated. There was no significant correlation found at the 0.05 alpha level.

Percentages obtained regarding mother's judgments provided an affirmative answer to research question 2. The majority of the mothers were able to correctly identify their infant's cry from the cries of other infants.

Analysis of Acoustic Data

Reliability. To evaluate the reliability of the examiner, a comparison of spectrographic judgments was made on two cry samples, one from each group, by a second examiner. The second examiner was a doctoral student trained in the interpretation of spectrographs. Percent agreement was calculated for each measure made on each of the two samples and is presented in Table 5. Percent agreement ranged from 71-99%.

To evaluate the stability of the infant's cry, one infant's cry (subject 15) was analyzed twice. Percent agreement was calculated for each measure made on each of the two samples and is presented in Table 6. Percent agrement ranged from 40-93% The two recordings were made 17 hours apart and the serum bilirubin concentration was higher at the time of the second recording. After examining the

Table 5. Percent Agreement Between Two Examiners of Spectrographic Measurements of Two Infant Cry Samples.

SUBJECT	CRY LATENCY	2ND PAUSE	MIN FO C1	MIN FO C2	PEAK FO C1	PEAK FO C2
5	95%	98%	98%	99%	98%	99%
12	99%	99%	99%	71%	94%	83%

Table 6. Percent Agreement Between Two Recordings of Spectrographic Measurements of The Same Infant.

SUBJECT	CRY LATENCY	2ND PAUSE	MIN FO C1	MIN FO C2	PEAK FO C1	PEAK FO C2
15	41%	40%	74%	61%	55%	93%

measurements made on each of the two cries, it is interesting to note that the values of all measurements were higher for the second recording.

Means and standard deviations for cry latency, 2nd pause, minimum Fo for the first and second cry segments, peak Fo for the first and second cry segments, continuity of the first and second cry segments, and furcation are presented in Table 7. Mean data were very similar between groups for the features of cry latency and continuity of the second cry segment. With respect to 2nd pause, a larger mean value was obtained for the bilirubin group. With respect to fundamental frequency, lower mean values for minimum Fo and higher mean values for the peak Fo were obtained for the bilirubin group. Mean values for the feature of continuity of the first cry segment indicated greater continuity for the normal group. The means do demonstrate a clear difference between groups for the presence or absence of furcation. Only the cries of the seven hyperbilirubinemic infants exhibited this characteristic.

Separate multivariant analyses of variance were performed to determine if statistically significant differences existed among groups for cry latency, 2nd pause, minimum Fo for the first and second cry segments, peak Fo for the first and second cry segments, and the continuity of the first and second cry segment. F values are presented in Table 8. These statistical tests provided an affirmative answer to research question 3. There was a presence of furcation in the

Table 7. Means and Standard Deviations for Cry Latency, 2nd Pause, Minimum Fo Cry Segments One and Two, Peak Fo Cry Segments One and Two, Continuity Cry Segments One and Two and Furcation Between Normal and Hyperbilirubinemic Infants.

	N		MSEC		HZ				+/-		
			CRY LATENCY	2ND PAUSE	MIN FO C1	MIN FO C2	PEAK FO C1	PEAK FO C2	CONT C1	CONT C2	FURC
NORMAL GROUP	7	$\bar{X}$	1463.87	2245.18	579.00	516.00	886.50	720.25	0.50	0.37	0.00
		SD	1014.94	2345.43	508.46	416.60	528.69	446.51	0.53	0.51	0.00
BILI-RUBIN GROUP	7	$\bar{X}$	1479.62	2653.50	420.50	435.50	1112.37	839.37	0.37	0.37	1.00
		SD	625.55	4277.23	137.37	171.24	572.78	401.99	0.51	0.51	0.00

Table 8. F Values of Cry Latency (MSEC), 2nd Pause (MSEC), Minimum Fo For Cry Segments One and Two (Hz), Peak Fo For Cry Segments One and Two (Hz), and Continuity For Cry Segments One and Two (Present or Absent) in Normal and Hyperbilirubinemic Infants.

ACOUSTIC CHARACTERISTIC	F VALUE	dF	P < 0.05
CRY LATENCY	0.00	1	0.97
2ND PAUSE	0.06	1	0.81
MIN FO C1	0.72	1	0.40
MIN FO C2	O.26	1	0.62
PEAK FO C1	0.67	1	0.42
PEAK FO C2	0.31	1	0.58
CONTINUITY C1	0.23	1	0.64
CONTINUITY C2	0.00	1	1.00

hyperbilirubinemic infant's cries, and it was not observed in the cries of normal infants.

Pearson product moment correlation coefficients were determined to examine correlations among cry latency, 2nd pause, minimum Fo of cry segments one and two, peak Fo of cry segments one and two, the continuity of cry segments one and two, furcation, birth weight, and the state of wakefulness of the infant. Results are presented in Table 9. A statistically significant correlation ($r=-0.65$, $df=15$, $p=0.01$) was obtained between cry latency and state of wakefulness. According to Guilford (1956), the strength of this correlation was moderate.

In summary, the three research questions were answered with affirmative results. Nurses judged a difference between the cries of normal and bilirubin infants. The bilirubin infants were judged as having a more piercing cry. Mothers can accurately identify their infant's cries from the cries of other infants. And finally, the feature of furcation was observed in all cries produced by bilirubin infants and none of the normal infant cries. A moderate correlation between state of wakefulness and cry latency was also determined.

Table 9. Correlations Between Minimum Fo: Cry Segments One and Two, Peak Fo: Cry Segments One and Two, Cry Latency, and 2nd Pause and Birth Weight and State of Wakefulness. r=Value From the Pearson Product Moment Correlation Coefficient. α=Significance Level. n=Number of Infants. df=n-1.

	HZ				MSEC	
	MIN FO C1	MIN FO C2	PEAK FO C1	PEAK FO C2	CRY LATENCY	2ND PAUSE
BIRTH WEIGHT	r= 0.13	r= 0.08	r= 0.07	r= 0.28	r=-0.09	r= 0.38
	df= 15	df= 15	df= 15	df= 15	df= 15	df= 15
	α= 0.62	α= 0.76	α= 0.77	α= 0.27	α= 0.71	α= 0.14
	n= 16	n= 16	n= 16	n= 16	n= 16	n= 16
STATE OF WAKE-FULNESS	r=-0.21	r=-0.29	r=-0.14	r=-0.33	r=-0.65	r= 0.00
	df= 15	df= 15	df= 15	df= 15	df= 15	df= 15
	α= 0.43	α= 0.26	α= 0.60	α= 0.20	α= 0.01	α= 0.99
	n= 16	n= 16	n= 16	n= 16	n= 16	n= 16

CHAPTER V

DISCUSSION

Perceptual Data

Only the perceptual parameter of piercing was significantly different ($\bar{x}$= 3.8 bilirubin group, $\bar{x}$= 3.02 normal group), between infant groups. (See Figure 2.) The perceptual parameter of piercing was thought to be the most closely related to the acoustic characteristic of pitch. It was interesting to note that when the nurses were asked "do you consider an infant with hyperbilirubinemia to be sick," their responses were an emphatic "no," yet their judgments of the health of these infants varies from healthy to sick.

Rating scales (Zeskind and Lester, 1978) have been utilized in other studies (Freudenberg et al., 1978; Friedman et al., 1981, and Weisenfeld et al., 1981). The judges were mothers, fathers, men, women, and students with varying degrees of infant contact. To date, no study has assessed primary caregiver (during the infants first few days of life), judgments. In addition, the present investigation examined normal and hyperbilirubinemic infants, while Weisenfeld (1981), Frodi et al. (1978), and Zeskind and Lester (1978) used older, premature, and high risk infants.

Zeskind and Lester (1978) studied the ability of men and women (not necessarily parents) to rate the cries of healthy

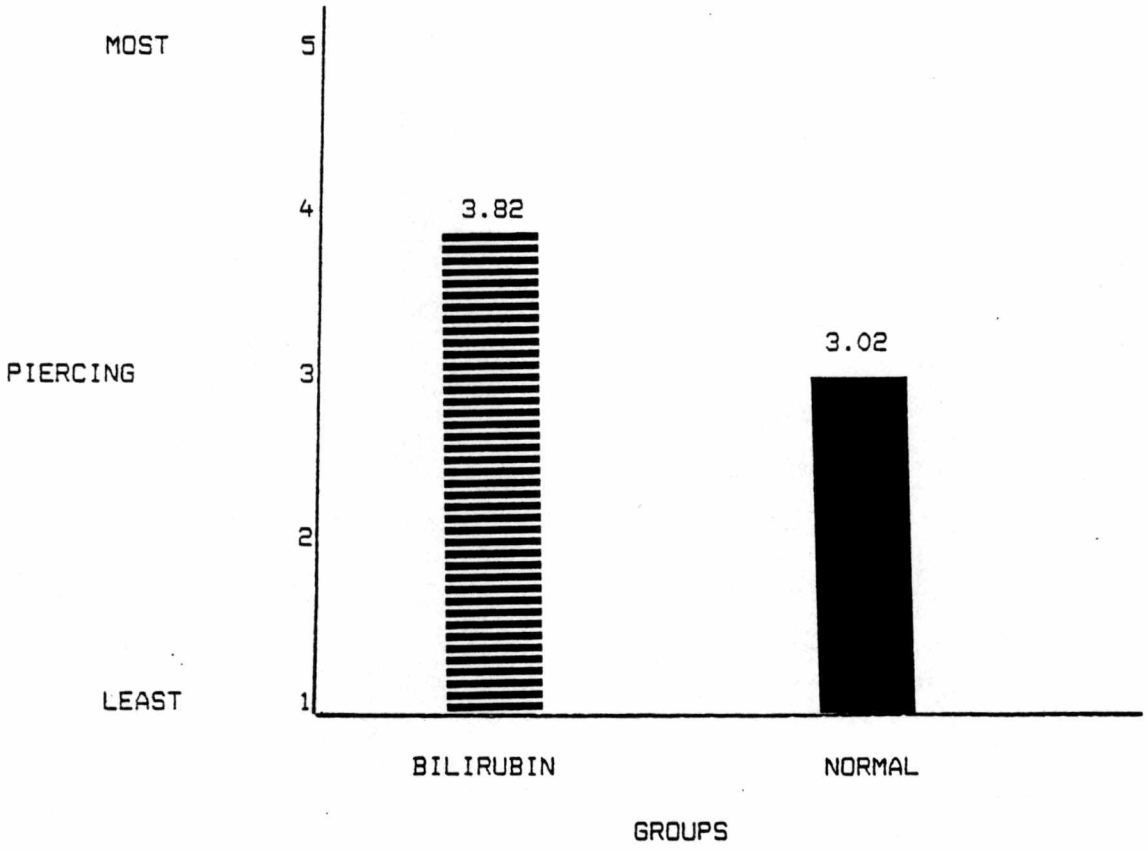


Figure 2. Results of nurses rating perceptual parameter of piercing between the pain cries of healthy and hyperbilirubinemic infants.

full-term neonates and neonates with differing degrees of perinatal complications. The judges rated the cries of infants with complications as being more urgent, sick, and discomforting to the listener. These judgments are similar to the findings of this study in that the hyperbilirubinemic infants' cries were judged to be more piercing than the cries of the normal newborn infants. The judges in this study formed a profile of the hyperbilirubinemic infants and tended to rate their cries as more urgent, less pleasing, less soothing, less comforting, more aversive and more distressing then the cries of the normal infants cries.

For research question 2, 71% of the mothers in this study were able to correctly identify their infant's cry from the cries of two other infants. Formby (1967) reported that the mothers of infants younger than 48 hours old could correctly identify their own infant only 52% of the time, whereas identification improved to 100% when mothers listened to infants older than 48 hours.

Although no correlation was found between the mother's ability to identify the cry of her infant and the amount of time the mother had spent with her infant since birth,, it seems that some amount of habituation and training occurs for a mother to recognize her infant's cry. This critical amount of time necessary for training to occur is undetermined at this time. Two mothers in the present study were unable to correctly identify their infants cry after spending 1 and 2

hours with their infant, yet a mother did correctly identify her infants cry after 5 hours with her infant. The mother's response and number of hours spent with the infant at the time of this evaluation are presented in Table 10. It was speculated that the ability to identify cry might be hormonally mediated or the result of some intrauterine imprinting. Fifty percent of the fathers participating in this study also correctly identified the cry of their infant.

Acoustic Data

Reliability between two cries recorded from the same infant was determined by percent agreement. Agreement ranged from 40-93%, with highest agreement calculated for the minimum and peak Fo measurements (55-93%). Ringel and Kluppel (1964) report a high degree of stability for the duration and frequency data.

Research question 3 examined differences in acoustic measurements between the cries of normal and hyperbilirubinemic infants. Although no statistically significant differences were found between groups with respect to the acoustic characteristics of cry latency, 2nd pause, minimum and peak Fo and the presence of continuity, the feature of furcation was present in all of the hyperbilirubinemic infants' cries and none of the normal infants' cries.

Table 10. Mothers' and Fathers' Identification of Own Infants' Cry and the Number of Hours Each Mother Spent with Her Infant Prior to the Identification Task.

PARENT	YES ID	NO ID	HOURS SPENT WITH INFANT
Mother			
1	X		17
2		X	26
3	X		5
4	X		20
5	X		14
6	X		10
7	X		12
8	X		10
9	X		16
10		X	2
11		X	1
12	X		11
13	X		10
14		X	15+
Father			
1	X		15
2		X	14
3	X		12
4		X	10

Furcation is a rarely seen characteristic in the analysis of infant cry and is thought to occur primarily in pathological infants cries. Many investigators mention the feature of furcation, but very few (Wasz-Hockert, 1971) have provided a detailed explanation and/or good spectrographic representation of this feature.

Wasz-Hockert et al. (1971) assessed the presence or absence of furcation in 45 hyperbilirubinemic infants. Forty percent of hyperbilirubinemic, ABO, and Rh immunization cases exhibited furcation in their cries. The authors discussed that furcation may be an early and temporary manifestation of cerebral involvement. Furcation was observed in the cries of infants with a relatively low (5.5 mg/dl) and relatively high (24.0 mg/dl) serum bilirubin concentration, therefore, it is concluded that the concentration of bilirubin in the blood reflected involvement of the CNS to a limited extent. Furcation was not observed in the group of infants with low serum bilirubin concentrations (< 8 mg/dl) in the present study. A spectrographic example of furcation can be seen in Figure 3.

The cry latency values observed in both infant groups ranged from 112.5 to 3012.0 msec, while Thoden and Koivisto (1980) and Sirvio and Michelsson (1976) calculated mean cry latencies of 120.0 and 140.0 msec, respectively. It was assumed that the mean state of wakefulness was higher in the

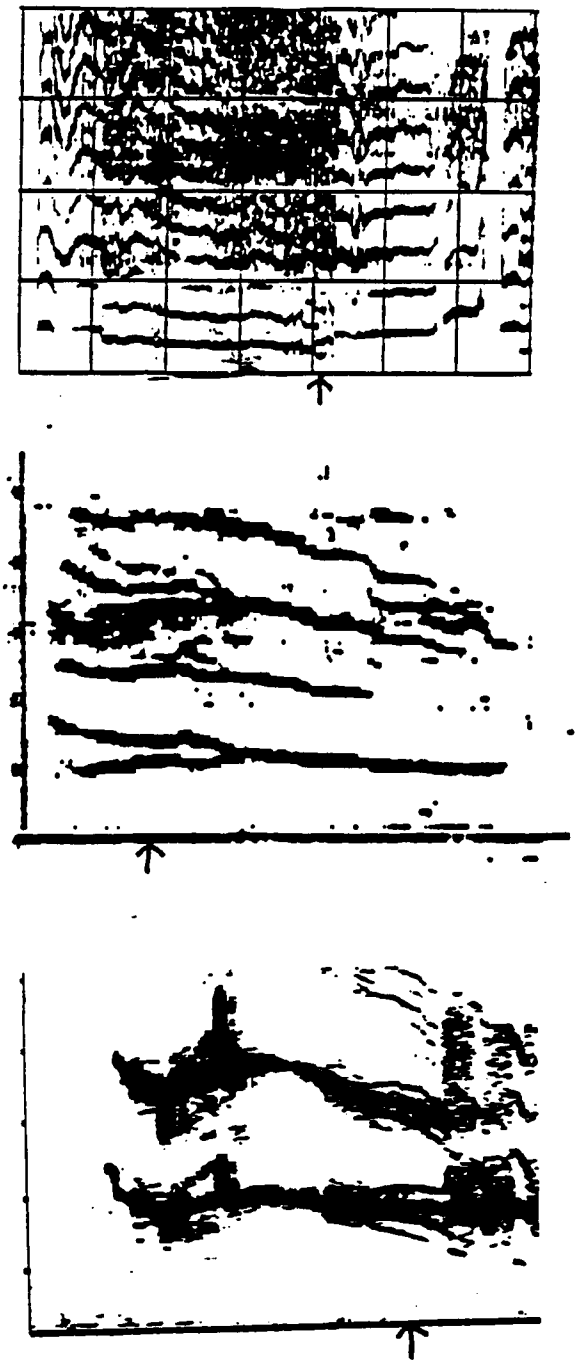


Figure 3. Furcation in an hyperbilirubinemic infant's cry.

previous two studies which could account for the shorter mean values. Neither investigation reported state of wakefulness.

The feature of 2nd pause ranged from 275.0 to 6262.0 milliseconds in the normal group and 125.0 to 9864.0 msec in the bilirubin group. Sirvio and Michelsson (1980) determined the 2nd pause to be abnormal of it exceeds 100 msec.

Although there seems to be discrepancies for the minimum and peak frequency values reported between studies (see Table 11), when comparing exactly the same cry segment in infants of the same health status and gestational age, agreement is found.

An interesting point should be discussed regarding the perceptual quality of the cries judged by the examiner and the assistant. The examiner and the assistant noticed a difference in the sound quality between the recordings of normal and bilirubin infants. The normal infants' cries sounded clear and each harmonic is distinctly seen on a narrow band spectrogram (Figure 4). The bilirubin infants' cries had a "raspy" sound quality. The spectrogram confirms this by a display of jagged harmonics which are not clearly distinct from each other. The quality difference may, in part, be accounted for by the presence of furcation. Wasz-Hockert et al. (1968), Michelsson (1971), Thoden and Koivisto (1980), and described this feature as vibrato, vocal fry of glottal roll. These features can be defined as a sound with a very

Table 11. Peak Fo and Minimum Fo Values from Four Studies.

STUDY	HEALTH STATUS OF INFANT	RANGE IN HZ PEAK FO	RANGE IN HZ MINIMUM FO
PETCHER (1989)	NORMAL	408-2020	160-1720
	MODERATE BILIRUBIN $\bar{X}$= 12.7	464-1500	100-584
THODEN & KOIVISTO (1980)	NORMAL	400-1800	130-770
RINGEL & KLUPPEL (1964)	NORMAL	290-508	NO DATA
WASZ-HOCKERT Et al.(1971)	HIGH BILIRUBIN $\bar{X}$= 16.4	1650-2660	NO DATA

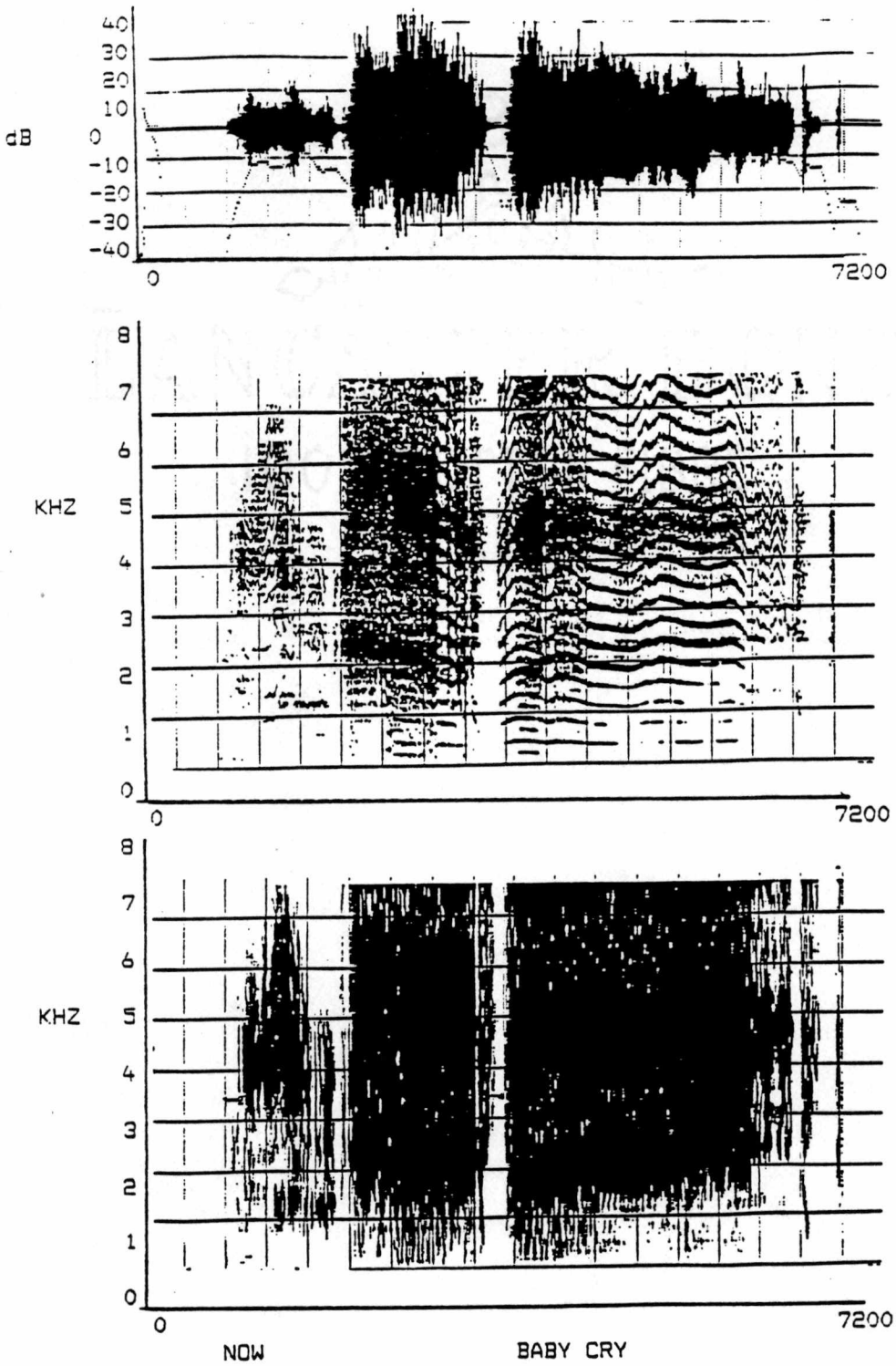


Figure 4. Wide band, narrow band and waveform spectrographic display of a normal newborn infant pain cry.

low pitched fundamental frequency, usually occurring at the end of a cry segment. A sample spectrogram from an infant with hyperbilirubinemia is seen in Figure 5.

Cry continuity was evaluated in both the first and second cry segments. A continuous signal was seen in 46% of the first cry segment and 40% of the second cry segment across both groups. Although the occurrence of a continuous cry signal was not found to be statistically significant between groups, these results were consistent with the results reported by Thoden and Koivisto (1980), at least for the first cry segment. They reported that continuity of the first cry segment occurred 32-66% of the time and continuity of the second segment occurred 68-92% of the time. It is unclear why the occurrence of continuity for the second cry segment in this study differs from the previously reported occurrence of continuity.

There was a significant correlation between the infant's state of wakefulness and cry latency (Figure 6). The strength of this correlation has been described as moderate according to Guilford's correlation classification (Table 12). While state of wakefulness has been discussed (Lind et al., 1966; Prechtl, 1974; Sirvio and Michelsson, 1976), a significant correlation between state of wakefulness and cry latency has not been determined. Michelsson (1976) stated that differences exist in the durational features with respect to

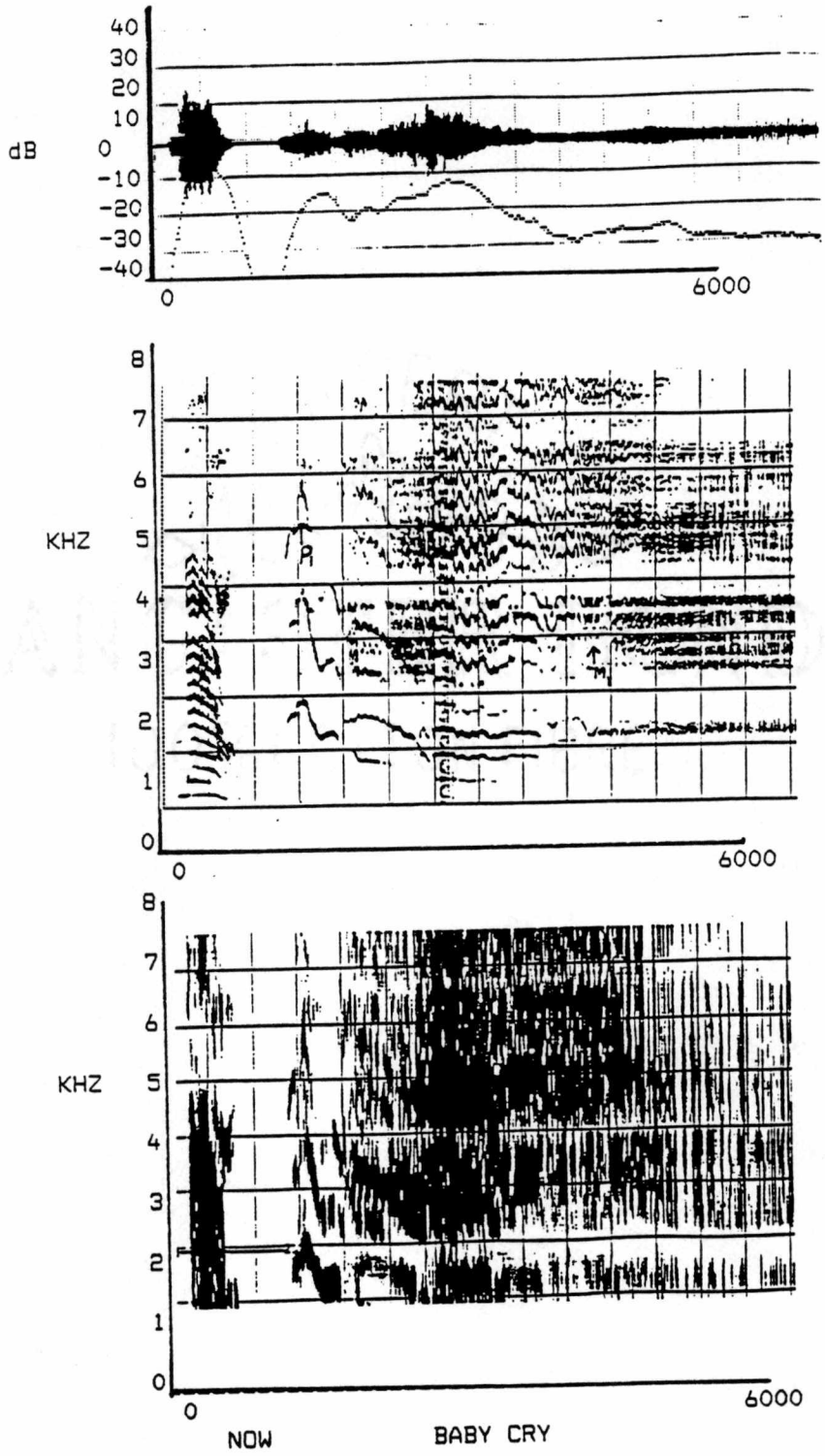


Figure 5. Wide band, narrow band, and waveform/amplitude spectrographic displays of a hyperbilirubinemic newborn infant pain cry.

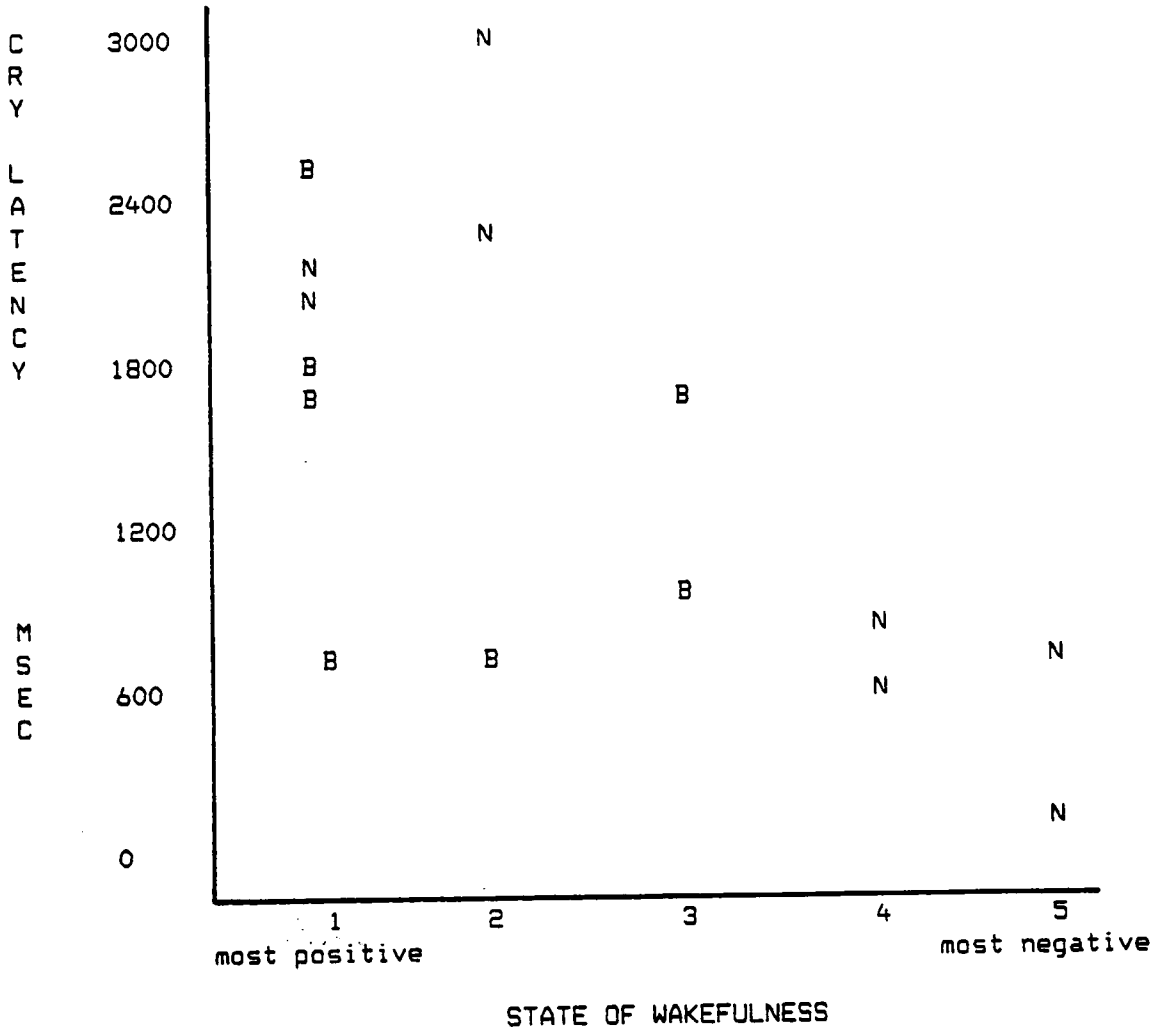


Figure 6. Significant correlation between the infant's state of wakefulness and cry latency.

Table 12. Guilford's Correlation Classification. From J.P, Guilford, Fundamental Statistics in Psychology and Education (New York: McGraw-Hill, Inc., 1956), p. 145.

less than .20.....	slight almost negligible relationship
.20 to .40.....	low correlation; definite but small relationship
.40 to .70.....	moderate correlation; substantial relationship
.70 to .90.....	high correlation; marked relationship
more than .90.....	very high correlation; very dependable relationship

state of wakefulness, but statistical significance has not been observed.

It was also noted that the formants of each of the infants cry from a wide band spectrogram revealed a similarity between the infants cries and the early developing sounds in the English language. Seventy-three percent of the infants in this study exhibited the /æ/ formant pattern with one infant cry each similar to the /ʌ/, /ɔ/, and /ɛ/ formant structures.

Ringel and Kluppel (1964) data show similarities to the vowels of /æ/ and /ʌ/, which were also consistent with the results of Irwin and Curry (1941) who report the vowels of /æ/, /ɛ/, and /ʌ/. Stark et al. (1972) also report similarities in the formant structure seen in the infants cries to the vowels /æ/ and /ʌ/. Murry and Murry (1980) state that the most used vowels of {æ, ɛ, ʌ, U} by infants prior to 20 weeks of age are indeterminate because they cannot be specified by a particular tongue position. The production of these vowel sounds requires minimal change from the "rest position," yet Irwin and Curry (1941) reported these vowel sounds as the first to be developed while a child is acquiring language.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Based on these results it is seen that changes in an infant's cry do occur with moderate levels of serum bilirubin (range 11.6-14.3 mg/dl). These changes are reflected in the findings of this study and include the perception of a more piercing quality and the presence of furcation. A profile was seen with respect to the nurses' ratings of the bilirubin cries as being more urgent, grating, sick, arousing, discomforting, aversive, and distressing. The parameter of piercing is also the most closely related to pitch in the evaluation of these cries.

Conclusions

Based on the results of technical and interactive evaluation of the infant cry, the utility of cry analysis might prove to be a powerful early diagnostic tool. Cry analysis could be used in the evaluation of subclinical and clinical repercussions of hyperbilirubinemia and other neonatal disorders. Even moderate serum bilirubin levels (8-12 mg/dl), which have traditionally not been implicated as a cause of overt pathology, now may need to be examined more carefully in the event that early medical intervention is required.

Limitations of the Study

To obtain tape recordings of infants' pain cries, the examiner was only permitted to make the recordings by following hospital procedure for obtain blood samples. These blood samples were collected only once every 12 to 24 hours; therefore, it limited the opportunity to make more comparisons between cries of the same infant.

Although many acoustic characteristics were addressed in this study, the feature of peak SPL could not be determined due to limited instrumentation. The shift of the infant's cry was not examined in this study, thereby making comparisons to various studies difficult. The acoustic characteristics evaluated in this study were limited to the most commonly documented features in order to make comparisons between these characteristics. The features of bi-phonation, glide, and duration were also not evaluated in this investigation.

The small number of subjects included in this study may have limited the results of significant differences between groups. Studying a larger number of infants could have provided more information regarding the differences between the cries of normal and hyperbilirubinemic infants.

The perceptual parameters used in this study (Zeskind and Lester, 1978) were redundant. The parameters of soothing, pleasing, and comforting seemed to assess the same feelings from the judges.

Suggestions for Further Study

The perceptual judgments and acoustic characteristics of the cries of hyperbilirubinemic infants have not been clearly established, and further research should be pursued. The following are suggestions to improve the present design or ideas for future study:

1. Further examination of the serum bilirubin concentration at which changes in the cry of hyperbilirubinemic infants occur should be performed. Moderate (8-12 mg/dl) levels of serum bilirubin have not been traditionally implicated; however, ABR and acoustic analysis of these infants' cries have reported changes (Vohr et al., 1988).

2. When using rating scales for perceptual judgments, discretion should be used when determining the number of parameters. This is an effort to reduce redundancy in the judgments. The parameters of soothing, comforting, and pleasing seemed to be assessing the same feelings from the judges.

3. Nurses' judgments should be included in future investigations. These professionals are the primary caregivers during an infant's first few days of life. If infant cry analysis is to be incorporated into nurseries as an early clinical diagnostic tool, nurses will be the first medical personnel alerted to a possible abnormality in the infant.

4. Further investigation into a "threshold of interaction between the mother/child pair" should be performed. Although research has shown that mothers can accurately identify their infant's cry from the cries of other infants, it is also true that this accuracy takes place after some amount of training and habituation. The critical amount of time that allows mothers to achieve this phenomenon remains unknown.

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APPENDIXES

APPENDIX A

HYPERBILIRUBINEMIA

Hyperbilirubinemia is the most common problem experienced by the full-term infant during the neonatal period. Hyperbilirubinemia occurs when there is an excess amount of bilirubin in the blood serum. The normal course of serum bilirubin concentrations occurs in phases. In the first phase, the serum bilirubin level peaks by the fourth day of life at approximately 7.5 to 8.0 milligrams per deciliter (mg/dL). By the tenth day of life, the serum bilirubin level is below 1.5 mg/dL. This normal course is called physiologic jaundice. If the serum bilirubin level is above 8 mg/dL during the first 48 hours of life or exceed 12 mg/dL, it is no longer considered normal physiologic jaundice, but is known as pathologic jaundice (Maisels, Gifford, Antle, and Gregory, 1988; Frank, Turner and Merenstein, 1985).

There are two types of bilirubin, conjugated and unconjugated, sometimes referred to as direct and indirect bilirubin. As red blood cells break down, unconjugated bilirubin is released into the serum. The unconjugated bilirubin is bound to plasma albumin and transported to the liver. Unconjugated bilirubin is potentially toxic if it reaches what is considered to be a toxic level of concentration. The unconjugated bilirubin is mixed with glucuronide in the liver to form the detoxified, conjugated

bilirubin. When bilirubin cannot be conjugated, it builds up in the serum until it crosses the plasma membrane and is deposited in the brain. Increased bilirubin levels can result in the condition known as kernicterus. Kernicterus is characterized by the yellow staining of the nuclei in the brain (Poland and Ostrea, 1979). Clinical signs of kernicterus include depressed reflexes, feeding difficulties, fever, hypotonia, high-pitched cry, and seizures (Lee et al., 1977; Poland and Ostrea, 1979). Severe cases may result in death.

The treatments for hyperbilirubinemia are designed to prevent the complications of kernicterus. Phototherapy and blood exchange transfusions are the two most widely used forms of intervention. Phototherapy works slowly and tends to stabilize the bilirubin level rather than reduce it. Phototherapy can also be useful to stabilize bilirubin levels following an exchange transfusion in an infant with hemolytic disease (Cashore, 1983). Phototherapy works by destroying bilirubin thereby lowering the serum bilirubin concentration in the infants blood. Phototherapy uses light bulbs with energy concentrated in the blue spectrum of visible light (400 to 500 nm wave length band). The decision of whether an infant needs phototherapy or an exchange transfusion depends on the infant's age in hours after birth, weight, and serum bilirubin concentrations. Although phototherapy has decreased

the need for exchange transfusions it would never be used as a substitute for an exchange transfusion (Cashore, 1983).

APPENDIX B

DEFINITIONS OF CRY TERMINOLOGY

During the years of infant cry research, some terminology has been established. The following are descriptions of each of the acoustic characteristics to be used in this study. These measurements were obtained from the spetrograms.

Latency: The time between the heelstick and the onset of the cry.

Second Pause (2nd): The time interval between the end of the first cry segment and the beginning of the second cry segment (Vuorenkoski, Kaunisto, Tjernlund. and Vesa, 1971).

Peak Fundamental Frequency: The highest peak fundamental frequency during the infant cry: first and second cry segments.

Minimum Fundamental Frequency: The lowest fundamental frequency during the infant cry: first and second cry segments.

Continuity: A measure of whether the cry signal is voiced, partly voiced/partly voiceless or completely voiceless.

Furcation: A "split" in the fundamental frequency (Fo) where a relatively strong cry signal suddenly breaks into a series of weaker ones, each one of which has its own Fo contour.

APPENDIX C

Table A1. Five Different Behavioral States in Infants (H.F.R. Prechtl 1974).

STATE	DESCRIPTION
1	eyes closed, regular respiration, no movements
2	eyes closed, irregular respiration, small movements
3	eyes open, no movements
4	eyes open, gross movements
5	crying (vocalizations)

APPENDIX D

Table A2. Perceptual Rating Scales (Zeskind and Lester, 1978).

MOST POSITIVE PARAMETER	RATINGS					MOST NEGATIVE PARAMETER
NOT URGENT	1	2	3	4	5	URGENT
PLEASING	1	2	3	4	5	GRATING
HEALTHY	1	2	3	4	5	SICK
SOOTHING	1	2	3	4	5	AROUSING
NOT PIERCING	1	2	3	4	5	PIERCING
COMFORTING	1	2	3	4	5	DISCOMFORTING
NONAVERSIVE	1	2	3	4	5	AVERSIVE
NOT DISTRESSING	1	2	3	4	5	DISTRESSING

APPENDIX E

QUESTIONNAIRE FOR MOTHERS

1. How many hours have you spent with your child since he/she was born?

2. Do you recognize your baby's cry?

3. Do you think your baby cries differently from other babies?

4. Do you think you can correctly identify your infants cry from the cries of other infants?

5. How would you describe your baby's cry?

   shrill?
   pleasant?
   squeaky?
   healthy?
   comforting?
   urgent?

APPENDIX F

RAW DATA

Table A3. Nurses' Responses to Cries on 1-5 Point Rating Scales.

SUB (NURSE)	P1 ABCDE	P2 ABCDE	P3 ABCDE	P4 ABCDE	P5 ABCDE	P6 ABCDE	P7 ABCDE	P8 ABDCE
1				COULD NOT EVALUATE				
2	44455	44444	14413	43345	32234	34235	32135	22335
3	53245	44235	12323	51345	41335	43235	41235	42225
4	51235	43434	14323	54345	44335	44435	53335	43335
5	51225	42335	23243	44345	53225	43345	43235	42335
6	21114	32324	13223	33334	24133	22234	21234	22334
7	45444	45445	14214	45453	15453	35552	25454	25453
8	25322	45333	13412	35332	25221	45431	25221	15321
9	45451	45453	13313	45352	45443	45444	45444	25545
10	55221	35332	33313	55333	25233	45334	45222	35224
11	45443	44443	13423	44534	44543	44433	54332	14432
12	44231	34333	33314	45334	43234	53333	33233	14435
13	23334	54435	14113	53435	42434	41335	43335	14435
14	44545	34445	13314	43445	44345	33445	54345	23445
15 A	13555	44445	13213	44455	54554	34555	44455	24555
15 B	44545	43545	14313	44455	34555	33455	44455	23555

Table A4. Nurses' Averaged Responses of Perceptual Ratings of Infant Cries on 1-5 Point Rating Scales.

	PERCEPTUAL PARAMETERS							
SUBJECT	P1	P2	P3	P4	P5	P6	P7	P8
2	4.4	4.0	2.6	3.8	2.8	3.4	2.8	3.0
3	3.8	3.2	2.2	3.6	3.0	3.4	3.0	3.0
4	3.2	3.6	2.6	4.2	3.8	4.0	3.8	3.6
5	3.0	3.4	2.8	4.0	3.4	3.8	3.4	3.4
6	1.8	2.8	2.2	3.2	2.6	2.6	2.4	2.8
7	4.2	4.4	2.4	4.2	3.6	4.0	4.0	3.8
8	3.0	3.2	2.6	3.8	3.0	3.8	3.0	3.2
9	2.8	3.6	2.2	3.2	2.4	3.4	2.4	2.4
10	3.8	4.2	2.2	3.8	4.0	4.2	4.2	3.8
11	4.0	3.8	2.6	4.0	4.0	3.6	3.4	2.8
12	2.8	3.2	2.8	3.8	3.2	3.4	2.8	3.2
13	3.0	4.2	2.0	4.0	3.4	3.2	3.6	3.4
14	4.4	4.0	2.4	4.0	4.0	3.8	4.2	3.6
15	4.4	4.2	2.0	4.4	4.6	4.4	4.4	4.2
15	4.4	4.2	2.6	4.4	4.4	4.0	4.4	4.0

Table A5. Milisecond Measurements For All Subjects By Group.

		MSEC	
	SUBJECT	CRY LATENCY	2ND PAUSE
	1	112.5	275.0
	2	750.0	4837.0
	3	3012.0	6262.0
	4	812.5	1500.0
NORMAL	5	2200.0	637.5
GROUP	6	2112.0	3625.0
	7	625.0	462.5
	$\bar{X}$ =	1374.8	2514.1
	RANGE =	112.5-3012.0	275.0-3625.0
	8	2550.0	537.5
	9	1762.0	362.5
	10	1650.0	337.5
	11	975.0	9864.0
BILIRUBIN	12	737.5	9289.0
GROUP	13	1612.0	400.0
	14	737.5	125.0
	$\bar{X}$ =	1432.0	2987.9
	RANGE =	737.5-2550.0	125.0-9864.0

Table A6. HZ Measurements for All Subjects by Group.

		HZ			
		MIN FO		PEAK FO	
	SUBJECT	C1	C2	C1	C2
NORMAL GROUP	1	352	308	776	460
	2	352	356	408	436
	3	730	1400	880	1680
	4	660	368	1320	436
	5	1720	880	2020	1120
	6	160	160	560	560
	7	344	280	763	576
	$\bar{X}$ =	616	536	961	752
	RANGE =	100-1720	160-1400	408-2020	436-1120
BILIRUBIN GROUP	8	264	312	50	464
	9	500	488	1060	600
	10	520	584	992	930
	11	289	100	1813	533
	12	293	560	693	600
	13	370	440	580	688
	14	480	380	1160	1500
	$\bar{X}$ =	388	409	97	759
	RANGE =	264-520	100-584	508-1813	464-1500

Table A7. Presence of Continuity and Furcation for All Subjects by Group.

	SUBJECT	CONTINUITY C1	CONTINUITY C2	FURCATION
	1	D	D	--
	2	C	C	--
NORMAL	3	C	C	--
GROUP	4	D	D	--
	5	D	D	--
	6	C	D	--
	7	C	D	--
	8	D	D	++
	9	D	C	++
BILIRUBIN	10	C	C	++
GROUP	11	C	D	++
	12	D	D	++
	13	C	C	++
	14	D	D	++

VITA

Leslie Gwen Petcher was born in San Francisco, California on August 23, 1966. She attended elementary schools in Portland, Oregon and graduated from Woodrow Wilson High School in June 1984. She went on to attend Case Western Reserve University in Cleveland, Ohio, receiving a Bachelor of Arts degree in Communication Disorders in May 1988. In the fall of 1988, she began her studies for the Master of Arts degree in Audiology at The University of Tennessee, Knoxville. During this time she earned an academic achievement award for outstanding scholarship. She is a member of the National Student Speech-Language-Hearing Association and the Tennessee Speech and Hearing Association. She was awarded the Master's degree in December 1989.