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ABSTRACT

Infant's crying may have an important mediating role in the formation of attachment behavior. The earliest vocalizations are discussed in terms of an acoustic communications model in which the baby's vocal repertoire becomes incorporated into a closed-loop, feedback system with his mother. Certain pre-lingual "signals" may be associated with those maternal actions which bring about a reduction in psychobiological stress, thus becoming one medium in which infant-mother attachments are formed. In order for a mother to determine a particular stressful state such as pain or hunger from the cry signal alone, crying would have to be acoustically distinctive to this state. To determine whether such distinctions exist, the vocalizations of twenty-two infants were tape-recorded under a variety of stressful conditions: pain stimulus, startle, evidence of hunger, etc. An ensemble technique of spectral analysis was developed to show that relatively long intervals of crying in one infant may indeed exhibit an average spectrum which is acoustically distinctive to the type of pain stimulus and to hunger. Less clear is whether such distinctions also transpose to groups of infants in a similar stressful state. (Author)

PRE-LINGUAL COMMUNICATION AND ATTACHMENT BEHAVIOR

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1. INTRODUCTION:

We have been particularly interested in one aspect of child development: that phase of his social development which has been called attachment behavior. This refers to the various stages in the way he forms attachments to other people and to objects. Comprehension of the infant's formation of attachments is paradoxical to any single overall view of the child's developmental process. We seem to be at a loss to entirely explain the phenomenon known as attachment behavior in terms of any one of the existing theories. Yet, it is an essential step in the infant's socialization process, one which will have to be better understood if we are to advance our notions about the child's social development.

We will follow Ainsworth (1963) in outlining four successive attachment stages during the infant's first year. There is a beginning stage in which the infant exhibits undiscriminating responsiveness to the people around him. Quoting Ainsworth "Next there is a stage of differential response to the mother, with continuing responsiveness to other people. Then there is a phase of sharply defined attachment to the mother, with a striking waning of undiscriminatory friendliness". The so-called stranger anxiety appears at this stage. Ainsworth continues: "This is quickly followed, and overlaps with, a phase of attachment to one or more familiar figures other than the mother".

The approximate time scale for the appearance of the various stages may be identified. Stage II appears at about 12 weeks, Stage III at about 8 months, and Stage IV at the end of the first year. A number of sequential features of the infant's vocal development have been isolated during this period. The relationship between attachment behavior and vocal development is discussed below.

If a child has motor difficulty, is mentally deficient, cannot vocalize or hear, or cannot see, then surely these handicaps would have an effect on the attachment process. Yet a perusal of the literature fails to uncover a systematic study which focuses directly on biological shortcomings, as they affect attachment in the suckling system. Here we discuss the role that the earliest visual and acoustic capabilities in both the normal and handicapped infant might play in this attachment phase of socialization.

2. CLOSED-LOOP COMMUNICATIONS MODEL:

The importance of signals in child development cannot be overstated. In the sense that the word is used here, signals include all the sensory and associated internal information which can be linked with a particular object or event. It is evident that such signals are an essential prerequisite to social development in the infant, since they are the substance of all the external communications received by him. Thus, the infant and his mother form a communications unit, as shown in Figure 1.

Note the triangle which represents the infant at the top of the figure. This represents the infant's part of a heuristic diagram of the information exchange between him and his mother. We note that two forms of information input occur with the infant: sensory inputs from acoustic, visual, and short-range channels, and internal inputs from immediate physiological stresses. By short-range sensory channels, we mean those that generally require a very short distance between the infant and his mother to become effective -- the touch, smell, and temperature-sensitive sensory systems for example. Both visual and acoustic signals may be transmitted and received through a longer distance; hence, we call them long-range channels.

We note that the infant may make some response to those signals which occur in the presence of his mother and eventually become associated with her. We show a variety of possible responses at the upper right in Figure 1. These in turn become the origin of the sensory and associated internal signals which the infant's mother receives and associates with her baby. She "processes" these signals and makes her own responses to them, as shown at lower left. Thus, we have the makings of a closed-loop communications network between the infant and his mother.

The diagram is a useful analogy, since we see that if one of the channels which would be normally used is impaired or lost in the infant or his mother, then the entire communications system will be affected. Consider the triangles representing the infant and his mother. A similar impairment in information processing and storage would also affect communications. In other words, we are talking about what would happen to this system if the infant or mother were deaf, or hard of hearing, were unable to vocalize or had a vocal handicap, were mentally deficient or seriously emotionally disturbed, etc.

3. VOCALIZATIONS AND ATTACHMENT:

Since the infant's relationship to his mother or a suitable substitute is crucial to the establishment of attachment behavior, this line of reasoning suggests that we may study attachments in relation to the communications process. We selected the acoustic communications system as a starting point for the study since vocal signals are highly "accessible" to analysis.

Clearly a starting point in any study of the baby's acoustic output as it relates to attachment behavior is this earliest infant vocalization species - his crying from birth to the first babbling stage. More particularly, one could ask a number of questions about crying. Is crying differentiated from birth with regard to a particular stage of immediate stress in the infant, such as pain, hunger, etc.? If not, then in the course of the infant's development, when does crying become differentiated, if ever? Even if it is differentiated, can the infant's mother really tell the difference between the infant's cry whe he's just "fussy", when something hurts him? What would be the effect on attachment behavior if the infant made a particular type of cry under certain stresses as opposed to a general undifferentiated cry, or, as Lenneberg (1967) puts it, if he "just blew his horn".

Let us consider the implications of the last question first. We presume that the early establishment of an acoustic communications system is favorable to the formation of an infant-mother attachment, and vice versa. Further, we assume that the sooner the infant may make differentiated vocal signals, and the sooner the child's mother perceives them and then associates them with his particular condition or need, then the more favorable will be the condition for the establishment of an infant-mother attachment. This is so because the baby may then more readily associate his mother with the re-establishment of a favorable homeostasis. Hence, he may then form an earlier dependency on her.

Similarly, the infant's mother has powerful maternal drives and other psychic forces which may be fulfilled in interaction with her baby. Thus, there is a mutuality in the attachment process, a set of mutual needs, drives, forces, etc., which have a common ground in a closer infant-mother relationship. If the mother can make early use of the infant's acoustic signals, she may in turn foster the formation of the attachment process.

4. CRY STUDIES:

Let us consider some other questions which were raised about infant's crying. First, is the infant's cry differentiated from birth with respect to pain, hunger, etc? It turns out that we are not sure yet. We have made an initial attempt to find out what is known about the properties of this acoustic signal and to find out whether any study we could undertake here might lead to some clarification of early crying.

We examined the considerable body of research which has been done on crying and found that there are two schools of thought. Members of the first school hold that the cry signal is "random", "non-expressive and diffuse", without specific signal characteristics which could become an acoustic link to a nurturing person. This view goes back to an early discussion by Sherman (1927), and has more recently been discussed by Miller (1951).

An opposing view is presented by Peter Wolff (1969), the Lind-Wasz-Hockert (1969) group in Finland, and others. Their studies followed the pioneering work of Samuel Karelitz (1963) and Vincent Fischelli (1962, 1964) who demonstrated quantitatively what pediatricians have known all along. The cry of a baby with Down's syndrome, kernicterus, "Cri-du-chat" etc. is markedly different from that of a normal infant when examined by VU graph or the sound spectrograph.

Karelitz (1960) also showed that pain and hunger cries in normal infants were different from the so-called spontaneous cry, for which no parallel psychobiological stress may be identified.

Using the sound spectrograph, rating scales by trained observers, etc., the Lind-Wasz-Hockert (1969) group launched a comprehensive study of infant's vocalizations in four categories: the birth cry, the pain cry, the hunger cry, and the later pleasure vocalization. They studied these cries for ten acoustic characteristics and found that they could indeed be differentiated from one category to another. Trained observers could group them, with a fairly good statistical validity, and the acoustic measurements could pick out certain characteristic features.

Peter Wolff (1969) used a different set of carefully-defined categories into which to separate crying: a "basic" or "hunger" cry; a "mad" cry; a "pain" cry; and crying provoked after the successive insertion and withdrawal of a pacifier. He found acoustic features on the sound spectograph which were distinctive to each of these cries.

We found that the existing forms of acoustic analysis used by these workers leave something to be desired. They do not describe random qualities in the cry signal, which varies with time in intensity, pitch, and rhythmicity time to another. The slow VU graph will tell us how sound intensity will change with time. The sound spectrograph will give an approximate spectral or frequency distribution for a particular on-going cry, approximate, because it lacks spectral resolution and because it represents sound intensity by opacity.

5. METHOD:

In this study, we utilized a new digital instrument for signal analysis, the Hewlett-Packard #5450A Fowler Analyser. The system features a 16,000 word computer, which is used to digitalize analog samples from the vocalization tapes, then convert them to an equivalent power spectrum by computing the algorithm for the Fast Fourier Transform. One may achieve spectral resolution far greater than that of the Sound Spectrograph (up to 100 times as much), and precise signal amplitudes we maintained in processing. Thus the instrument approaches the human ear in its capacity to distinguish between acoustic inputs.

One capability of the instrument made its use particularly attractive--it may be programmed to form ensembles of the spectra for individual samples. It is well known that vocalizations, including infants' crying, are highly variable. By computing the average spectrum is a large number of sample terms, we may precisely characterize the energy in a considerable number of different vocalizations. We may thus determine from a relatively long segment of crying data the appropriate average acoustic signal for a state of pain, hunger, spontaneous crying, etc., in a particular infant. In this way, excellent reproducibility of results is achieved.

6. <u>RESULTS:</u>

So far, useful data from some 22 infants has been accumulated. We have been able to use tapes for the pain cry of six infants, of a startle-type cry for an equal number, after the foot was tapped, of what was apparently a hunger cry for three infants, of the spontaneous vocalizations of 9 infants, of the cry just after being awakened for 4 infants, etc. We also have a lesser number of cries in other categories, including those for the premature and for an infant who may have had some neurological deficiency. This yield may seem small, but we could exercise no control over the circumstances of the taping in this initial study.

Figure 2 shows 3 plots of a one-week old girl baby's crying. The plots are for log display of the average spectral energy of the cry at most audible frequencies, vertical components proportional to the log of sound energy and horizontal components linear in frequency. Each trace represents the log for an ensemble average of 100 cry samples. The top 4 traces are the result of sampling an entire 70 second outburst of crying, after the infant's foot was tapped. Individual traces representing logs of 4 separate determinations superimpose almost exactly, showing how well the computer can reproduce the average sound energy.

The second graph is the result of applying the same procedure to only the first four cries in this outburst. Note that these cries are quite distinctive, whereas the 70-second series more neatly resembles the log for a single 100-term average from the "spontaneous" crying in the same infant, as plotted on the bottom graph of this figure.

In Figure 3, the same display is used for the traces of the "spontaneous" cry for three different infants: full-term (top), premature (middle) and possibly brain-damaged (below), the "spontaneous cry" occurring without apparent psychobiological stress or discomfort. Note the generally lower energy and different frequency patterns in the premature and possibly brain-damaged infants, as compared with the tracing for the normal baby.

The pain cry in one infant is quite different from the spontaneous cry in another infant. In Figure 4, we show the result of computer-analysis of crying in two such infants, using the ensemble technique of the previous Figures. The dark trace is the log for a 400-term average from the crying of a three day old boy after his thumb was pricked for a blood sample. In the same plot, the light trace is the log for a 400 term average for the "spontaneous" crying of a one-week old girl. Differences are most marked at 3 kiloHertz and at 5 to 7 kiloHertz, showing the "shiek" is the pain cry.

On the other hand, the plot for the pain cry in one infant shows a "family" similarity between two separate pain cry series of 400 terms each. In the bottom graph of this trace, the dark plot is the same as that for the top graph--that is, the pain cry of a three day old male after his thumb was pricked. The light trace of the lower graph is for the same infant's cry while his foot was being squeezed, following needle puncture, to accumulate another blood sample. The "shick" is somewhat different, as shown by the marked 5 kiloHertz peak for the foot squeeze cry. But the two traces are in other respects similar.

7. CONCLUSIONS:

Clearly, we still need more data, and the circumstances of the recordings must be under firmer control before more newly definitive conclusions are made. However, we have been able to determine the following facts from our initial investigation:

1. It is possible to distinguish between pain, hunger, and spontaneous types of crying at a very early age, perhaps from birth.
2. There is a marked difference between the cries of a full-term infant and one which is premature.
3. We have some reason to believe that a distinction exists in the cries of an infant with certain physiological disorders, such as mental deficiency or physical handicap.

These results, although as yet unconclusive, encourage us to believe that a great deal can be learned about human development from a further analysis of infant's cries. The next step is to study a large number of babies from three groups--normal, biologically handicapped, and environmentally deprived--and to sustain this study over the entire first year of each baby's life. At the same time, we would be noting the emergence of attachment behavior, with an eye to its correlation with vocal development. We hope to establish a more specific cause-and-effect relationship by analysing vocalization during situations which have a direct reference to attachment--as when the mother leaves the room, for example, or returns after a brief absence. In time, it may be possible for us to obtain a much fuller understanding of what the human infant is "telling" us.

Fig. 1. Closed-loop Infant-mother Communications System

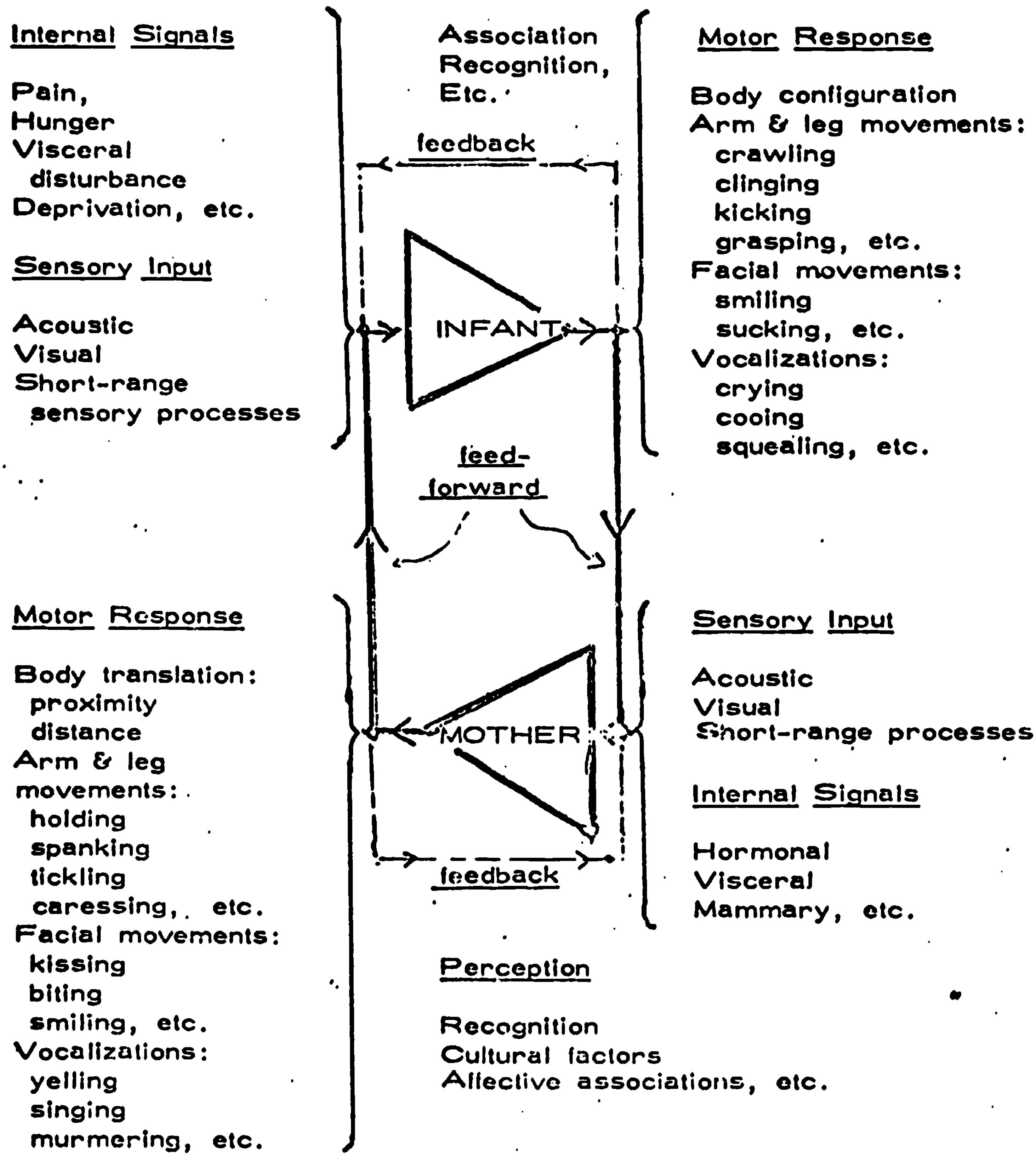
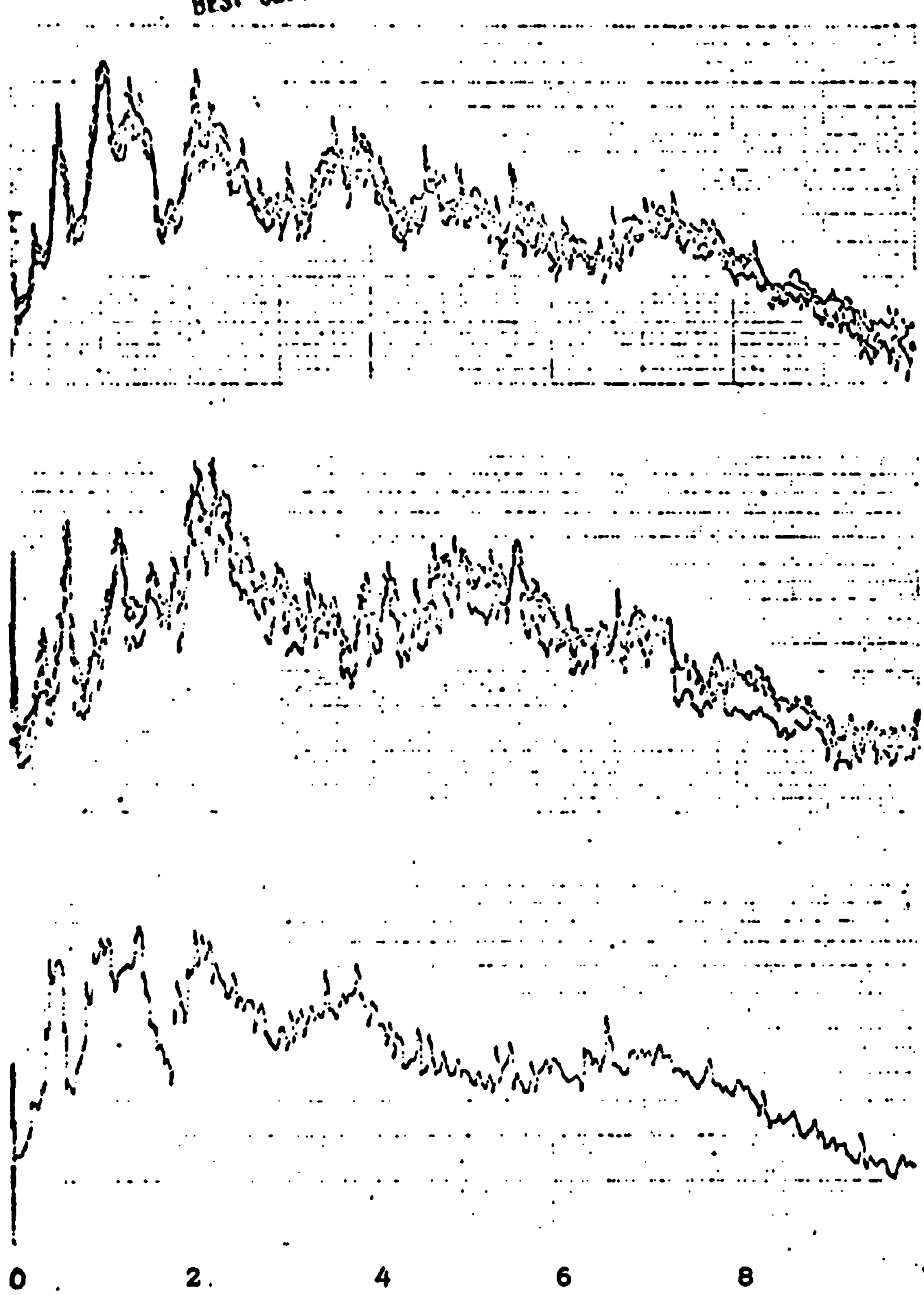


Fig. 2. Log $\overline{P}(f)$. Top 2 traces: superposition of 4 separate $\overline{P}(f)$ determinations for a crying episode after the infant's foot was tapped. Subject: #71-b, 1-week-old female.

Bottom trace: $\overline{P}(f)$ for the same infant's "spontaneous" crying.

$$\text{Log } \overline{P}(f) = \sum_{i=1}^{100} \log P_i(f).$$

Bandwidth: -3 dB between 245 Hz and 6 kHz. Block size: 256 blks./10 " .



Full 70-sec expiratory bursts after foot tapped. Approximately 3 data passes per burst ensemble.

-72 dB to -30 dB

Ensembles of first 4 expiratory cries after foot was tapped. 25 data passes per ensemble.

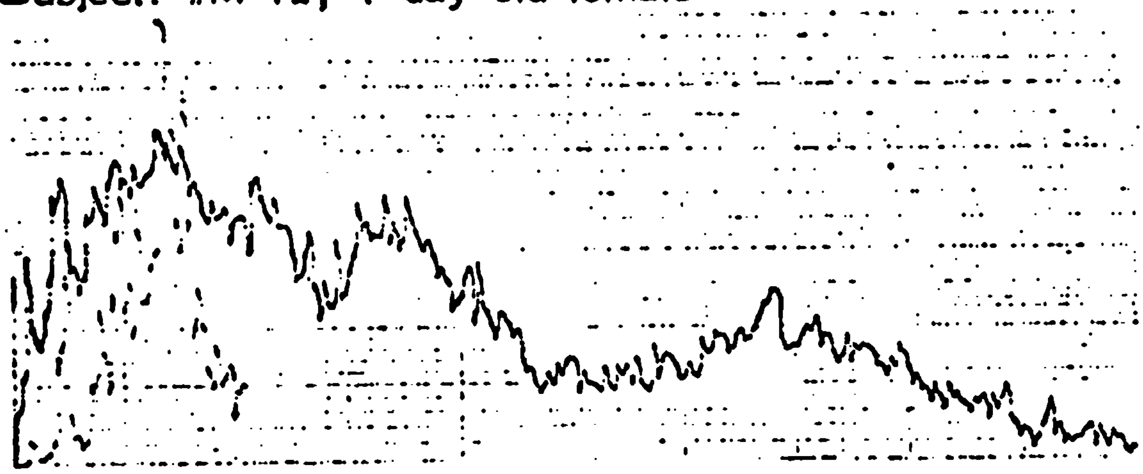
-70 dB to -26dB

Single ensemble of "spontaneous" expiratory cries. 1 3/4 data passes.

-74 to -34 dB

Fig. 3 Log $\bar{P}(f)$. Auto summation spectrum for samples of "spontaneous" expiratory cries for 3 different subjects: full-term, premature, and possibly brain-damaged infants. Bandwidth between 245 Hz and 6.2 kHz; scale: 0 - 10kHz. Resolution: 256 blocks/ 10 kHz, or 39 Hz/block

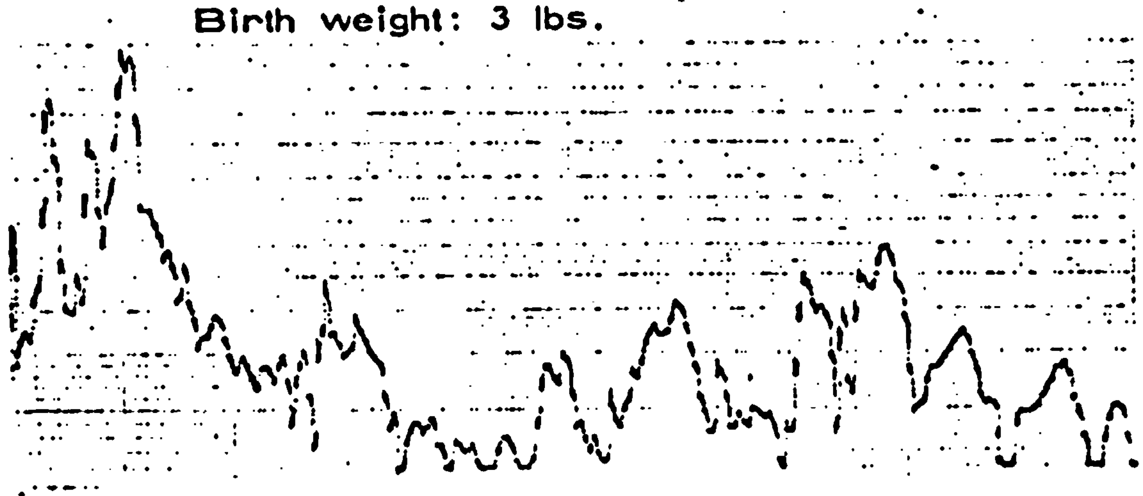
Subject: #M-72, 1-day-old female



100-term ensemble of 38 cries, 2.5 data passes.

-70 to -30 dB

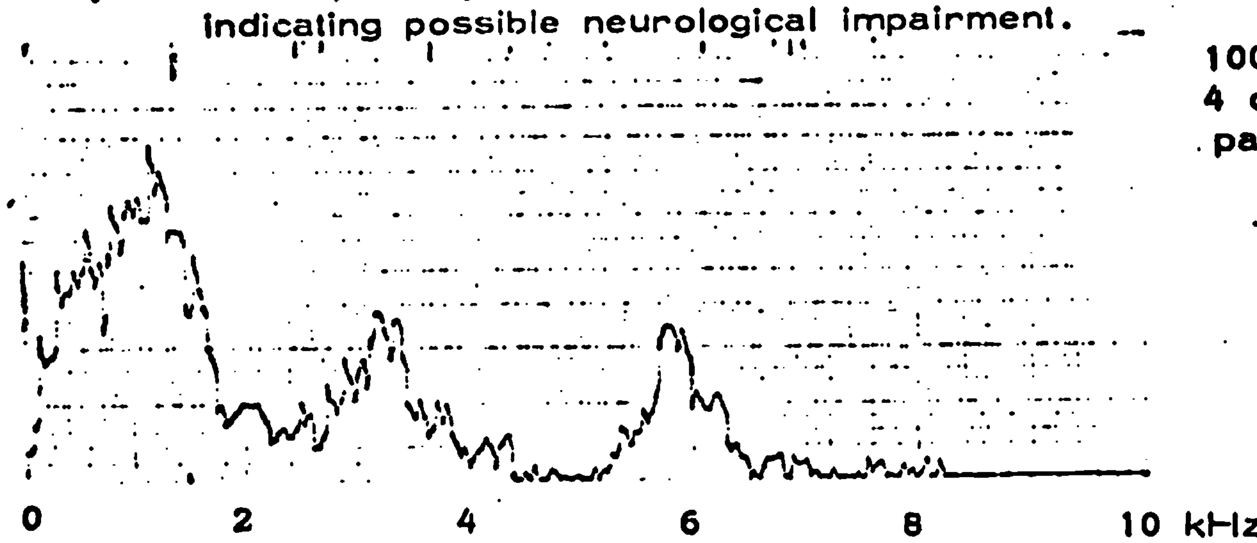
Subject: #D-71, 21-day-old premature male. Birth weight: 3 lbs.



9-term ensemble of single cry. 9 data passes. (Shortly after waking up).

-84 to -44 dB

Subject: #P-72, 1-day-old female with symptoms indicating possible neurological impairment.



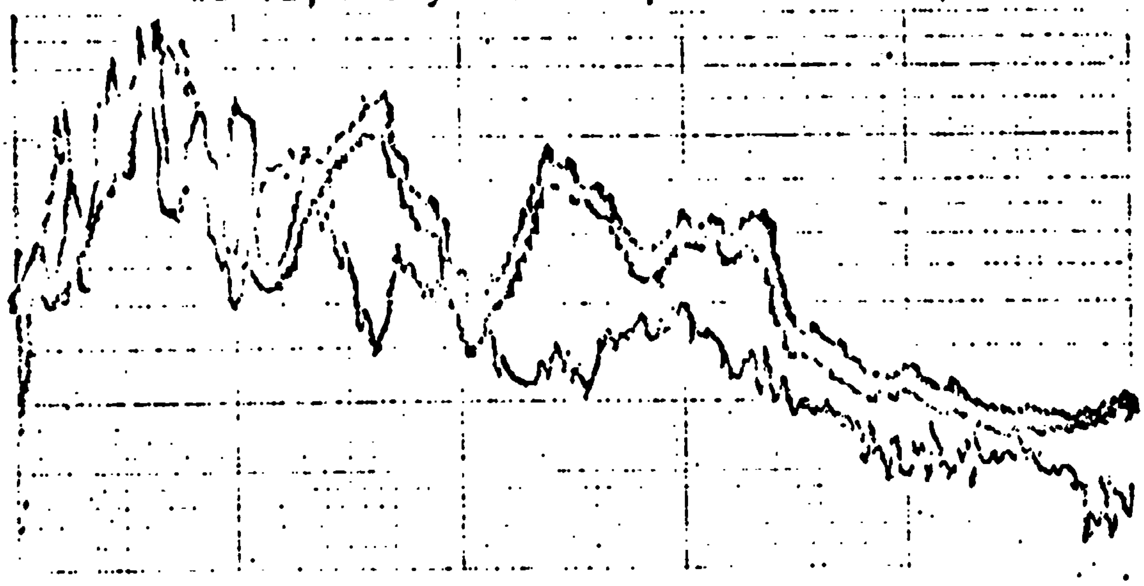
100-term ensemble of 4 cries. 25 data passes.

-70 to -30 dB

Fig. 4. Numerical average of 4 separate 100-term auto summation spectral averages of $\bar{F}(f)$. Results for 2 separate expiratory burst series for one infant, under 2 conditions of pain stimulus, are compared with the difference between one such plot and that for another infant who was crying spontaneously. Bandwidth: 245 Hz to 6.2 kHz. Resolution: 256 blocks/ 10 kHz, or 39Hz/ block. Scale: 0 - 10 kHz.

$$\frac{\sum_{i=1}^{4} \log \bar{F_i}}{4}$$

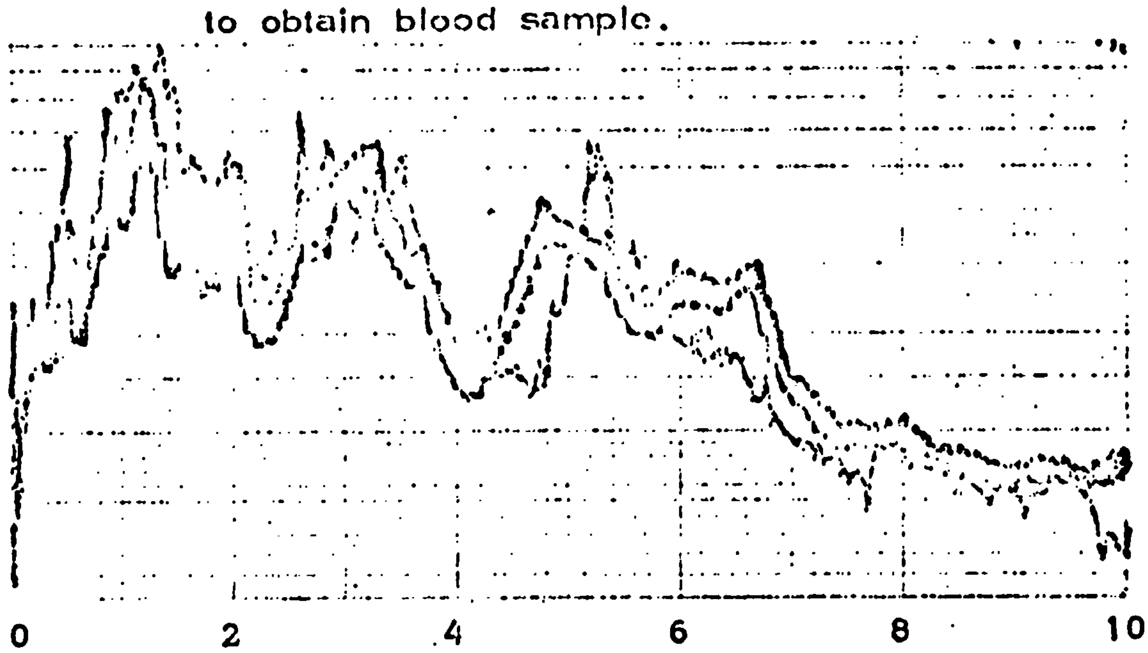
Subjects: #I-72, 1-week-old female, spontaneous crying, vs #J-72, 3-day-old male, after needle puncture of thumb



Dark: Subj. #J. 1 3/4 data passes, 52 expiratory bursts per ensemble.
Lite: Subj. #I. 4 data passes, 25 expiratory bursts per ensemble.

-72 to -32 dB

Subject: #J-72, 3-day-old male. Cry after needle puncture of thumb vs cry after heel prick and foot squeezed to obtain blood sample.



Dark: Cry after needle puncture of thumb. 4 data passes, 52 expiratory bursts per ensemble
Lite: Cry after heel prick and foot squeeze 4 data passes per ensemble, 25 expiratory bursts.

-72 to -32 dB

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