ANALYSIS OF INFANTS CRIES

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Introduction

' During infancy, the child's only mode of communication is the cry and we should listen to his vocalization and try to interpret it. When a ttaby is ill, the parents, too, are most eager and anxious to have some explanation of his prognosis and possible life-long defects. Any method which could provide further enlightenment should be thoroughly explored' (Siruio and Michelsson, 1976).

The importance of early identification of problems and abnormalities in childhood is increased because of the concept ' critical age ' (Lennerberg, 1967). Early identification is also important from the point of view of early intervention, Bess *et al.* (1976). Becker (1976) states that in addition to being desirable for the child's development, early detection also helps, parents to adjust more realistically to the child's problem. And it would make the rehabilitation economical (Downs, 1978). Some methods of early identification are: (1) Newborn Screening Programs, and (2) High Risk Registers.

The ' Apgar' score is designed to determine the physical condition of the newborn 60 seconds after birth. It comprises of five segments—Heart rate, respiratory effort, muscle tone, reflex irritability and colour. The response sought to respiratory effort and reflex irritability is a ' cry '. Studies done by Karelitz *et al.* (1966), have indicated that apart from the fact that crying activity enters twice in the apgar score, and contribute a great deal to the total score, it continues to contribute significantly even when it is analysed separately. The diagnostic value of the cry alone, suggested its potential importance.

During the last twenty years, research on infant crying has stimulated many research workers. The first cry studies were based on auditory analysis. Warz-'Hockert *et al.* (1964), found that when typical pain, hunger, and pleasure cries were played to 438 adults, those with more experience in child-care identified the cries more accurately than those who had no previous experience. Murry, Amundson, and Hollien (1977), noticed that an infant's sex could not be reliably identified on auditory basis. 'Partanen *et al.* (1967), found audible differences between the cries of healthy newborn infants and those with asphyxia, brain damage, jaundice and Down's syndrome were recognizable by paediatricians and medical students.

The phonetic structure of normal and abnormal infant cries was studied by Fisichelli *et al.* (1966). They found that normal infants produced more sounds totally than abnormal infants. Abnormal infants produce more nasal sound than , normal infants.

The cry duration in normal infants is found to increase during the first six weeks of life and decrease thereafter (Rebelsky and Black, 1972).

Some investigators have attempted to give a behavioural classification of infant cries. Warz-Hockert *et al.* (1962), analysed birth, pleasure, hunger and pain cries. Wolff (1969) described 3 cry types—the basic cry, mad or angry cry and the pain cry. Stark, Rose and Benson (1978), classified infant cries as cry sounds, discomfort sounds, vegetative sounds, laugh sounds, comfort sounds and speech of vocal play.

The mode of stimulus to elicit the cry has varied from the use of a rubber-band apparatus, to pinches and snaps. Preference has been given to pain-induced signals, because this cry type can be standardized. Parmlee (1962), stated that cry is always the maxium type of response to a stimulus, and therefore, the mode of stimulation is of less importance. This was supported by Murry, Hollien and Murphy (1975).

Fisichelli and Karelitz (1969), investigated the effect of stimulus intensity on the latency and total cry duration. They found that more intense pain produces a longer, more concentrated cry and latency not being affected. Cry latency is found to be a good indicator of normality or abnormality. Abnormal infants have been found to have longer latencies than normal infants (Fisichelli and Karelitz, 1963).

The cry threshold is the amount of stimulation required to elicit at least one minute of crying from the infant. Karelitz and Fisichelli (1962), found that abnormal infants required more stimulation than normal infants in order to evoke the same amount of crying.

The objective analysis of infant cries has been carried out by volume-unit graphs (Fisichelli *et al.*, 1961), Computer Analysis (Ostwald and Peltzman, 1974), and Sound Spectrography (Michelsson and Siruio, 1976). A sound spectrographic program for cry analysis was started in Helsinki, Finland in 1961. The cries in healthy infants and infants with various abnormalities have been found to differ when analysed acoustically on the basis of latency period, duration of the cry, maximum fundamental frequency, minimum fundamental frequency, shift, double harmonic break, glide, bi-phonation, furcation, noise concentration, vibrato, glottal plosives, melody type, and tonal pit (Warz-Hockert *et al.* 1982, Michelsson, 1971; Michelsson *et al.*, 1975; Siruio and Michelsson, 1976; Michelsson *et al*, 1982).

According to the reports of the above, the variation in the durational features in normal infants is quite large. The fundamental frequency is generally between 400 Hz and 600 Hz and frequencies upto 1500-2000 Hz can be noted. The melody type is usually falling or rising-falling. Bi-phonation,,gliding, furcation and noise concentration do not occur in the cries of healthy infants. Double harmonic break and glottal plosives are common.

In infants with brain damage, for instance caused by asphyxia, meningitis, or hydrocephalus, the cry becomes more high-pitched and the melody type changes to more rising, falling-rising and flat types. The fundamental frequency becomes unstable. Both bi-phonation and gliding occur. The duration of phonation

Can be very short or unusually long. Furcation occurs in newborn infants with jaundice and is seldom seen in other diseases. Noise concentration has been found in infants with brain infection caused by herpes virus. Tonal pit occurs in infants with anatomical defects of the oral cavity, like cleft palate.

The purpose of the present study was to find out the differences between normal and abnormal infant cries by spectrographic analysis.

Methodology

The study was carried out in the following steps '

1. Construction of a list of high-risk factors for hearing loss and mental retardation.
2. Collection of data from normal and high-risk infants.
3. Spectrographic analysis.
4. Follow-up of infants for hearing screening and to collect information about developmental milestones.

1. *Construction of a list of high-risk factors for hearing loss and mental retardation:*

The high-risk factors for hearing loss were taken from the ' High Risk Register' developed by Ashok, M.M. (1981). Along with this other pre-natal, peri-natal, and post-natal conditions like pre-maturity, asphyxia, etc., which may lead to CNS abnormality were added.

2. *Collection of data from normal and high-risk infants:*

Pain cries of 13 normal full-term infants and 28 infants considered to be high-risk according to the case history were included in this study. The age range of the infants was from 16 hours to 3 months.

Group I: The 13 infants in this group were taken from the neonatal wards of Cheluvamba Hospital, Mysore. These infants had no pre- natal, peri-natal, or post-natal factors, to place them in the high-risk category. They were born after 37 weeks of gestation and their birth cries were considered normal, as indicated by the hospital records. The pain cry was elicited by flicking the sole of the infant's foot with the index finger. If the infant did not cry immediately, it was stimulated again, till it cried for at least 30 seconds. The cries were recorded using a National Panasonic (UM 1RQ2157) Cassette tape recorder and a Piezo dynamic microphone. The cassette used was Sony CHF 90. The Tape recorder was battery-operated. Every day, prior to recording, the voltage of the batteries was checked. All the recordings were made at a constant intensity level. The microphone was held approximately 5 cms. from the infant's mouth to reduce background noise to a minimum.

Group 2: In this group, pain cries were elicited from 28 infants from the sick-baby ward of Cheluvamba Hospital, Mysore. Information obtained from the parents and the hospital records revealed that these infants had one or more

of the high-risk factors as listed in the case history. The procedure for eliciting pain cries and recording was same as that followed for Group 1 infants,

3. *Spectrographic Analysts;*

All these cry samples were transferred to the tape of the speech spectrograph (Voice Identification Inc. Series-700). These samples were analyzed to obtain narrow-band, bar-type spectrograms. These spectrograms were analyzed to obtain the following parameters: (1) Duration of the whole cry, (2) Maximum fundamental frequency, (3) Minimum fundamental frequency, (4) Shift, (5) Double Harmonic Break, (6) Bi-phonation, (7) Glide, (8) Furcation, (9) Noise concentration, (10) Glottal Plosives, (11) Vibrato, (12) Melody type and (13) Tonal-pit.

4. *Follow-up of the infants for hearing screening and to collect information about developmental milestones:*

Follow-up was done for the purpose of collecting information regarding developmental milestones and hearing sensitivity of the infants. A follow-up of all infants belonging to Group 2 and Group 1 was done after the infants were at least five months of age.

Results and Discussions: The frequency of occurrence of the various cry characteristics in group II infants. Significant differences between the cries of normal and high-risk infants were noted in some cry characteristics like fundamental frequency, duration of the cry, double harmonic break, noise concentration and glottal plosives. The fundamental frequency of the infants in Group 2 was found to be higher than that of the infants in Group 1. Double harmonic break and glottal plosives occurred more frequently in Group 1 infants than in Group 2 infants. On the other hand, noise concentration occurred more often in high-risk than in normal infants. No significant differences were observed in the cries of both normal and high-risk infants in cry characteristics like shift, bi-phonation, glide and tonal-pit. Hence, a comparison of normal group (Group 1) with a group of abnormal infants with various histories reveals that all these cry characteristics may occur in both the groups. However, some of these characteristics occur distinctively more number of times in infants with a particular history or problem.

Next, each high-risk category of infants with a specific history or problem were compared with Group-1 infants. In this study, the cry characteristics of infants in 8 high-risk categories—Prematurity, Asphyxia, Meningitis, Rh incompatibility, cretinism, convulsions and delayed birth cry were studied. When the frequency of occurrence of the cry characteristics of the infants in each of these high-risk categories were compared to those in the normal group, it was found that there were some cry characteristics which were distinctive of each group. Table-1, gives the mean of occurrence of the various cry characteristics in the normal and various high-risk categories. Table-2 indicates the distinctive cry characteristics of each high-risk category.

TABLE 1

Mean of occurrence of the various cry characteristics in the normal and high-risk categories

History	No. of subjects	Shift	Double harmonic break	Glide	Tonal pit	Furcation	Bi-phonation	Vibrato	Noise concentration	Glottal plosives	Melody	Max. freq.	Min. freq.	Duration
Normal	13	4.15	12.15	3	1.46	3.08	1.08	3.15	2.46	4.69	Rising-falling	1470.51 Hz	398.1 Hz	33.46 Secs.
Pre-mature	8	4.75	11.25	6.13	0.63	2	1.5	4.38	6.25	4	Rising-falling	2152.075 Hz.	366.65 Hz	35.38 Secs.
Asphyxia	6	3	10.17	1.5	0.5	0.17	0.17	3.5	4.8	3.33	Rising-falling	1891.66 Hz.	466.65 Hz	43.3 Secs.
Jaundice	4	7.6	12.2	2.4	0.4	5.6	0.6	2.2	4.4	3	Rising-falling	2083.32 Hz	366.6 Hz.	37 Secs.
Meningitis	4	2.5	9.5	0.75	1.25	3	0	1.5	4.6	1.4	Rising-falling	925 Hz.	229.15 Hz.	40.8 Secs.
Rh-incompatibility	2	1	11	1.5	0	3.5	1	2	4.5	6	Rising-falling	1625 Hz.	466.65 Hz.	29 Secs.
Cretinism	1	18	10	1	1	2	0	1	8	7	Rising-falling	800 Hz.	300 Hz.	38 Secs.
Convulsions	1	3	9	2	1	3	1	4	3	0	Falling	1250 Hz.	500 Hz.	43 Secs.
Delayed birth cry	1	2	11	5	0	2	1	0	0	5	Rising-falling	950 Hz.	500 Hz.	40 Secs.

Table 2

Problem	Distinctive Cry characteristics
Normal	Double harmonics break, glottal plosives, rising-falling melody typei
Pre-maturity	Glide, vibrato, noise concentration, high maximum fundamental frequency, longer cry duration.
Asphyxia	Noise concentration, high maximum fundamental frequency, longest cry duration
Jaundice	Shift, furcation, high maximum fundamental frequency, Noise concentration longer cry duration
Meningitis	Noise concentration, longer cry duration, lower fundamental frequency
Rh. incompatibility	Furcation, glottal plosives, high maximum fundamental frequency, least cry duration
Cretinism	Noise concentration, least maximum fundamental frequency, longer cry duration.
Convulsions	Falling melody type, longer cry duration
Delayed brith **cry**	Falling rising melody type, glide, longer cry duration.

Cry Characteristics:

1. *Fundamental Frequency:* The fundamental frequency is higher in the high-risk infants than infants in the normal category in this study. Among the high-risk categories, pre-mature infants have been found to have the highest maximum fundamental frequency (2152.lHz). The maximum fundamental frequency was highest in the infant which had lowest birth weight (Birth weight 1 kg.). This infant also had the lowest minimum fundamental frequency. Studies done by Michelson (1971) on 75 pre-mature infants has revealed that the fundamental frequency was highest in the smallest pre-matures. Greater variations and lower fundamental frequencies were also reported in the cries of the very small pre-matures. The present findings are in support of these results.

Lester and Zeskind (1978), have reported that the cries of full-term, but under weight infants had a shorter duration and higher fundamental frequency than babies of normal birth weight.

2.. Duration of the *Cry:* The next category with a high fundamental frequency was the group with jaundice (2083.32 Hz). These infants had a higher fundamental frequency than the normals, but lesser than pre-matures.

Warz-Hockert *et al.* (1971), reported a mean of maximum fundamental frequency of 2120 Hz in 45 infants with jaundice.

The crying in meningitic infants has also been found to be abnormal with respect to fundamental frequency. Michelson *et al.* (1977), found that cries

were higher-pitched in 14 infants with bacterial meningitis (1100 Hz). The results of the present study do not support the above finding. The mean of maximum fundamental frequency was found to be 925 Hz which is lower than that found in infants in the normal category.

Michelson (1971), compared cries of 205 infants with asphyxia with 50 healthy full-term and 75 pre-mature infants. The pitch of infants with asphyxia was reported to the higher than that of normal infants. The pre-mature infants with cerebral asphyxia had the highest maximum fundamental frequency.

The results of the present study agree with the above results. The infants with meningitis had a higher maximum fundamental frequency than the normal infants. One of the infants (No. 29) who was pre-mature and had-asphyxia had the highest maximum fundamental frequency in the whole group.

The cry in 4 infants with congenital hypothyroidism was studied by Michelson and Siruio (1976). They reported that the cry resembled those of normal infants, but was lower with respect to fundamental frequency. One infant with congenital hypothyroidism was available for cry analysis in this study. This infant had a lower fundamental frequency in comparison to the infants in the normal category and the infants in the other abnormal categories, which agrees with the results of the earlier study.

Thus, the present study confirms the results of the earlier investigations, that the fundamental frequency is a good indicator of abnormality, especially in conditions which could lead to CNS abnormality.

2. *Duration of the Cry:* The total duration of the cry was considered. The cry duration has been observed to be more in all abnormal groups than in the normal group. Among the various categories in Group 2, the cry duration was longest in the infants with asphyxia (43.3 seconds).

All the earlier studies have considered the mean duration of the first phonation Michelson (1971), Michelson *et al.* (1977), and Juntunen *et al.* (1978), have reported cry analysis of full-term infants with asphyxia, meningitis and malnutrition. A comparison of these results by Michelson and Warz-Hockert (1981), indicated that the mean duration of the first phonation was highest in infants with asphyxia. In asphyxia itself, two categories—peripheral and central asphyxia were considered. Among these two categories, infants with peripheral asphyxia had a longer mean duration of phonation.

Siruio and Michelson (1976), compared cry characteristics of healthy full-term and pre-mature infants, infants with cleft palate and infants with asphyxia. Infants with asphyxia has the longest median duration of phonation.

In the present study, infants with meningitis had a longer cry duration when compared to normal and pre-mature infants. This does not support the findings of the earlier investigators (Michelson, 1971; Michelson *et al.* 1977), who have

reported lesser cry durations in infants with meningitis when compared to normal and pre-mature infants. This may be because of the fact in the present study the duration of the whole cry has been considered.

The infants with history of Rh. incompatibility had the least cry duration when compared to the normal and other abnormal categories in the study. However, no information is available in the literature regarding the duration of the cry for this group.

3. *Shift:* Maximum amount of shifts occurred in infants with jaundice (Mean=7.6).

Michelson (1971), has not reported a significant difference in the occurrence of shift in normal infants and those with asphyxia. The present study supports this finding.

In cases of meningitis, shifts occur less frequently than in normal infants, as reported by Michelson *et al.* (1977). In this study also, less number of shifts were found to occur in infants with meningitis when compared to those in the normal category.

There was no significant difference in the frequency of occurrence of shifts in normal and pre-mature infants in this study. The results do not support the findings of Michelson (1971), who reported more number of shifts in pre-mature infants than in normal infants.

The least occurrence of shift was found in the infants with history of Rh incompatibility. But no data on this has been reported.

4. *Double Harmonic Break:* This characteristic occurred most often in normal infants than in any of the high-risk categories. It occurred least in infants with meningitis. In pre-mature infants it occurred lesser than in normals, but more than in any of the other high-risk categories except jaundice. The frequency of occurrence of double harmonic break in the decreasing order as found in this study are as follows : normals, premature, asphyxia, and meningitis.

These results support the findings of the earlier investigators (Michelson *et al.* 1971, Michelson *et al.* 1977). They also found that double harmonic break occurred most often in normals and least in infants with meningitis. In pre-matures it occurred less than in normals, but more than in cases of asphyxia. In asphyxiated infants it occurred less often than in pre-matures but more often than in infants with meningitis.

5. *Glide:* Glides have occurred most often in pre-mature infants. This finding does not agree with the results of Michelson (1971), who did not find the occurrence of glide in any of the pre-matures studied. Glide is an abnormal characteristic and has been found to occur more often in all high-risk categories. It is reported rarely in the cry of healthy infants.

Michelson (1971), found that gliding occurred in 14 per cent of cries of 205 infants with asphyxia. Gliding occurred in 11 per cent of the cries of 14 infants with meningitis as reported by Michelson *et al.* (1977).

In this study, glides occurred less in the other high-risk categories like asphyxia, meningitis, jaundice etc., than in the normal group.

6. *Tonal-pit:* Tonal pit occurred very rarely both normal and high-risk categories. Based on studies done, Michelson *et al.* (1975), have reported that this characteristic occurs more often in infants with anatomical defects of the oral cavity like cleft palate. The cries of 13 infants with cleft palate were analyzed. These infants' cries did not differ from the normals in tones of fundamental frequency, melody type and duration. Abnormal characteristics occurring in infants with CNS involvement such as biphonation and glide were not reported in infants with cleft palate. Only tonal-pit occurred in 22 per cent. The authors have concluded that the cry characteristics are different depending on whether the brain or the articulators are affected.

Infants with cleft palate were not available for this study.

7. *Furcation:* This characteristic was observed to occur maximum in infants with neonatal jaundice and history of Rh. incompatibility in this study,

These results are similar to those of earlier investigations. Warz-Hockert *et al.* (1971), studied 45 infants with jaundice and reported furcation to be a specific feature in pain cries of infants with jaundice.

Michelson *et al.* (1982), in a study of cries of 200 infants with various disorders also confirmed the finding that furcation seems to be specific to infants with jaundice.

8. *Bi-phonation:* In this study, bi-phonation occurred rarely in both the normal and high-risk infants. It occurred most frequently in pre-mature infants and did not occur at all in infants with meningitis. This result do not agree with the earlier studies. Michelson (1971), did not report the occurrence of bi-phonation in the cries of the 205 pre-matures studied. On the other hand, bi-phonation occurred (49 per cent) most frequently in cries of infants with meningitis when compared to infants with asphyxia (26 per cent) and malnutrition (23 per cent). (Michelson *et al.,* 1977; Juntunen *et al.,* 1978).

Bi-phonation has also been reported to occur in 49 per cent of the cries of 45 infants with jaundice (Warz-Hockert *et al.,* 1971). In this study, the occurrence of bi-phonation was very rare in the cries of infants with jaundice.

Bi-phonation did not occur in the cry of the infant with hypothyroidism. This supports the findings of Michelson and Siruio (1976), who did report its occurrence in the cries of four infants with hypothyroidism.

This supports the findings of Michelson and Siruio (1976), who did report its occurrence in the cries of four infants with hypothyroidism.

Michelson *et al.* (1982), have found bi-phonation and glide to be very sensitive in differentiating between normal and the disordered groups. In the present study, bi-phonation was not found to be very helpful in differentiating between the normal and high risk categories.

9. *Vibrato:* Vibrato occurred most often in pre-mature infants of this investigation. Michelson (1971), did not find its occurrence in the cries of 205 pre-mature infants. Michelson *et al.* (1981), have reported the occurrence of vibrato to be highest in infants with asphyxia when compared to infants with meningitis and malnutrition. Vibrato has been found to occur less in the high-risk infants except pre-mature infants than in the normal infants of this study. Earlier investigators (Michelson, 1977) have not reported its occurrence in normal infants.

This characteristic was also not very helpful in differentiating between the normal and high-risk categories in this study.

10. *Noise Concentration:* Noise concentration occurred more often in infants belonging to the high-risk category than in the normal infants. Pre-mature infants had maximum occurrence of noise concentration. In infants belonging to the other high-risk categories, the frequency of occurrence of noise concentration was similar.

There is no report available on the frequency of occurrence of noise concentration in normals and infants with pre-maturity, asphyxia, jaundice and meningitis.

Noise concentration has been observed in the crying of infants with herpes virus encephalitis by Pettay *et al.* (1977), and Michelson and Siruio (1976). It has been reported to occur in almost half of the signals in herpes encephalitis that were studied.

Michelson *et al.* (1982), found noise concentration in cries of infants with Iaryngomalacia, convulsions and a virus infection of unknown etiology.

11. *Glottal Plosives:* Glottal plosives occurred most often in infants, with history of Rh. incompatibility. There is no data in the literature available on occurrence of glottal plosives in these cases.

Apart from the above, it occurred most often in normal infants and least in infants with meningitis. Michelson (1971), has reported maximum occurrence of glottal plosives in normals and no occurrence of it in infants with meningitis. (Michelson *et al.,* 1977).

12. *Melody Type:* Most of the infants in this study, both normal and high-risk category has a rising-falling melody type (75 per cent). The other melody type which occurred was falling-rising. One pre-mature infant (No. 39), had no particular melody type.

Michelson (1971), did not report any difference in melody type between normal and pre-mature infants.

Michelson *et al.* (1977), reported an increase in rising and falling-rising types of melody in infants with asphyxia. In this study, all infants with asphyxia had a rising-falling melody type.

Michelson *et al.* (1977), reported an increase in rising, falling-rising and flat melody types of cries of infants with meningitis who were found to be abnormal on a follow-up examination. Michelson *et al.* (1982), found an increase in the rising and falling-rising types of melody in full-term infants with metabolic disorders and neurological symptoms. They imply that a change in melody is of CNS origin. The present study did not find melody type to be distinctive of any group; except in the infant with convulsions and delayed birth cry.

Results of the follow-up examination after 5 months: Information was collected regarding the developmental milestones and hearing ability of the infants, 5 months after recording the cries. It was possible to collect information from 8 infants in the normal category and 12 infants in the high-risk category. All the 8 infants in the normal category were found to be normal on follow-up examination. Four of the infants in the ' high-risk' category Were found to be ' normal' on follow-up. One infant had jaundice, one had meningitis, one had a delayed birth cry and had a history of Rh. incompatibility. It is possible that they were treated early enough and the problem was not so severe as to leave any after-effects. Eight infants in the high-risk category were confirmed to be ' abnormal' as they expired after a few days.

Thus, the results of the present study indicate that the cry characteristics which are found by spectrographic analysis may occur both in cases of normals and abnormals. Some of the characteristics are predominant in normal group and some are predominant in the abnormal group. Hence, cry analysis is helpful in differentiating between normal and abnormal infants. Based on-further analysis it has been found that each category of infants with a specific high-risk factor show the occurrence of certain characteristics more frequently than in other groups. So, the analysis of cries would be a valuable in differential diagnosis of different abnormalities in infants. Since cry analysis helps in diagnosis during the neonatal period, it is useful for early identification of abnormalities and thus in early rehabilitation.

Definitions used in the present study (Taken from Siruio and Michelson, 1976)

(1) *Duration of the whole cry or crying-time:* Has been defined as the time from the onset of crying until the child stops crying.

(2) *Maximum fundamental frequency:* refers to the highest measurable point of the fundamental frequency seen in the spectrogram.

(3) *Minimum fundamental frequency:* is the lowest measurable point in the fundamental frequency, seen on the spectrogram.

(4) *Shift:* denotes an abrupt upward and downward movement of the fundamental frequency and has been included in the measurements when it exceeds 0.1 seconds.

(5) *The melody type* of the fundamental frequency has been classified as falling, rising-falling, rising, falling-rising and flat. There should be at least a 10 per cent change in pitch level during more than 10 per cent of the duration of the cry for melody type to be identified.

(6) *Vibrate:* is considered to have occurred when at least four successive, rapid up and down vibrations have been noticed. There appear more clearly in the upper harmonics.

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