ANALYSIS OF INFANTS CRIES

Indira Nandyal

A DISSERTATION SUBMITTED IN PART
FULFILMENT FOR THE DEGREE OF
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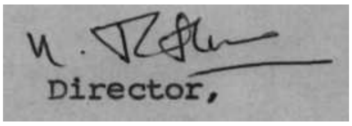
TO

MY LOVED ONES

WHO ALWAYS INSPIRE ME TO LEARN MORE

CERTIFICATE

This is to certify that the dissertation entitled "Analysis of Infants Cries" is the bonafide work in part fulfilment for M.Sc., Speech and Hearing, of the student with Register No: 4.



All India Institute
of Speech & Hearing
Mysore.

C E R T I F I C A T E

This is to certify that this dissertation entitled "Analysis of Infants Cries" has been prepared under my supervision and guidance.

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- Dr.Ankegowda, Cheluvamba Hospital, Mysore, for granting me permission to collect data at the hospital and for his suggestions.

- To the staff of Cheluvamba Hospital, Mysore, who helped me in collection of data.

- To all mothers, who so willingly allowed me to trouble their infants and make them cry.

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D E C L A R A T I O N

This dissertation is the result of my own study undertaken under the guidance of Sri.N.P.Nataraja, Lecturer in Speech Pathology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other diploma or Degree.

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CONTENTS

Chapter - I

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 baby 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." (Sjruio and MiChelson, 1976),

The importance of early identification of problems and abnormalities in childhood is increased because of the concept of 'Critical period' (Lennerberg, 1967). Early identification is also important from the point of view of early lntervention(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. An it would make rehabilitation economical.

Some methods of early identification are 'Newborn Screening Programs' and the 'High Risk Register'. They are in use with their own merits and demerits.

The 'Apgar' score is designed to determine the physical condition of the newborn 60 seconds after birth.

The response sought to two of the five segments in the score, involves 'Cry'. Studies done by Karelitz et al (1966) have indicated that apart from the fact that crying activity enters twice in the Apgar scale, and contributes a good deal to the total score, it continues to contribute heavily even when it is analyzed 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.

Wasz - 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 new born infants and those with asphyxia, brain damage, jaundice, and Down's syndrome were recognizable by pediatricians and medical students.

The phonetic structure of cries, cry duration, stimulus intensity, cry latency, and cry threshold have been found to be useful parameters in differentiating between normal and abnormal infant cries, (Fisichelli et al, 1966; Rebelsky and Black, 1972; Fisichelli and Karelitz, 1969; Fisichelli and Karelitz, 1963; Karelitz and Fischelli, 1962).

Objective techniques for analyzing infant cries are by volume - unit graphs (Fisichelli, Karelitz, Eichbarer, and Rosenfield, 1961) and computer analysis (ostwald and Peltzman, 1974).

In the objective analysis of the acoustical signal, a great advancement made in 1947, when Potter et al introduced their sound spectrograph. A sound spectrographic program for cry analysis was started in University of Helsinki, Finland in 1961. With narrow band analysis, the following cry characteristics have been measured from the spectrograms:-

1. Durational features like latency, duration of first phonation, second pause and crying time.

2. Maximum pitch, 3. Minimum pitch, 4. shift, 5. melody type, 6. Double harmonic break, 7. glide, 8. Bi-phonation, 9. furcation, 10. glottal roll, 11. glottal plosives, 12. noise concentration, 13. tonal pit and 14. Vibrato.

Cries of normal infants and those infants with various abnormalities have been differentiated based on the above cry characteristics, (Wasz - Hockert et al, 1971), Michelsson 1971, Michelssen et al, 1975, Sirino and Michelssen, 1976, Michelssen et al, 1982).

The purpose of the present study was to analyse normal and abnormal infant cries by spectrographic analysis and to note the specific characteristics which are distinctive to each abnormality.

The aim of the present study was to test the following null hypotheses:-

1. No significant differences is observed between the cries of normal healthy infants when compared to infants with history of high risk factors or other problems on the following cry characteristics- a) maximum fundamental frequency, b) minimum fundamental frequency, c) duration of the whole cry, d) double harmonic break, e) shift, f) glide, g) furcation, h) bi-phonation, i) vibrato, j) noise concentration, k) glottal plosives, 1) melody type and m) tonal pit.

Sub Hypotheses:-

1. No significant differences is observed on various parameters using spectrograms between the cries of normal, infants and pre-mature infants.
2. No significant differences is observed on various parameters using spectrograms between the cries of normal infants and infants with history of asphyxia.
3. No significant differences is observed on various parameters using spectrograms between the cries of normal infants and infants with jaundice.

4. No significant differences is observed on various parameters measured using spectrograms between the cries of normal infants and infants with meningitis.

5. No significant difference s is observed on various parameters measured using spectrograms between the cries of normal infants and infants with a history of Rh incompatibility.

6. No significant differences is observed on various parameters measured using spectrograms between the cries of normal infants and infants with hypothyroidism.

7. No significant differences is observed on various parameters measured using spectrograms between the cries of normal infants and infants with history of convulsions.

8. No significant differences is observed on various parameters measured using spectrograms between the cries of the normal infants and infants with history of delayed birth cry.

Brief Plan of the Study:-

The study was carried out in the following stages:-

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.

Implications of the study:-

(1) Cry analysis is helpful in differentiating between normal and abnormal infants.

(2) It is a valuable tool in the differential diagnosis of different abnormalities in infants.

(3) It is useful for early identification of abnormalities and thus in early rehabilitation.

Limitations:-

1. A small number of infants were included in each high risk category.

2. Only eight high risk categories were studied.

3. Only one follow up examination of the infants after five months was done.

3. Spectrographic analysis.
4. Follow up of the infants for hearing screening and to collect information about developmental milestones.

The list of high risk factors was constructed. Cries of 13 normal full term infants and 28 infants belonging to the high risk category according to the case history were recorded. The age range of the infants was from 16 hours to 3 months. Pain cries were elicited from these infants by flicking the sole of the infant's foot with the index finger, till they cried for at least 30 seconds. The cries were recorded and analyzed using a sound spectrograph to obtain narrow band, bar type spectrograms.

These spectrograms were analyzed to note the occurence of the following cry characteristics - 1. durationof the whole cry, 2. maximum fundamental frequency, 3. minimum fundamental frequency, 4. shift, 5. double harmonic break 6. glide, 7. bi-phonation, 8. furcation, 9. noise concentration, 10. glottal plosives, 11. tonal pit, 12. melody type and 13. vibrato.

A follow up examination of the infants was carried out, 5 months after the recording, for the purpose of the collection of information regarding developmental milestones and hearing ability of the infants.

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Definitions used in the present study:-

(Taken from Sirvio and Michelssen, 1976)

(1) Duration of the whole cry or crying time:-

It 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:- 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% change in pitch level during more than 10% of the duration of the cry for melody type to be identified.

(6) Vibrato:- Is considered to have occured when at least four successive, rapid up and down vibrations have been noticed. These appear more clearly in the upper harmonics.

(7) **<u>Double Harmonic Break</u>:-** Is defined as a parallel series of harmonics which have the same melody form as the fundamental frequency and occur simultaneously with the fundamental.

(8) **<u>Bi-Phohation</u>:**- Is considered as a double series of fundamental frequencies,, but the two or more series do not have a parallel melody form.

(9) **<u>Gliding</u>:**- Is a rapid up and / or down movement of the fundamental frequency; The change in frequency must be at least 600Hz in 0.1 seconds.

(10) **<u>Furcation</u>:**- Is a term denoting a split in the fundamental frequency, where a relatively strong cry signal suddenly breaks into a series of weaker ones, with each of them having its own fundamental frequency contour.

(11) **<u>Noise Concentration:</u>**- Refers to a clearly audible high energy peak of 2000 - 2500Hz found both in voiced and voiceless parts of the signal.

(12) **<u>Tonal pit</u>**:- Is a rapid downward and upward movement in the fundamental frequency. Here the fall in pitch exceeds, 30% and occurs within 0.4 seconds.

Chapter - II

REVIEW OF LITERATURE

"We should all be deeply concerned for the first two years of childhood, whether it is in relation to hearing problems, experimental deficits, nutritional deficiency. Vision defects, or any other physical or environmental problem. There must be a bountiful intake of sensory material in the first two years of the child's life if he is to attain his potential. There is no magic in the age of two years. We are simply biologically pre-programmed to develop early in life certain skills in response to certain inputs." (Downs, 1976).

If language is a biologically innate function as is presently believed (Lenneberg, 1967; Chomsky, 1966), then there are optimum times for its development just as in any biological function.

Menyuk (1977) maintains that there are "critical years for the language acquisition process", as demonstrated by the great progress in language development made during early years. For example, she states that the normal hearing child begins to put words together in sentences by 18 months of age. His sentences contain all the basic syntactic structures he will ever use. Even in the babbling period of the first few months of life, the infant is making both perceptual and productive categorizations which may be crucially important for later language development. Therefore, she says, the term 'early' in early detection turns out to be very early indeed.

Early identification is extremely important from the point of view of possible prevention and treatment. Take for example, an inborn error of metabolism - phenylketanuria which is inhibited in an autosomal recessive manner. In this case, there is good evidence that the foetus is protected from the consequences of the abnormal metabolic processes and that it is only after birth that these give rise to failure of normal mental development. Thus, if this is detected very early in llfe(in the first month preferably), a special diet can be given so that the hereditary error of metabolism, can be by-passed.(Fraser, 1974).

The value of early intervention in improving language skills has been demonstrated in studies of both deaf and normal hearing children. The Lexington School for the Deaf compared two groups of children, one group whose hearing loss has been identified, and train instituted, before the age of 16 months; the other group whose hearing loss was not detected nor training instituted, before the age of 16 months. The results showed that the children admitted prior to 16 months had significantly superior speech and language skills as compared with the after-16-months group. (Greenstein, et. al., 1976).

Autosomal recessive forms of deafness are the most common and when a couple has a child with hearing loss inherited in this manner, the chance that each subsequent child is affected is 25%, which is more than sufficient to place further pregnancies in a high risk register. Early detection is very important in this context also, so that the knowledge that hearing loss is present should be available before the couple embark on a further pregnancy (Fraser, 1974).

The classical signs of a deficiency in the function of the thyroid gland, hypothyroidism, do not manifest themselves when the child is born and often do not appear before the age of 3 months. However, early diagnosis is very important, because mental retardation is more frequent if adequate therapy is not initiated before 3 months of age (Maenpaa, 1972; Raiti and Hewns, 1971).

Illingworth (1971) asked innumerable mothers as to how soon they think that parents should be informed that their child is backward. Without exception they answered that they should be told as soon as possible.

The number of prenatal and peri-natal factors known to be related to the child's mental and physical development is steadily increasing. Some of the factors are described below:

Genetic Factors:-

Herediary factors play a part in the tendency of multiple pregnancy and premature labour, in the occurance of hereditary diseases and congenital malformations. Mongolian is in part a genetic condition. The overall risk of a mongol being born is 0.15% (Penrose, 1956).

Haemolytic disease and Kernicterus:- Gerrad (1952) found that out of 19 children with Kernicterus, only 6 had an IQ of 85 or more.

Defective Maternal nutrition :- Harrell et. al.(1956) showed that the mean IQ of 3 or 4 years old children of 612 women who had received vitamin supplements in pregnancy was significantly greater than that of controls.

Parents Age :- It has been found that the older the mother, the greater is the incidence of anamolies of the CMS. The role of the father's age is not yet certain. However, it is known, that achondroplasia and Alport's syndrome are associated with advanced paternal age and both are often associated with mental deficiency (Blank, 1959).

Pre-Mature delivery and small for-dates babies :-

Mc Donald (1967) followed up 1066 children with a birth weight of 4 lbs. or less. 13,6% of the surviving singletons and 5.9% of the twins or triplets had cerebral palsy, an IQ below 50, blindness or deafness.

Irradiation:- Courville and Edmondson (1958) referred to more than 60 cases in which mental deficiency was thought to have resulted from irradiation in utera.

Infection during pregnancy:- Jackson and Fisch (1958) found deafness occurred in 30% of children born of mothers who had rubella in the first 16 weeks of pregnancy.

Uterine anamolies :- An abnormal situation of the placenta (eg. placenta praevia) and retroversion of the uterus are associated with a higher than average incidence of prematurity and foetal anamolies. Bleeding during pregnancy is associated with a higher than average incidence of cerebral palsy, mongolism and prematurity in the foetus.

Stress during pregnancy:- When women gave birth to children within a year or so of release from concentration camps, the incidence of malformation in the children and of mongols was four or five times greater than the normal incidence (Stott, 1962).

Effect of drugs taken in pregnancy:- Methotrexate may lead to deformities of the nervous system. Drugs which increase the jaundice in a baby, may damage the brain, they include Promethazine, sparine, and large doses of Vitamin K (Miller, 1967).

Neonatal Asphyxia:- Ernhart et. al(1960) examined 355 children at the age of 3 years, in order to determine whether those who had anoxia at birth were in any way different from those whose condition at birth was satisfactory. There was a greater impairment in conceptual ability and the IQ score was slightly less in the anoxic children than in the normal controls.

Cretinism:- From a study of literature and other reported cases, it is concluded that the mean IQ of children treated early (in the first 3 months) was around 90 and that this figure was significantly better than that of untreated children, whost mean IQ was around 50.

Meningitis:- Wolff (1952) studied the intelligence of children who had meningitis 2 or more years previous to study. The mean IQ of 26 who developed meningitis before 6 months of age was 76.3; 4 were idiots. The mean IQ of 27 who developed it between 6-12 months was 90.8 and the mean IQ of those developing it over one year of age was 96.8.

Thus the review of literature regarding the factors leading to or associated with handicaps like hearing loss, mental retardation, cerebral palsy and others, shows that in most cases these have an important role in bringing about the problem very early in life.

It is also evident from the study of rehabilitation procedures that have been adopted that it is essential to identify the problem as early as possible to intervene the deteriorating condition of the case or to initiate the rehabilitation procedures, without losing the critical age for various developments.

Attempts have been made for early diagnosis of various problems. The implementation of 'High Risk Register' and infant screening programs have made early identification possible.

'Screening' as accepted by World Health Organization is defined as "the presumptive recognition of unrecognized disease or defects by the application of tests, examinations and other procedures which can be applied rapidly" (Roberts, 1977). They are not intended to be diagnostic. Persons with positive or suspicious findings must be referred to specialists for diagnosis and necessary treatment (Wilson and Laugner, 1968).

The concept of High Risk Register (HRR) was introduced to screen the hearing in the new born by Janet Hardy, a Pediatrician. Thus any child who has a suggestive history or by its physical appearance suggests an abnormality, is at risk. Such a child is considered as a High Risk Infant. In Hardy's concept, High Risk Register is an idea of registering every baby who is at risk, and carrying out systematic follow-up every few months, (Downs, 1978) for the purpose of early identification.

In the course of time however, the HRR has assumed another meaning, that is, it is a list of conditions that places the infant at risk (Davis, 1978).

Generally, the implementation of a HRR requires some one to collect information required for risk categorization from various sources like hospital records, interview with or a written questionairre given to a mother, physical observation of the child, etc.

There are a number of High Risk Programs, like The National Joint Committee (NJC) on early identification, The Utah state vide infant H.R. hearing program. The colorodo Infant Hearing Assessment Program, etc. In India, a High Risk Register for hearing loss in chidren was Ashok, M.M. (1981). Questions have been included to collect information regarding the following factors:

1) Family History of hearing loss.
2) Consanguinous parentage, primarily involving uncle-niece marriages.
3) History of rashes and fever during pregnancy irrespective of the trimester.
4) Report of Rh/blood group incompatibility.
5) Parental concern about their child's hearing.

The Apgar score is designed to determine the physical condition or viability of the newborn 60 seconds after birth, and it has established that there is a strong association between low scores and neonatal mortality. The scoring method is given in the following table.

Scoring Method in Evaluation of condition of Newborn Infant

Sign	score		
	0	1	2
l. Heart Rate	Absent	Slow(100)	100
2. Respiratory effort.	Absent	Weak cry, hypo-ventilation	Good strong cry
3. Muscle tone	Limp	Some flexion of extremeties	Well flexed
4. Reflex irri-tability (response of skin stimu-lation to feet)	No Response	Some motion	Cry
5. Colour	Blue, Pale	Body pink, Extremities blue.	Completely pink

Two of the five parts of the Apgar score are concerned with crying. The segment on respiration is a response to environmental stimulation,ie., change in the environment. If there is no crying it isscored zero. If it is a fair cry, it is scored one, and if it is, what Apgar calls, a good strong cry, it is cored two. The second sign(reflex irritability) lists 'cry' in response to a tangential foot slap. The diagnostic value of the cry along, suggests the potential importance of its role within the Apgar score (Karelitz et. al. 1966).

According to Karelitz(1966), it is possible to identify the age of an infant by listening to the cry of that infant. Further he also states that is would be possible to use this process of identifying age, baaed on cry abnormalities in the child. In this connection he narrates an instance which made him to develop this procedure for identifying abnormalities based on cry. According to him, he had identified the age of a child as four months based on the cry of an infant which was separated from him by a partition. But in actuality, the child was 11 months old. Further, it was found that the child was mentally retarded. Thus cry analysis was considered as a possible procedure in identifying the abnormalities.

Studies done by Karelitz and Fisichelli (1962, 63) show that there is difference in the latency and threshold of cries of normal infants and those with brain damage. The first cry studies were based on auditory analysis alone.

With the development of the sound spectrograph by Potter et. al. in 1940's, objective analysis of cry sounds has become possible. Since then, many reaearchers have been doing studies on cry characteristics of normal and abnormal infant cries. More than 20 different cry characteristics like latency, duration, continuity of the cries, shift, melody type, voice quality, fundamental frequency, the maximum and minimum frequency, have been measured. The occurence of double harmonic break, glottal roll, vibrato, bi-phonation, gliding, furcation, noise concentration, tonal pit and glottal plosives have also been identified and measured.

These studies have shown that cry analysis can be helpful in differentiating between normal and abnormal infants and thus it will become an additional valuable tool for arriving at the diagnosis and prognosis of newborn infants.

Crying is one of the first ways in which the infant is able to communicate with the world at large (Ostwald and Peltzman, 1974).

Different authors have offered various explanations for the first cry emitted by the child. The function of the birth cry is said to be entirely physiological, having to do with the establishment of normal respiration and the oxygenation of the blood. It constitutes the first use of the delicate respiratory mechanisms which are to be involved in speech. It is also the first time that the child hears the sound of his own voice, and, as much, has significance for language development (McCarthy, 1954).

The first cry is said to have other physiological purposes, such as to remove foreign material (Peto), to improve pulmonary capacity in the first days of life (Lang and Hull, 1961) or being a defense mechanism to increase body temperature (Watson and Laurey, 1951).

According to Karelitz (1969), the cry probably starts with a startle reaction created by the first breath. Hopefully, this cry is a good one, if not, a nurse or doctor in the delivery room tries to stimulate the infant to cry. It may be by slapping the infant on the foot, backside, back, or by one of several resuscitation techniques. The fact that the cry is an essential part of life, alone adds significance to the study of the infant's cry.

The first cry in the infant is said to be very important. The infant is no longer depending on the blood circulation from the mother, and thus the oxygen supply to the body must be taken care of by the infant itself. To achieve this, the infant takes the air into the lungs or inhalation takes place, which leads to the first cry. A delay in the cry would lead to the lack of oxygen in the body and thus the infant becomes blue. Blue infants are considered to be high risk infants, showing a history of brain damage. Therefore, whenever there is a delay in the first cry, the cry is elicited by using one of the several resuscitation techniques.

Crying is the result of the intense expulsion of air through tightened vocal cords into the pharynx and mouth as a resonating chamber. The character of the cry depends upon the intensity of air expulsion, the tension in the vocal cords and the shape and fixation of the resonating chamber, since crying is generally a maximal type of response, it reflects the capacity of the nervous system, to be activated and also the ability of the nervous system to inhibit or modulate this activation. The differences in the ability of different nervous system to respond could be in the peripheral sensory receptors, but it seems more complex that these differences are in the more complex activating systems of the brain, in the brainstem and thalamus. Likewise, the character of the motor responses could be due to changes in the peripheral motor control of the expulsion of air, vocal cord tension, and shape and tension in the supraglottal resonators. But it is more likely due to the effects of higher control centres in the brain, that act in a modulating or inhibiting fashion on the activating centres.

Thus, one might say that a 'good cry is one that is obtained with a moderate amount of stimulation, has a duration proportional to the degree of stimulation, but is readily terminated by central inhibition, and has some variability in tonal quality, implying lack of rigidity in the neurologic controlling mechanism. Therefore, detailed knowledge of the characteristic of crying sounds in various conditions may be expected to give considerable information about the nervous system (Parmlee,1962).

Borma et al (1965) suggest that neurological maturity is reflected in stability of laryngeal coordinations and the degree of mobility of vocaltract elements during crying. The sourcefilter theory of speech production provides a theoretical basis for inferring the effects of these vocal apparatus on the infant's cry. According to this theory, the power of the speech sound spectrum (P) at a frequency(f) is the product of 2 approximately indepen-dently controlled factors, the source spectrum(S) and the transfer function (T), that is, /P(f)/=/3(f)/ /T(f)/.

Vibrations of the vocal card in voiced speech produce a fundamental frequency (F_o) and its harmonies in the source spectrum. The vocal tract configuration determines regions of relatively effective transmission through the tract which are represented as resonante frequency in the transfer function. These resonance frequencies correspond closely to the frequency locations of formants which are peaks in the sound spectrum. Consequently, for most applications, resonance frequency and formant frequency may be used synonymously.

It may be deduced from the source filter theory of speech production that variability of vocal tract elements, which affects the resonance characteristics of the transfer function, is revealed in formant frequency variability in the cry sound spectra. In additions, it may be deduced that variability of vocal card movement, which affects the source spectrum, is reflected in variability of F_o in the cry spectra.

As the neuralogical mechanisms controlling the vocal apparatus mature, there is increased postural control of the vocal cards and the vocal tract and, as a result decreased variability in the functioning of these organs. Since there is greater variability of vocal apparatus for prematures than full term infants, it is hypothesized that the cry spectra of pre-mature infants shows greater variability of (a) Fundamental frequency and (b) of formants, than those of full term neonates.

Tenold et al(1974) have attempted to findout the spectral variability in the cries of pre-mature and full-term neonates. 9 full termand 5 pre-mature infants were taken for the study. There was no difference in variability of fundamental frequency between the 2 groups. But pre-mature infants showed greater variability of cry spectra than did the full-term infants. Sinoe formants are peaks in the sound spectrum, variability of formants will be reflected in spectral variability. Therefore, greater instability of cry spectra for premature infants may be interpreted as reflecting less postural stabilization based on the source filter theory of speech production.

Cullen et al (1968) have tried to study the development of auditory feedback monitoring in infants ranging from 24-168 hours of age. 11 males and 9 females were studied. Vocal cry samples of these 20 normal newborn infants were recorded under 2 test conditions - synchronous auditory feedback and a 200 msec. delay in auditory feedback(DAF).

Averages for cry duration, pause time and maximum sound pressure level were obtained for 16 of the 20 subjects. This study has demonstrated that a 200 msec. delay in the air conducted auditory feedback of the cry of a newborn infant is associated with a significant decrease in average cry duration. This result is at variance with the consistent observation that the average deviation of connected speech events far children and adults increases under DAP (Cullen, Fargo and Chase, 1968). The results, while not conclusive, indicate that cry behaviour may be under closed loop auditory-feedback control.

Karelitz(l969) carried out a longitudinal study on the normal development of cry in a baby firl. The first recording was made at the age of 2 days shortly before the infant was fed. The cry response came immediately after a finger flick was applied to the infant's foot. The duration of each burst of cry lasted as long as the infant had exhaled and was followed by a sharp intake of breath. The rhythm was rapid but regular and the intensity was great. The cry diminished in frequency and intensity gradually until it stapped, this sequence was repeated with each painful stimulus.

The cry at 4 days was similar to but, a bit stronger than at 2 days. At one month the cry was still rapid and rhythmic, and coughlike sounds could be heard. The cry at 2 months was still rhythmic, but this rhythm pattern was somewhat slowed by the lengthening of the inhalation and cry. Inflectional variations and a plaintive quality were evident at 3 months. The repetitive rhythmic pattern which is evident in a younger infant's cry was no longer characteristic of the cry at 6 months. At 9 months the cry was inflected and plaintive with greater variations in pitch, and the distinct syllable, "ah-ha" occured throughout. At 12 months, the qualities of the 9 month cry were still present but somewhat intensified. Recognizable words were interspersed throughout the crying at 18 months. At 2 years- the child communicated with words as well as with the cry.

Fundamental frequency characteristics of non-distress vocalizations produced by four infants during the first 24 weeks of life were examined by laufer and Haru (1977) Period-by-Period P melody plots and descriptive statistics for each utterance were derived from computer analysis. Mean F_o centered around 335 Hz with little variation. Individual F_o fluctuations deviating from the mean were felt to be associated with the infant's state, activity levels and changing vocal repertoire.

Keating and Buhr(1978) studied the fundamental frequency in the speech of 6 children, ranging in age from 33 - 169 weeks. Utterances were divided into 3 registers: fry register, modal register and high register. The overall range of frequency in fry register was 30-250 Hz. Utterances containing modal register comprised the bulk of the samples for each child and the overall range of frequency in modal register was 150-700 Hz. In addition to these high modal values, the occurance of a separate high register was also noted, The data for this sample of 6 children shows that both very low and high fundamental frequencies are common at all stages of language acquisition.

The course of crying activity was traced at successive intervals after birth: one minute, ten minutes, then 2, 4, 6, 24, 48, 72 and 94 hours after birth, for 24 infants with Apgar scores from 8-10(High Apgar group) and 12 with Apgar scores from 4-6(Low Apgar group). These 36 infants were studied longitudinally, in addition, 70 infants were studied 'cross-sectionally' (ten at each of seven time intervals corresponding to those in the longitudinal group). A cry index (C.I) was devised incorporating cumulative time of crying, the number of bursts in the cry, and threshold. The findings indicate: (1) The curves describing cry activity show a drop at 4-6 hours for all three groups with subsequent recogery for all.

(2) No differences were found between the 'Low' Apgar and the 'cross sectional' groups in crying activity.
(3) It is suggested that the depression in crying activity for the majority of infants between 2 and 6 hoursafter birth is traceable to 'fatigue'. The effort expended in the act of birth, the transition from placental to pulmonary breathing, the violent and sudden extension of the diaphragm, possible chilling in the immediate postnatal period, the type of delivery, perhaps even the sedative effects of drugs administered to the mother in labour, all may contribute to the depression found in these early hours of life (Eisichelli, Karelitz and Haber, 1969).

A similar study was carried out by Fisichelll et al (1974). 71 male and 87 female normal full term infants were taken and their crying activity in response to painful stimulation was recorded at successive ages from 5 hours through 52 weeks of age. They found that, although there is considerable variability in the crying response to stimulation which is painful, at any of the age levels specified in the study, reactivity is low at 5 hours of age, increases at 2 days of age, and then remains relatively stable upto 12 weeks. Thereafter, it diminishes markedly, or at the least, the overt cry reaction is suppressed.

Thus, it has been stated that the course of the cry reaction curve is primarily a function of age. This view has been supported by additional findings, which also rule out the major determinants, i.e., systematic adaptation affects, sex differences, and gross differences in IQ levels within the group studied. The authors hypothesize that, this lack of cry reaction is a maturing response and that it may be related to the corresponding maturation of central nervous processes within the individual at 3 or 4 months of age.

Karelitz et. al.(1964) explored the relation between the crying of infants four to ten days of age and intelligence as well as speech development level at 3 years of age. The cry samples were taken from 36 infants 4 to 7 days of age, one infant of age 8 days and another of age 10 days. 30 were given the Catell Infant Intelligence scale between 15 and 20 months of age. All 38 were retested at 3 years for intelligence with Form L of the Stanford-Binet. Also they were given a speech evaluation test, which was primarily an array of articulation, using a picture test. Crying scores showed a significant correlation (.45) with Stanford-Binet 10 at 3 years, a borderline correlation (.32) with Catell 10 at 15 to 20 months, and a non-significant trend with speech ratings at 3 years. Although no correlations were adequate for individual prediction, the authors consider that further investigation of infant crying as a possible indicator of intellectual potential should be done.

Lieberman et.al.(1971) studied the neonatal cry and compared it with vocalization of non-human primates. The spectrogram of the cry of a male infant during the 1st five minutes of life revealed a fundamental frequency of phonation of 400 Hz. Energy concentrations appeared approximately at 1.1, 3.3 and 5.8 KHz. The authors say that one can infer the configuration of the infant's supra-laryngeal vocal tract for this vocalization by making use of the acoustic theory of speech production (Pant, 1960. This theory allows one to infer that the supralaryngeal vocal tract configuration of this infant approximated a 7.5 cms long uniform tabe open at one end. The formants of such a tube will occur at 1.1, 3.3 and 5.5 KHz., since it will have resonances at intervals of $\frac{(2K+1)C}{4L}$ where C= velocity of sound, L= Length of tube and K is an integer 0.

Lieberman et. al.(1971) believe that the energy concentration at widely spaced regular intervals, reflect the formants of a supra-laryngeal vocal tract shape that resembles a uniform tube that has similar open boundary conditions at each end. Similar effects also appear to occur during the vocalization of non-human primates like apea and monkeys. It is also found that fundamental frequency of phonation, in general, was not stable during the neonatal cry.

The infant cry sound has interested researchers of different disciplines for a long time and several methods have been utilized for cry analysis. Cry studies of infants have been done by auditory analysis, with musical notes, phonetic transcription, volume unit graphs and analysis by using electro-laryngograph, spectrograph and computer analysis.

Auditory Investigations:-

One of the first reports of the acoustic structure of infant cries was published in 1838 by William Gardiner. He described the cries and calls of both humans and animals by means of musical signs. According to Gardiner, the tones of infant crying generally lie between the notes A and E in the middle of the piano key board. The initial expiratory component is usually the most prominent features of the cry; it lasts about a second on the average and has an up and down melodic pattern. The inspiratory component of the cry is much shorter.

Charles Darwin (1855) was also interested in the crying of infants. He made notes on screaming and weeping of infants and was mainly concerned with the vocal anatomy and developmental physiology of speech in relation to the expression of emotion.

Flatau and Gutzman (1906) used musical notation and phonetic alphabet to describe the cries' vocalic and consonantal features. They recorded the cry of an infant with troubled breathing. The pitch of crying was about one octave higher than that of normal infants.

Sherman (1927) tested auditory identification of infant cries. The infants were placed behind a curtain and different kinds of stimuli like cold, hunger, and anger were used to evoke cries. Sherman (1927) found that graduate students in psychology, medicine and nurses were unable to differentiate between the various cries. Others like Bayley (1932), Fairbanks (1942), and Mc Carthy (1952) have found differences in infant crying with various stimuli.

Warz-Hockert et.al.(1964) constructed an experimental listening tape with 24 selected short cry samples from normal, healthy children. The cries were classified as birth,pain, hunger and pleasure cries. These cries were played to 483 adults, and it was found that those who had various degrees of experience in child care could identify the cries more accurately than those who had no previous experience of infant cries. Due to their ability to recognize the birth cries, midwives obtained the highest percentage of correct responses. Also, it was found that training increased the ability to recognize different kinds of cries.

Similar results were found by Morsback and Murphy (1979). The hunger cry of five full term infants was recorded between 2 and 4 days of age. 20 pairs of cries were played back to subjects, who were asked to judge whether each pair represented the cries of the same baby or of different babies. Subjects belonged to five sub groups - midwives, parents with children above one year, non-parents who some times have contact with babies or small chidren, and non-parents who have no contact with babies or small children. Results showed that there was no significant difference between the last four groups. The percentage of correct matching by midwives was higher than that of the other groups. This seems to indicate that the ability to discriminate between baby cries is not mainly due to the amount of exposure to one particular infant, but to the amount of handling of several infants in a professional capacity.

The ability of mothers to recognize the vocalizations of their own infants has been confirmed by valanne et.al. (1967).

Hollien, Muller and Murry (1974) studied the ability of 18 months to to perceptually differentiate cry samples elicited by 3 different stimulus conditions - Hunger, pain and auditory stimulation. In some instances, the mothers were evaluating cries produced by infants with whom they were unfamiliar and in other cases they judged cries produced by their own infant. The results indicated that the 18 mothers were unable to successfully match the cry samples with the 3 cry evoking situations. The authors hypothesize therefore, that within the normal home situation, the cry generally acts simply to alert the mother, and that any of her suppositions concerning the situation that evoked the crying behaviour must be based upon additional environmental cues.

Murry, Amundson, and Hollien (1977) noticed that an infant's sex could could not be reliably identified on auditory basis.

Auditory differences between the crying of sick infants and healthy ones have often been recognized by pediatricians. Illingworth (1955) states that, "a clinician recognises the hoarse, gruff cry of cretinism, the hoarse cry of laryngitis, cerebral irritability, the grunting cry of pneumonia, the feeble cry of amytonia or a severely debilitated infant, and the whimper of the seriously ill child."

Various groups of physicians, nurses, students and others have been tested on their ability to distinguish between 'normal' and 'abnormal' cry samples. The results were not statistically significant. Rosenfield (1959) states that, "while these data based on 4 normal and 4 abnormal cases may not support the generalization that the population of abnormal infant cries is recognizably different from the population of normal infant's cries, they strongly suggest that this is a possibility that should be and is being explored."

Partanen et. al.(1967) found that audible differences were recognizable when the cries of healthy newborn infants and those with asphyxia, brain damage, jaundice or Down's syndrome were compared by 45 pediatricians and 37 medical students.

The test tape included 20 pain cry signals representing 8 normal and 3 cries each from the other groups. A few months training improved the ability of medical students to recognize cry types.

Tape recorded cries of 21 infants with Down's syndrome were analyzed for audible characteristics such as bursts, whimpers, gasps, etc by Flsichelli et.al.(1966). These cries were compared with cries of 21 normal infants matched for age and sex. Nearly all the characteristics measured showed significant differences. In general, the cry of the normal infant is more active and lasts longer than that of the mongoloid infant. The normal infant also shows greater sensitivity than the mongoloid infant; the normal infant requires less stimulation to produce crying and his reaction time is faster than that of the infant with Down's syndrome.

The phonetic structure of the cry was studied in a further effort to differentiate between the cries of normal and abnormal infants (Eisichelli et. al., 1966). Tapes of 10 abnormal infants randomly selected at each of three age levels - the first week of life, approximately 6 months, and close to one year, were matched with tapes of normal subjects according to age and sex. The phonetician then transcribed the recordings in the 'International

Phonetic Alphabet'. The following results were obtained (1) The phonetic content of the cry for both normal and abnormal infants is predominantly made up of vowel sounds. These tend to decrease with age as the number of consonant sounds increases.
(2) There is no significant difference between normal and abnormal infants in the percentage of specific sounds produced.
(3) Normal infants produce significantly more total sounds than do abnormal infants; they also produced more vowel sounds than do abnormal infants. Abnormal infants produce significantly more nasal sounds than do normal infants.

The amount of crying or cry duration of small babies has also interested researchers. Aldrich et.al. (1945) measured the amount of crying in 50 newborn infants. The average crying time during the first 8 days of life was 117 min./day. Less crying occured in infants with more nursing care. The main cause for crying was identified as hunger.

Greenberg et. al.(1967) found that 7 newborn babies who were clamped early after delivery were more alert and cried more than 7 late-clamped infants.

Rebelsky and Black (1972) found that 1-3 week old infants cried 14-34 min./day during a 7-8 hour period. The amount of crying increased during the first six weeks of life from an average 22 min./day to 34 min/day and decreased thereafter. The number of hours in which there was some crying did not change much between 1 and 13 weeks of age.

Fisichelli and Karelitz (1969) investigated the effect of the stimulus intensity on the latency and total time - the time in seconds spent in crying (not more than 60 seconds) including interruptions in the cry (lasting less than 10 seconds). 2 rubber bands - No. 32 and No.30 with impact forces of 4.2 and 6.2 respectively were used to induce the pain cry. Two groups of normal infants, who were 2 days of age, 10 in each group, were studied. The first group received the more painful No.30 first and second group received No.32 first. Fisichelli and Karelitz (1969) state that "within the limits prescribed by the conditions of this study, more intense pain produces a longer, more concentrated and more productive cry: Latency is not affected."

Rosenhouse (1980) analyzed the cry recordings of her own daughter at the age of 6-8 weeks along the time axis. 3 types of cries were recorded : hunger, pain and illness cries. For the duration analysis, the recorded tapes were passed through a ferrograph tape recorder to a Buel and Kjaer level recorder. By showing down the recorded cries to half their normal speed and adjusting the paper and pen speed of the level recorder, a good display of the cries were obtained. The distances on the paper were then converted into time units (ms). Each cry was ticked individually as it was heard, while, simultaneously watching the pen motion.

From the cries as heard by the ear and seen on the level recorder tracings, it was clear that different cry types have different structures.

The single cries were classified into 3 groups:-

(1) Short cries, of upto about 600 msec.

(2) medium cries, upto about 1.5 sec.

(3) long cries, above 1.5 secs. The longer the cries, the more space there is for intonation - structuring complexity. (example - rise-fall-rise vs rise-fall in various sizes of 'medium' hunger cries).

The pauses were classified into 2 types:-

(1) Inhalation pauses - short pauses of about 300 msec which serve only for rapid intake of air between consecutive cries.

(2) pauses which are longer than 300 msec, and serve besides inhalation, also for rest or relaxation of the baby.

This group of pauses were divided into 2 sub-classes: pauses upto about 1.5 - 2 secs, which do not necessarily seem to signify the end of a cycle of crying and above 2 secs, which always indicates an end of a cycle.

Rosenhouse, found the relation between the cries and pauses of the different cry types by observational comparison of the figures of cries and pauses.

(1) Pain sequences - when there is a long cry, next to it there is usually a long pause, when the cries are short, there are usually short pauses next to the cries (symmetry).

(2) Hunger sequences - When there is a long cry, there is a short pause next to it and when there is a short cry, next to it there is usually a long pause(antimetry).

(3) Illness sequences - No obvious relation between length of cries and pauses such as the 2 above, has been found (irregularity).

(4) Fatigue sequences - These combine both the antimetric patterning of hunger sequences and the symmetric patterns of pain sequences, with some preference to the antimetric pattern.

Rosenhouse further reports that sub-cycles and linking units are internal parts of cycles of cries. sub-cycles are similar to cycles in that they have patterning of the cries in durational and acoustic terms, but they are not cut off from one another by long pauses like cycles. Sub-cycles may be on edges or the inside of a cycle, and they are separated by linking units on one side at least. The linking units are small groups of short cries surrounded by pauses longer than those cries and which are found within the cycles only.

Rosenhouse (1980) concludes that these findings support the assumptions that the feature of duration is not accidental in this baby's cries. Duration is also an important feature of language structure.

Studies on cry latency have also been done, as it is known to be a reliable indicator between normal and abnormal cries. Cry latency is defined as the time which elapses between the moment of painful stimulation and the onset of cry.

Fisichelli and Karelitz (1963) measured the cry latencies of 117 normal and 69 abnormal infants. They found that - (1) 46% of all the abnormal infants and 45% of the matched abnormal infants gave no response at all to the first stimulus. 12% of all the normal infants and 9% of the normal ones in the matched group, did not respond to the first stimulus. (2) For the infants who responded, the mean latency time of the normal matched group was 1.6 seconds and the mean of the abnormal matched group was 2.6 seconds. (3) The difference between cry latencies of males and females was not statistically reliable.

In the analysis of 50 pre-matures (39 healthy and 11 with pulmonary disorders), Gliss and Holen (1968) found latency variations from 0.9 to 6.0 seconds. The latency period decreased with repeated stimulation.

According to Siruio and Michelson (1976), the wakefulness of the infant i.e., whether the infant is deeply asleep or awake, is also an important factor in determining durational features, especially latency. Latency, according to the above authors, is also influenced by the inspiration - expiration cycle, i.e., whether the stimulus is given during the inspiration or expiration period.

The cry threshold is the amount of stimulation required to elicit at least one minute of crying from the infant. Studies on cry threshold have been carried out by Karelitz and Fisichelli (1962). They subjected 293 children to a standardized stimulation procedure in order to determine their cry thresholds. They found that abnormal infants require more stimulation than normal infants in order to evoke the same amount of crying. Also, the diagnosis of 'normal' or 'abnormal' based on whether the infants responded with one full minute of crying or not was statistically significant. Younger normal infants did not cry as readily as older normal infants. In the abnormal group, they found that older abnormal infants cried more readily than younger abnormal infants, but not as readily as normal infants of the same age group. Thus, they have concluded that the age of the subjects seems to be a critical fattor in responding to stimulation. No significant sex differences were found. Karelitz and Fisichelli (1969) also noted that eight rubber band stimuli were the maximum number required to elicit the cry.

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 cries, as this cry type can be standardized. Electric or thermal stimulation used by some as painful stimuli were not recommended, because of possible objection by parents.

The stimulus used by Karelitz and Fisichelli (1962) to induce crying was supplied by the map of a rubber band, stretched from its ordinary length of 7.4 cms to about 23 cms on a gun-shaped apparatus. A new band was used for each infant. The time when the stimulator was placed at the centre of the sole of the infant's foot and the time when the rubber band was released was noted. If there was no response or the crying stopped quickly, 10 seconds rest was given before the stimulation procedure was repeated. This was repeated only 7 times and if it did not produce one full minute of continuous crying, it was followed by 3 clusters of 5 scratches with the nail of the index-finger on the sole of the foot. If this also did not induce crying, the centre of the sole of the foot was flicked once with the index finger.

According to Siruio and Michelson (1976), a pinch of the infant's beceps or ear is a good way of eliciting a pain cry signal.

Parmlee (1962) has stated that the cry is always the maximum type of response to a stimulus and the mode of stimulation is therefore, of less importance. This has also been supported by Murry, Hollien and Murphy (1975), who did not find any correlation between different types of stimuli and cry.

Volume-unit graphs is another technique for analysing infant cries. Basically, here the tape recordings of infant cries are converted into printed records.

The equipment consists of a magnetic tape recorder-player equipped with a V.U meter which permits visual monitoring of the signal. The deflections of the needle in this meter is recorded graphically by connecting this to a graphic- milliammeter. The signal is amplified before being relayed to the graphic-ammeter. This provides a variable control of the signal entering the ammeter.

The V-U graphs depict the continuous volume changes occuring in the infant's cry. The V-U graph presents a clear picture of the onset of crying, the number of bursts, their relative intenslty, and the pattern of ascent and descent. Since the graphic ammeter runs on a synchronous motor, time is readily measured. Thus, given a stimulus to induce crying, the cry latency period can be measured to a fraction of a second. The duration of each burst and the intervals of silence can be measured in the same way. The height of each curve is ameasure of its intensity expressed in milliamperes. The ordinate scale is from zero to five milliamperes.

The clearly observable curve characteristics may be transformed numerically in the following manner: Each curve has an ascending period, a peak, and a descending period. The simple peak consisting of an ascending period, a peak and a descending period may be given the notation 0-0-0. No volume change, in addition to the fundamental upswing and fall, occur during ascent (first position), at the peak or during the fall. When additional volume activity does occur, the order of notation will indicate whether it occured during ascent (first position), at peak (second position), or during descent (third position). Cardinal numbers may be used in these three positions to indicate the number of volume changes which appear. The notation 1-2-3 describes a curve in which the ascent shows one instance of additional activity, the peak shows two such changes and the descent shows three. The peak of 1-2-3 curve has three points since the notation indicates thattwo additional changes have occured.

The relative intensity of each curve is measured directly from the graduated chart as is the duration of the outburst. The complete notation for a particular curve may read 0-0-0-4. 3-1.4: This spike of intensity is 4.3 milliamps and lasting 1.4 seconds. The V-U charts have been especially useful in providing a means of measuring the temporal relationships within the cry (Eisichelli, Karelitz, Eichlauer, and Rosenfield, 1961).

The frequency and amplitude characteristics of infant cries have been analyzed using computer. The frequency and amplitude characteristics are directly analyzed by means of a digital computer programmed for processing of such data (Ostwald and Peltzman, 1974).

Computer method of analysis are available for testing the hypotheses of greater variability of fundamental frequency and of cry spectra for pre-mature infants. When a fundamental and its harmonics are present in the log power spectrum, a peak appears in the cepstrum (the power spectrum of the log power spectrum) at a 'que frequency' in msecs, which is reciprocal of the fundamental.

The test for stationarlty may be used to determine the variability of cry spectra. In this method of time series analysis, the data are divided into equal parts and a spectrum is estimated for each part. The test for stationarity determines whether the true spectrum is the same for all parts or different, that is, whether the time series is stationary (non-variable) or non-stationary (variable). (Tenold, et. al., 1974).

In the objective analysis of the acoustical signal, a great advancement was made in 1947, when Potter et.al., introduced their sound spectrograph. A sound spectrographic study program was started in Helsinki, Finland, in 1961. In sound spectrography, the cry signals are converted into a permanent visual recordings where different parameters present in the cry signal can be measured. There are several brands of sound spectrographs available; however, the principles of operation are basically the same.

The analyzing mode can be either time versus frequency or amplitude versus time. The spectrographic paper is rolled on the rotating drum of the apparatus. 2.4 seconds of acoustical information can be displayed.when the drum rotates, a stylus moves from the bottom of the drum to the upper part of it and bums the paper depending upon the frequency and intensity of the signal, with the time on the horizontal axis and the frequency distribution on the vertical axis. The intensity of every point in time is seen as a variation in the darkness of the marking.

In the normal mode of operation, analysis of the signal upto 8000HZ is possible. In cry analysis, however, an upper limit of 4000 - 5000 Hz is usually sufficient to cover the frequency range. There are two types of filters, the narrow band filter with the band width of 45 Hz and the wide-band filter of 300 Hz. The narrow band filter displays the fundamental frequency and its harmonic overtones on the spectrogram as dark lines and is usually preferred in cry analysis. In the narrow band analysis, the first horizontal line in voiced cries is the fundamental frequency and represents the rate of vibration of the vocal cords. The harmonics are seen on the spectrogram as precide multiples of the fundamental. In analysis, with the wide band filter, the fundamental frequency can be calculated from the number of vertical striations per second.

Michelson and Siruio (1976) have indicated the various parameters that can be measured from the spectrograms of cries.

Durational Features:-

The latency period is defined as the time between the application of the pain stimulus and the onset of crying. In most studies, the latency measurements are started at the moment on the spectrogram or oscillogram when the person recording the cries says a word as a marker to note the application of the stimulus. Sometimes, the very first sound emitted by the infant is a cough-like sound. The difference in the latency period when measured from the stimulus to the 'main cry', instead of the first audible sound, is notable. Ringel and Kluppel (1964) took two measurements to determine the latency period, the time from the stimulus to the first response of the infant and the time from this first short sound to the main signal. The states of arousal and hunger can change the latency period. The latency period can also be influenced by the time when the pinch is given during the respiratory cycle (i.e., during inspiration or expiration).

Duration:- is measured from the onset of the crying to the end of the signal, and consists of the 'total vocalization occuring during a single expiration or inspiration'. At the onset of crying, the intensity of the voice is usually very high. The end of the cry signal can be characterized as a 'fade-out' where the intensity of the signal gradually decreases. This sometimes causes problems in measuring as the signal is audible although it is not visible on the spectrogram or oscillogram. The end of the vocalization can be visualized by increasing the reproduce level on the sound spectrogram.

The identification of the inspiration is often difficult on the spectorogram. Auditorily, the inspiration can be identified on the recording tape and a comparison of the auditory and visual impression, makes the recognition on the spectrogram possible.

In their first studies, Warz-Hockert et. al.(1968) did not measure signals less than 0.4 sec if located at the beginning or the end of the phonations. In the studies carried out by Siruio and Michelson (1976) all durational features exceeding 0.1 second were included in the measurements.

The term 'second pause' has been given different explanations by different investigators, Vuorenkoski et.al.(1966) and Michelson (1971) defined the second pause as the time between the first and second vocalization. Siruio and Michelson (1976) refer to it as the time interval between the end of the signal and the following inspiration. In studies by Lind et. al.(1966) and Michelson (1971), the second pause was considered as abnormal if it exceeded one second.

In measuring the above durational features, a change in the measuring criteria is made. Changes in inter-relations of the three factors would also occur.

The crying time has been defined as the time from the onset of crying until the child stops crying.

The fundamental frequency

Maximum Picth:- This feature refers to the highest measurable point of the fundamental frequency seen in the spectrogram.

Minimum Pitch :- is the lowest measurable point in the fundamental frequency seen on the spectrogram. The minimum pitch is measured in the lowest part of the fundamental frequency, where the harmonics are still clearly visible.

When the cry is voiceless or contains noise elements, the fundamental frequency cannot be determined. In glottal plosives and glottal roll, the fundamental frequency cannot be measured.

Shift denotes an abrumpt upward and downward movement of the fundamental frequency. The shift part has been included in the measurements when the signal exceeds 0.1 sec (Michelson et.al., 1977) or 0.2 secs.(Warz-Hockert et.al., 1968; Michelson, 1971). The number of shifts, the pitch, the duration,and the melody type of the shift part can be used to specify the cry type, but has not been investigated.

The shorter part of the phonation has been considered the shift; this is in agreement with the audible expression of the sound. Stark, Rose, and Mc Lagen (1975) define the shift as a pitch break not due to halving or doubling of the fundamental frequency. But in studies by the Finnish research group, it has been noted that when a shift occurs it is often due to an exact halving or doubling of the fundamental and, because of this, it is sometimes difficult to differentiate the shift from the double harmonic break.

In cries of healthy infants, the cry often starts with a shift part, whereas, in cries of infants with Central Nervous System disorders, it seems as though shifts in the middle and the end of phonations are common and that there is an overall instability of pick. Whenever two or more shifts occur in the same cry signal, only the maximum frequency of the shift is measured.

The melody type of the fundamental frequency has been classified as falling, rising-falling, rising, falling-rising, and flat. When the frequency is very unstable, voiceless, or consists only of glottal plosives, often no melody type is detectable. Warz-Hockert et.al.(1968) define the cry type as falling or rising when there is at least 1 10% change in pitch level during more than 10% of the duration of the cry. Stark et. al.(1975) have defined the melody as a flat, rising, or falling pitch contour, or a combination of these contours.

The glottal roll, or vocal fry, is a sound with very low pitched, voiced fundamental frequency and usually has a low intensity. Glottal roll occurs often at the end of the phonations. Duration measurements in cries which end with glottal roll can sometimes be difficult to determine as the intensity of the glottal roll decreases, which usually will not be within the dynamic range of the sound spectrograph. When it is within the dynamic range, an increase in the mark level of the spectrograph makes the glottal roll visible on the spectrogram.

The glottal roll can be preceded by a Vibrato or vibrato can occur by itself. Vibrato is considered to have occured when at least four successive, rapid up and down vibrations have been noticed. Vibrato is characterized by frequency vibrations that appear more clearly in the upper harmonica.

Cry signals have been classified as continuous or interrupted based on the continuity of the signal.

There are other features related to fundamental frequency. Double Harmonic break (or sub-harmonic break) is defined as a parallel series of harmonics which have the same melody formas the fundamental frequency and occur simu-taneously with the fundamental. There may be a double or treble series of parallel harmonics.

According to Stark, Rose and Mc Lagen (1975), the double harmonic break gives an impression of roughness of voice, but not a pitch change.

Bi-phonation or diplophonation is considered as a double series of fundamental frequencies. In bi-phonation, the two or more series do not have a parallel melody form. One series can be falling, while the other can be simultaneously rising, unlike in double harmonic break. (Michelson et. al., 1977).

Gliding is a very rapid up and/or down movement of the fundamental frequency,and its duration is generally very short. The change in the frequency of the fundamental tope must be at least 600 Hz in 0.1 seconds to be considered as gliding. Gliding should be measured only from the fundamental frequency, and not from the harmonics. eliding seldom occurs in cries of healthy infants.

Furcation is a term denoting a 'split' in the fundamental, where a relatively strong cry signal suddenly breaks into a series of weaker ones, with each of them having its own fundamental frequency. This feature is seen only in pathological cries. Noise concentration denotes a clearly audible, high energy peak of 2000-2500 Hz, found both in Voiced and Voiceless parts of the signal. This is uncommon in the cries of healthy babies.

Tonal pit refers to a rapid downward and upward movement in the fundamental frequency. When the fall in pitch exceeds 30% and occurs in less than 0.4 secs, then this characteristic is considered to have occured.

Glottal plosives have not been defined clearly. The term is somewhat misleading, because it denotes not only glottal plossives, but also, all other kinds of plosives.

The loudness of the cry sound is displayed on the sound spectrograph by darkness of the lines. The loudness of the cry sound is dependent on the distance from the microphone to the infants mouth and is difficult to standardize.

Based on the above characteristics it has been posible to identify abnormalities in infants. Apart from analyzing the various acoustic features of infant cries, some investigators have attempted to give a behavioural classifications of infant cries.

In 1962, Warz-Hockert et. al. reported their first findings on sound spectrographlc analysis of birth, pleasure, hunger, and pain cries.

Wolff (1969) described three cry types: the basic cry, the mad or angry cry, and the pain cry.

Stark, Rose and Benson (1978) designed a study based on the assumption that more information would be yielded by first classifying infant vocalization behaviour and then comparing the auditory and the acoustic features of each class, then by using any of these levels of analysis along. Cross sectional data were obtained from frcm infants whose birth and neonatal histories were normal. 2 infants were recorded at each of the following ages: 2, 4, 8, 12, 16, 20, 30, 35 and 40 weeks. 3 judges, all of them had prior experience in listening to infants, classified the vocalizations. The definitions prepared by the listeners are as follows:

cry sounds(C) - Series of sounds produced in acute distress due to hunger, pain, temporary absence of parent, etc.

Discomfort sounds (D) - Sounds which are produced in distress of a lesser degree than in(C).

Vegetative sounds (v) - Cough, burp, sneeze, hiccup, sucking, snort, etc. Grunts made with effort or in the course of activity; sighing after effort; grunts and sighs made as breathing is interrupted by swallowing or other vegetative activity.

Laugh sounds (L) - Series of sounds produced in delight.

Comfort sounds (K) - Sounds produced in comfort eg., when bed and diaphered.

Speech of vocal play (S) - Sounds which result from movement of the supra-glottic articulators(eg. friction sounds, stops or clicks). Also, series of vowel-like sounds with overall intonation contours which seems speech-like.

Rosenhouse (1977) studied different cries of her own two month old child in order to understand better, the differences between cries which are apparently elicited by different stimuli. The recorded cries were later analyzed by the Sonagraph 6061 B (Kay elemetrics). Subjective analysis of the cry types was also carried out.

Four groups of cry-types were classified : pain, hunger, illness and alarm cries.

(1) Hunger cries:- Hunger cries have a very long introductory stage. In the introductory stage, the cries are rather short, relatively low-voiced and separated by long pauses. As the baby's awareness of the sensation of hunger gets more acute, in the second stage, the cries become gradually longer, louder and with shorter pauses. There is a typical intonation pattern associated with these cries (rising-falling-rising). After a while the cries became 'frantic' or 'angry' to use a subjective expression, and this state does not change until the baby is given her meal.

(2) pain Cries:- Pain cries start abruptly and is characterised by loud cries and short pauses between single cries. The cries of this sort vary in loudness and intonation patterns along the cry sequence(unlike the gradual building up of hunger cries). Apparently, these fluctuations in intensity and pitch are in conformance with the intensity and kind of pain which the baby feels. Once the pain decreases, the baby slowly relaxes and the cries gradually subside, though not in a 'linear' line.

(3) Illness cries:- Illness Cries have been described as moans of a weak and tired person. These cries have extremely high pitch, rather low intensity and rather long pauses between cries and cry cycles.

(4) Alarm Cries were elicited when the baby was suddenly awaken by a sudden loud noise from outside. In intensity and intonation patterns, they are similar to pain cries, but, the sequence structure is somewhat different. It would seem that in alarm cries, the subsiding stage starts earlier than in pain cries. Likewise, the 'peaks' during the subsiding stage are more numerous in pain cries than in alarm cries.

For the spectrographic analysis, the patterns of energy-bands were divided into 4 groups: level, level + up, level + down, and Up + down. 'Level' means that one band of frequency is standing out along the cry; 'level + up' means that the band of exphasized frequencies changes somewhere along the cry into a band of higher frequencies and so on. The data in this study were summarized as follows:

In hunger cries, the group 'level + down' is the most common. The remaining three groups may occur equal number of times, in pain cries, the 'up + down' group is the biggest one, with 'Level + down' as the smallest group. In illness cries, the 'up + down' pattern is again the biggest group. In alarm cries, 'level' is the preferred group, without any examples of the 'level + up' pattern.

No examples with a 'down + up' pattern have been found in this sample. This last pattern exists mainly in cries of 'brain-damaged' infants (Wartz-Hocert et. al., 1968).

The overall energy distribution of the frequency spectrum was also analyzed. In illness cries, three regions of varying intensity distribution could be distinguished: the lowest (upto 2500 Hz) had the highest intensity, the middle region (upto about 5000 Hz) was less intense than the first one, and the highest region (above 5000 Hz) had the lowest intensity (almost white on the spectrogram). In hunger cries, the lowest region had very weak intensity with white spots (i.e., silence or breaks), the middle region had the highest intensity on the spectrograms, and in the highest region, the intensity was weaker again, weaker even than the lowest region. In pain cries, no definite regional structure could be found, because the intensity in the spectrograms was distributed in numerous complex forms.

Rosenhouse (1977) further classifies cries into 'level units', that is, single cries, cycles and sequences, She concludes that it seems possible to classify the cries into linguistic elements - single cries are comparable to phonemes or morphemes (depending on the complexity of their inner structure) in adult language; cry-cycles are analogous to morpheme-combinations or sentences or 'semantic units' (Menyuk, 1971) and cry sequences are comparable to a complete paragraph of speech. For any mother (or nurse) usually senses the baby's needs not by a single cry, but by a cycle, at least, or a whole sequence, and the overall impression it gives.

Cry in Healthy Infants

In healthy newborn infants, the features of the cry signals can be divided into two main groups, features related to the duration and features related to the fundamental frequency.

The fundamental frequency in crying of healthy infants varies between 350 Hz and 650 Hz. The cry in healthy infants often has falling or rising-falling melody type with a stable pitch. Shifts with a higher pitched frequency occur mainly at the beginning of the signals and especially in pain cries in which almost every third cry has a shift part. Occurance of glottal roll is quite common at the end of the phonations, and vibrato sometimes precedes the glottal roll part. Bi-phonation and gliding are quite rare. The signals are voiced and continuous in about two-thirds of the cries.

The variation in the duration features in normal newborn infants is quite large. According to different authors, the latency period is from 0.6 to 3.6 secs. This variation is attributed to measuring techniques and the infant's wakefulness. But it may also be due to the fact that the latency period is not quite uniform in healthy neonates. The first latency is often longer than the latency of immediately repeated stimulations. Various reports have given different durations of phonations depending on the analyzing technique used. The average reported is from 1.1 to 2.8 secs. (Siruio and Michelson, 1976).

Another characteristic response of the normal infant, a few days old, has been reported by Karelitz and Fisichelli (1969). When the rubber band snap was used as a means of stimulation to elicit the pain cry, there was a startle reaction followed by a period of breath-holding. The arms and hands are extended, his facial expression is that of fright, and a loud burst of crying is followed by several bursts which are similar to the first. As the child continues to cry, the bursts taper off to a stop. In the case of an older child, he might sob for some time. Sobbing is not observed in severely brain-damaged infants.

Cry in Various Conditions and Diseases:-

When a child is sick and the cry changes from normal to abnormal, it can be caused by disturbances in the larynx or in the oral cavities. It can, however, also reflect the function of the brain as the neural impulses to the larynx originate in the brain.

Parmlee (1962) has stated that crying "reflects the capacity of the nervous system to be activated and also the ability of the nervous system to inhibit or modulate this activation. The differences in the ability of different nervous systems to respond could be in the peripheral sensory receptors, but it seems more likely that these differences are in the more complex activating systems of the brain."

Cry in Newborn low birth weight infants

Michelson (1971) analyzed cry samples of 105 symptomless low birth weight infants. Results showed that there was no difference in the cry of low-birth weight infants and 50 healthy full-term infants with normal birth weights. The mean of the maximum fundamental frequency in the infants with low birth weight was 640 Hz.

The pre-mature infants were divided into 2 groups: those born at 35 - 37 gestational weeks and those born at 34 gestatlonal weeks or earlier. Results showed that the younger infants cried with a higher pitch. The fundamental frequency was highest in the youngest prematures with a mean of maximum pitch being 1360 Hz and a mean of minimum pitch being 590 Hz.

The dominating melody type in all pre-mature infants was falling or rising-falling, similar to the controls. Bi-phonation and gliding occured in the cries of the prematures 5 - 14% of the times. No significant changes were seen in the continuity and voicing of signals and also in the occurence of double harmonic break, or in the second pause. As the pre-mature infant grew older, its cry became similar to that of a healthy child born at term.

Tenold et. al.(1974) found a median fundamental frequency of 752 Hz for 5 premature infants and 518 Hz for 9 full term infants,

Lester and Zerkind (1978) found that the cries of full term, but underweight infants had a shorter duration

(2.0 secs) and a higher fundamental frequency(740 Hz) than babies of normal birth weight (4.9 secs and 467 Hz respectively).

Cry in Chromosome Abnormalities:-

Lind et.al.(1970) have studied cry samples of 120 normal infants 0-8 months old and 30 infants with Down's syndrome (21 - trisomy). The results have shown that when compared to the cries of 120 healthy infants of corresponding age, the cries in Down's Syndrome had a long duration with a mean of 4.5 seconds. In addition, they were lower pitched with a mean of maximum pitch being 510 Hz and a mean of minimum pitch being 210 Hz. The melody was flat in 63% of the samples, bi-phonation occured in 23%, and stuttering in 53%.

The cry of children with a deletion of chromosome 5, the "cri du chat" syndrome, has been studied by Vuorenkoski et.al.(1966), Luchsinger et.al.(1967), and Baner (1968). Vuorenkeski et.al. have noticed a general pitch of 860 Hz in 8 children 4 - 48 months old. They also found a flat melody type in 36% of the cries and a rising melody type in 23%. Baner (1968) has found a fundamental frequency of 800 Hz in the "cri du chat" syndrome and 400 - 500 Hz in the control group. Luchsinger et.al.(1967) have found a fundamental frequency between 600 - 1000 Hz in an infant with "cri du chat" syndrome. The control group had a fundamental frequency of 290 - 440 Hz. ostweld et.al.(1970) have reported the cry of an infant with 13-trisomy. A peak was noted in the fundamental frequency at 405 - 680 Hz, and the crying resembled that of Down's syndrome more than that of the "cri du chat" syndrome.

Michelson et.al.(1980) have analyzed 135 cries of 14 infants aged 0-7 months, who exhibited various chromosome abnormalities, except Down's syndrome. Two of the infants had the "cri du chat" syndrome, two, a deletion of chromosome 4, three had 13-trisomy, three had 18-trisomy, and one case each of abnormalities of chromosomes 1, 2, 8 and 20.

The duration of the cries in the chromosomally abnormal infants had a wide range from 0.3 secs to 18.7 secs. The maximum and minimum pitch were significantly higher in cases with short arm, deletion of chromosome 4 or 5, in the case with a partial trisomy 1, and in one case with trisomy 18. A significantly lower maximum and minimum pitch were noted in a case with extra chromosome material at the distal end of chromosome 1, a lower maximum pitch in one case of trisomy 18, a lower minimum pitch in one case with trisomy 13 and another with trisomy 18.

The cry in the "cri-du-chat" syndrome differed from the cries of the other chromosomal abnormalities as it was more high-pitched and had a flat monotonous melody type. Shifts occured in almost every second cry. Shift and flat melody type were less common in the cries of infants with anamoly of chromosome 4. The lack of shifts and the frequent occurence of glottal roll in 13 and 18-trisomy accentuated the hoarse low-pitched cry in these infants. The dominating melody type in 18-trisomy warn falling or rising-falling and more flat signals occured than in the controls. In 13-trisomy, signals with flat melody type were also increased, when compared with the controls.

It was also found that the pitch characteristics in chromosomally abnormal infants were different from those in infants with other diseases affecting the brain, such as asphyxia, hyper-bilirubinaemia, hypoglycaemia, and meningitis, in which more high-pitched cries occured. In asphyxia and meningitis, an increase in rising and falling-rising melody types and a more frequent occurence of bi-phonation and gliding have been observed. No bi-phonation and occured in the cries of infants with 13- and 18- trisomy. Gliding occured in only one case. This was the only infant who had Apgar scores at 5 minutes. The asphyxia might have affected the cry results in this case.

The anatomical defects of physiological mechanisms that change the cry pattern in chromosome anamolies are not known (Michelson, Tuppurainen and Aula, 1980).

Fislchelli and Karelitz (1966) obtained samples of crying from four male mongoloid infants, six months of age and four normal infants matched for age and sex and fed it into the panoramic sonic analyzer in order to survey the frequency content of the cries. Results showed that the cries of normal infants were relatively homogenous. The spectra of the mongoloids showed greater variability. Within each spectrogram, more peaks and troughs were discernible indicating that the intensity variations are much greater for the mongoloid than they are for the normal. The frequency content of the spectrograms of normal infants were much richer than that of spectrograms of mongoloids. But the spectral range covered by the mongoloids cry was same as that of the cry of normal infants.

Cry in Newborn Infants with Asphyxia:-

The crying of infants with asphyxia in the newborn period have been studied by Michelson, 1971. Cries from 205 infants during the first 3 days of life were collected. Only the first phonation after the pain stimulus was used for analysis, and only one cry from each child was obtained.

The children were divided into two groups whether the asphyxia was of mainly pulmonic or cerebral origin. Since it has been shown that the newborn premature infants cry differently than the full-term infants, these infants with asphyxia were further divided into two groups according to gestational age. The cry characteristics of the asphyxicated infants were compared with the cryind of 50 healthy full term or 75 premature infants, depending upon whether the neonate with asphyxia was full term or premature at birth. In both gestational age groups, the cry was found to be more abnormal in those infants in whom the asphyxia was considered to be of cerebral origin.

In full term infants with cerebral asphyxia, the mean of the maximum pitch was 1320 Hz; the minimum pitch 640 Hz. In the prematures with cerebral asphyxia, the corresponding values were 1730 Hz and 930 Hz. Bi-phonation occured in 26% of the full term and in 27% of the prematures and gliding in 14% and 11% respectively. In the central asphyxia rising and fall-rising types of melody were found to be more.

It was found that in those cry characteristics where the asphyxiated infants differed significantly from the controls, the differences were often more marked in the newborn who had suffered more severely from asphyxia.

Michelson (1977) analyzed the cries of 45 full term newborn infants with Apgar scores of 6 or less. The results showed that in infants who were found to be neurologically damaged at the check-up at 2 - 8 years, the cry characteristics were more abnormal. The signals were shorter, the maximum and minimum pitches were higher, bi-phonation and gliding were more common, and the melody type was often abnormal. Thus, it is indicative that the cry analysis not only has diagnostic, but also prognostic value.

Cry in Other Metabolic disturbances

The cry of 45 newborn infants with jaundice, caused by hyperbilirublnaemia, was reported by Warz-Hockert et. al.(1971). The mean of the maximum fundamental frequency was found to be 2120 Hz and the mean of the minimum pich was 960 Hz. Bi-phonation occured in 49% of the cries and furcation in 42%. Furcation was found to be a specific feature in pain cries of infants with jaundice.

A cry score rating system that was developed by Vuorenkeski et.al.(1971) has been used in analyzing cries of the 45 infants with hyperbilirubinaemia. Each of the 13 cry features were assigned a weightage of 0 to 4, and the cry score was the sum of these ratings.

A score of 0 - 3 was defined as normal, and a score of 4-50 was defined as abnormal. A mean score of 4.4 was found in the case of infants with hyperbilirubinaemia as compared to a score of 1.4 in the group of control infants. Only one of the 45 infants with jaundice had a normal score.

Koivisto et.al.(1974) reported on the cries of 15 full-term infants with low blood sugar, hypoglycaemla. A median maximum pitch of 1600 Hz was noted with a minimum pitch of 610 Hz. The beginning of the phonation was often unusually high-pitched, vibrato was seen in 11, bi-phonation in 10, and gliding in 3 of the cries.

In analyzing cries of newborn infants of diabetic mothers, Thoden and Michelson (1979) found higher fundamental frequency with a mean maximum pitch of 1180 Hz. The maximum pitch was still higher when the child in the neonatal period additionally had hypoglycaemia (1520 Hz) or hyperbilirubinaemla (1790 Hz) or both simultaneously (1980 Hz). The minimum pitch in cries of infants of diabetic mothers was 510 Hz. When the babies additionally had both hypoglycaemia and hyperbilirubinaemia, the minimum pitch was 690 Hz. Thus the study clearly shows that the cry analysis is an indicator of the severity of the diseases in the neonatal period.

The cry in congenital hypothyroidism, studied in 40 cries of four infants by Michelson and Siruio (1976) resembled that of norma crying, but was lower in the fundamental frequency than that of healthy babies. The median value of the maximum pitch was 470 Hz and the median value of the minimum pitch was 270 Hz. The low number of shifts and the frequenty occurence of glottal roll at the end of the phonation, accentuated the perception of a hoarse, low pitched cry. Cry characteristics which occur in brain-damaged infants, such as the change in the melody type and occurence of bi-phonation and gliding, did not occure in hypothyroidism. Thus the changes seen in hypothyroidism do not resemble the changes seen in brain damage and seem to be of a more peripheral nature. Perkins (1971) and Barnett (1972) state that the hoarseness in hypothyroidism is due to oedema in the larynx.

Vuorenkeski et.a1.(1973) reported one case of congenital hypothyroidism studied with a monitoring apparatus and found signals with an unusually long duration and with a fundamental frequency below 1000 Hz.

<u>Cry in Cleft Palate Infants</u>

Massengill (1969) investigated to determine whether the speech clinicians who have worked with cleft-palate children could differentiate between cleft-palate and cleft-lip babies from the recordings of their cries. He also investigated to see if there was any significant correlation between the length of the cry and the judged nasality of the cry. 30 infants in the age range of 1-24 months were taken. The timing of the cries was recorded using a polygraph. The results indicated that judges were not able to find any difference in nasality between the cries of babies with cleft palate only, with cleft lip only, and babies with both cleft lip and palate. Correlation between the length of the cry print and judged nasality of the cry; and the age of the child and the nasality of the cry were not statistically significant. Generally, the longer cry prints were from the older children.

Sound spectrographic cry analysis of cleft palate infants has been made by Michelson et.al.(1975). The purpose of this study was mainly to find out what kind of changes in the cry characteristics are caused by anatomical defects in the oral cavities and if these changes are different from those seen in infants with central nervous system disorder.

Fifty-two cries from 13 infants with cleft palate were analyzed. No changes were noted in the fundamental frequency, melody type, and duration when compared to controls. Tonal pit occured in 22%. Abnormal characteristics occuring in infants with central nervous system involvement, such as bi-phonation, gliding and a change in the melody type, did not occur in infants with cleft palate. Michelson et.al.(1971) consider that cry evaluation is useful in assessing the condition of the central nervous system and thus it has a diagnostic value.

Cry in infants with Central nervous system diseases

The crying of 14 infants with bacterial meningitis aged 4 days to 6 months was investigated by Michelson et.al.(1977). The cries were of higher pitch and the mean of the maximum pitch was 1100 Hz and of minimum pitch was 560 Hz. The dominating melody type, which in healthy infants is falling or rising-falling was seen in only every other cry in meningitic babies. Bi-phonation occured in 48%, gliding in 11% and glottal roll in 25%. Those infants with meningitis who at a later time were abnormal also had more abnormal cry characteristics.

The cry of infants with herpes virus encephalitis has been studied by Michelson and Siruio, 1976; and Pettay et.al., 1977. A voiceless fricative noise was noted in the frequency region of 2000 - 2500 Hz and was seen in both voiced and voiceless parts of the signals. The meaning and specificity of the noise concentration is still unknown. Since it occured in almost half of the signals in herpes encephalitis that were studied, the cry analysis is used by the above investigators in clinical work when herpes encephalitis is suspected.

A pair of twin girls were born,joined at the head. It was uncertain whether or not the two infants had independently functioning nervous systems. The cries of infant A were louder, more sustained and longer than those of infant B. The spectrograms of infant A's cries looked normal. The tone increased in pitch and remained relatively steady and then fell off smoothly, all within one exhalation. Infant B's sound spectrograms were clearly abnormal. Interruptions in the middle of an exhalation were seen. The cries were short and there was significantly less acoustic energy than infant A's. The results of the acoustic analysis indicated that infant A's nervous system was apparently functioning normally, but that of infant B's nervous system appeared to have been impaired in some way (Ostwald and Peltzman, 1974).

Lind et.al.(1965) reported a cry analysis of one infant with brain damage from a birth injury. They found a fundamental frequency of 450 - 2070 Hz as compared to

280 - 900 Hz of a group of 20 controls.

Michelson et.al.(1980) analyzed the cry in hydrocephalus. cries with a mean of maximum pitch over 1000 Hz, were noted in these infants, who in addition to the hydrocephalus had congenital malformation of the brain (Rorenoephalus or hydranencephalus). The cry changed to a more normal one after the shunt operation for hydro-cephalus when the increased intra-cranial pressure was normalized.

Cry in infants with malnutrition

Malnutrition is a problem in most countries of the developing world. According to Stock and Smythe (1967) marasmic malnutrition during the first year of life can cause irreversible intellectual impairment and organic brain dysfunction. Sound spectrographic investigations of the cries of 5 infants, age 7 months to 2 years, with severe malnutrition (one with Kevashiorkar and four with marasmus) were compared with the cries of 15 healthy children of corresponding ages. In marasmus the cry was high-pitched and monotonous. The mean maximum pitch was 1340 Hz, the minimum pitch was 730 Hz; bi-phonation occured in 6, and 6 of the 26 cries had a flat melody type, in Kevashiorkar, the pitch was 290-460 Hz which was like the normal control cases (Juntunman et.al., 1972).

Lester (1976) analyzed the cries of 12 well-nourished and 12 mal-nourished infants using a Real Time analyzer. He found that the crying of malnourished children had a higher pitch, lower amplitude, longer duration, and longer latency to the next signal, compared to the normal subjects: The cries of the 12 mal-nourished infants was 2.66 versus 1.52 sec for the controls. The pitch was 480 Hz as compared to 308 Hz for the controls.

Cry in infants with hearing impairment

Collins (1954) in a symposium on the deaf child, has written that deaf babies coo and gurgle in a normal fashion and that from 9-18 months, they appear to be developing speech, saying 'mumum', 'dadada', but that no further progress in speech is then made. Congenitally deaf babies do vocalize and their vocalization undergoes changes leading upto spontaneous and playful sounds. Tape recordings of infants of congenitally deaf parents and of normal parents showed no differences. The vocalizations, cooing and crying were identical, and were regarded as developmental.

A comparitive study of the pre-linguistic vocalizations of deaf and normal hearing infants was done using sound spectrography analysis by Stanley (1976). The infants ranged in age from 17 to 24 weeks. A significantly greater number of identifiable stops and greater voice lag times were found in the deaf infant vocalization patterns.

Cry in infants with Various Disorders

Ostwald et al.(1968) determined the relationship between clinical diagnostic ratings and 2 acoustical characteristics, pitch and duration. The subjects were 5 normal infants, 5 questionably impaired and 5 abnormal. Duration measurements showed no differences between the groups. The infants rated as impaired or abnormal had cries with a high frequency of 300 - 2875 Hz and the normal group had a frequency of 360 - 785 Hz.

Blinlck et.al.(1971) have stated that 11% of 338 normal infants and 50% of 31 newborn infants of narcotic addicted mothers showed abnormal birth cries with a higher fundamental frequency.

A study of the cry of a four-day old full term normal baby, who at six months died suddenly, showed that the cry in sudden infant death syndrome (SIDS) had a higher frequency, more shifts and more extremes in frequency (Stark and Nathanson, 1975).

Anderson-Huntington and Rosenblith (1976) also mentioned abnormal cries in their report of babies who died of SIDS.

Kittel and Hecht (1977) found that the cry in a child born to a mother with floride syphilis had a fundamental frequency of 206 Hz compared to 42 Hz in 50 healthy newborns.

Tardy-Renucci and Appaix (1978) found a mean fundamental frequency of 512 Hz in a group of 68 infants with various neonatal disorders, such as hyperbilirubi-naemia, malformation syndromes, anoxia and respiratory disorders. They have defined the cry as a "reflex motor action under the dependency of the nervous centres" and further have stated that the cry "can be modified by diverse physiologic and pathologic processes". The highest mean fundamental frequency in four infants with jaundice was 630 Hz and in three who had been resuscitated after birth, 613 Hz. In 9 control infants, it was 470 Hz.

Lester and Seskind (1978) found a mean pitch of 814 Hz in the cries of 24 healthy newborn infants with maternal and parturital risk factors when compared to 468 Hz for 24 healthy newborn infants without pre- or perinatal complications. In infants with risk factors, the cry was elicited after repeated snaps(312). The latency of infants with risk factors was 21.1 secs and for those without risk factors it was 1.4 secs. The infants at risk cried less (13.7 secs) than infants with no risk factors (21.3 secs).

Thoden and Michelson (1979) analyzed the cries of 3 infants with Krabbe's disease. They noted a mean of maximum pitch being 1120 Hz and a mean of minimum pitch being 590 Hz in these infants. The control group had a mean maximum pitch of 520 Hz and a mean minimum pitch of 370 Hz. There were significantly less falling and rising-falling melody types in the Krabbe group, and these children also produced continuous signals less often.

Michelson et. al (1982), collected during a two month period, the cries of all infants admitted to the Ward for newborn and small babies. The sound spectrographic cry analysis was performed blindly without any knowledge of the infant and its clinical diagnosis to confirm whether cry analysis is useful in neonatal diagnostics and especially if it can be an additional means of estimating the condition of the central Nervous System. The infants were divided into four groups and the results of the cry analysis for the full term and the premature babies were considered separately in each group. The four groups were:
(1) Observation group, (2) Cardio-pulmonary disorder group, (3) metabolic disturbances, and (4) Neurological symptom group. The control series consisted of 110 pain cry signals

from healthy, full term 0-3 month old infants. The results reported are as follows:

Fundamental Frequency - This study confirms the previous investigations as the pitch was higher in the cries of infants with metobolic and neurologic disturbances. In the other two groups, there was no significant increase in fundamental frequency. In the observation group, the highest pitch was found in an infant, delivered with the help of vacuum extraction, which might possible have affected the CNS. In the cardio-pulmonary group, the highest fundamental frequency was noted in the infants with cyanotic congenital heart diseases which can affect the brain structures through hypoxia. In the neurological symptom group, the highest maximum pitch was observed in a child with bacterial meningitis and lowest in those with microphalus. This indicates that acute cerebral damage gives rise to more changes in cry characteristics than pre-natally developed anamolies.

Melody type - There was an increase in the rising and falling-rising types of melody in full term infants with metabolic disorders and neurological symptoms. This indicates that change in melody is determined by CNS.

Bi-Phonation and glide - which are rare in cries of healthy infants, occured more often in all abnormal groups in the full-term infants, but the significance level was greater in the cardio-pulmonary, metabolic and neurological groups than in the observation group.

Furcation has previously been connected with hyperbilirubinaemia (Warz-Hockert et.al., 1971). In this study, 2 of the five cries with furcation were from infants with hyperbilirublnaemia.

Noise concentration was observed in five of the cries. One of these infants had laryngomalaria and convulsions and one had a virus infection of unknown etiology.

Durational features - The latency of the cries in all the disorder groups was longer than the latency of the controls. No differences in latency could be seen between the disorder group.

The authors imply that their data provide a firm foundation for a critical objective evaluation of the cry in sick infants, especially when the CNS is involved.

Thus, the review of literature indicates that it is possible to differentiate various abnormalities of the nervous system and various pathological conditions affecting the development of the child, by analyzing the cries acoustically. This helps in early identification of various abnormalities.

Early identification of an abnormality is an essential and important step in the rehabilitation of the handicapped. The advantage of this technique is that it does not requird the voluntary participation of the child like in other tests that have been used to diagnose various abnormalities and this procedure is an objective one. The parameters used for differential diagnosis in this procedure can be measured objectively and the data collected or norms developed have universal application. This procedure is also inexpensive. It seems to be very useful in our country where the facilities for early diagnosis are very poor. This technique has not been tried in our country as the present investigator is aware of. Therefore there is a need to use this particular technique and develop norms for various groups of abnormalities in our set-up.

The present study is planned to analyze the cries of both normal infants and infants with high-risk factors. It is intended to analyze the cries acoustically, using sound spectrograph.

Chapter - III

METHODOLOGY

The aim of the study was to findout the differences in 'normal' and 'abnormal' infant cries by spectrographic analysis.

For this purpose, 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. Spectrographlc analysis of the infant cries.
4. Follow-up of the infants for hearing screening and to collect information about developmental milestones,

1. Construction of a list of high-rist 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, perl-natal and post-natal history like pre-maturity, asphyxia, Jaundice etc., which may lead to Central Nervous system abnormality were also considered. The case history drawn up with all these factors has been presented in the Appendix(l).

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

Infant cries of 13 normal full-term infants and 28 infants considered to be high-risk according to the case history were recorded. The infnats were from the neonatal and sick-baby wards of Cheluvamba hospital, Mysore. The age range of the infants was from 16 hours to 3 months.

Group - 1:-

In this group, pain cries of 13 normal infants - 9 males and 4 females, from the neo-natal wards were recorded. The age range was from 16 hours to 12 days. These infants had no pre-, peri-, 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. This was confirmed after questioning the mothers and from the information collected from the hospital records.

The pain cry was elicited by flicking the sole of the infant's foot with the index finger. When 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-1 RQ 2157 cassette tape recorder and a Piezo dynamic microphone. The cassette used was Sony CHF 90. The tape recorder was battery-operated. Everyday, prior to recording, the voltage of the batteries were checked. All the recordings were made at a constant intensity level. The microphone was held approximately 5 cms from the infants mouth to reduce background noise to a minimum.

Group-2:-

In this group, pain cries of 28 infants-18 males and 9 females, from the sick-baby ward, who were considered to be in the high-risk category were recorded. The procedure for eliciting pain cries and recording of cries was same as used in group-1. Information obtained from the mothers and the hospital records revealed that these infants had one or more of the high-risk factors considered in the case history. The table below gives details of the different high-risk groups considered, number of infants in each group, age range and sex.

-PROBLEM	NO._OF_SUBJECTS	SEX	AGE_RANGE_
l)Pre-maturity	8	5 M 3 F	1 day - 8 days
2)Asphyxia	6	3 Males 3 Females	Few hours to 2 days
3)Jaundice	5	3 Males 1 female	2 days - 2 1/2 months
4)Meningitis	4	3 Males 1 female	1 1/2 months – 3 months
5)Rh Incompatibility	2	1 Male 1 female	1 day - 5 days
6) Cretinsm	1	Female	1 month 20 days
7) Convulsions	l	Male	2 months
8) Delayed Birth cry	1	Male	3 days

In the group with Jaundice, the cry recording of one infant had been taken before and after occurence of Jaundice. This infant was considered to be normal during the first recording. Later, a second recording was obtained as it had developed Jaundice.

Thus, altogether 41 cries were recorded from 40 infants, both normal and high-risk.

3. <u>Spectrographic Analysis</u>:-

All the above cry samples were transferred to the spool tape of the speech spectrograph(Voice identification Inc. series-700). These samples were analyzed to obtain narrow-band, bar-linear type spectrograms. As the cries ranged in duration from 17 seconds to 75 seconds, it was necessary to obtain 13 spectrograms on an average for each cry sample, so as to analyze the complete cry of each infant. Thus a total of 533 spectrograms were obtained analyzing each sample of cries of all the infants belonging to group 1 & 2.

These spectrograms were analyzed to obtain the following parameters:-
(1) Total duration of the cry. (2) Maximum fundamental frequency of the cry. (3) Minimum fundamental frequency of the cry. (4) Shift. (5)Double Harmonic Break (6)Melody type (7) Bi- phonation (8) Gliding (9) Furcation (lO)Noise concentration (11) Glottal plosives. (12)vibrate (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. The follow-up was carried out for all infants belonging to group 1 and 2, 5 months after data collection, so that the infants were atleast 5 months of age by that time.

Follow-Up was done in 2 ways;

(1) For local residents of Mysore, the investigator visited each infant at his/her home. Auditory screening of the infants was carried out with toys emitting low and high-frequency sounds. Questions regarding developmental milestones like 'head held up', 'grasping', etc were asked to the parents and information was collected (Questionnaire is appended). 21 of the subjects were local residents of Mysore. It was possible to follow-up 14 of them. For the other 7 infants, either they were no longer available at that address or the house could not be located. So, follow-up of these infants was not possible.

(2) For non-local residents of Mysore, follow-up was done through correspondence. A Questionnaire (appended) including questions about developmental milestones and the hearing ability of the infants was sent to the parents. 20 of the subjects were non-local residents. Only 3 parents replied

back to the questionnaire.

It had been possible to obtain information about 3 of the infants at the hospital itself, as they died after a few days.

Criteria for Normalcy

The norms established for Indian Population by Hegde (1971) were used to find out if the milestones of the infants were normal or delayed, if the infants responded well to screening, their hearing ability was considered 'normal'. Those who did not respond properly to screening were classified as 'abnormal' and the parents were advised to bring the child for a follow-up regularly to 'All India institute of Speech and Hearing', Mysore to confirm or rule out the hearing loss. similarly, for the infants who had delayed milestones, the parents were advised to bring the child for a follow-up regularly.

Chapter - IV

RESULTS AND DISCUSSION

The cries of 13 healthy infants and 28 infants with various high-risk factors like pre-maturity, asphyxia, jaundice, meningitis, Rh incompatibility, cretinism, convulsions and delayed birth cry were analysed. The spectrograms were analyzed to obtain the following parameters: (1) Duration of the cry, (2) Maximum fundamental frequency, (3) Minimum fundamental frequency, (4) Shift, (5) Double Harmonic break, (6) Glide, (7) Tonal pit, (8) Furcation, (9) Bi-phonation, (10) Vibrato, (11) Noise concentration, (12) Glottal plosives and (13) Melody.

Group 1 :- Cry in Healthy infants

13 infants - 9 males and 4 females in the age range of 16 hours to 12 days were considered here. The results of the cry analysis of healthy infants is given in Table 1. Here, the results are presented considering the group as a whole, that is, both males and females, as no significant difference was found between cry characteristics in males and females when they were considered separately. No differences between the cries of males and female infants are reported in the literature.

The mean of maximum fundamental frequency noted was 1470.50 Hz. The range was from 2900 - 800 Hz. Infant

No.12 had the highest range of fundamental frequency (2900 - 550 Hz) and infant No.19 had the lowest range of fundamental frequency (800 - 225 Hz). The mean of minimum fundamental frequency noted was 398.1 Hz. The range was 600 - 225 Hz. The mean duration of cry was observed to be 33.46 seconds.

Most of the infants had a rising-falling melody type (76.9%). The rest had a falling-rising melody type (23.1%). Double Harmonic break occured in almost every cry(mean= 12.15). Shifts(mean = 4.15) and glottal plosives (mean = 4.69) occured most often among all the characteristics. The next most frequently occuring characteristics were furcation (mean = 3.08), vibrato (mean = 3.15) and glides (mean = 3). Noise concentration (mean = 2.46), Tonal pit (mean = 1.46) and bi-phonation (mean = 1.08) occured rarely. Results are given in Table 1.

Group 2: Cry in infants with various high-risk factors

28 infants - 18 males and 9 females in the age range of 18 hours to 3 months were considered. All the high-risk infants were considered as a group. The results are tabulated in Table 2. The mean of maximum fundamental frequency was 1747.6 Hz. The range was from 3300-700 Hz. infant No.21 had the highest range of fundamental frequency

Table - 1

NORMAL GROUP

	SUBJECTS		CRY CHARACTERISTICS												
NO.	Age	Sex	Shift	Double Harmonic Break	Glide	Tonal pit	Furcation	Biphonation	Vibrato	Noise Concentration	Glottal Plosives	Melody	Max-Freq	Min-Freq	Follow-up Results
1	4 Days	M	7	13	4	1	0	0	0	0	11	Rising-Falling	2600	500	-
3	3 Days	M	4	12	2	2	1	2	2	1	6	Rising-Falling	1350	500	Normal
4	16 Hours	M	5	10	0	1	2	2	1	1	6	Rising Falling	1450	400	—
5	9 Days	M	3	12	7	2	2	1	3	0	6	Rising Falling	1100	300	Normal
7	7 Days	M	2	9	0	2	3	0	7	2	1	Rising-Falling	1100	300	Normal
9	8 Days	M	2	12	2	1	5	0	5	0	0	Rising-Falling	900	300	Normal
10	12 Days	F	6	8	6	2	2	0	0	4	5	Falling-Rising	2900	550	-
11	6 Days	M	6	16	4	3	4	1	5	7	2	Rising-Falling	1150	366.6	Normal
12	2 Days	F	0	12	9	1	4	5	3	5	3	Rising-Falling	950	433.3	-

Table-1 Contd...

SUBJECTS			CRY CHARACTERISTICS												
No.	Age	sex	Shift	Double Harmo-nic Break	Glide	Tonal pit	Fur-ca-tion	Bi-pho-na-tion	Vib-rato	Noise con-cen-tra-tion	Glot-tal Plo-sives	Melody	Max-Freq	Min-Freq	FolloW-Up Results
14	1 Day	F	0	7	1	0	0	0	1	3	5	Falling-Risng	366.6	600	Normal
18	5 Days	M	9	17	4	3	10	3	4	5	6	Rising-Falling	2650	300	Normal
19	6 Days	M	9	16	0	1	4	0	5	1	10	Rising-Falling	800	225	-
24	2 Days	F	1	14	0	0	3	0	5	3	0	Falling-Rising	1300	400	Normal
TOTAL			54	158	39	19	40	14	41	32	61	Rising-Falling	19116.6	5174.9	
MEAN			4.15	12.15	3	1.46	3.08	1.08	3.15	2.46	4.69		1470.51	398.1	

(3300 - 233.3 Hz) and infant No.17 had the lowest range of fundamental frequency (750 - 325 Hz). The mean of minimum fundamental frequency was 382.7 Hz and ranged from 950 - 166.6 Hz. The mean duration of cry was observed to be 38.21 seconds. Results are given in Table 2.

On the whole, the mean of fundamental frequency of the infants in the high risk category has been observed to be higher than those infants in the normal category. The mean cry duration for the infants in the high-risk category has also been observed to be more than that of infants considered to be normal.

75% of the infants had a rising-falling melody type. 21% had a falling-rising melody type. One infant, had no particular melody type. Maximum amount of noise concentration appeared in the cry of this infant. Double harmonic break occured less in the cries of these infants (mean = 10.79). Noise concentration was observed more often than in healthy infants (mean = 4.96). No significant differences were seen in the occurence of shift (mean = 4.61), bi-phonation (mean = 0.71) and glide (mean = 3) in high risk infants when compared to healthy infants. Glottal plosives (mean - 3.14), vibrato (mean = 2.96), Eurcation (mean = 2.43) and tonal pit (mean = 0.61) occured less often in high-risk infants than in healthy infants.

Table 2 - HIGH-RISK GROUP

SUBJECTS			CRY CHARACTERISTICS								
No.	Age	sex	Shift	Double Harmo-nic Break	Glide	Tonal pit	Furca-tion	Bi-phona-tion	Vib-rato	Noise Concen-tration	G] tc P] Sj
2	2 Days	M	1	4	0	0	0	1	1	1	]
6	8 Days	F	4	12	3	2	8	2	4	1	
8	3 Days	M	1	15	7	1	0	4	2	3	(
13	2 Days	M	8	12	3	2	8	2	3	5	
15	1 Month 20 Days	F	18	10	1	1		0	1	8	
16	3 Montns	M	1	13	0	1	5	0	2	4	1
20	2 1/2 Months	M	13	15	2	0	5	0	0	6	
21	10 Days	M	5	12	3	0	6	0	2	7	
22	7 Days	F	5	9	1	0	5	0	1	2	1
13	4 Days	M	7	13	3	0	4	1	5	2	1
25	3 Days	M	2	11	5	0	2	11	0	0	5
27	1 Day	M	1	9	0	1	0	0	8	4	11
27	5 Days	M	2	13	2	0	1	2	4	4	7
28	1 Day	F	0	9	1	0	3	0	1	0	5
29	1 Day	F	0	11	6	0	1	0	5	6	5
30	1 Day	M	8	9	9	0	0	2	2	3	2
31	1 Day	M	2	11	5	0	3	0	7	2	2
32	1 Day	M	3	8	11	0	0	1	10	6	6
33	1 Day	M	3	13	2	0	0	0	4	9	0
34	2Months	M	4	10	2	1	1	0	1	13	0
35	7 Days	M	11	13	4	0	2	1	4	9	5
37	18Hours	F	7	10	1	2	0	0	0	9	3
36	1 Day	F	6	15	2	2	3	2	5	9	4
38	1 Day	F	4	14	0	0	0	0	3	0	0
39	3 Days	F	3	7	8	0	0	0	1	17	5
40	2Months	M	3	9	2	1	3	1	4	3	0
41	l 1/2 Months	M	1	5	1	2	1	0	2	2	1
17	2 1/2 Months	F	4	10	0	1	5	0	1	4	5
	TOTAL		129	302	84	17	69	20	83	139	88
	MEAN		4.61	10.79	3	0.61	2.43	0.71	2.96	4.96	3.1'

Thus the null hypothesis that no significant differences will be observed between the cries of normal healthy infants when compared to infants with history high-risk factors or other problems on the following characteristics (1) Maximum fundamental frequency, (2) Minimum fundamental frequency (3) Duration of the whole cry (4) Double Harmonic break (5) Shift (6) Glide (7) Furcation (8) Bi-phonation (9) vibrato (10) Noise concentration (11) Glottal plosives (12) Melody type and (13) Tonal pit as measured using spectrograms, is partly accepted and partly rejected. It is partly rejected, as 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 null hypothesis is partly accepted as no significant differences were observed in the cries of both the normal and high-risk infants in cry characteristics like shift, bi-phonation, glide and tonal pit.

Having 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, review of literature indicates that some of these characteristics occur distinctively more number of times in infants with a particular history or problem.

It has also been reported that double harmonic break occurs more in healthy babies than in abnormal infants (Michelson, 1971; Mechelson et.al., 1975). Similarly, in the present study, double harmonic break has occured more number of times in the cries of healthy infants.

The review of literature available to the present investigator has shown no studies comparing normals with abnormals(having different histories and problems like pre-maturityl asphyxia, meningitis, jaundice, etc.) as a whole group. However, several studes comparing groups of abnormal infants having a particular history or problem with infants are found in the literature (Michelson, 1971; Micheslson,et.al., 1975; Michelson and Siruio, 1976; Michelson, Tuppurainen and Aula, 1980; Michelson et.al, 1982).

The present comparison of normals with abnormals has shown that certain characteristics like double harmonic break and glottal plosives occur more number of times in normals than in abnormals. On the Contrary, the abnormal group has shown occurence of a higher fundamental frequency, longer cry duration and more noise concentration than in normals. Not much difference has been found on other parameters. This may be because of the fact that some of the characteristics are presented more number of times.

by some infants in the normal group. For example, subject 18 has shown furcation 10 times and all other infants have shown the same characteristic less than 5 times whereas the same characteristic has occured 8 times as maximum in abnormals. None of them have shown the characteristic to occur beyond 8 times. Therefore, when a comparison is made considering all the abnormal infants, with various histories as a group, it may not be possible to find distinguishing characteristics of abnormal groups with specific history or problem. Hence, it was decided to compare each abnormal group with specific history or problem considered as a separate group, with normals.

Cry in infants with various high-risk categories

(a) Pre-maturity:- The cries of 8 infants - 5 males and 3 females ranging in age from one day to 8 days have been analyzed. The mean of maximum fundamental frequency was 2152.1 Hz. The range was 3150 - 866.6 Hz. Infant No.31 had the highest range of fundamental frequency (3150 - 233.3 Hz). This infant also had the lowest birth weight of 1 Kg. Infant No.39 had the lowest range of fundamental frequency. The highest mean of maximum fundamental frequency has been noted in this group. The mean of minimum fundamental frequency was 366.6 Hz and ranged from 566.6 to 233.3 Hz.

The melody type was rising-falling in 75% of the infants. One infant had no particular melody type. The same infant had maximum amount of noise concentration. The mean duration of cry was 35.3 seconds. There was no significant difference in the occurence of shift (mean = 4.75), double harmonic break (mean = 11.25) and Bi-phonation (Mean = 1.5) between pre-mature and healthy full-term infants. Noise concentration (Mean = 6.25) Vibrato (Mean = 4.38) and glides (Mean = 6.13) were observed more often in pre-matures than in healthy Infants. Glottal plosives (Mean = 4), furcation (Mean = 2) and Tonal pit (Mean = 0.63) occuredless in the cry of infants in the normal categor of prematures compared to the cry of infats in the normal category. Results are given in Table 3.

(b) <u>Cry in infants with Asphyxia</u>

6 infants - 3 males and 3 females in the age range of few hours to 2 days were considered as belonging to this group. The mean of maximum frequency was 1891.66 Hz and ranged from 3250 - 1000 Hz. Infant No.29 had highest range of fundamental frequency (3250 - 950 Hz) and infant No.27 had the lowest range of fundamental frequency (1000-200 Hz). The mean of minimum fundamental frequency noted was 466.65 Hz and ranged from 950 - 200 Hz. The mean duration of cry was 43.3 seconds . This group had

Table - 3

HISTORY - PREMATURITY

SUBJECTS			CRY CHARACTERISTICS											
No.	Age	Sex	Shift	Double Harmonic Break	Glide	Tonal pit	Furcation	Biphonation	Vibrato	Noise Concentration	Glottal Plosives	Melody	Max-Freq	Min-Freq	Follow-up Results
6	8 Days	F	4	12	3	2	8	2	4	1	2	Rising-Falling	1000	300	
8	3 Days	M	1	15	7	1	0	4	2	3	6	Rising-Falling	1450	566.6	Expired
30	1 Day	M	8	9	9	0	0	2	2	3	2	Rising-Falling	3150	433.3	
31	1 Day	M	2	11	5	0	3	0	7	2	2	Rising-Falling	3150	233.3	Expired
32	1 Day	M	3	8	11	0	0	1	10	6	6	Rising-Falling	2400	500	
35	7 Days	M	11	13	4	0	2	1	4	9	5	Rising-Falling	2850	300	Expired
36	1 Day	F	6	15	2	2	3	2	5	9	4	Falling Rising	2350	350	Expired
39	3 Days	F	3	7	8	0	0	0	1	17	5	No Melody type	866.6	250	
TOTAL			38	90	49	5	16	12	35	50	32	Rising-Falling	1721.6	2933.2	
MEAN			4.75	11.25	6.13	0.63	2	1.5	4.38	6.25	4	= 75%	2152.07	366.65	

the longest cry duration. When compared to all other groups.

The melody type was rising-falling in all infants. Noise concentration occured more often in these intants (Mean=4.8) than those in the normal category. The frequency of occurence of vibrato in this group and in the normal category were the same. The other characteristics like double harmonic break (Mean=10.17), shift(Mean=3), Gllde(mean=l.5), Tonal pit (mean=0.5), Furcation(mean=0.17), Bi-phonation(mean=0.17), and glottal plosives(mean=3.33) occured loss in this group when compared to the infants in the normal category. Results are given in table-4.

C) Cry in infants with Jaundice:- In this group, 4 infants- 3 males and 1 female in the age range of 2 days to 2 1/2 months were available. The mean of maximum fundamental frequency was 2083.32 Hz. and ranged from 3150-800Hz. Infant No.21 had the highest range of fundamental frequency(3300-233.3Hz), One infant's cry had been recorded before and after development of Jaundice. It was observed that the maximum fundamental frequency in this infant, increased after it developed Jaundice. The mean of minimum fundamental frequency noted was 366.66HZ. It ranged from 600-233.3Hz. Infant No.22 had the lowest range of fundamental frequency (800-300Hz). The mean cry duration was 37 seconds, which was more than that in healthy infants.

Table - 4

HISTORY - ASPHYXIA

SUBJECTS			CRY CHARACTERISTICS												
No.	Age	Sex	Shift	Double Harmonic Break	Glide	Tonal pit	Furcation	Biphonation	Vibrato	Noise Concentration	Glottal Plosives	Melody	Max-Freq	Min-Freq	Follow-up Results
2	2 Days	M	1	4	0	0	0	1	1	1	1	Rising-Falling	2750	450 -	
27	1 Day	M	1	9	0	1	0	0	8	4	11	Rising-Falling	1000	200 -	
29	1 Day	F	2	11	6	0	1	0	5	6	5	Rising-Falling	3250	950 -	
33	1 Day	M	3	13	2	0	0	0	4	9	0	Rising-Falling	1200	400	Expired
37	18 hours	F	7	10	1	2	0	0	0	9	3	Rising-Falling	1900	433.3 -	
38	1 Day	F	4	14	0	0	0	0	3	0	0	Rising-Falling	2850	366.6 -	
TOTAL			18	61	9	3	1	1	21	29	20	Rising-Falling = 100%	11350	2799.9 -	
MEAN				10.17	1.5	0.5	0.17	0.17	3.5	4.8	3.33		1891.66	466.65	

The melody type was rising-falling 60% of the time. Furcation(mean=5.6) and shift (mean=7.6) occured more often in these infants than in the normal category. There was no difference observed in the occurence of double harmoni break between this group(mean=12.2) and the normal category. Noise concentration occured more often in this group (mean=4.4) when compared to healthy infants. Glide(mean=2.4), tonal pit (mean=0.4), bi-phonation(mean=0.6), vibrate(mean=2.2) and glottal plosives(mean=3) were observed to be less in this group. Results are given in table-5.

d) Cry in infants with meningitis:- 4 infants-3 males and 1 female in the age range of 1 1/2 to 3 months were studied. The mean of maximum fundamental frequency was 925Hz. and ranged from 1300-700HZ. This is less when compared to the maximum fundamental frequency of the normal category. Infant no.34 showed highest range of fundamental frequency (1300-225Hz) and infant no.17 showed lowest range of fundamental frequency(750-325Hz). The mean of minimum fundamental frequency was 229.15Hz which is lower than that found in healthy infants. The range was 325-166.6Hz. The mean duration of cry was 40.8 seconds. This is more than that of normal category.

The melody type was rising-falling in all infants of this group. Noise concentration was observed more often

Table - 5

HISTORY - JAUNDICE

SUBJECTS			CRY CHARACTERISTICS												
No.	Age	Sex	Shift	Double Harmonic Break	Glide	Tonal pit	Furcation	Biphonation	Vibrato	Noise Concentration	Glottal Plosives	Melody	Max-Freq	Min-Freq	Follow-up Results
13	2 Days	M	8	12	3	2	8	2	3	5	3	Rising-Falling	1733.3	600	Normal
13	4 Days	M	7	13	3	0	4	1	5	2	1	Falling-Rising	3150	350	-
20	2 1/2 Months	M	13	15	2	0	5	0	0	6	3	Rising-Falling	1433.3	350	Expired
21	10 Days	M	5	12	3	0	6	0	2	7	7	Rising-Falling	3300	233.3	-
22	7 Days	F	5	9	1	0	5	0	1	2	1	Falling Rising	800	300	-
TOTAL			38	61	12	2	28	3	11	22	15	Rising-Falling = 60%	10416.6	1833.3	
MEAN			7.6	12.2	2.4	0.4	5.6	0.6	2.2	4.4	3		2083.32	366.66	

in this group (mean=4.6) than in healthy infants. The occurence of tonal pit (mean=1.25) and furcation(mean = 3) is the same as in healthy infants. Shift (Mean = 2.5), double harmonic break (mean = 9.5), Glide (mean = 0.75), Vibrato (mean = 1.5) and Glottal plosives (mean = 1.4) was observed less often when compared to the normal category. Bi-phonation did not occur at all in the cries of this group. Results are given in Table 6.

(e) <u>Rh incompatibility</u>:- 2 infants - one male and one female, age 1 day - 5 days were available for this study. They had a mean of maximum fundamental frequency of 1625 Hz. The female infant had the higher frequency (2400 Hz) and the male the lower frequency (850 Hz). Similar results were obtained for minimum fundamental frequency. The mean of minimum fundamental frequency was 466.65 Hz. Mean duration of cry noted was 29 seconds which is less than those infants in the normal category. The melody type was rising-falling in the male infant and falling-rising in the female infant. Noise concentration (mean = 4.5) and Glottal plosives (mean = 6) occured more often than in healthy infants. Furcation (mean = 3.5) and Bi-Phonation (mean = 1) was observed as frequently as in the normal category. Shift (mean =1), Double Harmonic break(mean=ll), Glide (mean = 1.5), Vibrato (mean = 2) occured less often than in healthy infants. Tonal pit did not occur at all in this group. Results are given in table 7.

Table - 6

PROBLEM - MENINGITIS

SUBJECTS			CRY CHARACTERISTICS												
No.	Age	Sex	Shift	Double Harmo-nic Break	Glide	Tonal pit	Fur-ca-tion	Bi-pho-na-tion	Vib-rato	Noise Concen-tra-tion	Glottal Plosives	Melody	Max-Freq	Min-Freq	Follow-up Results
16	3 Months	M	1	13	0	1	5	0	2	4	1	Rising-Falling	700	166.6	-
17	2 1/2 Months	F	4	10	O	1	5	0	1	4	5	Rising-Falling	750	325	-
34	2 Months	M	4	10	2	1	1	0	1	13	0	Rising-Falling	1300	225	Normal
41	1 1/2 Months	M	1	5	1	2	1	0	2	2	1	Rising-Falling	950	200	Expired
TOTAL			10	38	3	5	12	0	6	23	7	Rising-Falling = 100%	3700	916.6	
MEAN			2.5	9.5	0.75	1.25	3	0	1.5	4.6	1.4		925	229.15	

Table - 7

HISTORY - RH INCOMPATIBILITY

SUBJECT			CRY CHARACTERISTICS												
No.	Age	Sex	Shift	Double Harmonic Break	Glide	Tonal pit	Furcation	Biphonation	Vibrato	Noise Concentration	Glottal Plosives	Melody	Max-Freq	Min-Freq	Follow-up Results
27	5 Days	M	2	13	2	0	1	2	4	4	7	Rising-q Falling	850	333.3	Normal
28	1 Day	F	0	9	1	0	3	0	1	0	5	Falling-Rising	2400	600	Expired
TOTAL			2	22	3	0	4	2	5	4	12	Rising-Falling = 50%	3250	933.3	
MEAN			1	11	1.5	0	3.5	1	2	4.5	6		1625	466.65	

(f) **Cry in other high risk categories:-** one infant each with cretinism (1 month 20 days; female), Convulsions(2 months; male) and delayed birth cry (3 days; male) were studied.

The infant with cretinism had a maximum fundamental frequency of 800 Hz and a minimum fundamental frequency of 300 Hz. This is lower than that of the infants in the normal category. The cry duration was 38 seconds, which is also longer than that of healthy infants. Shift and double harmonic break occured often. Bi-phonation did not occur at all. Glide, tonal pit, vibrato and furcation occured rarely. Noise conoentration and glottal plosives occured less frequently than shift and double harmonic break.

The infant with history of convulsions had a maximum fundamental frequency of 1250 Hz and a minimum fundamental frequency of 500 Hz. Cry duration was 43 seconds. Glottal plosives did not occur at all. Tonal pit and bi-phonation were rare.

The infant with delayed birth cry had a maximum fundamental frequency of 950 Hz and aminimum fundamental frequency of 500 Hz. Cry duration was 40 seconds. Tonal pit, vibrato and noise conoentration were not observed. Double harmonic break, glide and glottal plosives occured often shift, furcation and bi-phonation were rare. Results of these 3 infants are given in table-8.

Cry characteristlcs:-

(11) **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=lKg). This infant also had the lowest minimum fundamental frequency. Studies done by Michelson(1971)on 75 premature infants has revealed that the fundamental frequency was highest in the smallest pre-matures. Greater variations and lower fundamental frequencies were also repeated in the cries of the very small pre-matures. The present findings are in support of these results.

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

Tenold et.al(1974) found that the median fundamental frequency of the first phonation in 5 prematures was 752HZ and, 518HZ for full-term infants.

Table - 8

HISTORY - CRETINISM

SUBJECT				CRY CHARACTERISTICS											
NO.	Age	Sex	Shift	Double Harmonic Break	Glide	Tonal pit	Furcation	Biphonation	Vibrato	Noise Concentration	Glottal Plosives	Melody	Max-Freq	Min-Freq	Follow-up Results
15	1month 20days	F	18	10	1	1	2	0	1	8	7	Rising-Falling	800	300	-

HISTORY - CONVULSIONS

SUBJECT				CRY CHARACTERISTICS											
No.	Age	Sex	Shift	Double Harmonic Break	Glide	Tonal pit	Furcation	Biphonation	Vibrato	Noise Concentration	Glottal Plosives	Melody	Max-Freq	Min-Freq	Follow-up Results
40	2month	M	3	9	2	1	3	1	4	3	0	Falling-	1250	500	-

HISTORY - DELAYED BIRTH CRY

No.	Age	Sex	Shift	Double Harmonic Break	Glide	Tonal pit	Furcation	Biphonation	Vibrato	Noise	Glottal Plosives	Melody	Max-Freq	Min-Freq	Follow-up Results
25	3days	M	2	11	5	0	2	1	0 0		5	Falling-Rising.	950	500	Normal

The next category with a high fundamental frequency was the group with Joundice(2083.32Hz). 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 2120Hz in 45 infants with Jaundice.

Tardy-Renucci and Appaix (1978) found a higher fundamental frequency of the first phonation (630 Hz) in four infants with hyperbillrubinaemia than in the control group (470 Hz).

The crying in meningitic infants has also been found to be abnormal with respect to fundamental frequency. Michelson et. al(1977) found thatcries 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 be 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 Central Nervous System 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 ingroup 2, the cry duration was longest in the infants with asphyxia (43.3 seconds). Infant No.33 had the longest cry duration in this category (65 secs.). The infant died later.

All the earlier studies have considered the mean duration of the first phonation. Michelson (1971), Michelson et.al.(1977), and Juntunen et.al.(1972) 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 prematures infants, infants with cleft palate and infants with asphyxia. Infants with asphyxia had the longest median duration of phonation. In the present study, infants with miningitis 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 that 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 this study. However, no information is available in the literature regarding the duration of the cry for this group. Results are given in Tables 9 and 10.

(3) <u>Shift:-</u> Maximum amount of shifts occured in infants with jaundice (mean = 7.6). in this group, the cry of infant No.20 had the maximum occurence of shift. This infant also had congenital bilateral atresia. The infant died later. Literature on frequency of occurence of shifts in infants with jaundice was not available to the present investigator.

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

In cases of miningitis, 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 occurence of shifts in normal and pre-mature infants in this study. The results do not support the findings

Table - 9

CRY DURATION IN SECONDS

NORMAL GROUP		HIGH-RISK GROUP	
SUBJECT NO.	DURATION IN SECS.	SUBJECT NO.	DURATION
(1)	30	(2)	25
(1)	27	(6)	32
(4)	31	(8)	41
(5)	33	(13)	35
(7)	41	(15)	38
(9)	25	(16)	33
(10)	17	(20)	55
(11)	55	(21)	41
(12)	45	(22)	20
(14)	20	(13)	34
(18)	48	(25)	40
(19)	32	(27)	24
(24)	31	(27)	34
		(28)	24
		(29)	60
		(30)	22
		(31)	30
		(32)	26
		(33)	65
		(34)	75
		(35)	45
		(36)	37
		(37)	50
		(38)	36
		(39)	50
		(40)	43
		(41)	20
		(17)	35
TOTAL	435	TOTAL	1070

Normal group: Mean duration of cry = 33.46 Secs.

High-risk group: Mean duration of cry = 38.21 Secs.

Table - 10

CRY DURATION IN DIFFERENT HIGH-RISK CATEGORIES IN SECONDS

NO.	PREMATURITY	ASPHYSIZ	JAUNDICE	MENINGITIS	RH INCOMPATI-BILITY	CRETINISM	CONVUL-SIONS	DELAYED BIRTH CRY
1.	32	25	35	33	34	38	43	40
2.	41	24	34	35	24			
3.	22	60	55	75				
4.	30	65	41	20				
5.	26	50	20					
6.	45	36						
7.	37							
8.	50							
TOTAL	283	260	187	163	58	Cry duration	Cry Duration	Cry Duration
MEAN	35.38	43.3	37	40.8	29	= 38	= 43	= 40

of Michelson (1971), who reported more number of shifts in pre-mature infants than in normal infants.

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

(4) <u>Double Harmonic Break</u>:- This characteristic occured most often in normal infants than in any of the high-risk categories, it occured least in infants with meningitis. In pre-mature infants it occured lesser than in normals, but more than in any of the other high-risk categories except jaundice. The frequency of occurence of double harmonic break in the decreasing order as found in this study are as follows: normals, pre-mature, asphyxia, and meningitis.

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

(5) <u>Glide</u>:- Glides have occured most often in pre-mature infants. This finding does not agree with the results of Michelson (1971) who did not find the occurence 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 occured in 14% of cries of 205 infants with asphyxia. Gliding occured in 11% of the cries of 14 infants with meningitis as reported by Michelson et.al.(1977).

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

(6) Tonal Pit:- Tonal pit occured very rarely both in 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 differe from the normals in terms of fundamental frequency, melody type and duration. Abnormal characteristics occuring in infants with CNS involvement such as bi-phonation and glide were not reported in infants with cleft palate. Only tonal pit occured in 22%. 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) <u>Furcation</u>:- 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) <u>Bi-Phonation</u>:- In this study, bi-phonation occured rarely in both the normal and high-risk infants. It occured most frequently in pre-mature infants and did not occur at all in infants with meningitis. These result do not agree with the earlier studies. Michelson (1971) did not report the occurence of bi-phonation in the cries of the 205 pre-matures infants studied. On the other hand, bi-phonation occured most frequently (49%) in cries of infants with meningitis when compared to infants with asphyxla(26%) and malnutrition(23%)(Michelson et.al., 1977; Juntenen et.al., 1978).

Bi-phonation has also been reported to occur in 49% of the cries of 45 infants with jaundice(Warz-Hockert et;al., 1971). in this study, the occurence 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 occurence 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 occured most often in pre-mature infants of this investigation. Michelson (1971) did not find its occurence in the cries of 205 pre-mature infants. Michelson et.al.(1981) have reported the occurence 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 investigations (Michelson, 1971) have not reported its occurence in normal infants.

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

(10) <u>Noise concentration</u>:- Noise concentration occured more often in infants belonging to the high-risk category than in the normal infants. Pre mature infants had maximum occurence of noise concentration almost throughout the cry. There was very little voicing and the cry did not have any particular melody type. In infants belonging to the other high-risk categories, the frequency of occurence of noise concentration was similar.

There is no report available on the frequency of occurence 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 (1978). It has been reported to occur in almost half of the signals in herpes virus encephalitis that were studied.

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

(11) <u>Glottal plosives</u>:- Glottal plosives occured moat often in infants with history of Rh incompatibility. There is no data in the literature available on occurence of glottal plosives in these cases.

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

(12) <u>Melody type</u>:- Most of the infants in this study, both normal and high-risk category has a rising-falling melody type(75%). The other melody type which occured was falling-rising. One pre-mature infant(No.34) had no particular melody type.

Michelson(1971) 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.

The findings of the present study are summarised in the tables 11 and 12 below. The table also indicates characteristics distinctive of each group.

Table - 11

SHOWING OCCURENCE OF CRY CHARACTERISTICS IN EACH GROUP-WHETHER THEY ARE MORE, LESS OR EQUAL IN OCCURENCE WHEN COMPARED TO THE NORMAL GROUP

History	Shift	Double Harmonic Break	Glide	Tonal pit	Furcation	Biphonation	vibrato	Noise Concentration	Glottal Plosives	Melody	Max-Freq	Min-Freq	Duration
Normal	4.15	12.15	3	1.46	3.08	1.08	3.15	2.46	4.69	Rising-Falling	1470.51	398.1	33.46 Secs.
Prematurity	equal	less	Highest Occurence	Less	Less	More	Highest Occurence	Highest Occurence	Less	equal	Highest	less	more
Asphyxia	Less	Less	Less	Less	Less	Less	More	More	Less	euqal	More	More	Highest
Jaundice	Highest Occurence	equal	Less	Less	Highest Occurence	Less	Less	More	Less	Less	More	Less	More
Meningitis	Less	Less	Less	Less	Less	Nil	Less	More	Less	equal	Less	least	More
Rh incompatibility	Less	Less	Less	Nil	More	Less	Less	More	Highest Occurence	equal	More	More	Less
Cretinism	More	Less	Less	Less	Less	Nil	Nil	More	More	equal	Least	Less	More
Convulsion	Less	Less	Less	Less	Less	Less	equal	Less	Nil	Falling	Less	More	More
Delayed birth cry	Less	Less	More	Nil	Less	Less	Nil	Nil	euqal	Falling-Rising	Less	More	More

Table - 12

Problem	
Normal	Double Harmonic break, glottal plosives, Rising-falling melody type.
Pre-maturity	Glide,Vibrato,Noise concentration, High maximum fundamental frequency, longer cry duration.
Asphyxia	Noise concentration, high maximum fundamental frequency, long cry duration.
Jaundice	Shift, furcation, High maximum fundamental frequency,Noise concentration longer cry duration.
Meningitis	Noise concentration, longer cry duration, Lower fundamental frequency.
Rh Incompatibi-lity	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 birth Cry.	Falling-rising melody type, Glide, longer cry duration.

*****

Thus, the null hypothesis that no significant differences can be observed on various parameters measured using spectrograms between the cries of normal infants and (a) Pre-mature infants, (b) Infants with asphyxia, (c) Infants with jaundice, (d) infants with meningitis, (e) Infants with history of Rh incompatibility, (f) Infants with hypothyroidism, (g) Infants with convulsions and (h) Infants with delayed birth cry, is rejected.

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 intants in the normal category and 12 infants in the high-risk category. The inability to collect information regarding all the infants was due to the following reasons: (1) The cries were recorded when the infant was in the hospital and the information collected later from their homes. Some of the subjects were no longer available at the address given and in some cases, the house could not be located. (2) Of the subjects for whom follow-up was done through correspondence, only three of the parents replied back to the questionnaire.

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 one had a history of Rh incompatibility. In case of infants with jaundice and meningitis, it is possible that they were treated early and the problem was not so severe as to leave any after-effects. The baby who had a history of Rh incompatibility had Rh positive blood and had no other pre-, peri- or post-natal history. For the infant with delayed birth cry, resuscitation has been done early enough, so the baby might not have suffered from lack of oxygen.

The infants considered to be normal had (1) Normal hearing ability on an informal hearing screening test and (2) The milestones were reported to be normal.

8 infants in the high-risk category were confirmed to be 'abnormal' as they expired after a few days. They were four pre-matures and one infant each with asphyxia, jaundice, meningitis and history of Rh incompatibility.

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 pre-dominant in normal group and some are pre-dominant in the abnormal group. Some of them may occur in equal number in both the groups. However, based on further analysis, it has been found that each category of infants with a specific high risk factor show the occurence of certain characteristics more frequently than in other groups. Therefore, the analysis of cries would be very useful in early identification of abnormalities. Further, it would also help in confirmation of diagnosis when abnormalities are suspected.

Further the follow-up analysis has confirmed the findings that the infants included in the abnormal group were abnormal infact (At least 12 of them - four of these have been treated for the abnormality and have became normal). However, all the 12 infants have shown specific cry characteristics which are in useful confirmation with the earlier reports. Thus the cry analysis of infants is a useful tool in diagnosis of abnormality in infants.

Chapter - V

SUMMARY AND CONCLUSIONS

The study of infant cry has provoked researchers for many years. In the beginning, cry studies were done based only on auditory analysis. Auditory differences, between the cries of risk infants compared to healthy infants, have been recognized by pediatricians.

According to Illingwarth(1955)- "a clinician recognizes the hoarse, gruff cry of cretinism, the hoarse cry of laryngitis, the shrill cry of hydrocephalus, meningitis, or cerebral irritability, the grunting cry of pneumonia, the feeble cry of amyotonia or a severely debilated infant, and the whimper of a seriously ill child."

The auditory investigations of infant vocalization have been mainly observations of when, why, and how long babies cry (Michelson, 1981).

The objective analysis of the infant cries became possible when Potter et.al.(1947) introduced the sound spectrograph. The first investiggtion of infant cries by sound spectrographs was done by Lyrip (1951) who found out the fundamental frequency of early non-crying utterances. Later studies were carried out by Warz-Hockert et.al. (1961, 1968, 1971), Ringel and Kluppel(1964), Michelson(1971), Michelson et.al.(1975, 1976, 1977, 1980) etc.

For the past twenty years, a research group at the University of Helsinki, Finland has been carrying out cry analysis using sound spectrograph, as a diagnostic and prognostic tool in the neonatal period. With narrow-band analysis, the following cry characteristics have been measured from the spectrograms: (1) durational features such as latency, duration, continuity of the cries, and the second pause. (2) Maximum fundamental frequency. (3) Minimum fundamental frequency. (4) Shift (5) Melody type. (6) Double Harmonic break (7) Vibrato (8) Bi-phonation (9) Glide (10) Noise concentration (11) Glottal plosives (12) glottal roll (13) Tonal pit (14) Furcation (15) Voice quality (16) Nasality.

Based on the above cry characteristics they have tried to identify abnormalities. They have also tried to not the kind of cry characteristics which are typical of certain specific diseases, especially in the newborn period.

The purpose of the present study was to find out the differences in 'normal' and 'abnormal' infant cries using spectrographic analysis.

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 the infants for hearing screening and to collect information about developmental milestones.

The list of high-risk factors was constructed from the high-risk register developed by Ashok M.M.(1981) and other pre-natal, peri-natal, and post-natal factors like pre-maturity, asphyxia, etc., which may lead to abnormalities were added.

Cries of 13 normal full-term infants and 28 infants belonging to the high-risk category according to the case history were recorded. The infants were from the neonatal and sick-baby wards. The age range of the infants was from 16 hours to 3 months. Pain cries were elicited from these infants by flicking the sole of the infant's foot with the index finger, till they cried for atleast 30 seconds. The cries were recorded using a cassette tape recorder. The recordings were made at a constant intensity level with the microphone held approximately 5 cms from the infant's mouth to reduce background noise to a minimum.

The cry samples were analysed to obtain narrow-band, bar-type spectrograms. These spectrograms were analyzed to note the occurence of the following cry characteristics — (1) Duration of the whole cry, (2) Maximum fundamental frequency, (3) Minimum fundamental frequency, (4) Shift, (5) Double Harmonic break, (63 Glide, (7) Bi-phonation, (8) Furcation, (9) Noise concentration, (10) vibrato, (11) Glottal plosives, (12) Tonal pit and (13) Melody type.

A follow-up examination of the infants was carried out, 5 months after the recording, for the purpose of collecting information regarding developmental milestones and hearing ability of the infants.

Based on the analysis and interpretation of the spectrogram* for the various cry characteristics, the following conclusions have been drawn:

(1) Significant differences exist between the cries of normal and high-risk infants in some cry characteristics like fundamental frequency, duration of the cry, double harmonic break and glottal plosives which are found more in the cries of normal infants.

(2) NO significant differences were observed in both the normal and high-risk infants in cry characteristics like shift, bi-phonation, glide and tonal pit.

(3) 8 categories of high-risk infants were studied. It was found that each group exhibited cry characteristics which were distinctive to infants with that particular problem or history.

(a) <u>Pre-maturity</u>:- Among the high-risk categories, pre-mature infants have been found to have the highest maximum fundamental frequency. The highest occurence of Glide, Vibrato and noise concentration has been observed in these infants. The cry duration was longer than in normal infants.

(b) Asphyxia:- infants with asphyxia have a high maximum fundamental frequency and the longest cry duration, among the high-risk categories. The frequency of occurenoe of noise concentration is higher than in normal infants.

(c) Jaundice:- A high occurence of furcation and shift seems to be a specific feature of this problem. In addition, higher maximum fundamental frequency, longer cry durations and more amount of noise concentration occurs in infants with this problem.

(d) Meningitis:- A high occurence of noise concentration, longer cry duration and lower fundamental frequency are characteristic of infants with meningitis.

(e) Rh Incompatibility:- Maximum occurence of furcation and least cry duration were observed in infants with a history of Rh incompatibility. The maximum fundamental frequency was higher than in normal infants. Frequent occurence of glottal plosives was seen in this group.

(f) Cretinism:- Most of the cry characteristics in infants with hypothyroidism is similar to those of normal infants. The distinctive feature is that the least maximum fundamental frequency is observed in these infants. Longer cry duration and high occurence of noise concentration is also seen.

(g) Convulsions:- The cry in the infant included in this group had a falling melody type and the duration was longer than in normal infants.

(h) Delayed birth cry:- Increased occurence of falling-rising melody type, glide and longer cry durations were seen in the cries of the infant in this category.

Therefore, it can be concluded that cry analysis is a valuable tool in diagnosis of abnormalities in the new-born period i.e., it is useful in early diagnosis.

Implications of the Study:-

(1) Cry analysis is helpful in differentiating between normal and abnormal infants.

(2) It is a valuable tool in the differential diagnosis of different abnormalities in infants.

(3) It is useful for early identification of abnromalities and thus in early rehabilitation.

Recommendations:-

(1) A large number of infants belonging to different high-risk categories may be studied.

(2) A follow-up of the infants in the high-risk category upto one or two years to confirm or to rule out the abnormality would be useful.

(3) Recordings of the infant cries at the follow-up examination would be useful.

(4) A team approach with members from different disciplines like pediatrics, neurology, physiology and communication would be useful to further develop the field of cry research.

(5) The usefulness of cry analysis in everyday clinical use may be explored.

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APPENDIX - 1.

List of High-Risk factors

Father's Name: Age:

Mother's Name: Age:

Address:-

Age of Child: Sex:

Questionnairre

1) Has any of your close relatives had a hearing loss since birth? Yes/No?
2) How is he or she related to this child?
3) Do you know when and how he/she became deaf?
4) Have you married your maternal uncle? Yes/No.
5) During your pregnancy did you have a rash with fever? Yes/No.
6) Did anybody tell you that you and your husband's Rh or blood groups do not match? Yes/No
7) Prenatal-During the 1st trimester of pregnancy, was the Mother's health seriously affected as the result of injury or emotional trauma?

-Nausia	- Anemia	- Accidents	- Virus infection
- Vomitting	- Bleeding	- Nutritional deficiency	- Drugs
- toxaemia	- X-ray		

8) Was there any history of miscarriages or still birth? Yes/No.

9) <u>perinatal:-</u>

a) Duration of labour

b) Labour induced - Yes/No.

c) Delivery - Normal/Caesarian /Forceps /Breech

d) Barbituates given to mother - Yes/No.

10) <u>Condition of baby</u>

a) Birth cut. -

b) Jaundice -

c) Blueness - Asphyxiated

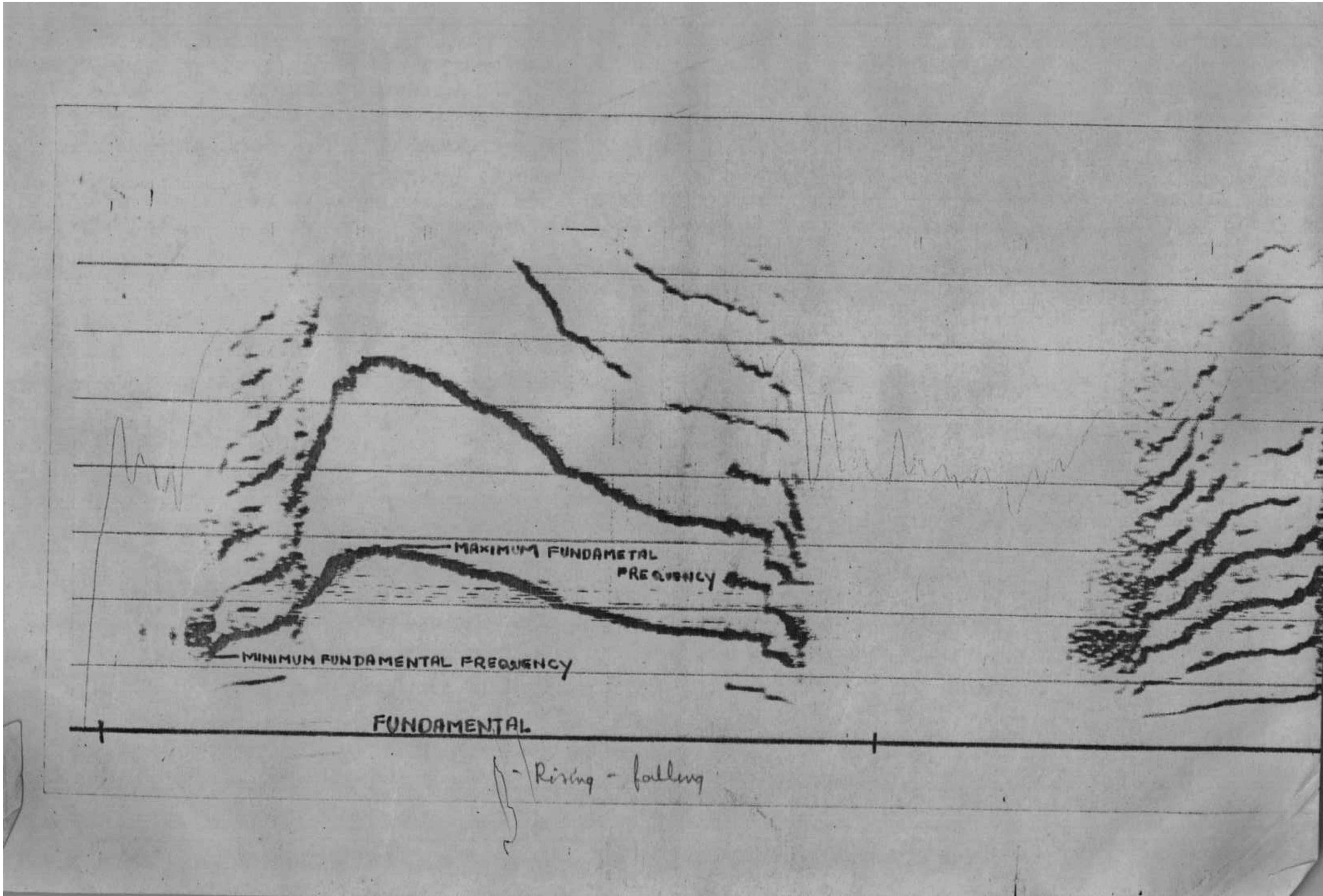
d) Full-term /Premature /Postmature

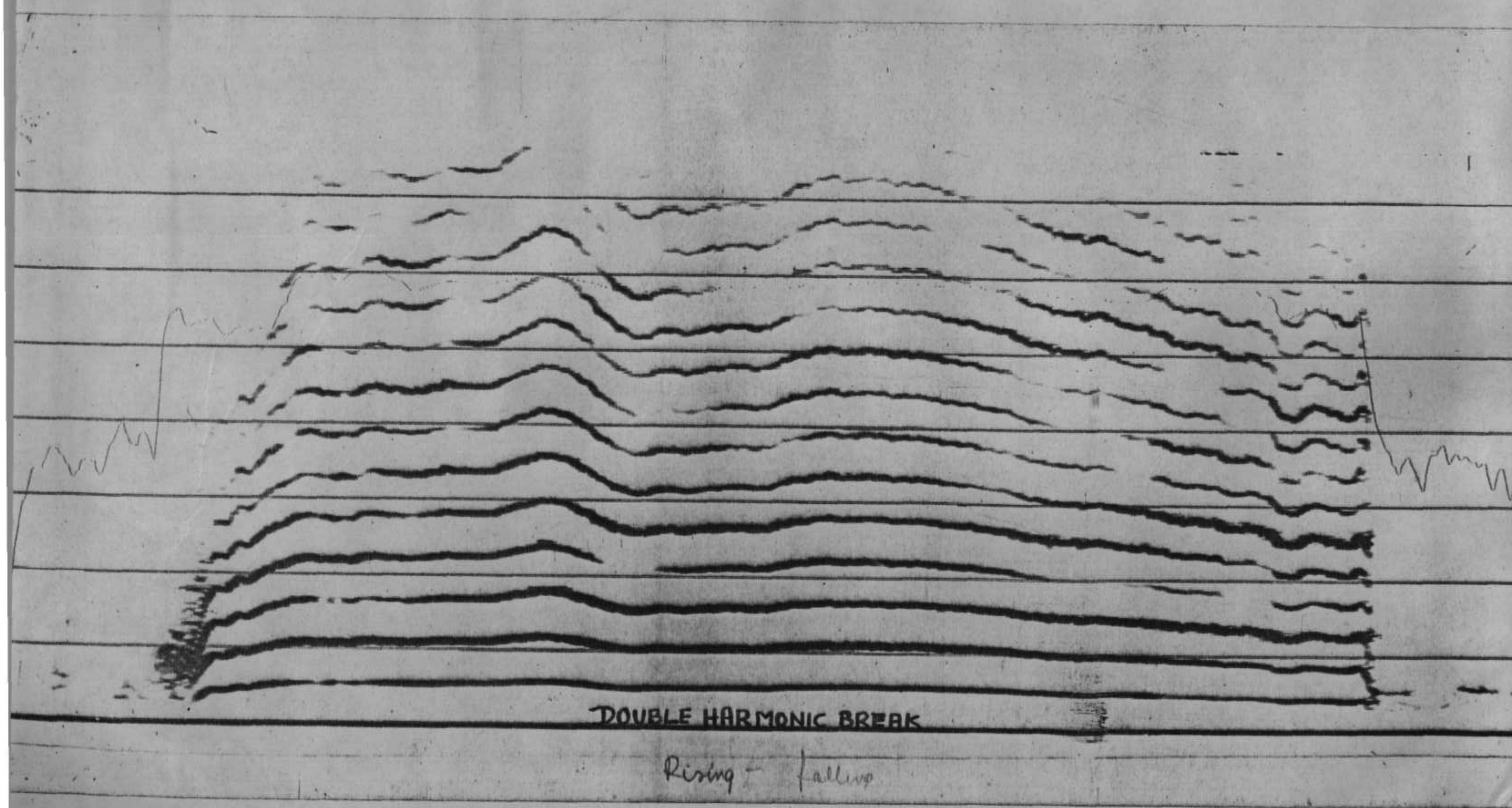
e) Birth cry - Present /absent/delayed.

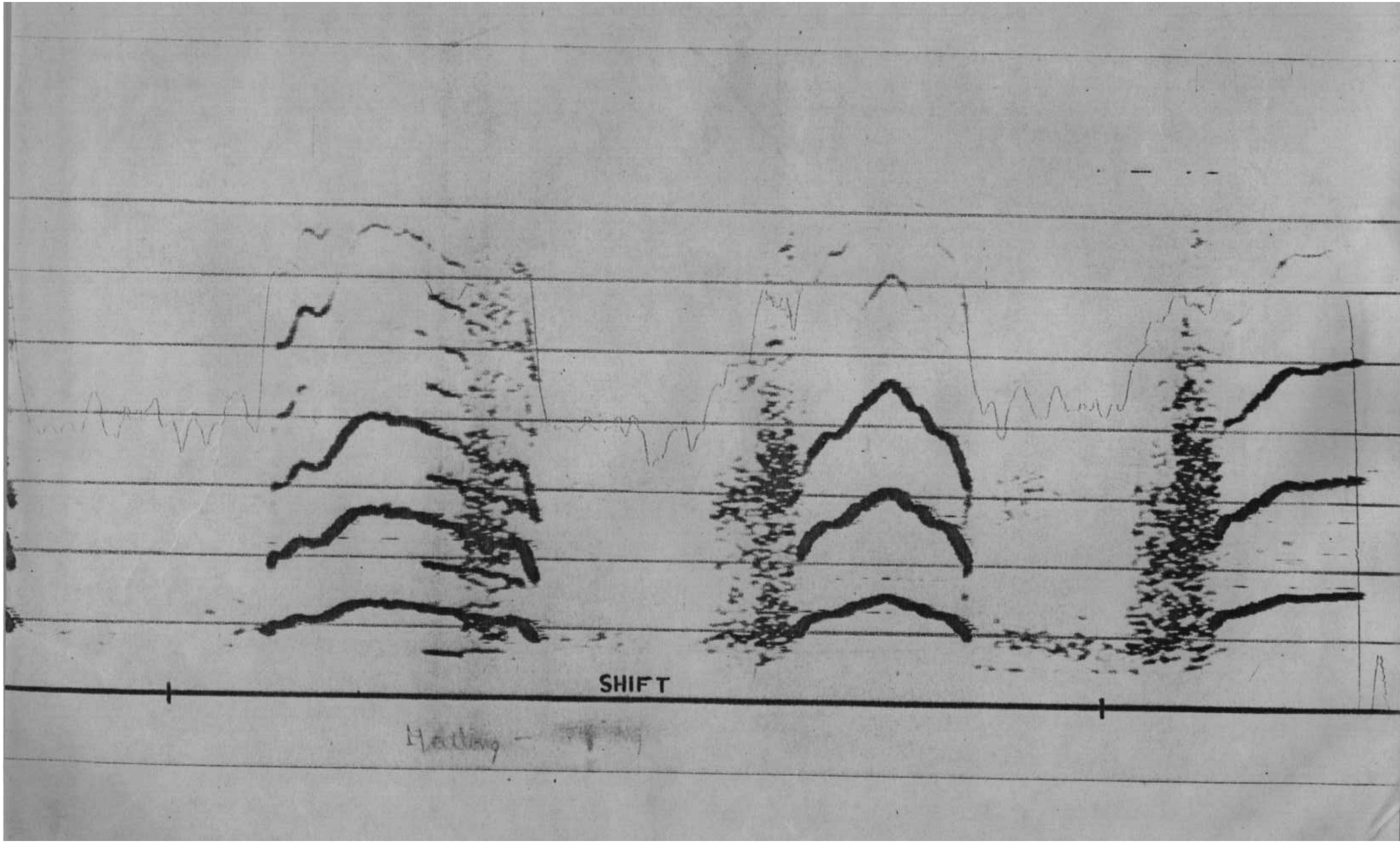
f) convulsions / twitching / drowsiness/Listlessness

g) Administration of Oxygen.

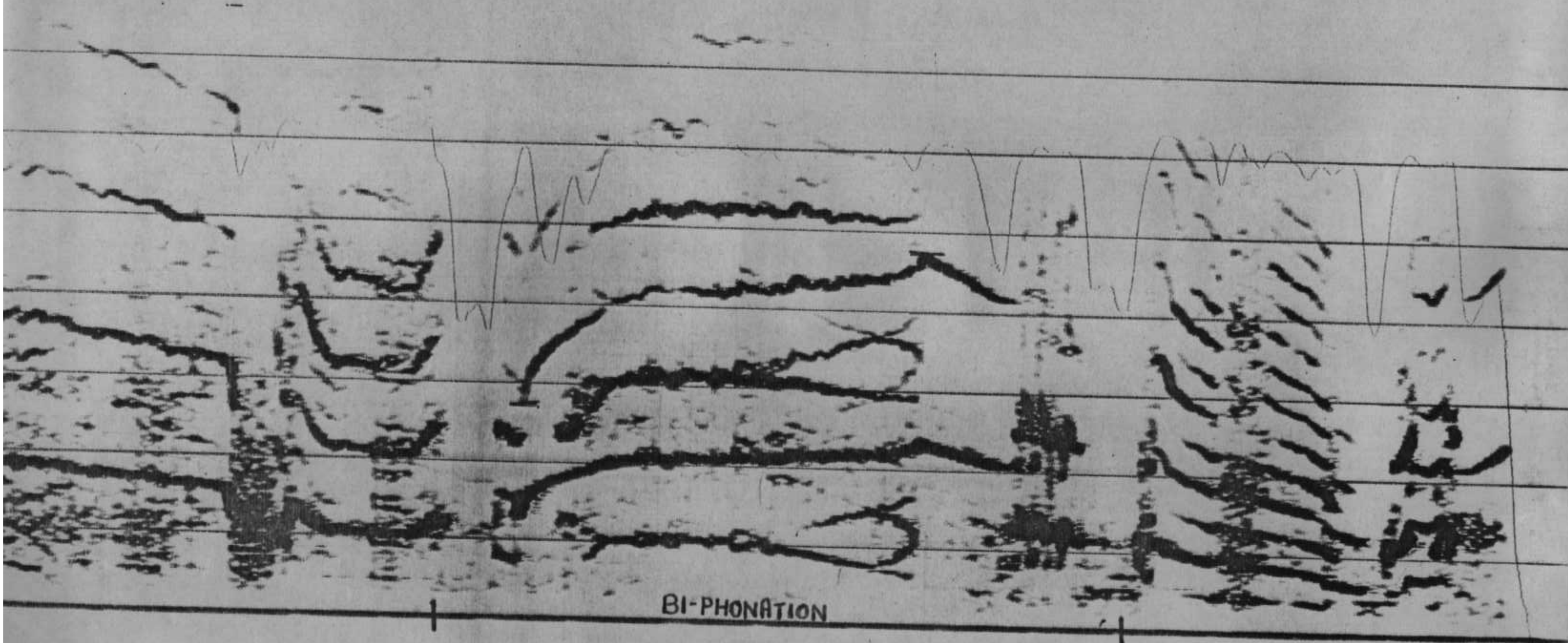
h) Incubator care - Yes/No.


MAXIMUM FUNDAMETAL FREQUENCY
MINIMUM FUNDAMENTAL FREQUENCY
FUNDAMENTAL
Rising - falling

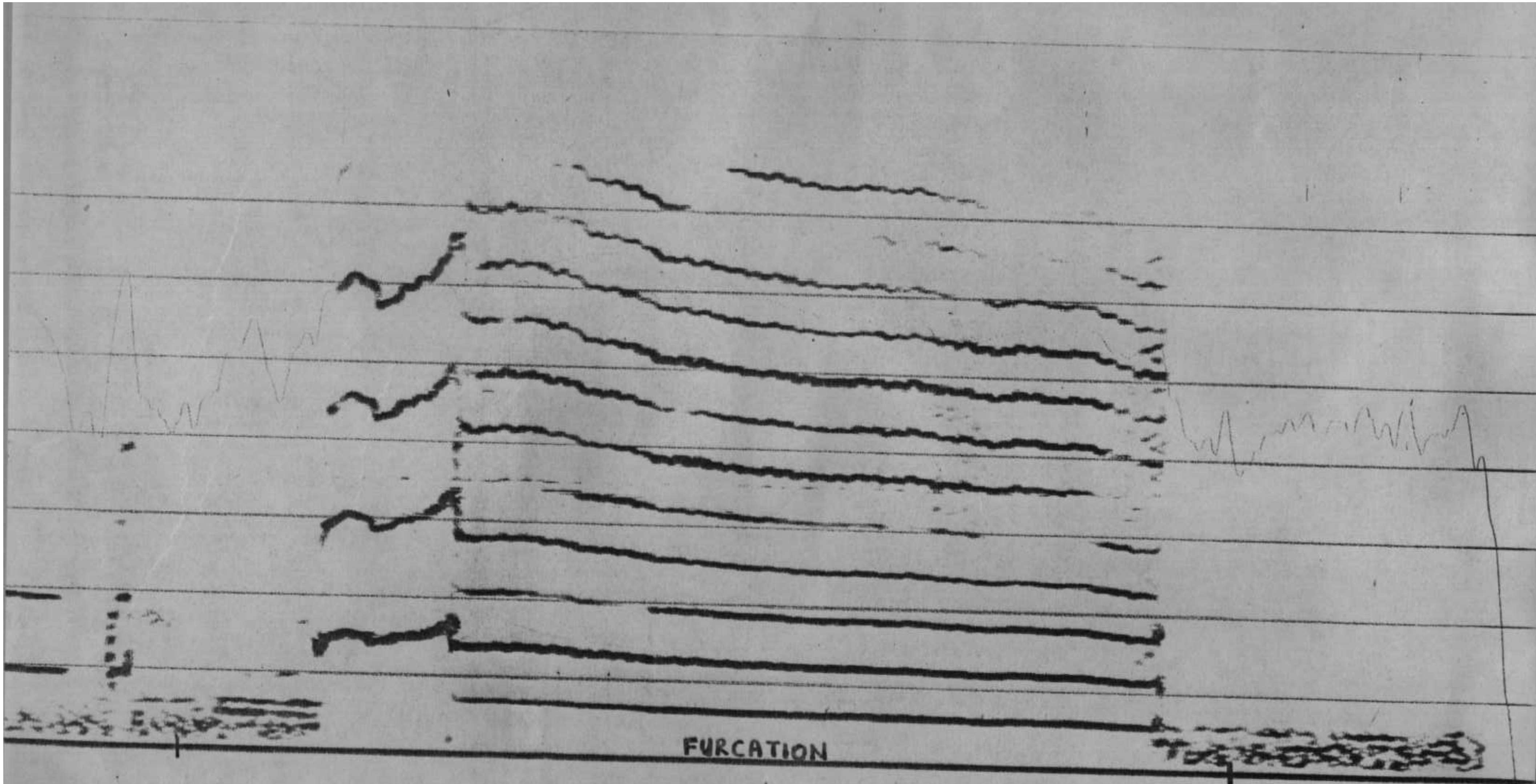

DOUBLE HARMONIC BREAK
Rising + falling


SHIFT

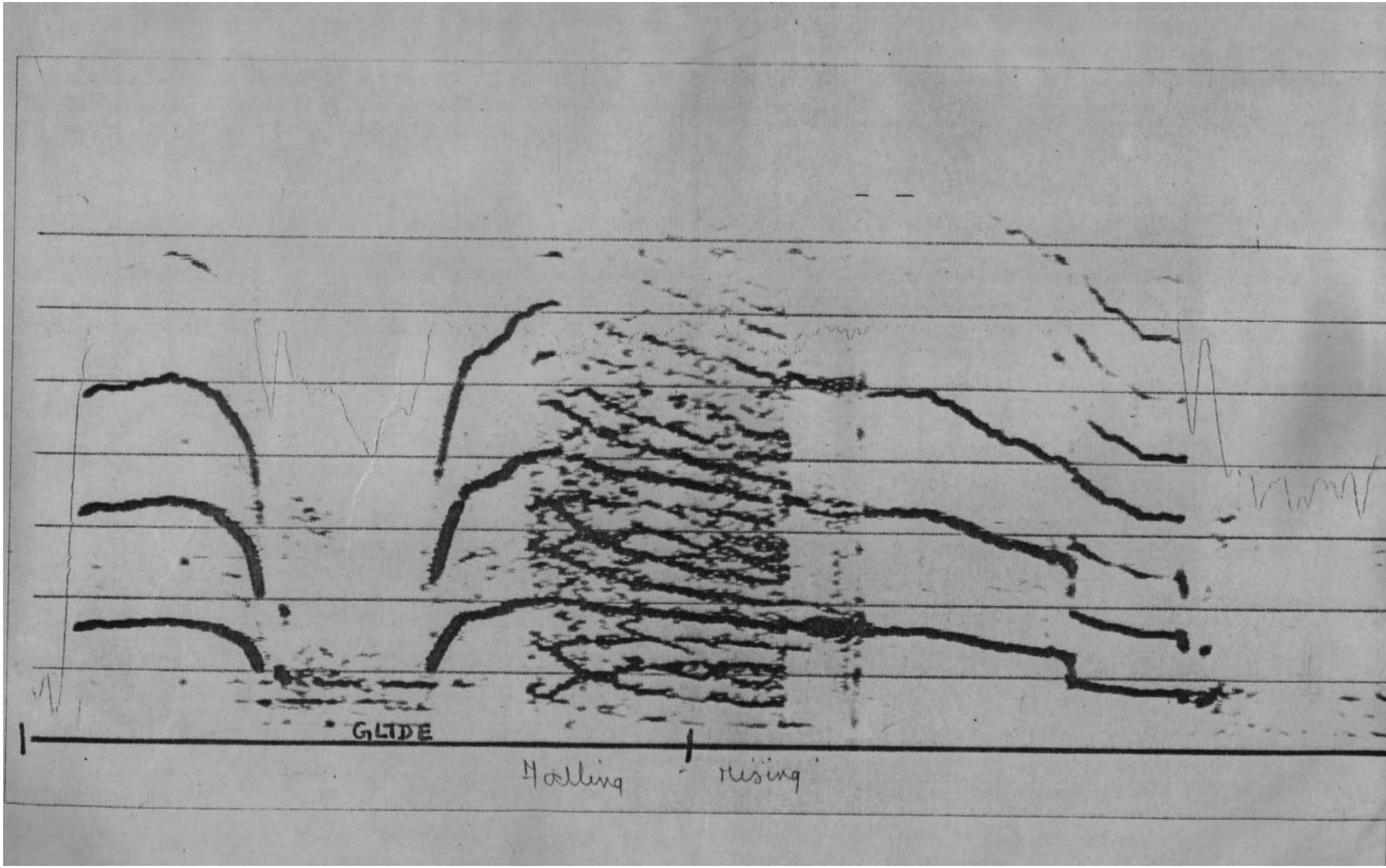
Bi-phonation

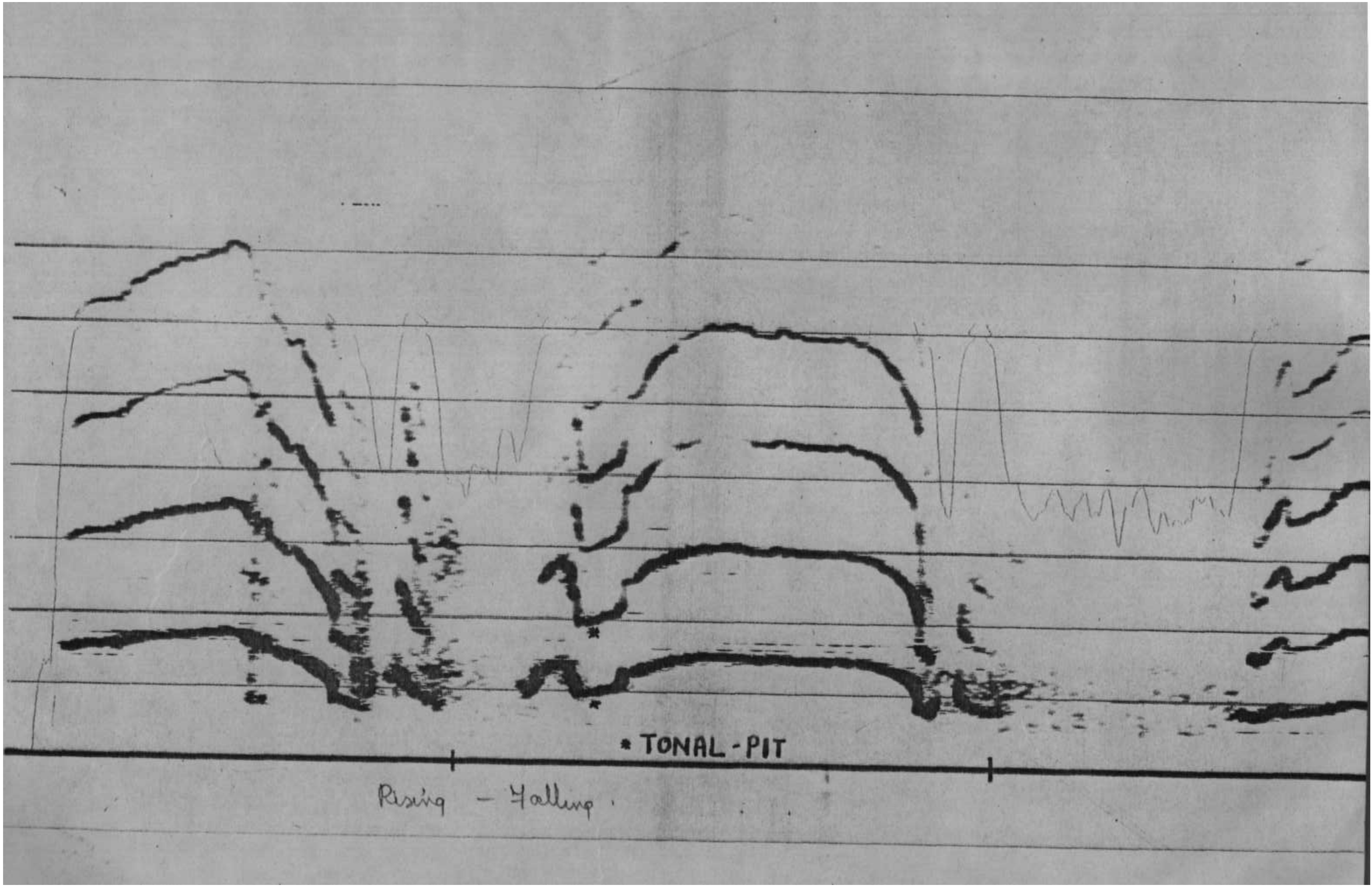


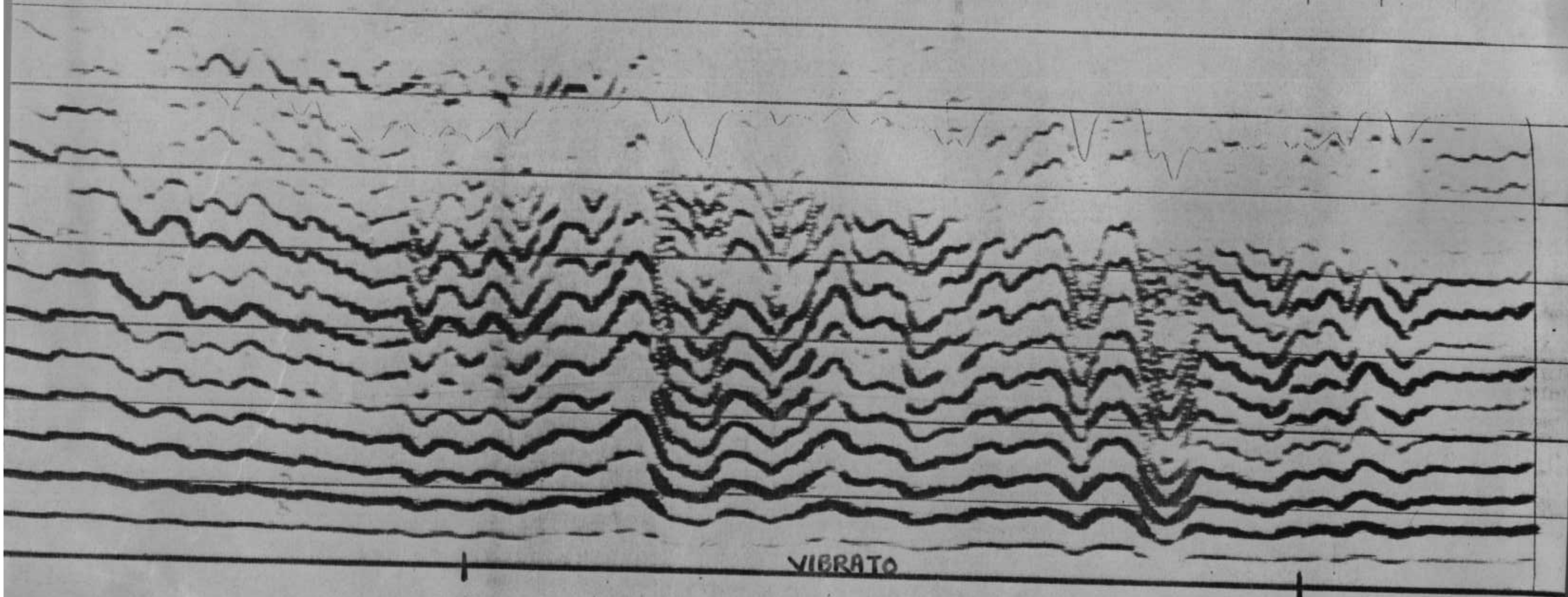
Rising - falling - Rising



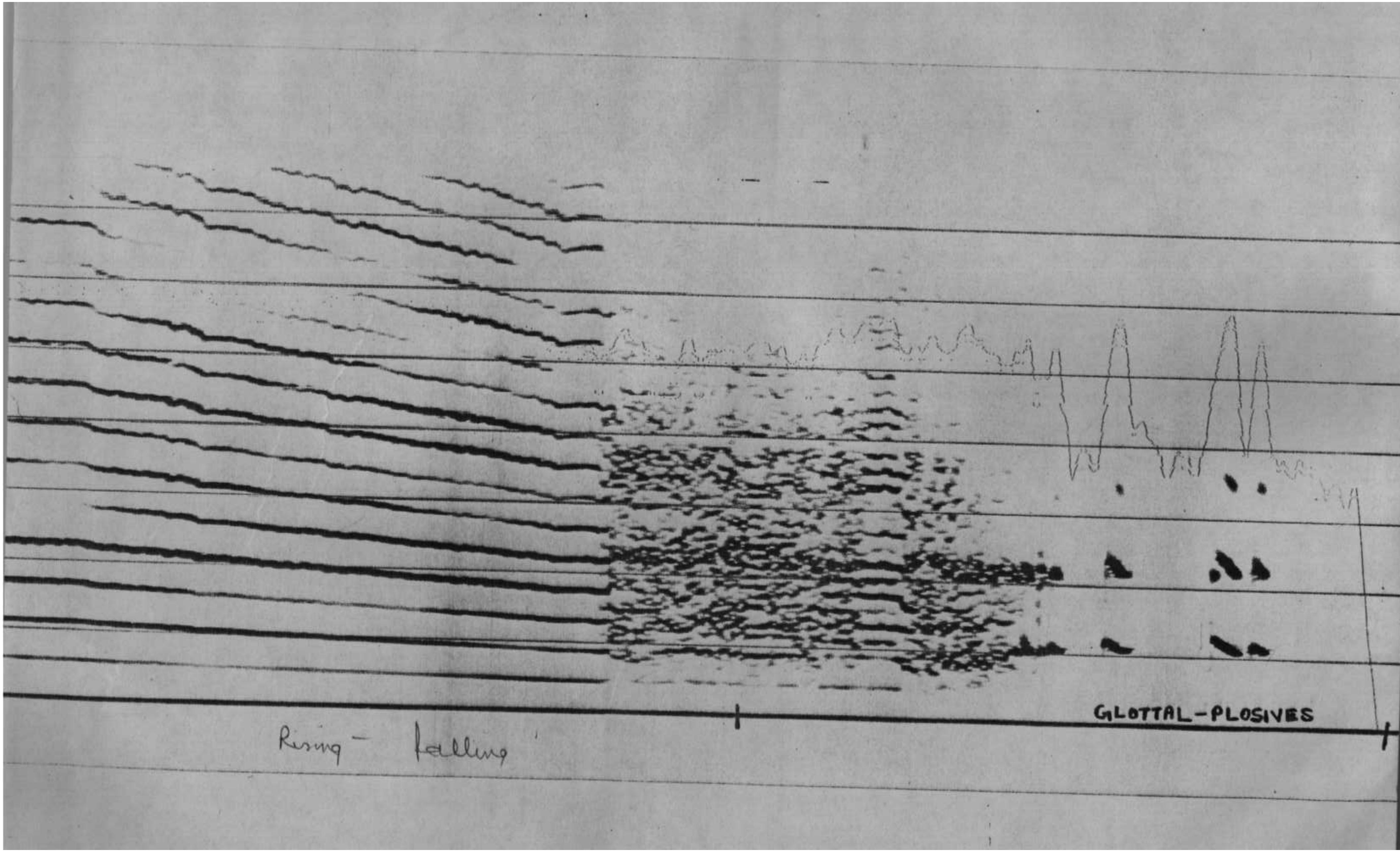
Rising – falling !

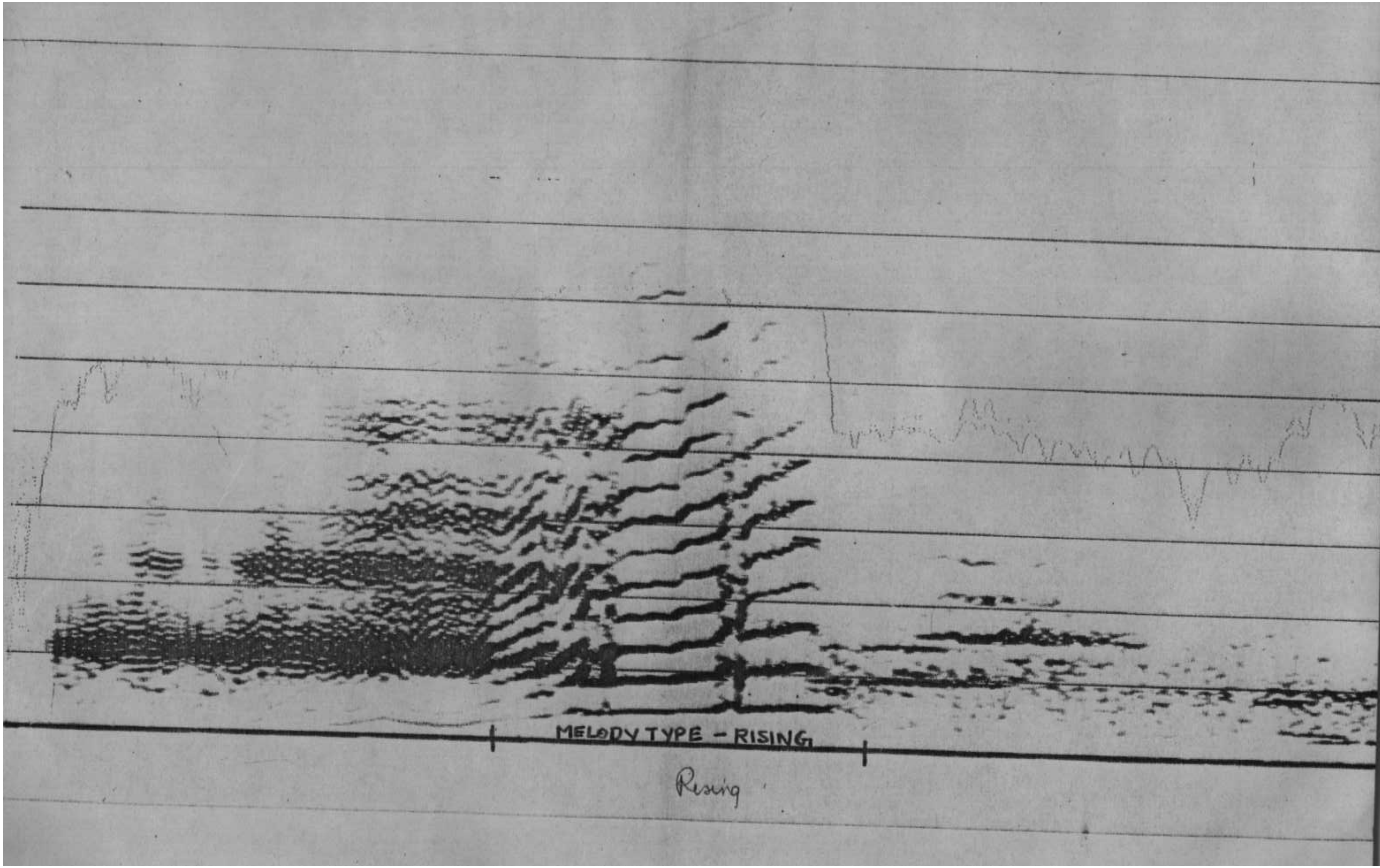

GLIDE
falling
rising

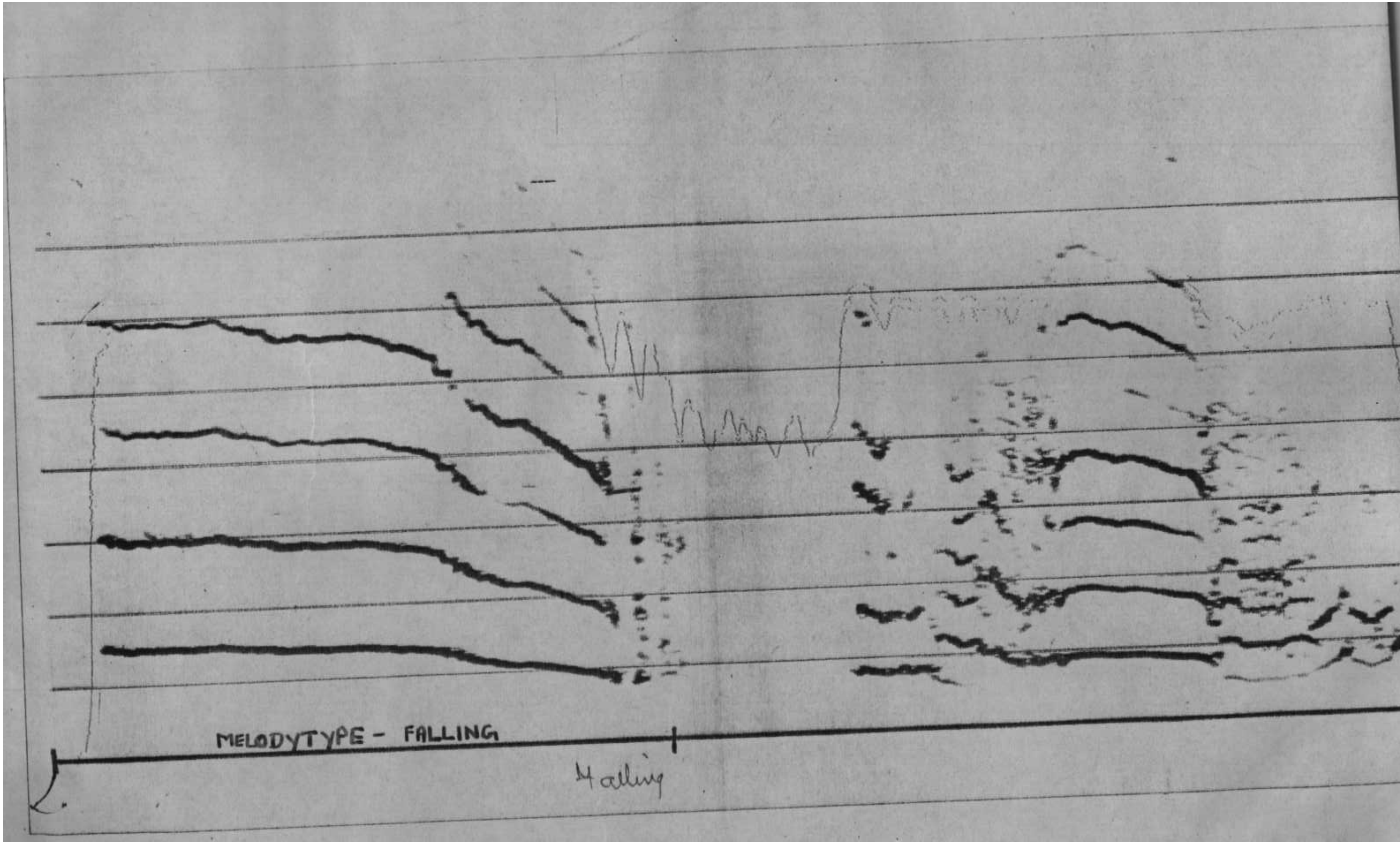

* TONAL-PIT
Rising - Falling.

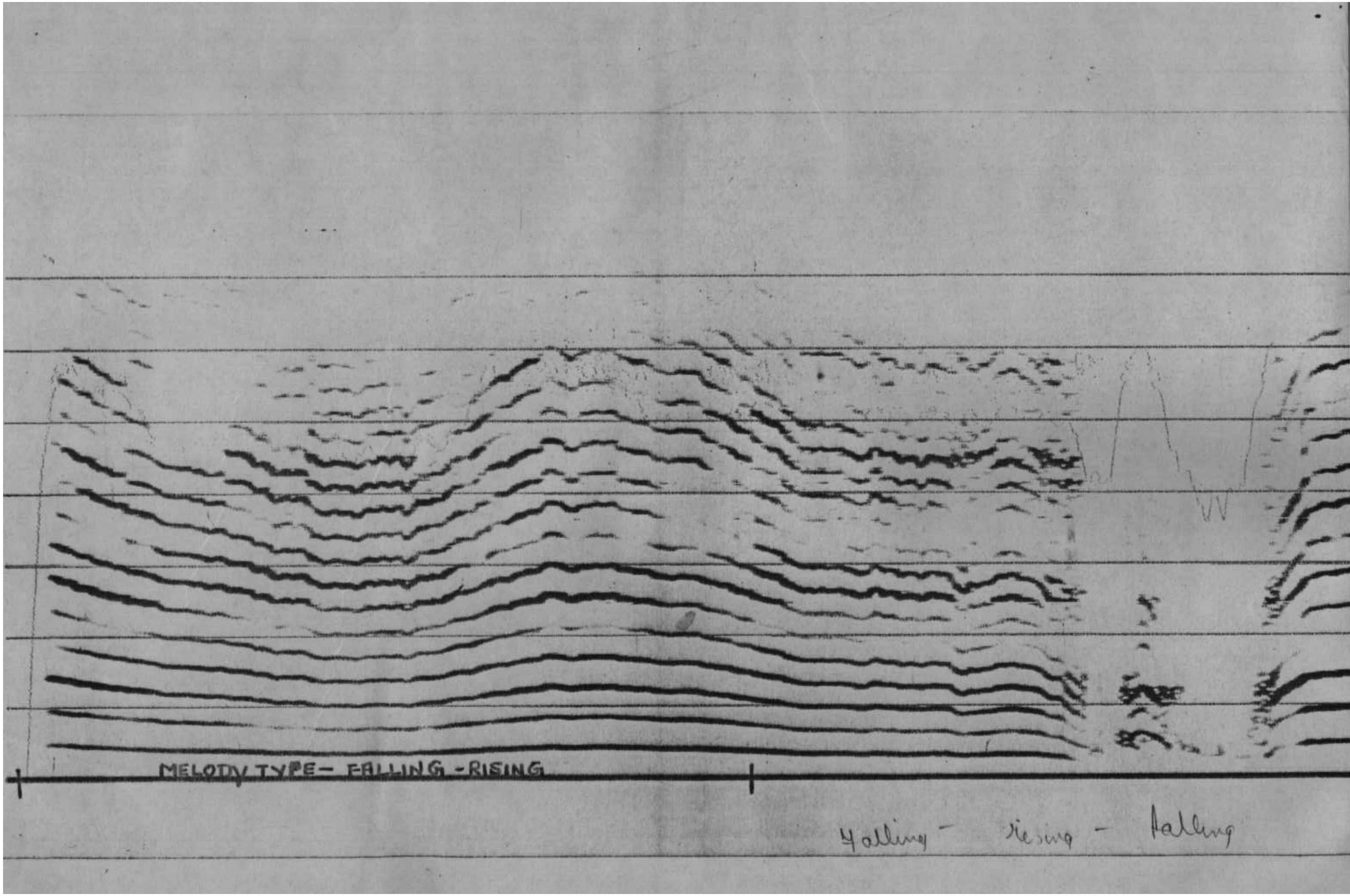


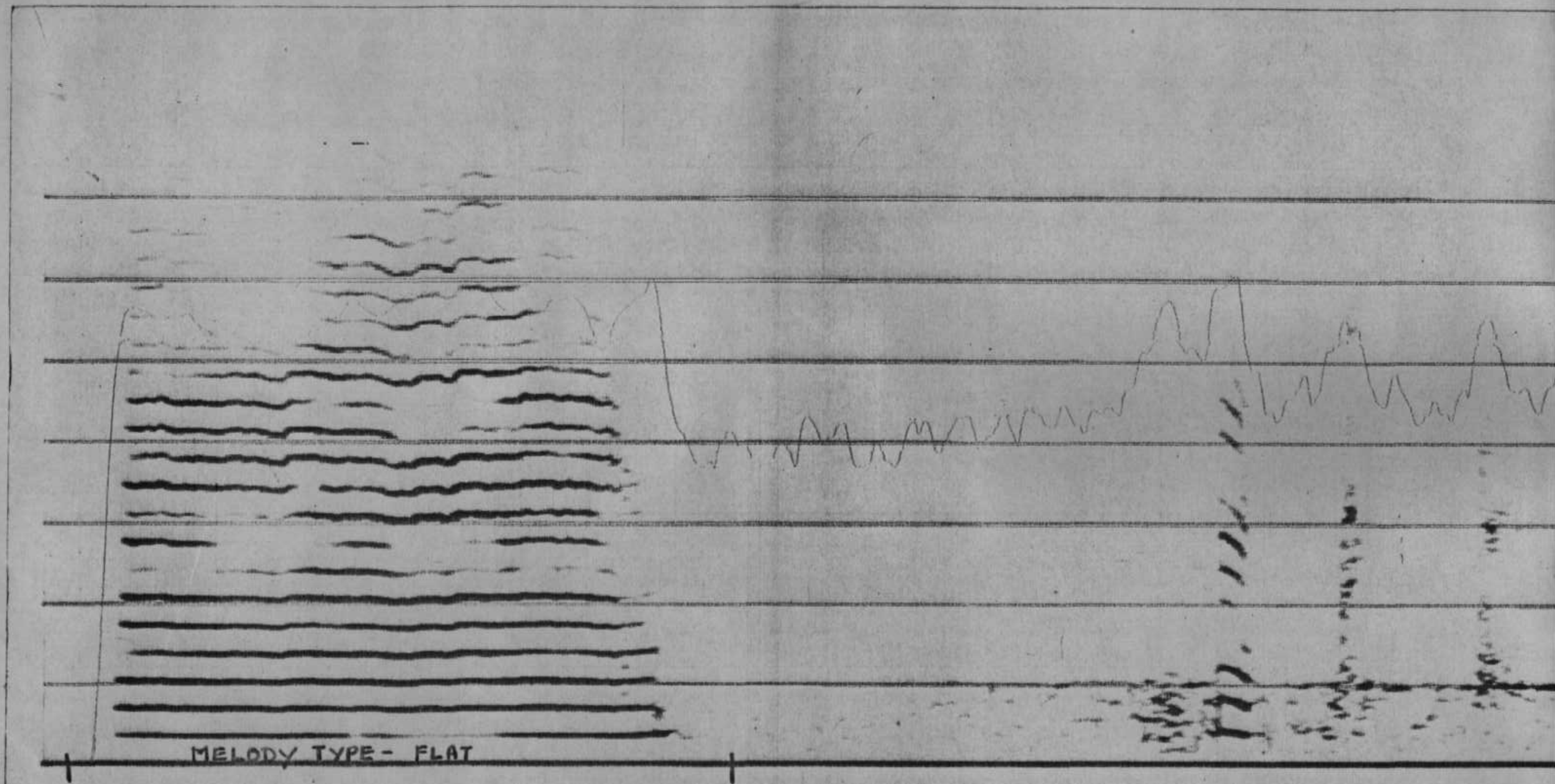
Rising - falling - Rising


GLOTTAL-PLOSIVES
Rising - falling

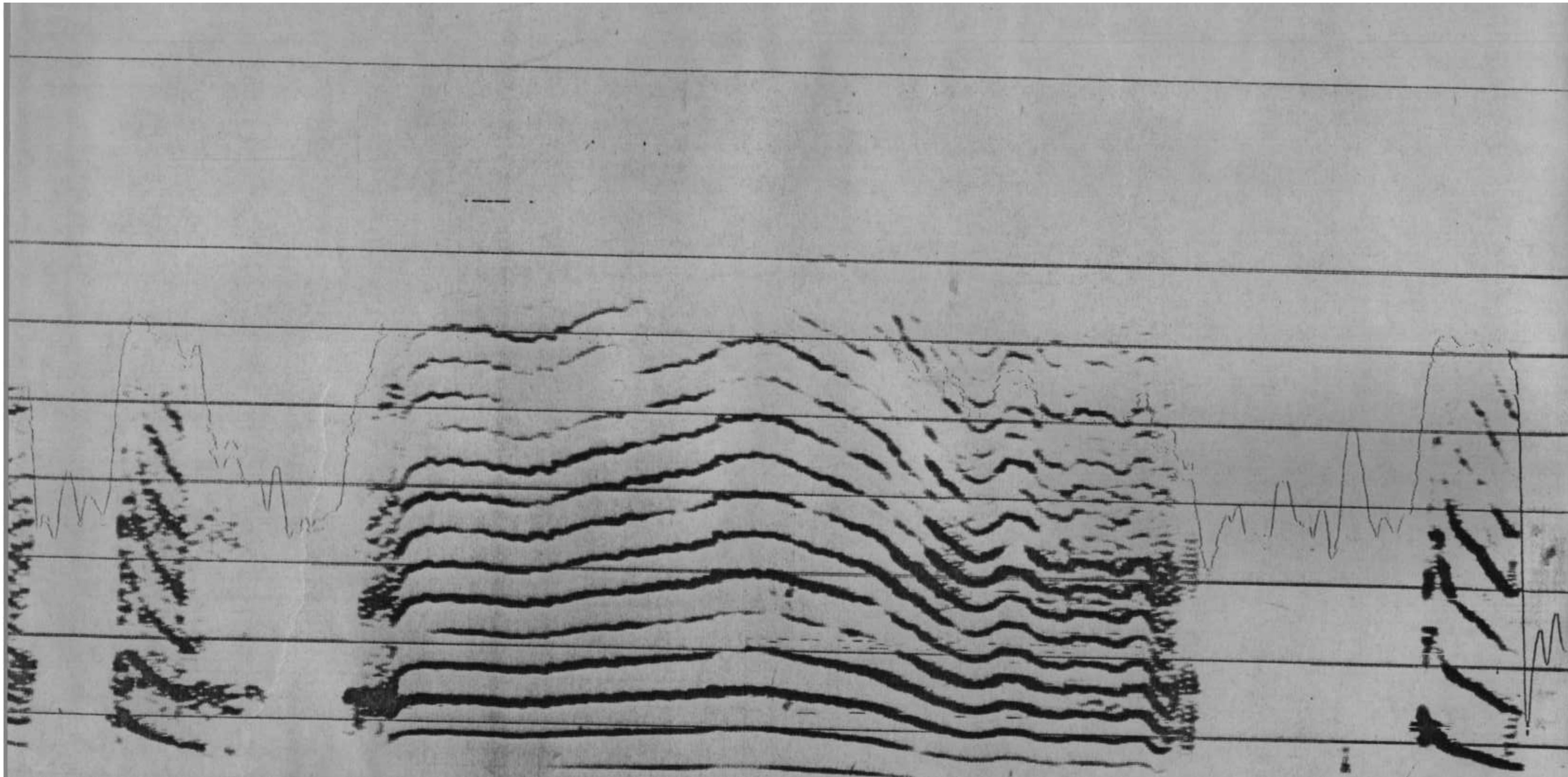

MELODY TYPE - RISING
Rising


MELODYTYPE - FALLING
Falling


MELODY TYPE- FALLING -RISING
falling - rising - falling

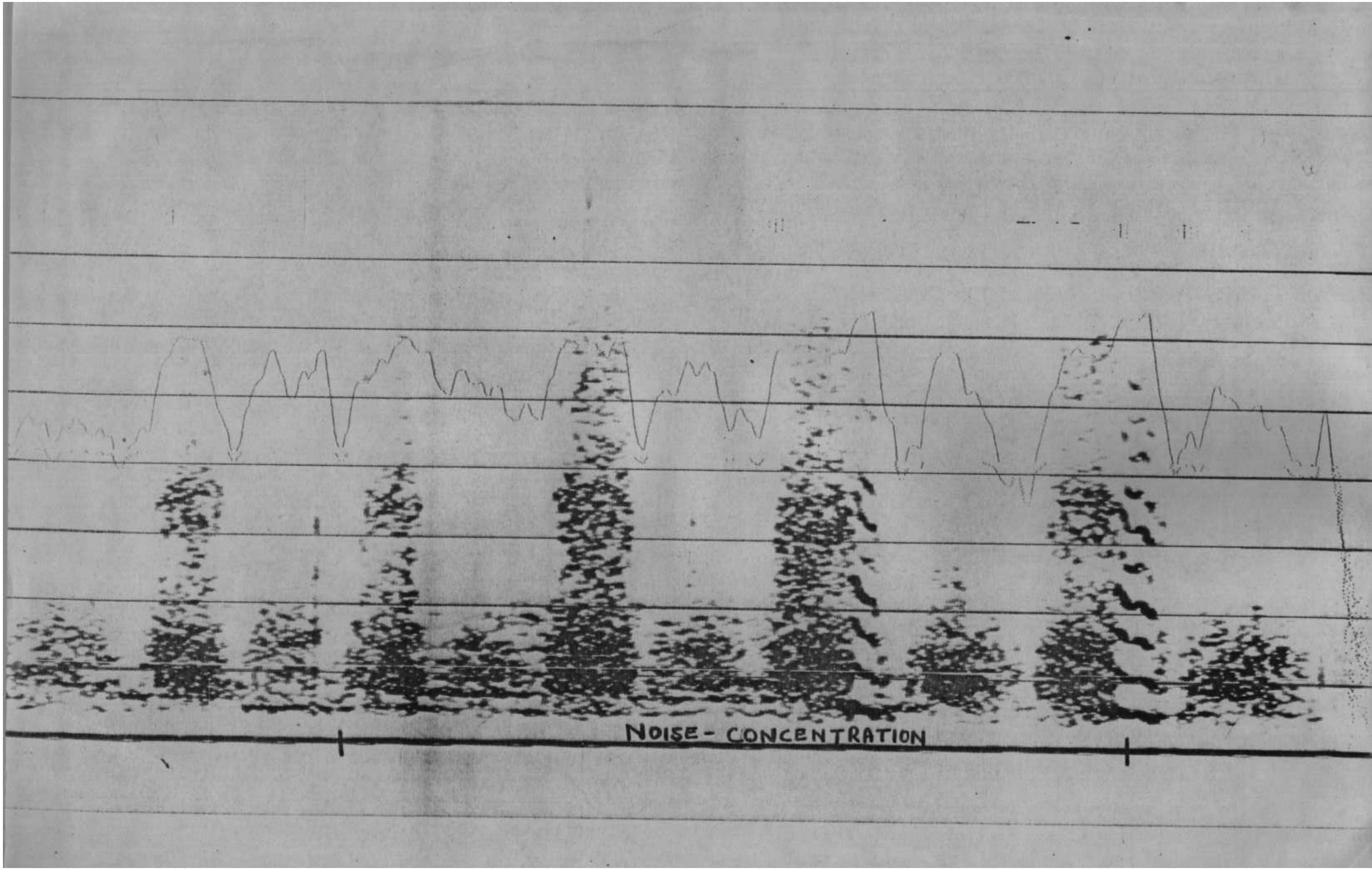


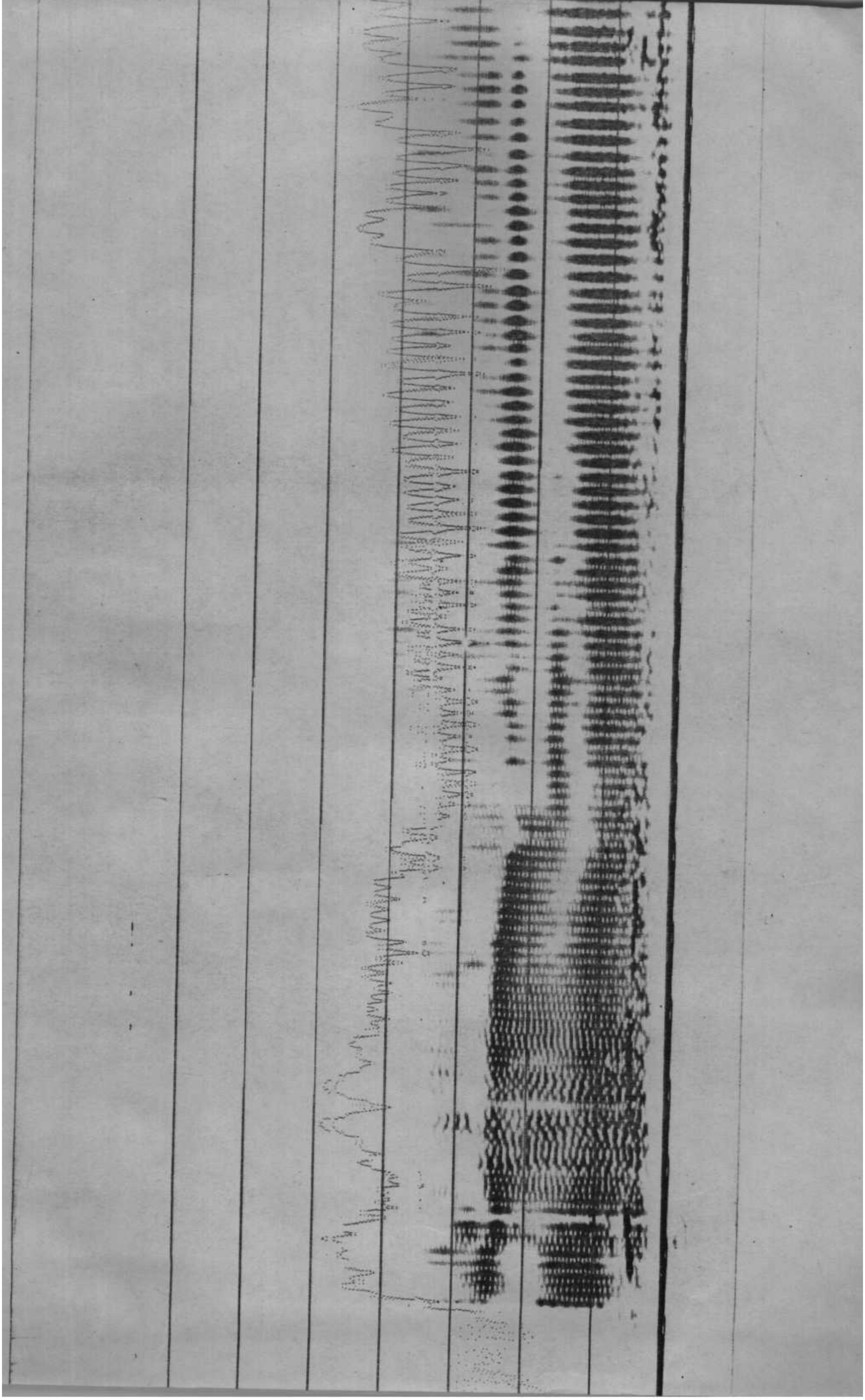
Flat



MELODY TYPE - RISING - FALLING

Rising - falling


NOISE - CONCENTRATION



APPENDIX - 3

INFORMATION COLLECTED DURING FOLLOW-UP

Name: Age: Sex:

Developmental milestones:-

1) Is the child able to hold head up steadily? Yes/No.

   If so, by what age was the child able to hold up his head? -

2) Is he able to grasp objects? Yes/No.

3) Does he try to roll-over? Yes / No.

4) Does he recognize his mother? Yes / No.

Auditory screening

Responds to:-

1) Name -
2) Clap -
3) Rattle -
4) Horn -
5) Kanjeera -
6) Squeaper -
7) Whistle -