THE DEVELOPMENT OF SPONTANEOUS CRYING IN EARLY INFANCY: THE ONTOGENY OF AN ACTION SYSTEM

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ABSTRACT

The spontaneous cryings of 10 infants observed longitudinally, in five sessions each, starting from immediately after birth to three months, were analysed from the point of view of the development of an action system. It was postulated that the cry expression action system, some of whose components existed at birth, underwent reorganization with the appearance of some critical component(s), and developed toward a goal-directed action system.

It was demonstrated that both the cry vocalization and other concurrent behaviours showed great changes between the first week and 4 weeks. Specifically, duration of cry vocalization and cry interval increased, indicating the decrease of intensity of crying; frequency of glottal plosive in the beginning phase of crying sequence increased, indicating the appearance of a mode of activation different from that of the first week; the co-occurrence of vocalization and visual exploration during crying increased drastically at 4 weeks, indicating the possibility of closer coordination between the infant's perception of events in the environment and the ongoing behaviour of cry vocalization.

These results suggest that infant crying begins as a simple on/off system with vocalization and other components such as respiration and facial expression in coordination. Also with the incorporation of components such as eye opening (or the maintenance of the awake state) and visual exploration during crying, the system develops into a goal-directed action system, capable of modulating aspects of vocalization in accordance with feedback from the environment.

It was concluded that the action systems theory provided useful guidance for understanding the development of cry expression, and that the insight gained from adopting such an approach would have further implications in understanding the development of the infant's relationship with his/her care-giver. The implications of the appearance of the new mode of crying (i.e., eye opening and visual exploration while fussing/crying) were discussed in terms of their effects on the development of the infant's inter-personal relationship with the caregiver.

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It goes without saying, however, that the author alone is responsible for those defects that remain in this text.

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Chapter I. Introduction

1.1 Objective

In this dissertation the development of spontaneous crying of human infants in the first three months will be the topic of investigation. The selection of infant crying for a developmental study was mainly based on two considerations; one from a functional point of view, and another, from a theoretical one.

Crying is observable immediately after birth, and continues to be observable in adults. It serves as one of the most important means of communication for the infant during the first months. Starting as a behaviour which is often characterized as reflexive, the vocalization of an infant soon develops into a sign system of social expectation (Lamb, 1981, Lamb & Malkin, 1986) or a means of expressing his/her intention (Harding & Golinkoff, 1979). In this dissertation, one main focus is to document how the reflex-like neonatal crying which seems to burst out suddenly develops into a seemingly calculated and controlled "looking and vocalizing" type of crying a few weeks later. The theoretical point of view adopted is that of the action systems (Reed, 1982). The ultimate objective of this dissertation is to present a model for understanding the process of the development of the infant's cry expression action system.

1.2 Background and Theoretical Issues

Infant crying has attracted the attention of professionals for a long time. As has already been expounded and elaborated both by the present author and by various other writers, infant cry serves important functions in the development of the infants during the first months (Chen, 1986). The fact that cry vocalization serves as the infant's only effective means of communication in the early weeks is partly related to the aversiveness of the cry sounds (Murray, 1979). As post-partum mothers are usually exhausted and weak, without an effective method to wake them up or to motivate them for action, the helpless neonates might not be able to obtain the care they need for survival. The urgency that the cry sound arouses makes a response to it obligatory, and thus effective (Ostwald, 1963). In addition, the aversiveness of infant cry sound often occasions interaction of intense emotional nature between the infant and the caregiver. It can evoke strong feelings of concern and protectiveness, or of extreme hostility and destructiveness

(Ostwald, 1963).

Infant-caregiver interaction in the early months is typically not free from infant fuss/cry episodes. So much so that one of the important tasks of a caregiver, professional or otherwise, can be said to be in keeping the infant in a good mood by preventing the infant from unnecessary crying, or in failing that, to stop the infant's crying as soon as possible. It should be pointed out that while fuss/cry is difficult to avoid, interaction involving infant crying and the caregiver's coping with it nevertheless serves a useful function in the development of the infant's relationship with the caregiver. With respect to infant fuss/cry, a typical infant-caregiver interaction in the early months can be conceived of as consisting of a sequence of events involving the caregiver's response to, or coping with, infant crying, and the infant's response to the caregiver's manner of treatment of his/her crying, continuing for an indefinite period of time, depending on various factors of both the infant and the caregiver. This sequence of events, called distress-relief-sequence, has been considered as important in the discussion of the infant's socio-emotional development, and the formation of attachment (Lamb, 1981, Lamb & Malkin, 1986).

As an expression of an infant temperamental disposition called irritability, crying or fussing is also considered an important behavioural index in the discussion of the development of temperament in infancy and childhood (Bates, Freeland, & Lounsbury,1979, Miyake, Chen, & Campos, 1985).

A further issue concerning the functional significance of crying concerns the role of cry vocalization in speech development (Wolff, 1969, Stark, 1978). Although both Lenneberg and Jakobson proposed that there was a sharp discontinuity between the first word and earlier sound production (Lenneberg, 1967, Jakobson, 1968), recent studies have reexamined their views critically and suggested a positive relationship between the early vocalization and later speech (D'Odorico, Franco, and Vidotto, 1985, Stark, 1978).

In addition to these mentioned above, the present topic was selected on the basis of another consideration, that of a theoretical nature. In traditional studies of infant crying, various approaches have been adopted. While these approaches were adopted for addressing issues ranging from relationship between the amount of crying (and/or fussing) and maternal sensitivity, to the diagnostic utility of cry sound analysis, infant crying has seldom been examined from the point of view of the development of an action system. The cry of the infant has often been regarded as a response or reaction to a certain range of stimuli, such as pain, hunger, discomfort, or loneliness, etc. Partly because it was taken as a reaction response, the focus has been on the most obvious, the cry sound. Furthermore, the cry of the infant, especially the cry sound, has been considered as an index of some other variables in which the researchers happened to be interested. For example, Bell and Ainsworth (1972) assessed the amount and frequency of crying and fussing of infants during an extended period of time, and correlated these quantities with the aspect of maternal behaviour they called maternal sensitivity, thus making the amount of crying an index of maternal sensitivity. Likewise, many studies investigated the relationship between the acoustic features of single cry signals and some known clinical conditions of the young infants, thus treating some aspects of cry sound as indices of the integrity of the nervous system. However, infant crying has never been investigated as a phenomenon in its own right, with the sound and the concurrent behaviours constituting an integrated sequence of action as can be observed in real-time. In other words, like other topics in the field of motor control, infant cry has been conceptualized in terms of "static and mechanistic physiology of reactions" (Reed, 1982). In contrast, in this study, infant crying will be approached from the point of view of the physiology of activity, or as action system (Bernstein, 1967, 1984, Reed, 1982).

A further important theoretical issue to be emphasized in the present dissertation is the adoption of a developmental approach. It has been pointed out more than once in recent reviews that there was a lack of developmental viewpoint in the field (c.f., Hopkins & von Wulfften Palthe, 1987, p.165, Wolff, 1985, p.352, Zeskind, 1985). Although there were a number of studies that attempted to look into some aspects of infant crying, these efforts were limited by narrow perspectives, in the sense that attention was limited to the crying of the first week, or that only the cry sound or only one aspect of the cry act, such as the facial expression, was included for investigation, as we mentioned above (Ames,1941, Caldwell & Leeper, Jr. 1974, Prescott, 1975, Prechtl, Theorell, Gramsbergen, and Lind, 1969, Stark & Nathanson, 1974). As a result, a considerable amount of research on crying has been concentrated in the newborn period and little is known about the development after this period. In this dissertation, one main objective is to document the development of crying after the first days. The theoretical objective of this dissertation is the formulation of a model for the development of crying as an action system in the first three months. Two features that distinguish the approach to be adopted here from that in other previous studies are: 1) the view that crying is considered as an action in real-time, 2) the development of the crying system is viewed as consisting of parallel subsystems, or components. These points will be briefly discussed.

Crying as an action in real-time: A considerable amount of studies on crying has focused on analysing the acoustic features of single signals elicited by a painful stimulus. In these analyses, as the main objective was to obtain some quantitative values about the acoustic properties of the cry sounds, single signals were the targets, rather than cry sounds in their natural order. The procedure often selects only those "signals" that are above a certain duration (e.g., 0.4 sec in Wasz-Hockert et al. 1968). In contrast, some studies on infant cry focused on crying at a macro-level, measuring the amount of crying in an extended period of time, such as weeks or months (Aldrich, Sung, and Knop, 1945 a,b,c, Bell & Ainsworth, 1972, Brazelton, 1962). These procedures or methods of analysis imply a totally different view of crying from the one that considers crying as an action in real-time. In these studies, cry was considered as a response or an output triggered by some known or unknown stimuli. From the latter point of view, the key concept is crying, the crying action, which consists of not only the movements of the vocal tract but also that of other parts of the body, constituting an organized system in action occurring in real-time.

Parallel subsystems: It is surprising that although crying was recognized early as consisting of cry sounds and the cry act (Lind, 1965), very few subsequent studies have actually attempted to do justice to such a view by investigating the relationship between the component subsystems. Further, even when motor movement was included, it was taken to mean either the motoric motions of the vocalizing system, such as the pharyngeal, laryngeal, and thoracic adaptation during crying (Bosma, Truby, & Lind, 1965), or to mean body posture or facial gestures (Ames, 1941, Stark & Nathanson, 1974). While these intra-organismic motions were important in the cry expression system, they were only a part of the picture. Another equally important aspect is what can be called the "inter-organismic" act, such as orientation to external stimuli, or visual exploration. The concept of action systems implies a regulation, or controlling process during the action and the process of perception which guides action (Pick, 1989, Reed, 1982). In other words, the utterance of fuss/cry sounds and the execution of various perceptual/motoric behaviours can be conceived as having been carried out in coordination with each other, and toward some goal.

This aspect of the action of crying is considered a subsystem of the cry expression system, and the development of motor skills related to it not only creates the impression that the crying comes under voluntary control of the infant, but also makes it possible for the caregiver to intervene distally, thus creating a new mode of interaction between the infant and the caregiver. As a result of the recent interest in motor development, especially from an action-based perspective, a variety of developmental domains, for example, motor skills and communication, have been approached from this perspective (Pick, Jr., 1989, Thelen & Fogel, 1989). Of course, viewing movements as expression of systems, and trying to understand the development of these systems is not totally new. As has been pointed out by some theorists already, Gesell and Piaget, for example, held similar views

(Thelen, Kelso, and Fogel, 1987). One feature that distinguishes the present perspective and that of the older views is the view that behaviour is an emergent systems property of multi-level parallel developmental processes. In other words, no single developmental event in itself can be defined as the cause of development.

In recent literature, the theoretical approach adopted in this dissertation is variably referred to as "the dynamic systems approach", "action-based theory" (Thelen & Fogel, 1989, Thelen, 1989, Fogel & Thelen, 1987), or as "action systems theory" (Reed, 1982). While the theoretical origin of the present formulation can be traced back to various sources such as the thinking of J. J. Gibson (1966, 1979), and Bernstein (1967, 1984), or to a general theory about the thermodynamics of complex systems (Kugler, Kelso, & Turvey, 1982, Prigogine and Stenger, 1984), the initial efforts to apply the theoretical perspective to the problem of behaviour development, especially to the issue of motor development and the development of communicative action, have been that of researchers such as Thelen and Fogel and others (c.f., Developmental Psychology, vol. 25, Number 6 for some representations of research on the issue).

The following is a summary of the dynamic systems theory, especially as applied to early action development (Fogel & Thelen, 1987, Thelen, Kelso, & Fogel, 1987, Thelen, 1989). Two features which are often mentioned by these theorists will be summarized: One is that living systems acting in a context are dynamically self-organized, and the other is that dynamic self-organization creates regularities or patterns rather than random associations. One implication of these views is that the patterned regularities that we observed are not "caused" by some higher order control center, as many developmental theories would have it, but rather, the result of the emergent property of the system. In other words, patterned regularities are to be considered as emerged from the dynamic interaction of the components of the system. This view further implies that no single component or subsystem has ontological priority over the others. However, in most of the studies using this approach, the roles of mastery over muscles for movements of the limbs and maintenance of body posture are often emphasized (e.g., Fogel & Thelen, 1987). This is to be understood as emphasizing the importance of the various components, at various levels, of the system for creating a certain state of development of the infant's actions. In traditional approaches, these factors were often treated as being "peripheral", and therefore were mere recipients of instructions from a neurologically encoded scheme or internal organizer(Thelen, Kelso, & Fogel, 1987).

The dynamic systems approach considers the muscles at the periphery of the body and the social context in which the expression occurs are sources of order instead.

The basic concept of the theory of action systems is the concept of action system. Action systems involve sensory as well as motor processes; they are not organized into response hierarchies, but rather in coalitional structures of adjustable movements and postures. Action systems theory emphasizes that actions are always controlled, never merely triggered (Reed, 1982, p. 117). Based on Gibson's view (Gibson, 1974, 1982), Reed suggests that the components of actions are postures and movements, both of which can be controlled by perceptual systems(Reed, 1982, p. 117-118).

At an abstract level, many of the ideas mentioned above have been anticipated by Gesell. In particular, the schematic representation of his complex model of the dynamic morphology of behaviour (Gesell, 1945) has been a guiding image of the present study. The present author's attempt to approach infant crying from the viewpoint of morphology, can find its intellectual origin in Gesell's view that development was a morphological process. Furthermore, his assumption of a nonlinear developmental progression and a time-space interaction of contributing subsystems or traits renders his model in surprisingly contemporary terms and, according to Thelen, provides a means to account for pattern generation without invoking infinite regress as is the case in more "prescriptive" theory of motor development (Thelen, 1987). For a recent re-evaluation of Gesell's ideas and work, the reader is referred to Thelen's recent paper (1987).

1.3. Review and Comments on Some Methodological Issues

Two issues which are both theoretical and methodological will be reviewed and discussed below.

1) The temporal aspects of cry vocalization

It is to be pointed out that in many previous studies, cry interval was simply neglected. This was not surprising in view of the fact that the main focus of many of these studies was on cry sounds, and the interest of these studies was in identifying various acoustic features of the cry vocalization. In other words, crying was investigated mainly as an acoustic phenomenon, or a response in itself, rather than as a part of a motor act in its proper context with cry vocalization and the pause in between forming a complete cycle.

In studies that dealt with cry interval, although statistics were reported, its significance was not elaborated. For example, three of the classic studies in infant cry investigated respiratory activity during crying for infants from 1 day to 13 weeks (Deming & Washburn, 1935, Halverson, 1941, Wasz-Hockert, et al., 1968). However, two of them did not address the issue of developmental changes over the range of age in question, and presented data only in terms of grouped information covering the entire age range. In a more recent study, Wasz-Hockert et al. (1968) reported no significant developmental changes in the acoustical attributes of the cries they studied, after the early days. While the length of cry signals was reported, they did not include cry intervals. One of the few studies that saw the significance of cry interval dealt with respiratory activity during crying (Wilder & Baken, 1978). Unlike in the present study, these researchers investigated the temporal aspects of crying by examining respiratory activity during crying in 10 infants aged two days to eight months. The results showed that over the first eight months there was a steady increase in the mean duration of respiratory cycles which was reflected in a more than 50 percent decrease in the mean respiratory rate (BPM) during crying (p.227). The authors pointed out that the decrease in BPM was accounted for entirely by increased duration of the expiratory phase, which more than doubled. In addition, according to their report, the duration of inspiration was found to remain stable during the eight months.

Because there are several procedural differences between this study and the present one, no comparison will be attempted here. However, the differences will be briefly sketched below. Firstly, although spontaneous crying rather than pain-elicited one was investigated, the authors stated that the cryings were hunger cries, which was different from the cries investigated in the present study. Secondly, the 25 respiratory cycles each time from each of the 10 subjects for 4 data-collection sessions (resulting 1000 data) were taken from a midpoint of the crying activity. Thirdly, respiratory cycle is conceptually different from cry interval, which is only a part of the cycle, and, is considered to include the last fraction of expiration, inspiration, and the first fraction of expiration before the cry sound is uttered.

2)Parallel processes

In the majority of previous studies, crying has mainly being treated as an index of something (e.g., of the integrity of the nervous systems, of infant tempermental characteristics , or of maternal sensitivity), or as a signal of distress to be communicated to the caregiver. Indeed, crying of the young infant does possess these aspects, and these are important aspects of infant cry. However, as it was already pointed out, the crying of infants has never been approached from the point of view of action system. In this paper it was demonstrated that exactly because crying serves important functions in the development of the infant during the first months, it would be important to understand the process through which it develops. As has been mentioned before, one of the most important views in this connection is to emphasize the multiplicity of crying behaviours. In this paper, one important and more prominent component of crying, the cry vocalization, will be examined from a developmental point of view. Here, another important aspect, the cry act, and its development will be discussed.

It is to be pointed out that what is called 'cry act' here consists of a multiple of behaviours, and has been described by previous researchers. For example, in his observation of his own children, Darwin wrote :

> "...on his eighth day he frowned and wrinkled the skin round his eyes before a crying fit, but this may have been due to pain or distress, and not to anger..." (Darwin, 1877,1980)

This was based on his diary written some 37 years before, and the publication of this paper in the magazine Mind in 1877 was stimulated by the appearance of the translation of Taine's article on language development in a previous issue of the same magazine. Five years before this, in his "The Expression of the Emotions in Man and Animals", Darwin devoted a whole chapter to a detailed description of weeping or crying of children. In this chapter Darwin placed great emphasis on the movements of the facial muscles (the corrugator supercilii of the brow, the orbicularis palpebralum of the eyes, and the pyramidalis nasi of the nose). He also mentioned respirations, sobbing and the shedding of tears in older children. While these descriptions and explanations constituted a part of Darwin's means for advancing his theory that behaviour patterns are, like other morphological structures, the characteristics of species, the focus was not on the ontogenetic development of behaviours. Although he described the emotional development of his own children and made many comments on the development of emotion (M notebook and N notebook), the thesis that Darwin was trying to establish was that much emotional expression was unlearned and instinctual, and that an evolutionary link could be found uniting human and animal emotions (Darwin, 1872,1982).

In an attempt to "determine whether or not any specific motor behaviors, other than the traditional face-mouth behaviors described by Darwin, characterize the crying of the human infant during the first year of life," Ames conducted a study of the motor correlates of spontaneous infant crying, paying special attention to the patterns of the movement of limbs (Ames, 1941). It was concluded that apart from facial patterns, crying in the human infant was characterized by marked limb activity, greater leg than arm activity, unilateral rather than bilateral and flexor rather than extensor movements, and the breaking up of postures prevailing at the time of its onset. Here again, the developmental view point was lacking.

A more modern attempt to document cry act of the infant can be found in Stark & Nathanson's paper, entitled "Spontaneous cry in the newborn infant; sounds and facial gestures" (Stark & Nathanson, 1974). In this study, while more attention seemed to have been paid to cry sounds, especially the temporal aspect of cry sounds, some efforts were made to look at the facial gestures and head and body postures. The authors approached the subject of infant crying from the point of view of the development of speech, and in this study they attempted to see the relationship between head and body postures and "certain auditory and spectrographic features of cry" (p.340). In the judgement of the present author, in spite of their efforts, they did not seem to have asked the critical question; namely, the relationship between facial expression (and indeed, other concurrent motoric acts too), and cry sound. They did not adopt a developmental approach either.

To the knowledge of the present author, the only study that both approached infant cry developmentally and included other concurrent behaviours was the one by Hopkins and von Wulfften Palthe (1987). In this study, infant cry was conceived as one of the states, "state 5, the crying state", and the development of the crying state was investigated from 3 to 18 weeks. In the authors' own words, three main questions were addressed: in healthy infants between 3 and 18 weeks at what ages do developmental changes in state 5 occur for the first time? If they occur, are these changes only found in a particular situation(e.g., during interaction with the mother)? Do such changes precede, succeed, or coincide with transformations in other aspects of motor development such as the appearance of voluntary-like fine-distal movements(e.g., mutual manipulation of fingers)? The study found the presence of a major change in state 5 around 3 months which they termed "interrupted fussing".

In distinguishing crying from fussing, the authors used behavioural criteria; namely the flexed and abducted arms with a rigid posture of the trunk in partial extension with eyes closed for crying. Interrupted fussing was defined as a situation in which three alternations between fuss and cooing sounds within 1 minute after the onset of a state 5 with a fuss (or cry) vocalization (Hopkins & von Wulfften Palthe, 1987).

Unlike these previous studies, the present study considered crying as an action, that is, a series of behaviours directed towards a goal. Under this view, both the cry sounds and the cry acts are to be included and treated as comprising a system of behaviours. Furthermore, the process of how different components become integrated into a behaviour system serving the need of the infant will be demonstrated from a developmental point of view. One thing to be emphasized here is the appearance around 4 weeks of the ability to maintain open eyes and to visually explore the auditory or visual stimuli in the environment while producing cry vocalization. This new component has great importance in the infant's development of crying as action. On the one hand, it has the effect of changing the state of the infant. Thus, during the initial phase of fussing or crying, visual exploration of, or paying attention to, external stimuli tends to compete with other ongoing behaviour such as vocalization. In other words, visual exploration and/or attention has the effect of suppressing fussing or crying. Further, when the infant can pay attention to the events in the environment, the infant's goal can constantly be compared with the ongoing situation so that a closer appraisal of the attainment of his/her goal can be effected, and in turn the result of the appraisal will be fed back for making further decisions concerning vocalization. In sum, visual exploration and/or attention while crying or fussing contributes to the self-regulatory function of the infant by providing a better check on the consumption of energy and by providing a cognitive skill that is indispensable for a more effective goal-attaining action system.

Chapter II. METHOD

2.1. Subjects

The main subjects of this investigation consist of 10 healthy Japanese newborn infants, 5 males and 5 females. Except for one boy who was delivered by Caesarean section (the mother's age was 39), the others were all normally delivered. They were born in a private hospital in the city of Sapporo. Except for two infants who had to stay more than one week with their mothers in the hospital, the other infants and their mothers were discharged from the hospital one week after delivery. All the subjects were children from intact nuclear families.

As shown in Table 2.1, the subjects varied in gestational age from 38 weeks 0 days to 41 weeks 5 days (mean=40 weeks and 4 days), and in birth weight from 2720 g to 3500 g (mean=3190 g). Six subjects (four boys and two girls) are the first born, three subjects are the second and one is the third child of the family. Mother's age at the birth of the subjects ranges from 23 to 39 years (mean=30.4 years).

Permission for observation was obtained from the individual mothers through the obstetrician and the chief

Table 2.1 List of Subjects and Their Clinical Status at Birth

#	name	sex	weight (g)	height (cm)	circum-ference(cm)	gestation age(wk+day)	parity order	apgar 1m.	apgar 5m.	mother's age	duration of labour 1 stage	duration of labour 2nd stage
1.	I. C.	F	3070	49	33.5	41+0	I	9	9	28	6 h 14 m	24 m
2.	O. T.	M	3470	50.8	34	41+0	II	9	9	34	6 h 27 m	17 m
3.	K. T.	M	2720	48.8	33	38+5	I	9	10	33	3 h 38 m	5 m
4.	W. T.	F	3200	48	33.2	41+3	III	9	9	35	2 h 22 m	7 m
5.	I. S.	F	3230	49	33	41+2	I	9	9	27	6 h 15 m	32 m
6.	K. S.	M	3310	50	34	41+5	I	9	10	24	4 h 4 m	20 m
7.	H. H.	M	3020	46.5	34	38+0	I	9	10	39	[Caesarean section]	
8.	T. E.	F	3500	50.2	34	41+4	I	9	9	23	10 h 5 m	31 m
9.	S. A.	F	2880	48.8	33	39+1	II	9	10	27	1 h 51 m	3 m
10.	T. Y.	M	2960	48.8	32.5	38+0	I	9	9	25	5 h 45 m	22 m

g.a.= gestational age
apgar = Apgar score
circumference = head circumference (cm)
C. section = Caesarean section

nurse. On behalf of the researcher, the chief nurse approached each mother before delivery and obtained permission for observations to be carried out immediately after the subject was born and during the one week lying-in period. Although agreement for continuing observation at home was obtained while the mother and her child were still at the hospital, the schedule for home visit observation was arranged by a telephone call before each home visit.

For the observation immediately after birth, the chief nurse informed the researcher of the presence of expected delivery on that day, about two to three hours in advance whenever possible. The result showed that the time of birth ranges from 9:00 in the morning to 4:55 in the afternoon. For logistic and personnel reasons, no cases earlier or later than the ones mentioned above were included. Home observation took place either in the morning or in the afternoon; no observation took place after 5 PM or before AM 9:30. However, observations both in the hospital and at home occurred in all days of the week.

2.2. Procedure for Data Collection

For each subject, five sessions of data collection were carried out until the third month after birth: 1) First day (mean = 30.4 minutes), 2) 2nd-3rd day (mean=59.6 hours), 3) 4 weeks (mean = 31.9 days), 4) 8 weeks (mean=58.8 days), and 5) 12 weeks (mean=89.1 days). For brevity, the first day (or 0 day), 2nd day, 3rd days observations will be referred to hereafter as "0 day", "3 days" or sometimes as "first week". These data points were selected to cover the different periods in early infancy when the development of crying, in terms of manner of vocalization as well as other concurrent behaviours, was considered to show some drastic changes. With the exception of 2 infants whose mothers needed to stay more than 2 weeks after delivery, observations after the first week were carried out during home visits to the infant's home. Due to mechanical failure, one observation sheduled on the third day after birth had to be excluded.

Permission to make home visit was obtained through neogotiation with the parents (mostly the mothers of the subjects) by telephone calls. The mothers were informed about the purpose of the home visit and of the observations. The schedule for home visits was decided at the advice of the mothers.

Each mother was told that the researcher would like to observe the infant's spontaneous crying, beginning when the infant was under the following conditions: 1) Awake and not fussing, 2) Properly fed but not immediately after feeding, 3) With a clean and dry diaper. As these conditions were difficult to satisfy perfectly, additional visits within a few days were made to make up missing data whenever necessary. This resulted in the presence of a few observations which were not exactly as scheduled. In one case, Subject I. S., no crying was observed at 8 weeks observation. However, except for 12 weeks, which included 4 observations when the subjects were 13 to 15 weeks old, the range of variability of the subject's age was within one week (see Table 2.2).

The total number of cry and/or fuss vocalizations analyzed was 2516 units, and the number of cry intervals (or pause) between two consecutive cry vocalizations was 2209 units.

2.3. Context of Crying

Spontaneous crying is defined across all the observation periods as "crying that was not triggered by any known causes", such as the ones mentioned above (e.g., sleepiness, hunger, a wet or dirty diaper)(Stark & Nathanson, 1974).

In the majority of the cases, the infants were lying supine, on a matress, carpet, or in a cot. Observation

TABLE 2.2 Ages of Subjects at the Time of Observation

	0 DAY	2-3 DAYS	4 WKS.	8WKS.	12WKS.
I.C.	24min	32hrs.	5w.6d.(41days)	7w.4d.(54days)	14w.0d.(98days)
O.T.	18min	48hrs.	4w.4d.(32days)	9w.4d.(67days)	13w.0d.(91days)
K.T.	78min	72hrs.	4w.5d.(33days)	7w.6d.(55days)	13w.1d.(78days)
W.T.	29min	71hrs.	3w.6d.(27days)	8w.5d.(61days)	13w.5d.(96days)
I.S.	13min	46hrs.	3w.5d.(26days)	8w.2d.(58days)	13w.6d.(97days)
K.S.	24min	73hrs.	4w.3d.(31days)	8w.3d.(59days)	13w.0d.(91days)
H.H.	20min	- -	4w.6d.(34days)	8w.6d.(62days)	12w.2d.(86days)
T.E.	55min	69hrs.	4w.6d.(34days)	8w.2d.(58days)	11w.6d.(83days)
S.A.	25min	72hrs.	4w.5d.(33days)	8w.3d.(59days)	12w.4d.(88days)
T.S.	18min	53hrs.	4w.0d.(28days)	7w.6d.(55days)	11w.6d.(83days)
MEAN	30.4 m.	59.6 h.	31.9 d.	58.8 d.	89.1 d.

w = week
d = day
hr = hour
min = minutes

usually started when the infant was awake and not fussing. Often, the infants were put down for observation after the researcher had prepared the camera and recording device. When no fussing or crying was observed for over an extended period of time (i. e., ten minutes), the mother would be asked to engage in a brief face-to-face play with the infant, and then to put down and leave the infant for further observation. For older infants, this manoeuvre sometimes elicited fussing and crying.

Whenever the subject's lower limbs were visible, the whole body was filmed; when lower limbs were covered by clothes, focus was placed on the upper part of the body. In data analysis, notice was made whenever any part of the subject's behaviors or part of the body was out of sight, and these were excluded from the final data for further analysis.

In order to ascertain the nature of the crying, mothers were asked to comment on the possible cause of the crying episode just observed. The most frequently made comment was that the infant wanted to be picked up. However, as the infant grew older, it was difficult to rule out the factor of "strangeness as entailed by the researcher's presence" as one possible cause for the crying of older infants, although it was never mentioned by the mothers.

2.4. Apparatus:

Spontaneous crying was recorded using a camcorder (SONY, CCD V-200). To one audio-input jack was connected a microphone (Electro-Voice, Model 613B), which was positioned about 15 cm away from the subject's mouth during the first two data collection sessions when control was easily feasible. During home observation, however, the microphone was kept as close as possible towards the direction of the subject's mouth. The camcorder was supported by a tripod, and was about 1.5 meters away from the subject. When there was no convenient place for fixing the microphone, it was held close to the source of the crying sound in hand by the observer. The original observations were all recorded on 8 mm video cassette tapes (SONY P6-90MP). Using a video-audio recorder (SONY, SL-HF 3000), the video and the audio signals from the original tapes were duplicated onto Beta cassette tapes, with a time code (min, sec, 1/100 sec) generated by a video-timer (FOR-A, VTG-22k), superimposed. The duplicated Beta cassette tapes were used for analysis. For details concerning the set-up of the different input-output devices, the reader is referred to the block diagram in Appendix A.

2.5. Data Analysis

For the present dissertation, data analysis was conducted on two aspects of infant crying, namely, cry sounds (including cry intervals) and behaviours concurrent with cry vocalization.

Analysis of cry sounds and cry intervals

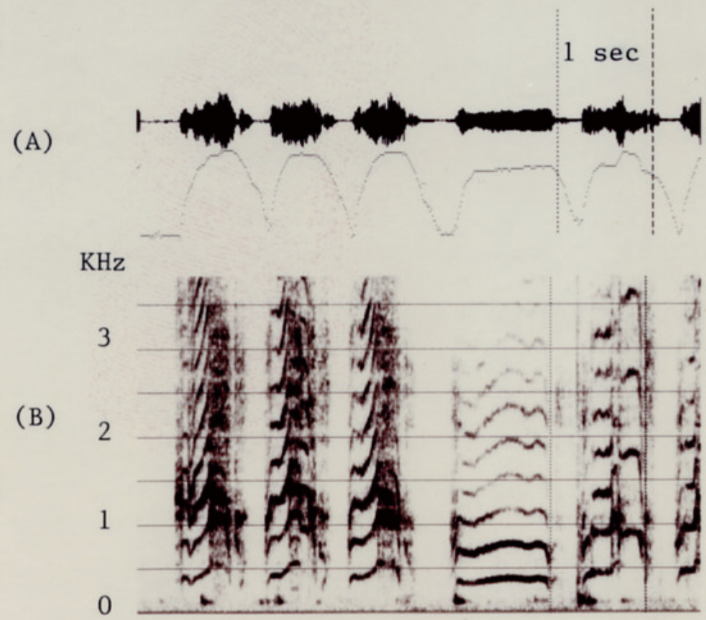
1)Structure of a cry vocalization

Conceptually a cry vocalization is typically composed of the egressive and the ingressive phases, corresponding to the expiratory and the inspiratory phases of the respiratory cycle. In this dissertation a complete set of these two phases of crying is referred to as a unit of cry cycle. For the present analysis, as in most previous studies that dealt with this level of analysis, a cry vocalization is considered as beginning with the egressive phase and ending with the ingressive phase. When crying is intense, the egressive phase can be further divided into the vocal section and the voiceless section, as often observed in the crying immediately after birth. In more intense crying, the egressive voiceless part is either continuous or discontinuous.

The ingressive phase of crying is either a relatively short (usually under 300 msec) audible sound of inspiration when crying is more intense, or is inaudible. In the latter case, the duration of this voiceless ingressive phase is considered the same as the duration of cry interval.

2)Temporal parameters

For data extraction, the duplicated Beta cassette tapes were replayed and cry sound signals from the audio track of the tape were fed into a Sona-Graph (Kay Elemetric Corp. Model 5500) through an audio amplifier via the aux input jack. The Sona-Graph was set to display both the sonograms on the lower half of the monitor, and wave form and amplitude tracings on the upper half of the monitor(Figure 2.1). The built-in memory of the machine has the capacity for acquiring up to 38 min of signals at 4 kHz. By manipulating the appropriate keys, the entire cry signals acquired can be reviewed, audially, visually, and duration measured. The movement of the cursors allows the duration of any part of the signals to be measured up to millisecond precision. However, for the present analysis, the precision of the time resolution was set at the 75 millisecond order. In other



The upper half (A) shows the sound wave of the cry sounds together with tracing of amplitude change. The lower half (B) shows the sonograms of cry sounds. Horizontally movable, the doted lines are used to measure duration of vocalization or interval between vocalizations. (Narrow bandwidth, 59 Hz)

Figure 2.1 A Print-out of the Output of SONA-GRAM Model 5500 words, the duration measurement employed in this study allowed an error of 75 milliseconds.

3)Typology of cry sounds

In order to examine the order of cry vocalization in terms of the manner of phonation, two dimensions, the temporal dimension and the structural dimension, were employed. The former refers to the duration of cry vocalization and was obtained by the use of the device described above. The structural dimension refers to the manner of phonation as inferred from the three-dimensioned visual representation of the sonogram.

In the temporal dimension, four classes were created. The criterion for each class was as follows:

Class a: over 1600 msec

Class b: 800 to 1599 msec

Class c: 250 to 799 msec

Class d: below 249 msec

For the structural dimension, eight categories were created. They included the three types which were first proposed by Truby and Lind (1965) and adopted in subsequent research (e.g., Golub, 1980). Since the classification proposed by Truby and Lind was for the cry sounds of the neonates, five other categories which were either neglected by them or not present in the neonatal periods were added. A brief description of them is provided in Table 2.3, and their sonograms shown in Figure 2.2. Note that category L (low intensity) was not shown in the figure, for the sonogram of this category of vocalization did not present a clear pattern. The classification was mainly based on auditory judgement.

Table 2.4 shows the classification scheme combining the two dimensions, containing 32 classificatory cells.

Each cry vocalization was classified into one of the 32 categories first by viewing the visual materials (i.e., the sonograms, the sound wave tracings, and the result of duration measurement described above), and then by double-checking the classification through auditory and visual examination by use of DSP Sona-Graph as described above.

As a result, a cry series, defined as a sequence of cry sounds within the boundaries of two silent intervals lasting more than 3000 millisec, was represented by a series of bracketed letters and numbers. Thus, (Pa1)(Dc5)(Ld2)(Pb4) denotes that the sequence consists of one cry vocalization of the Pa category, followed by five cry vocalizations of the Dc category, followed by two cry vocalizations of the Ld

Table 2.3 Descriptions of Different Types of Cry Vocalization

P (phonation):	Visually the vocalization is characterized by clearly sepoarated frequency bands. Auditorily, the vocalization is free from raucous or kreaky noise. Presumably it is the product of optimal coordination in the vocalizing system.
H (hyperphonation):	Visually it appears as sudden, drastic frequency shift. It leaves an auditory impression of extremely high-pitched vocal performance.
D (dysphonation):	Characterized by vagueness or absence of visual pattern. Such vocalization is felt by the listener to have a definite "raucousness" or "roughness" or harshness".
F (glottal plosive):	Visually slightly difficult to recognize. It sounds like coughing.
S (glottal stop):	Appears as narrow vertical line separated by a segment of silence from the preceding section of the vocalization.
K (complex):	Consists of phonation, dysphonation and hyperphonation, within one expiratory vocalization.
B (babblling-like):	Vocalization that contains babblling-like element(s). Usually longer than many other types of cry vocalizations.

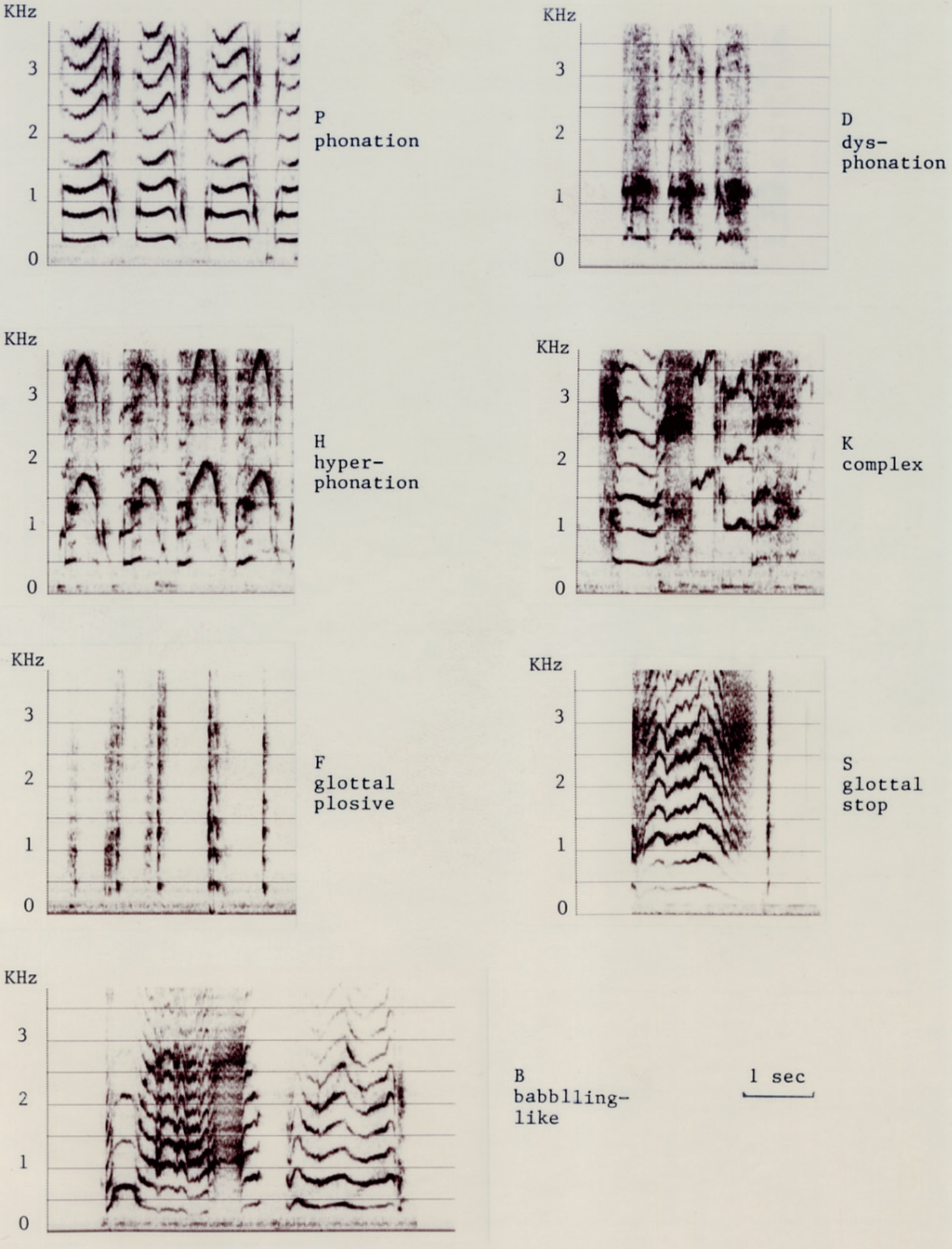


Figure 2.2 Sonograms of Different Types of Cry Vocalization

Table 2.4 Scheme for the Classification of Cry Vocalizations

	a 1600 msec up	b 1599-800msec	c 799-250 msec	d under 249 msec
P (phonation)				
D (dys-phona- tion)				
H (hyper-phon- ation)				
G (glottal plosive)				
S (glottal stop)				
L (low inten- sity)				
K (complex: P + H + D)				
B (babble)				

category, and ended by four cry vocalizations of the Pb category. The sequential order of different types of cry vocalizations will be referred to as temporal patterns of cry vocalization in the result section.

Analysis of concurrent cry behaviors

VTR records were played back and scanned for fussing and crying episodes. Upon finding such an episode, while the duration of each vocalization and the intervals between two vocalizations were measured using the Sona-Graph (as has been described above), the infant's behavior sequence was coded using categories as follows:

a. Vocalization (V): any sound produced by the infant, except "vegetative sounds" such as hiccups, coughs, etc. Hedonic quality of the vocalization (e.g., positive, neutral, negative) was also rated. Audible respiration was also noted.
b. Movement (M): large movement of the upper and/or the lower limbs. Movements such as hand-to-mouth or hand-to-face were not distinguished, but included as one category. Movement of finger(s) only was not counted as movement.

c. Eyes (E): eye(s) opening with a duration over one second.

d. Visual exploration (X):orientation or attention to auditory or visual stimuli in the environment.

e. Grimace (G):grimace, knitting of the brows, downward curving of the mouth.

These categories were chosen as a result of considerations based on theoretical ground as well as obtained from previous observations of infants of similar age. In particular, theoretical guidance was obtained from several sources such as Reed(1982), Gibson(1974 in 1982), and Thelen, Kelso, & Fogel(1987). The emphasis on the role of perception in human or animal action in these sources led to the selection of visual exploration as one important measure, while the selection of the item for "eyes open" was based on two considerations, namely, that state change would play some role in the expression of cry, and that eyes open is a prerequisite of visual exploration. The inclusion of other categories was based on the author's previous experience with young infants and the results of previous studies.

1)Data Analysis

Analysis was based on video records of spontaneous infant crying collected from 10 subjects from immediately after birth to three months. The general profiles of both the subjects as well as data collection were described in another section of this paper.

For the present analysis, episodes of infant spontaneous crying were selected from the main body of records. In general, whenever possible, an episode started 1 to 5 seconds before any cry vocalization and ended 1 to 5 seconds after the cessation of any cry vocalization. Typically an episode consisted of 240 seconds (4 min.) observation of infant behaviours with crying or fussing occupying some part of the total duration. Episodes shorter or longer than 4 minutes (e.g., when infant crying was interrupted, or ended before the end of 4 minutes, or when a cry bout exceded 4 minutes) were also included. A total of 73 episodes were analysed.

The five behavioural categories as described in Chapter 2 were employed. The video records were scanned for the detection of the presence or absence of each category. Absence of a certain category over one second was noted; discontinuity under one second was disregarded. This analysis procedure resulted in an actogram-like data sheet as shown in Figure 2.3. In a few occasions when any portion of the video records was not clear, due to accidental occlusion or

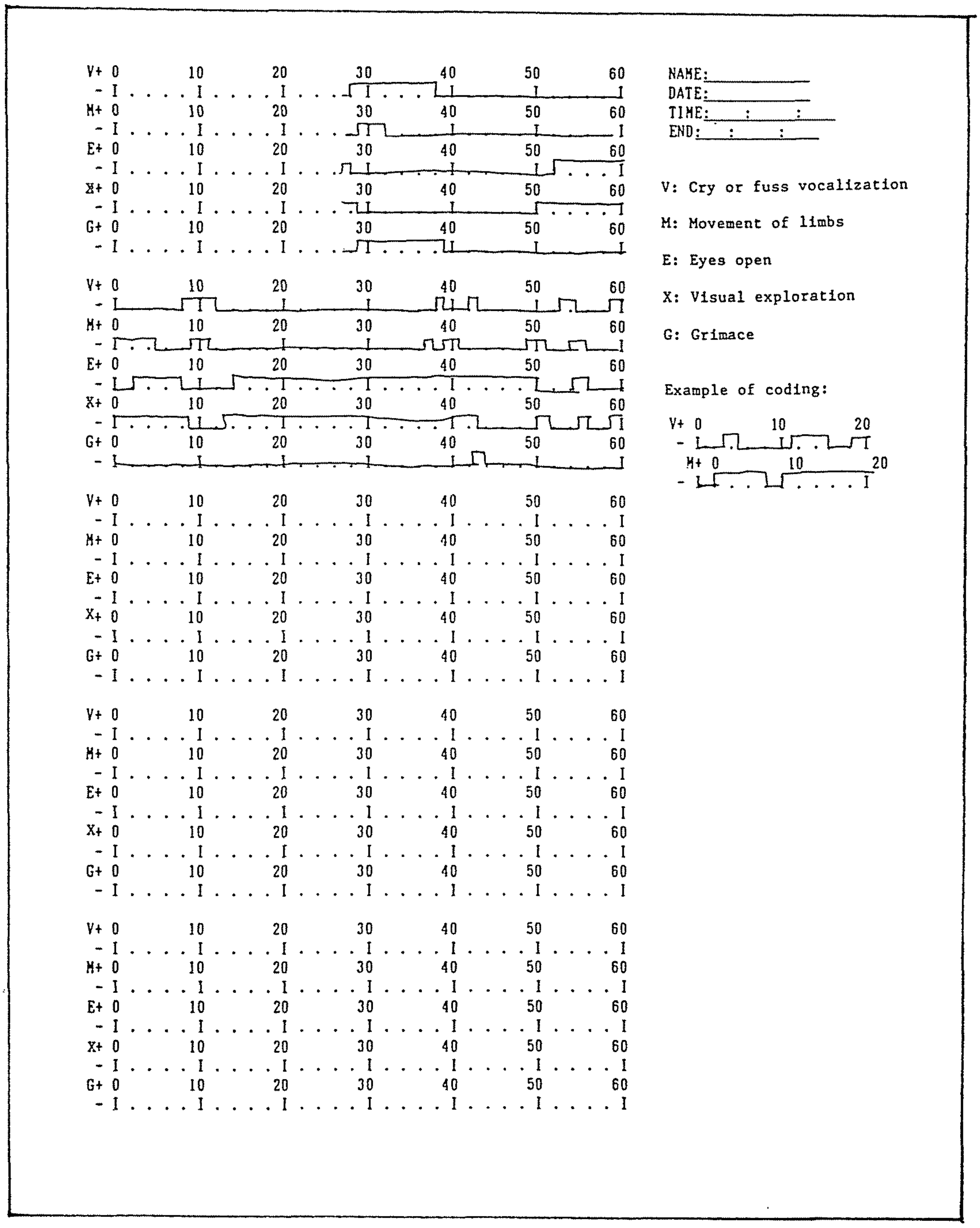


Figure 2.3 A Sample Coding Sheet for Analysis of Concurrent Behaviours.

blurring in the video picture, or to non-optimal angle of filming, etc., that portion of the observation was excluded from the final data.

The second step in data analysis consisted of the calculation of the total number of seconds of each category of behaviour in each episode. As the total number of seconds of observation varied, the total duration for each category was then divided by the total number of seconds of observation to yield a proportional value for each category in one episode.

CHAPTER III. RESULTS AND DISCUSSIONS

It seems clear, from our knowledge in the development of neuromotor functioning, that the act of crying demands a great degree of coordination between the respiratory and phonatory mechanisms. The coordination, as will be demonstrated in this paper, is achieved mainly through neuromotor maturation in the first few months. While coordination between respiratory and phonatory systems can be conceptualized as occurring in the organism (i.e. within the boundary of the infant's body), and therefore can be referred to as "intra-organismic" process, the development of the infant's crying expression system also includes another type of coordination, the coordination between the infant and the environment. The latter process, the details of which will be demonstrated later, will be referred to as "inter-organismic" process.

In this chapter, empirical data concerning the developmental changes of infant crying, as resulted from the present analyses, will be presented. Empirical data will be presented in two parts; the first is concerned with cry vocalization, and the second is concerned with concurrent behaviours. In the first part, the temporal aspect of cry vocalization will be examined at two levels, namely, the macro and the micro levels. The former will be focussed on developmental changes as revealed by the temporal organization of cry vocalizations across the age periods. In contrast, at the micro level, focus will be placed on the order of cry vocalizations in a series, as revealed by the manner of phonation. Developmental patterns across the 5 periods will be examined in detail. It is to be added that as an inseparable part of vocalization, the temporal patterns of cry interval, or pause between cry vocalizations, will also be examined. In the second part, the focus will be placed on the analyses of five categories of behaviours concurrent with the utterance of cry sounds.

Part 1.

3.1 Duration of Cry Vocalization and Cry Interval

The temporal patterns of early infant crying showed marked changes as a function of age. The developmental changes will first be described at two levels; the single cry vocalization level, and the cry sequence (or cry bout) level.

1) Duration of cry vocalization

A total of 2516 units of cry vocalization were anlysed.

700, 503, 453, 435, and 425 units were from 0 day, 2-3 days, 4 weeks, 8 weeks and 12-13 weeks, respectively. As the sample of this study was comprised of 10 infants, for each age period, each subject provided an average of 70, 50, 45, 43, and 42 units of cry vocalization. The mean duration of the 2516 cry vocalization is 0.877 sec. The mean duration of cry vocalization for the 5 age periods is shown in Figure 3.1.1.

The longest mean duration (0.9814 sec) was observed immediately after birth in the first day, while the shortest mean duration (0.716 sec) was observed at 8 weeks. These results are in agreement with the impressions obtained by the present author of the crying of individual infants. The longest mean duration of cry sounds at 0 day was partially a reflection of the occurence of extremely long cry vocalizations characteristically observed immediately after birth. Some examples will illustrate this view. Subjects T. E. and I. C. were observed to produce expiratory cry vocalizations which lasted 13.22 sec, and 8.125 sec in the observation immediately after birth. During the next three months, the mean duration of cry vocalizations did not rise until at 12 weeks when it reached 0.915 sec, a level next to that of the 0 day. However, as far as vocalization was concerned, what distinguished the cry vocalizations of the

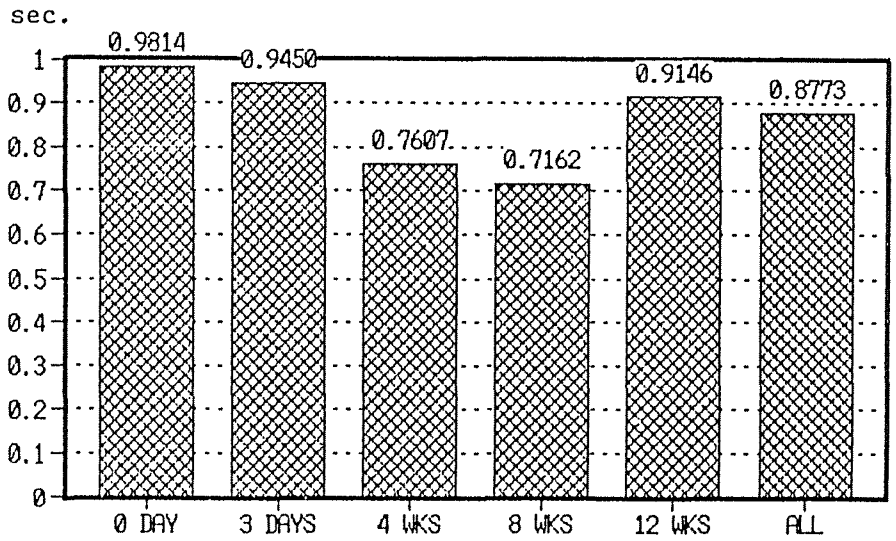


Figure 3.1.1 Developmental Change of Mean Duration of Cry Vocalization

two periods was the manner of phonation. In particular, a comparison of the manner of phonation of the extremely long cry vocalizations of the 0 day and the 12 weeks showed that the fomer were characterized by the occurence of silence, or voiceless segments, within one expiratory vocalization. The cry vocalizations of the 12 weeks and after could be long (e.g., Subject E.C.'s 4.7 sec at 10 weeks, Subject K. S.'s 3.05 sec, and 2.39 sec at 13 weeks were among the few long vocalizations), but they never showed long voiceless segments as were common in the cry vocalizations in the first day.

The mean duration of cry vocalizations at 4 and 8 weeks fell to 0.761 and 0.716 sec, respectively. ANOVA revealed that the factor of age had a significant effect on the difference in mean durations ($F=10.119$ $df= 4,2511$, $P<.001$). Further analysis indicated that the difference between the shorter durations of 4 weeks and 8 weeks (0.761, 0.716, sec respectively) and that of the longer durations of other age periods were significant. For the results of statistic tests, see Appendix B-1(a).

2)Duration of cry interval

While the length of cry vocalization does not tell us much about how cry vocalization was executed, the length of cry intervals contains information concerning the intensity of cry vocalizations. This is because a shorter cry interval implies a quicker succession of cry vocalizations. In other words, a shorter mean duration of cry intervals is the result of a higher local rate of cry vocalization, thus implying a more intense cry sequence. Here, "local rate" is defined as "the number of component acts per unit time spent performing the activity" (Roper, 1984). In contrast to the interval between cry vocalizations, the length of cry vocalization itself does not contain information about the intensity of the cry vocalizations. The increase of mean durations of cry intervals after 4 weeks, therefore, suggests that cry vocalization becomes less intense after 4 weeks. This tendency becomes even clearer at 8 and 12 weeks when the mean durations of cry interval reach 605 and 618 msec, respectively. While statistics based on data reduction at this level do point to a general tendency as described above, the result obtained inevitably contains some noise, and therefore does not give a more realistic picture of the phenomena as occurred in real-time.

A total of 2209 cry intervals were analysed. 685, 432, 478, 374, and 240 units were from the 5 age periods respectively. The mean duration of the 2209 cry intervals was 0.471 sec. The mean durations of the 5 age periods are given in Figure 3.1.2. Just as the mean durations of cry vocalizations changed markedly during the first three months, so did the mean durations of cry intervals. Figure 3.1.2. shows the developmental changes of the mean durations of cry intervals during the first 12 weeks. The shortest mean duration was observed at 3 days, and the longest, at 12 weeks. ANOVA indicated that the age factor had a significant effect on the mean duration of cry intervals. Further analyses showed that except for the difference between 8 weeks and 12 weeks, differences between all other periods were significant. For results of statistic tests, see Appendix B-1(b).

In contrast to the static aspect of infant crying just described, a more dynamic aspect of infant crying emerged from analyses of data involving the developmental changes of the durations of both cry vocalization and cry interval. As preliminary analyses of the distribution of cry vocalization and cry interval indicated that in both cases durations under 1 sec accounted for over 60 % of all samples observed, the cumulative per centages of cry vocalizations and cry intervals under 1 sec were calculated for each age period.

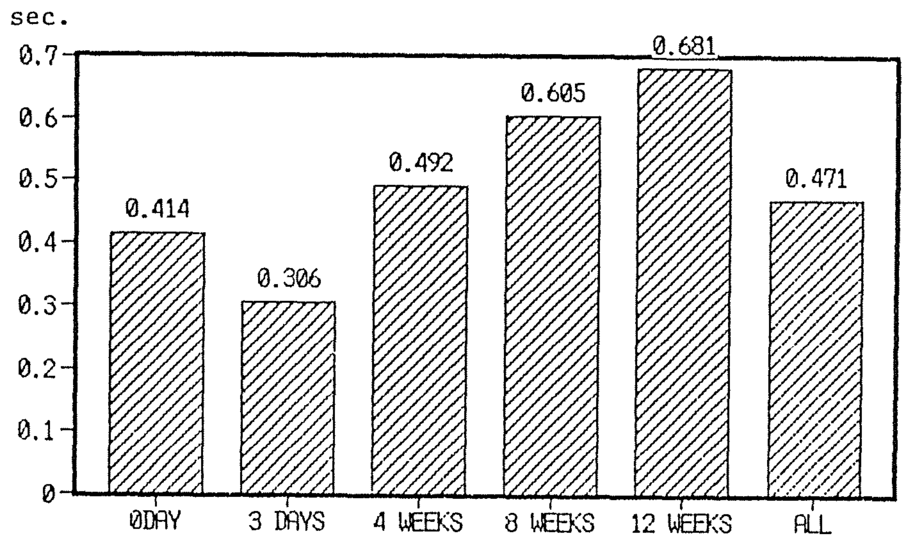


Figure 3.1.2 Developmental Change of Mean Duration of Cry Interval

For cry vocalization, while about 15% (15.29% and 15.31%) of all cry sounds observed were under 0.4 sec during the first week (0 day and 3 days), more than 30% (39.07%, 49.43%, 32.47%, respectively) of cry sounds observed at 4 weeks, 8 weeks and after 12 weeks were under 0.4 sec. The results are shown in Figure 3.1.3.

Further examination using the same interval (0.1 sec) in setting the upper limits indicated that the distribution of cry vocalizations at different age periods showed very different patterns. For example, the three most frequent durations of cry vocalization observed at the 5 age periods were 0.5, 0.6, 0.7 sec for 0 day, 0.8, 1, 1.1 sec for 3 days, 0.2, 0.4, 0.6 sec for 4 weeks, 0.2, 0.3, 0.4 sec for 8 weeks and 12 weeks respectively (see Table 3.1).

As for cry interval, further analyses also revealed developmental changes. During the first week(0 day and 3 days), more than 60% (65.94%, 70.37%) of all cry intervals were under 0.3 sec. In contrast, at 8 weeks and 12 weeks, cry intervals under 0.3 sec accounted for only 33.96% and 29.71% (for details see Table 3.2(a) and Table 3.2(b)). The three most frequent durations of cry intervals(pause) observed at the 5 age periods were 0.2, 0.25, 0.15 sec for 0 day, 0.25, 0.2, 0.15 sec for 3 days, 0.3, 0.25, 0.35 sec for 4 weeks,

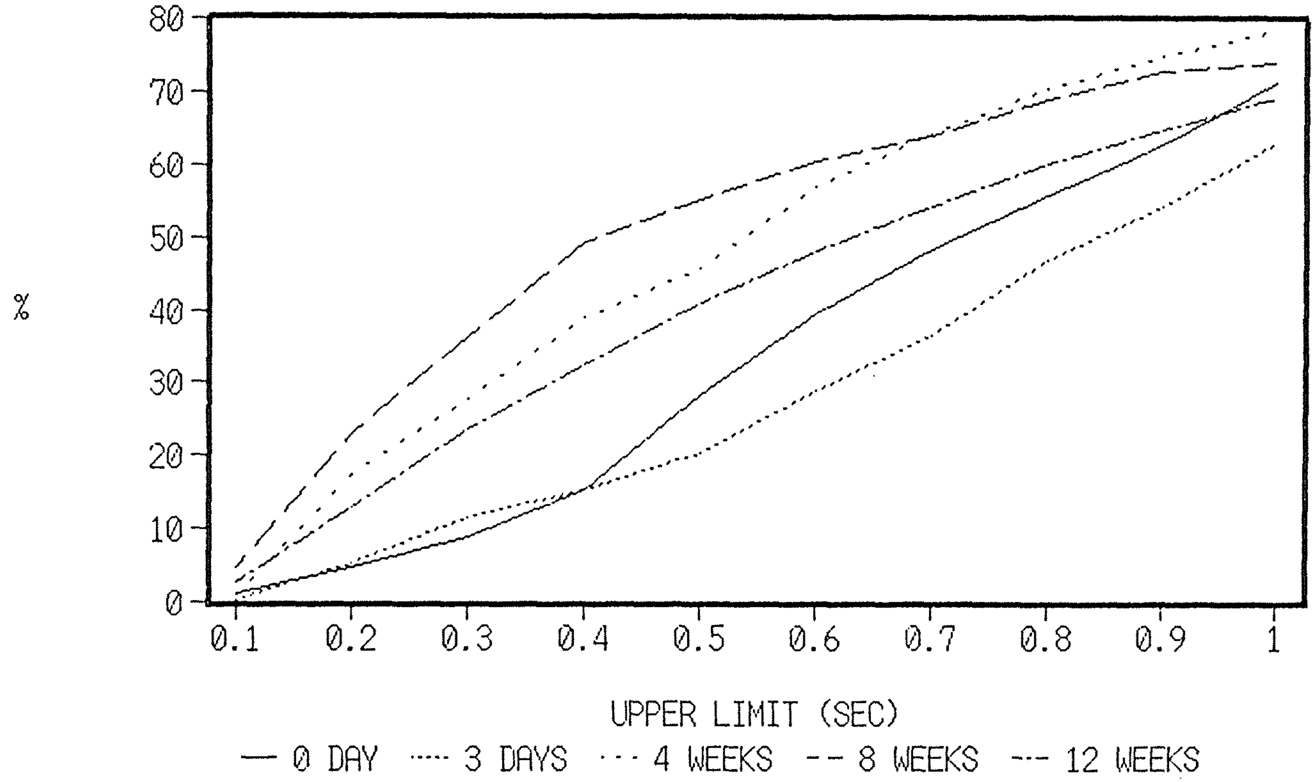


Figure 3.1.3 Developmental Change of Length of Cry Vocalization As Indicated by the Cumulative Percentages of Different Durations.

Table 3.1 Distribution of Cry Vocalizations Durations

upper limit (sec)	0 day f	0 day %	3 days f	3 days %	4 weeks f	4 weeks %	8 weeks f	8 weeks %	12 weeks f	12 weeks %
0.1	8	1.14	1	0.20	4	0.88	20	4.60	11	2.59
0.2	25	3.57	25	4.97	75	16.56	80	18.39	44	10.35
0.3	28	4.00	32	6.36	47	10.38	58	13.33	45	10.59
0.4	46	6.57	19	3.78	51	11.26	57	13.10	38	8.94
0.5	92	13.14	25	4.97	30	6.62	25	5.75	37	8.71
0.6	77	11.00	43	8.55	51	11.26	23	5.29	29	6.82
0.7	63	9.00	39	7.75	33	7.28	16	3.68	27	6.35
0.8	51	7.29	52	10.34	28	6.18	22	5.06	25	5.88
0.9	51	7.29	37	7.36	20	4.42	16	3.68	20	4.71
1.0	60	8.57	45	8.95	17	3.75	5	1.15	19	4.47
1.1	35	5.00	45	8.95	7	1.55	11	2.53	12	2.82
1.2	29	4.14	28	5.57	6	1.32	12	2.76	16	3.76
1.3	19	2.71	25	4.97	5	1.10	11	2.53	8	1.88
1.4	21	3.00	19	3.78	8	1.77	12	2.76	12	2.82
1.5	7	1.00	10	1.99	5	1.10	11	2.53	6	1.41

f = frequency

Table 3.2 (a) Distribution of Cry Interval Durations

upper limit (sec)	0 day		3 days		4 weeks		8 weeks		12 weeks	
	f	%	f	%	f	%	f	%	f	%
0.05	10	1.46	5	1.16	1	0.21	4	1.07	0	0.00
0.10	69	10.09	51	11.81	3	0.63	7	1.87	5	2.09
0.15	82	11.99	53	12.27	20	4.18	8	2.14	14	5.86
0.20	126	18.42	59	13.66	33	6.90	33	8.82	15	6.28
0.25	99	14.47	86	19.91	54	11.30	40	10.70	16	6.69
0.30	65	9.50	50	11.57	83	17.36	35	9.36	21	8.79
0.35	51	7.46	30	6.94	54	11.30	33	8.82	25	10.46
0.40	24	3.51	21	4.86	44	9.21	26	6.95	28	11.72
0.45	15	2.19	17	3.94	28	5.86	17	4.55	10	4.18
0.50	14	2.05	17	3.94	24	5.02	22	5.88	5	2.09
0.55	14	2.05	5	1.16	21	4.39	12	3.21	12	5.02
0.60	12	1.75	5	1.16	21	4.39	12	3.21	5	2.09
0.65	7	1.02	5	1.16	11	2.30	12	3.21	3	1.26
0.70	4	0.58	1	0.23	7	1.46	8	2.14	2	0.84
0.75	6	0.88	5	1.16	7	1.46	10	2.67	5	2.09
0.80	5	0.73	3	0.69	6	1.26	5	1.34	7	2.93
0.85	4	0.58	1	0.23	6	1.26	8	2.14	2	0.84
0.90	3	0.44	3	0.69	5	1.05	7	1.87	5	2.09
0.95	6	0.88	2	0.46	2	0.42	5	1.34	2	0.84
1.00	3	0.44	0	0.00	4	0.84	4	1.07	4	1.67

f = frequency

Table 3.2(b) Cumulative Percentages of Cry Interval Durations

upper limit (sec)	0 day		3 days		4 weeks		8 weeks		12 weeks	
	f	cum.%	f	cum.%	f	cum.%	f	cum.%	f	cum.%
0.05	10	1.46	5	1.16	1	0.21	4	1.07	0	0.00
0.10	69	11.55	51	12.96	3	0.84	7	2.94	5	2.09
0.15	82	23.54	53	25.23	20	5.02	8	5.08	14	7.95
0.20	126	41.96	59	38.89	33	11.92	33	13.90	15	14.23
0.25	99	56.43	86	58.80	54	23.22	40	24.60	16	20.92
0.30	65	65.94	50	70.37	83	40.59	35	33.96	21	29.71
0.35	51	73.39	30	77.31	54	51.88	33	42.78	25	40.17
0.40	24	76.90	21	82.18	44	61.09	26	49.73	28	51.88
0.45	15	79.09	17	86.11	28	66.95	17	54.28	10	56.07
0.50	14	81.14	17	90.05	24	71.97	22	60.16	5	58.16
0.55	14	83.19	5	91.20	21	76.36	12	63.37	12	63.18
0.60	12	84.94	5	92.36	21	80.75	12	66.58	5	65.27
0.65	7	85.96	5	93.52	11	83.05	12	69.79	3	66.53
0.70	4	86.55	1	93.75	7	84.52	8	71.93	2	67.36
0.75	6	87.43	5	94.91	7	85.98	10	74.60	5	69.46
0.80	5	88.16	3	95.60	6	87.24	5	75.94	7	72.38
0.85	4	88.74	1	95.83	6	88.49	8	78.07	2	73.22
0.90	3	89.18	3	96.53	5	89.54	7	79.95	5	75.31
0.95	6	90.06	2	96.99	2	89.96	5	81.28	2	76.15
1.00	3	90.50	0	96.99	4	90.79	4	82.35	4	77.82

f = frequency

cum.% = cumulative percentage

0.25, 0.3, 0.2 (and 0.35) sec for 8 weeks, and 0.4, 0.35, 0.3 sec for 12 weeks. The cumulative percentages of different cry interval durations showed that while cry intervals under 0.25 sec accounted for more than 50% (56.43% and 58.8%) of all the cry intervals observed at 0 day and 3 days, cry intervals of the same duration (under 0.25 sec) only accounted for less than 25% (23.22%, 24.60%, and 20.92%) at 4 weeks, 8 weeks and 12 weeks.(Table 3.2 (b)). The cumulative percentages of different duration of cry intervals in Figure 3.1.4 shows the different patterns in the 5 age periods.

It is of interest to note that in the case of cry vocalization, the lines representing cumulative growth of increasing durations for 0 day and 3 days show gradual rise as compared to those of 4 weeks and 8 weeks which show a much sharper rise. This relationship reverses in the case of cry interval, thus, while 0 day and 3 days show a sharper rise up to 0.35 sec, the lines for 4 weeks, 8 weeks and 12 weeks show a gradual rise. During the first three months, cry interval showed gradual decrease in cumulative growth, whereas cry vocalization showed gradual increase in cumulative growth up to 8 weeks, and then decreased at 12 weeks (Figure 3.1.3. and Figure 3.1.4.).

These data together suggest that during the first week(0

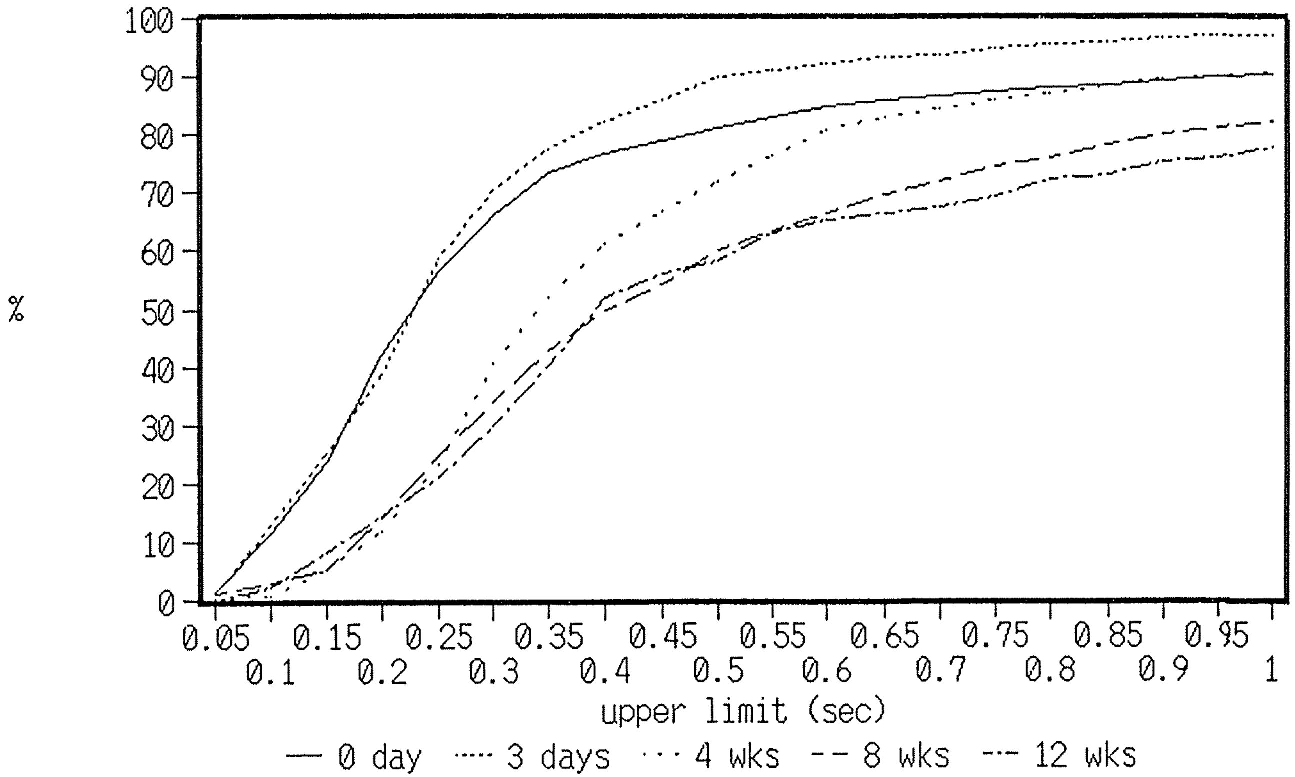


Figure 3.1.4 Developmental Change of Length of Cry Interval As Indicated by the Cumulative Percentages of Different Durations.

day and 3 days), the crying of the infant was of a longer duration for each vocalization and more intense(in terms of the number of cry vocalization uttered in a period of time). In contrast, the crying at 4 weeks and 8 weeks was less intense and each vocalization was of a shorter duration. At 12 weeks, the infant's crying was of a lower intensity and a midium length for each vocalization. As will be demonstrated and documented in more detail later, at 8 weeks and after, infants began to show two modes of crying, the lower intensity mode and higher intensity mode. A fuss or cry sequence usually began with a lower mode, typically with a glottal plosive or glottal stop. As the intensity built up, as resulting partially from repeating an unpleasant motor act of uttering cry sounds with a glottal plosive and/or glottal stop, and partially from failure in perceiving a sign of goal-attainment, the crying then shifted to a higher intensity mode, with longer and louder vocalizations punctuated with glottal plosives. This state of events was different from that of the first week when a cry sequence tended to start abruptly and either to be maintained for a relatively short period of time at a high intensity level(as in the crying of the 0 day), or to be further escalated and thus extended the sequence greatly as in the cryings of 3 days. Adopting a cross-sectional method, Futatuki (1979) studied the crying of 60 infants whose age ranged from 2 days to 85 days. It was reported that the cry pattern of infants up to 2 weeks was rhythmical, while this rhythm began to disappear and all the cryings became irregular after 7 weeks. While in this study the crying of the infant was elicited by pain-stimulus, and therefore, the results were not directly comparable with that of the present study, the picture presented by the author was an oversimplified one. The oversimplification resulted from the fact that observation was limited to a window of only 6.6 sec for each subject. This seems to reflect the fact that crying was considered as a response or reaction, and not as an action or activity, as pointed out in the introduction.

3.2 Duration of Cry Sequence (or Cry Bout)

Crying usually consists of a series of vocalizations lasting from several seconds to several minutes. Although there is no natural boundary between one sequence(or bout) of crying and another, a conceptual unit can be created(and operationally defined) which can reveal some important aspect of the development of crying as an action system for expression.

Using pain stimuli to elicit crying, Truby and Lind(1965) observed that there were 9 stages in a series of action sequences which they termed "rousal". In stead of specifying the boundary, they elaborated on the order of these stages and their acoustic characteristics (pp.37-43).

Stark and Nathanson(1974) instead labeled this unit "cry cycle" and defined it as "crying which is bounded at its beginning and end by a silent period, i.e., one in which there are more than two breaths in which no vocalization is produced."(p. 325) However, they did not discuss this topic further.

In the present study, the cry sequence(or cry bout) was defined by the boundary of silence that lasted longer than 2.99 sec. The results are given in Figure 3.2. ANOVA indicated that the mean length of a cry sequence (in terms of the number of cry vocalizations) differed significantly among the 5 age periods ($F=26.399$, $DF=4,197$, $P<0.001$). The longest mean cry sequence was observed at 3 days, and the shortest, at 12 weeks. The relatively short cry sequence at 8 weeks and 12 weeks might have reflected the nature of the low intensity mode of crying with which infants at these age periods tended to begin a cry sequence, as has already been mentioned. It is ethically undesirable to demand that the cry

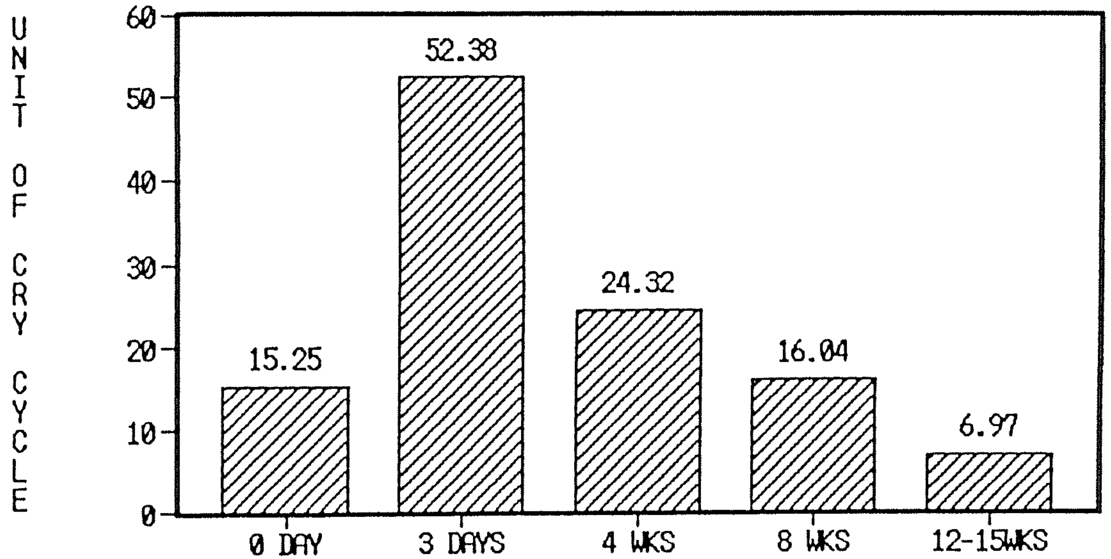


Figure 3.2 Developmental Change of the Length of Cry Sequence As Indicated by the Number of Cry Cycle.

be continued until the subjects shift to the higher mode of crying. One caution has to be made here not to take these values as absolute, for they may vary depending on the criterion employed for defining the length of a cry sequence. In addition, during data collection, the practical consideration of allowing intervention to occur when the crying had continued for an extended period of time might have biased the data. However, as far as the criterion of 2.99 sec of silence was a reasonable one, these data still suggested some important aspect of the development of the crying of infants at these age periods, especially when considered together with other findings reported so far or to be presented in the remainder of this chapter.

3.3 Real-Time Cry Sequence and the Typology of Vocalizations

1)One subject's cry sequences in real-time

The cry sequences observed at the 5 age periods from a female subject, T. E., are presented in Figures 3.3.1-a, 3.3.1-b, 3.3.1-c, 3.3.2-a, 3.3.2-b, 3.3.3-a, 3.3.3-b, 3.3.4-a, 3.3.4-b, 3.3.5-a, and 3.3.5-b. This subject was selected mainly on account of the relative completeness of her recordings. In addition, the extremely long cry vocalizations of this infant observed immediately after birth were something of a record in the experience of the present author, and were thought to illustrate the point mentioned. In these figures, as the time scale employed was the same, the relative length of the sonograms is indicative of the relative length of the cry sequences shown . In addition, the three-dimensioned visual representation of individual cry sounds as shown by the sonograms also indicate different manner of phonation at different age periods. The wave forms and the tracings of amplitude change are indicative of the relative amplitude of cry sounds at different ages.

It is to be noted that while figures for the first week (i.e., Figures 3.3.1-a, 3.3.1-b, 3.3.1-c, and Figures 3.3.2-a , 3.3.2-b) show single cry sequences, figures for 4 weeks and after (i.e., Figures 3.3.3-a, 3.3.3-b, Figures 3.3.4-a, 3.3.4-b and Figures 3.3.5-a, 3.3.5-b) show several short cry sequences.

i. The first day:

Figures 3.3.1-a, 3.3.1-b, and 3.3.1-c show three cry sequences consisting of 10, 17 and 14 cry vocalizations respectively. In these cry sequences, the first one or two vocalizations were extremely long. The first expiratory cry vocalization in Figure 3.3.1-c lasted for 13.22 sec, the

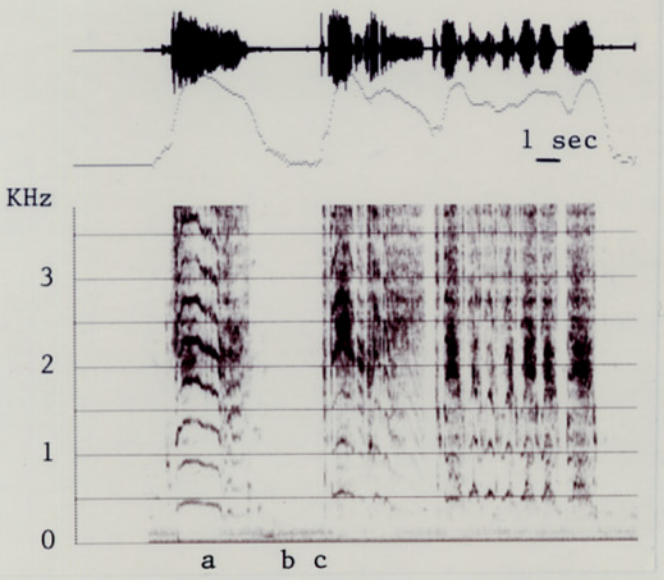


Figure 3.3.1-a

A Cry Sequence (0 Day)

10 units of cry vocalization are shown in this sequence. The first cry unit consists of the first vocalic expiratory section (a), the second voiceless section(b), and the last short inspiratory sound (c).The first three units are relatively long vocalizations. For schematic representation of cry sequences in this and the next two figures, see Figure 3.3.A.

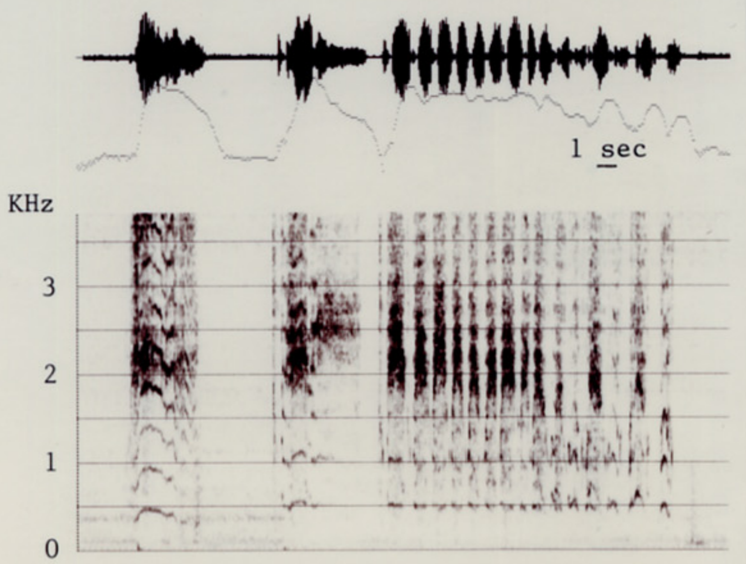


Figure 3.3.1-b

A Cry Sequence (0 Day)

This sequence consists of 17 units of cry sounds. The first two units are relatively long.

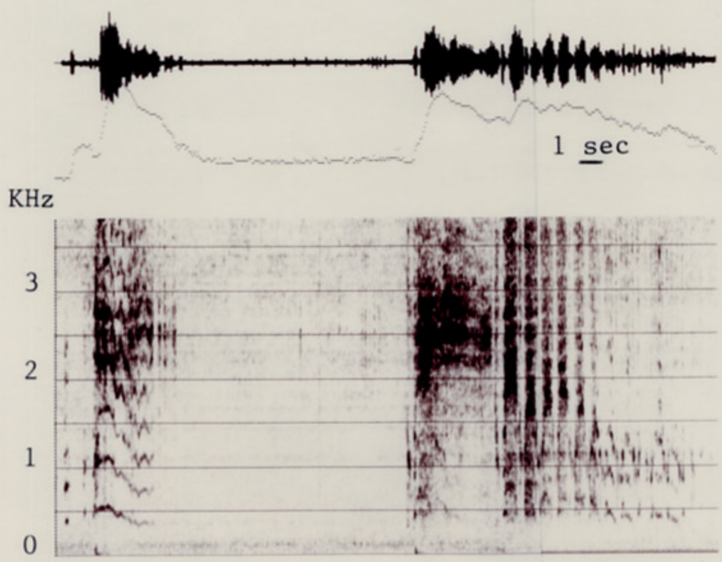


Figure 3.3.1-c

A Cry Sequence (0 Day)

This sequence consists of 14 units of cry sounds. The second unit has a duration of 13.22 second. The first unit,appearing as two doted lines, is a short and weak vocalization.

longest ever observed by the author who has analysed more than 5000 cry sounds representing more than 120 young infants. The first two expiratory cry vocalizations in Figure 3.3.1-b lasted 6.2 and 4.1 sec respectively, and the duration of the first cry sound in Figure 3.3.1-a was 6.7 sec. In all these long expiratory cry phonations, a voiceless segment was included. These voiceless segments suggest the great intensity of the cry, a characteristic often observed in pain cry (Wolff, 1969, p.85 and plate 13). The subsequent cry vocalizations in these figures all showed great rhythm. The extremely long expiratory vocalization and the rhythmic expiratory vocalization of a medium length (400 - 600 msec) constituted the cry sequence at this age.

ii. 3 days:

Figure 3.3.2-a and Figure 3.3.2-b show two cry sequences in 3 days. Notice the appearance of short glottal plosives at the beginning and the subsequent intrapolation of cry vocalizations much longer than what constituted the cry sequences after the extremely long vocalizations as were observed in 0 day. These longer vocalizations ranged from 1200 to 1800 msec. Another distinguishing feature was the obvious lengthiness of the sequences. More than 48 expiratory cry vocalizations were counted in these cry sequences when

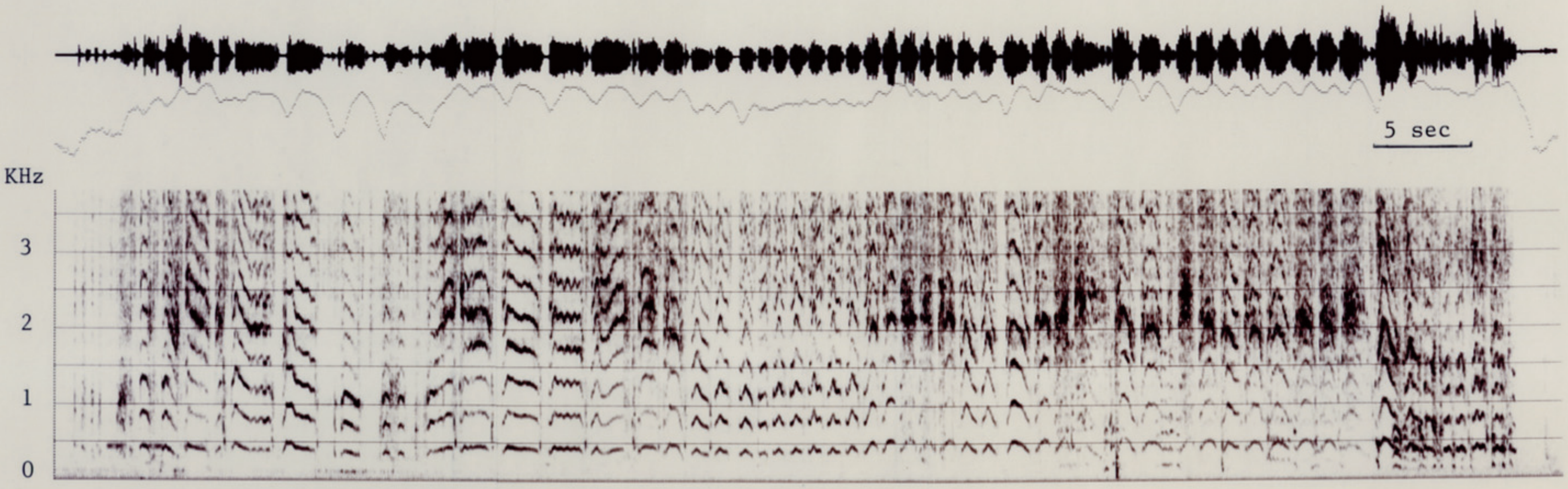


Figure 3.3.2-a A Cry Sequence (3 Days)

The sequence consists of 55 units of cry sounds. It was interrupted by the examiner at this point. The first few units were short glottal plosive cry sounds. After these glottal plosive sounds, the sequence continued with several slightly long cry vocalizations, then it developed into a long series of dysphonations. See Figure 3.3.A for schematic representation of cry sequence in this and the next figure.

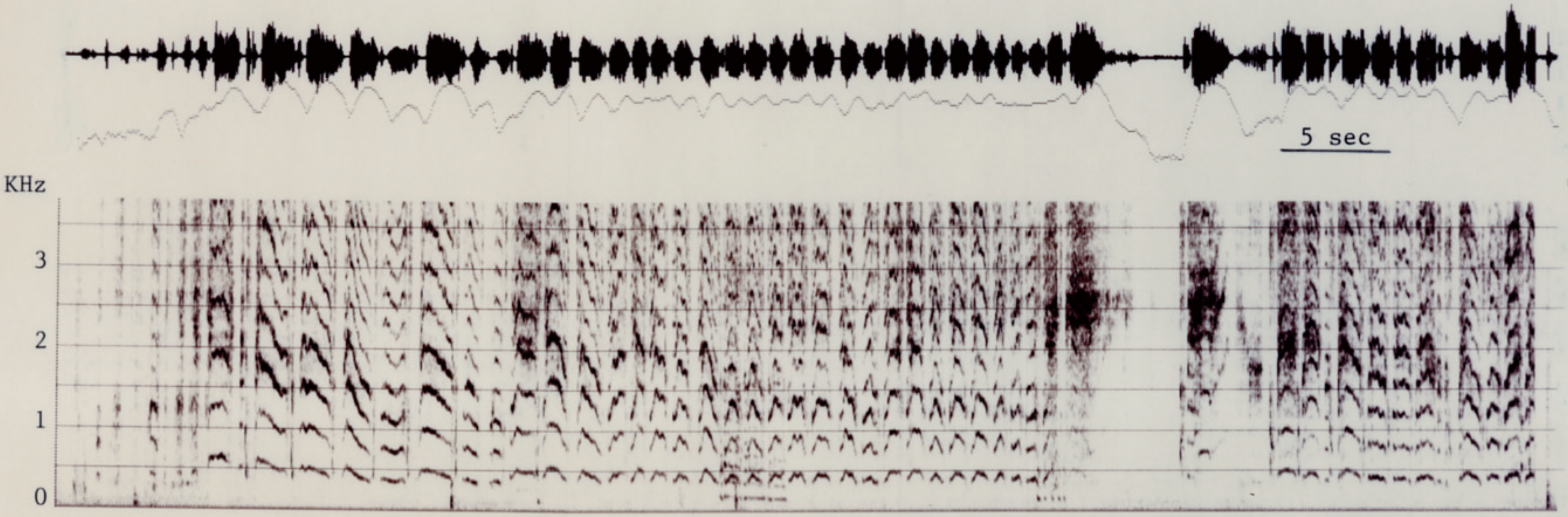


Figure 3.3.2-b A Cry Sequence (3 Days)
The sequence was interrupted by the examiner around 48th unit. The pattern is similar to that in the previous figure (Figure 3.3.2-a).

intervention, either by the mother or by the observer, was introduced. In addition to the darkness of the sonograms which indicates the high concentration of energy on the frequency (vertical) axis, the intensity of the crying at this age can also be inferred from the large amplitude of the sound wave tracings shown above the sonograms.

In contrast with crying in 0 day, Figure 3.3.2-a and Figure 3.3.2-b showed the appearance of dysphonation (indicated by the dark, fuzzy background and the disappearance of clear bands or wavy strips) with the continuation of crying. This seems to reflect the lack of balance between the excess pressure generated and the ability to modulate the vocal tract (Truby and Lind, 1965).

iii. 4 weeks:

Figures 3.3.3-a and 3.3.3-b show several cry sequences at 4 weeks. Notice the low amplitude in the sound wave tracings above the sonograms, and the frequent silent sections exceeding 2.99 sec which resulted in the shortness of the sequence as compared with that of the previous periods. As these two figures represent a continuous observation lasting more than 150 secs, they illustrate how the level of activation gradually increased, as is indicated by the appearance of vocalizations of longer duration and

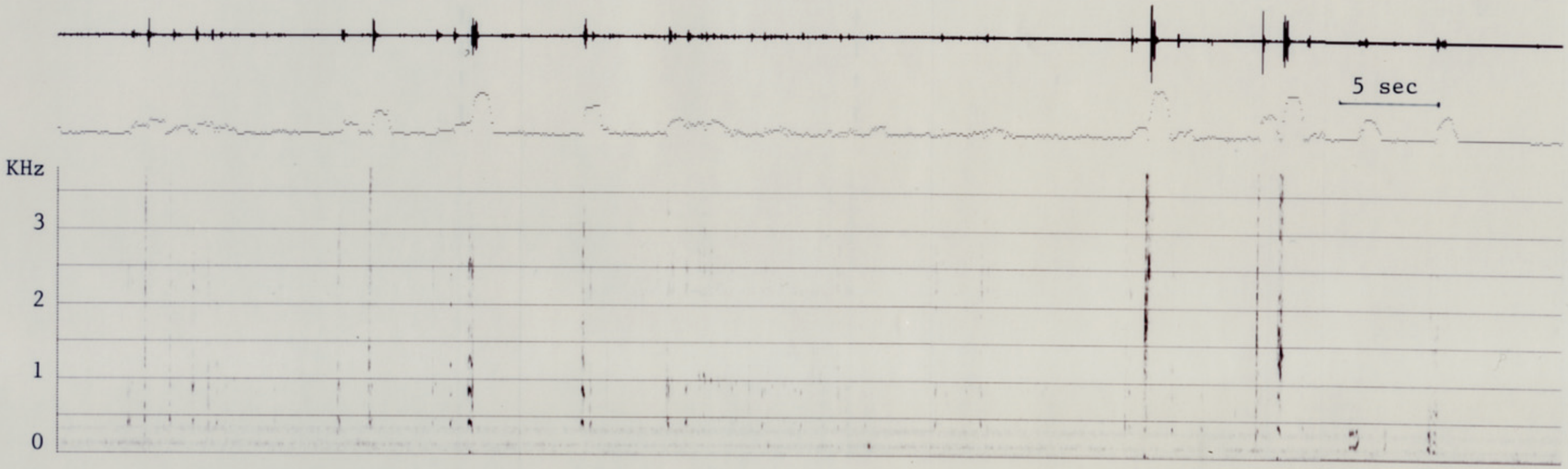


Figure 3.3.3-a Several Cry Sequences (4 weeks)

Sequences consist of short glottal plosive cry sounds. Only a few units were observed in each sequence. For schematic representation of sequences in this figure and the next figure (3.3.3-b), see Figure 3.3.A.

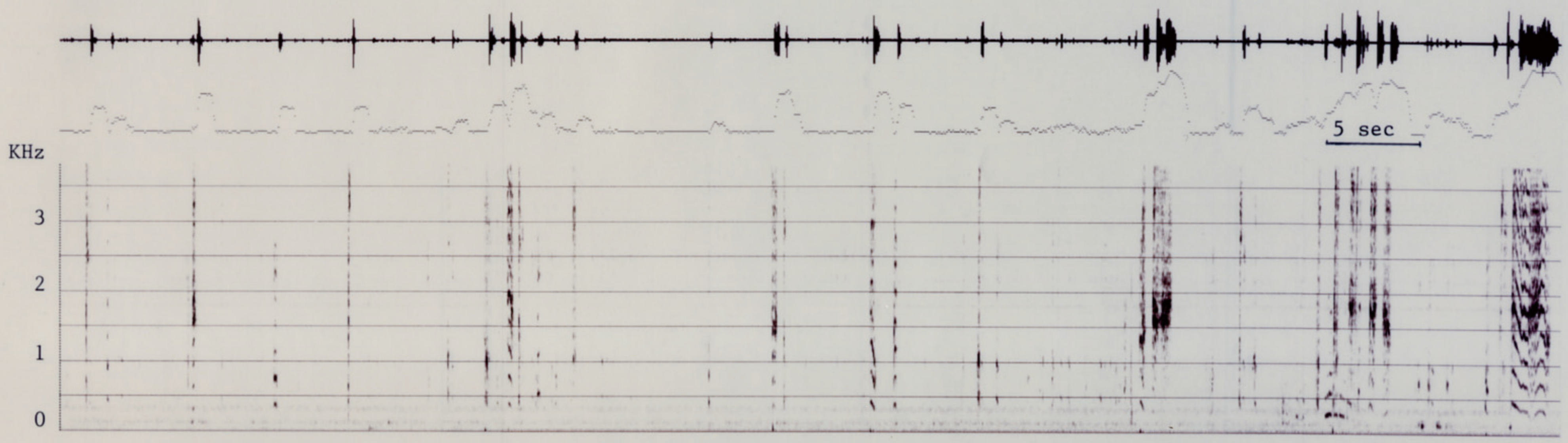


Figure 3.3.3-b Several Cry Sequences (4 weeks)

Following the cry sequences shown in previous figure (Figure 3.3.3-a), sequences of greater magnitude appear as time goes on.

greater amplitude at the end when the observer intervened verbally.

iv. 8 weeks:

At 8 weeks, a cry sequence was observed to begin with a series of powerful glottal plosives to be followed by one or two longer expiratory cry vocalizations which sometimes turned into a neutral vocalization (Figure 3.3.4-a and Figure 3.3.4-b). Notice that the long event observed was also interrupted by frequent silent periods exceeding 2.99 seconds, thus resulting in many short sequences. However, once the level of activation exceeded a certain level, the expiratory cry vocalization became more powerful and longer, with either short glottal plosives, or vocalizations with a glottal stop, or gasping sounds punctuating in between.

As will be shown later in this chapter, changes were not only observed in the manner of sound production. Beginning from 4 weeks, infants began to keep their eyes open and engage in visual exploration of the environment while cry sounds were being uttered. Furthermore, unlike in the first days, crying at this age became susceptibile to being inhibited by stimulus presented distally.

v. 12 weeks:

Figure 3.3.5-a and Figure 3.3.5-b show three sequences

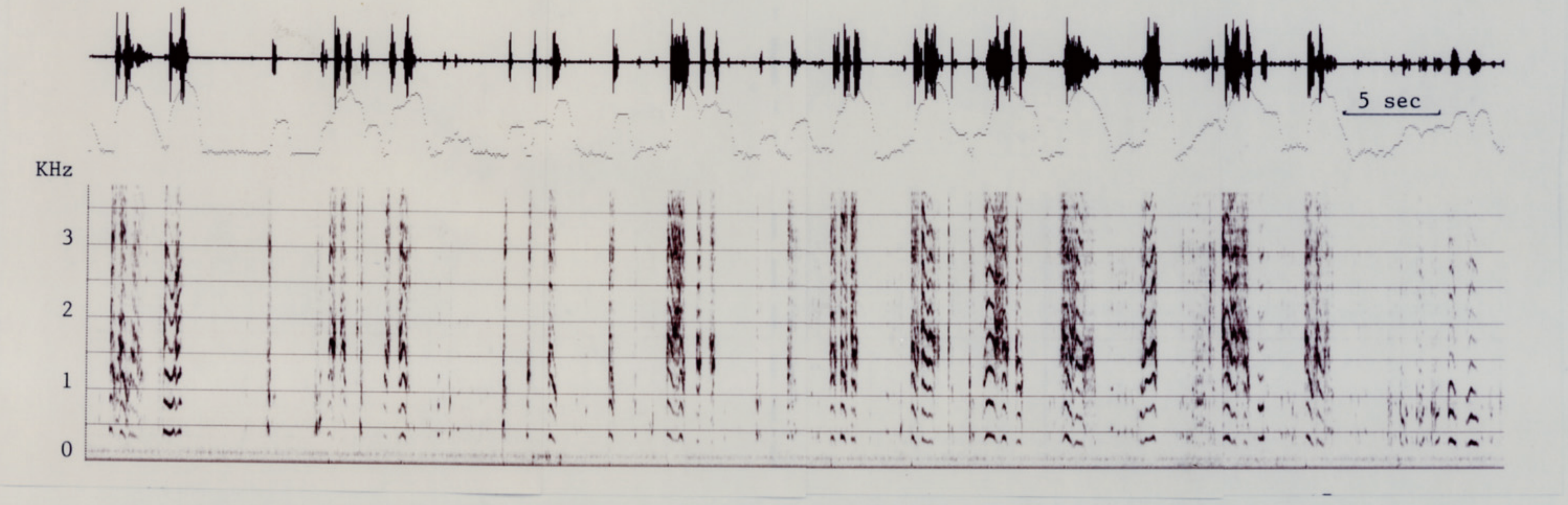


Figure 3.3.4-a Several Cry Sequences (8 weeks)

For schematic representation of sequences in this and the next figure, see Figure 3.3. A.

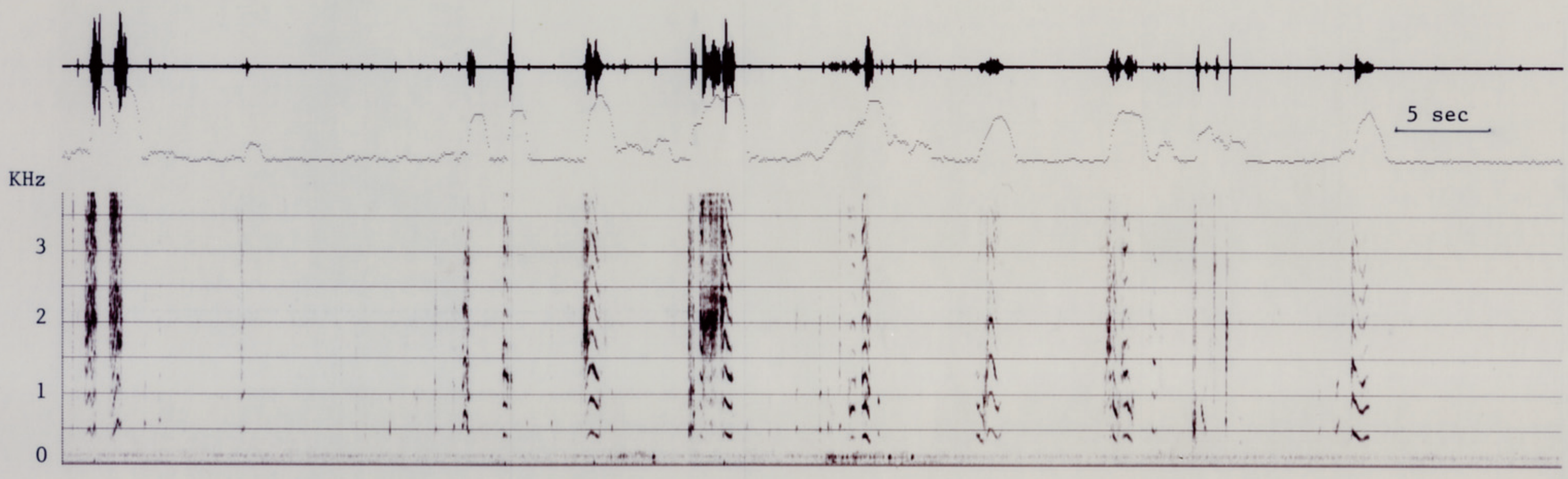


Figure 3.3.4-b Several Cry Sequences (8 weeks)

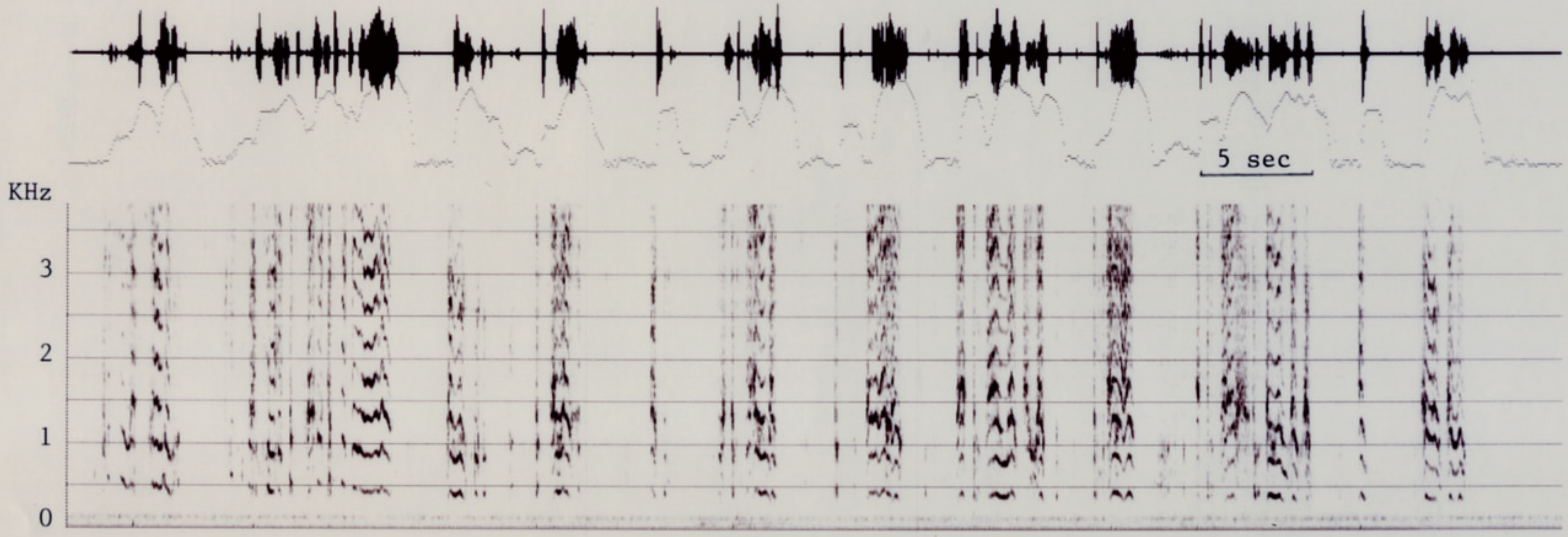


Figure 3.3.5-a Several Cry Sequences (12 weeks)
Longer and more continueous sequences appear. For schematic representation of sequences in this and the next figure, see Figure 3.3. A.

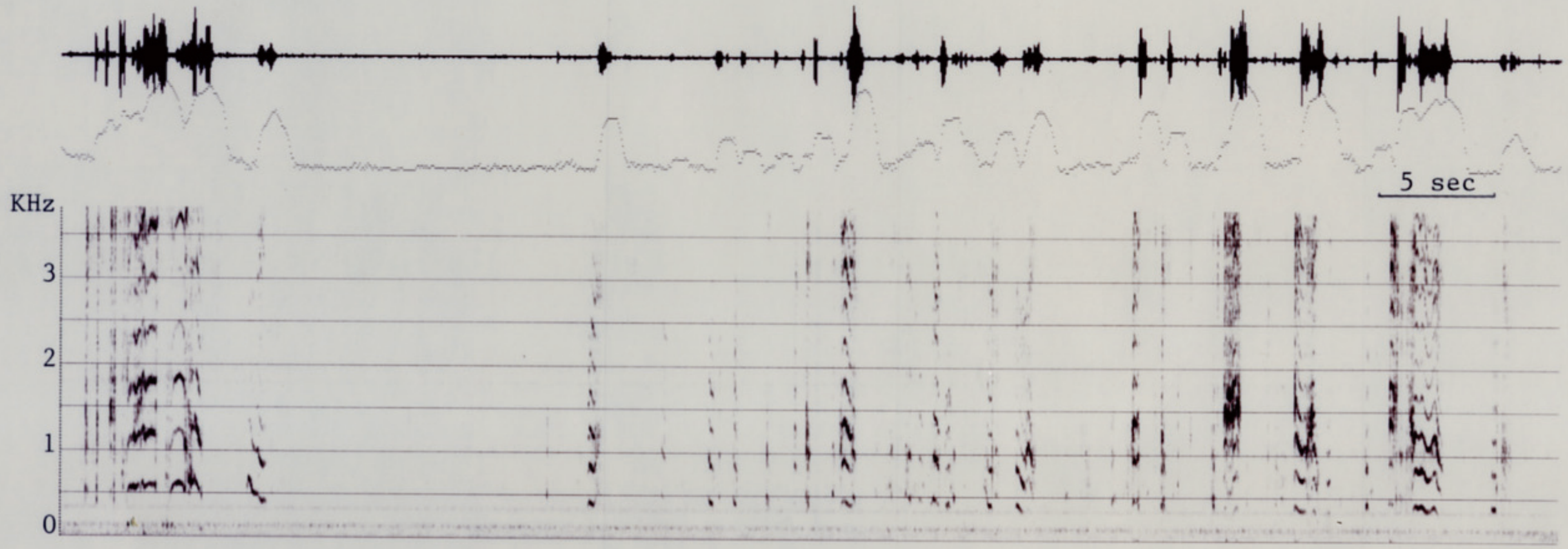


Figure 3.3.5-b Several Cry Sequences (12 weeks)

of crying at 12 weeks(2 sequences in Figure 3.3.5-a and 1 sequence in Figure 3.3.5-b). In general, crying at this age seemed to continue all the characteristics as observed at 8 weeks. One feature that seemed to have added to the infant's repertory was the more frequent occurrence of babbling- or cooing-like vocalization in the midst of a cry sequence, a phenomenon reported to be observable at 3 months by Hopkins and von Wulftten Palthe who called it "interrupted fussing state" (1978).

Figure 3.3.A. provides a summary of the patterns of crying in the first three months, showing in particular the sequences of vocalizations.

2)Temporal Order of Cry Vocalizations

All the cry vocalizations contained in 20 of the cry sequences collected from subject I. S. were analysed according to the procedure described in Chapter II. This subject was selected randomly from among the ten subjects under investigation. The cry sequences were also randomly selected from the subject's records, with the only purpose of showing how manner of phonation changes with age. Table 3.3. shows the result of this analysis.

The relative frequencies of occurrence of different types of cry vocalization in each of the 4 age periods

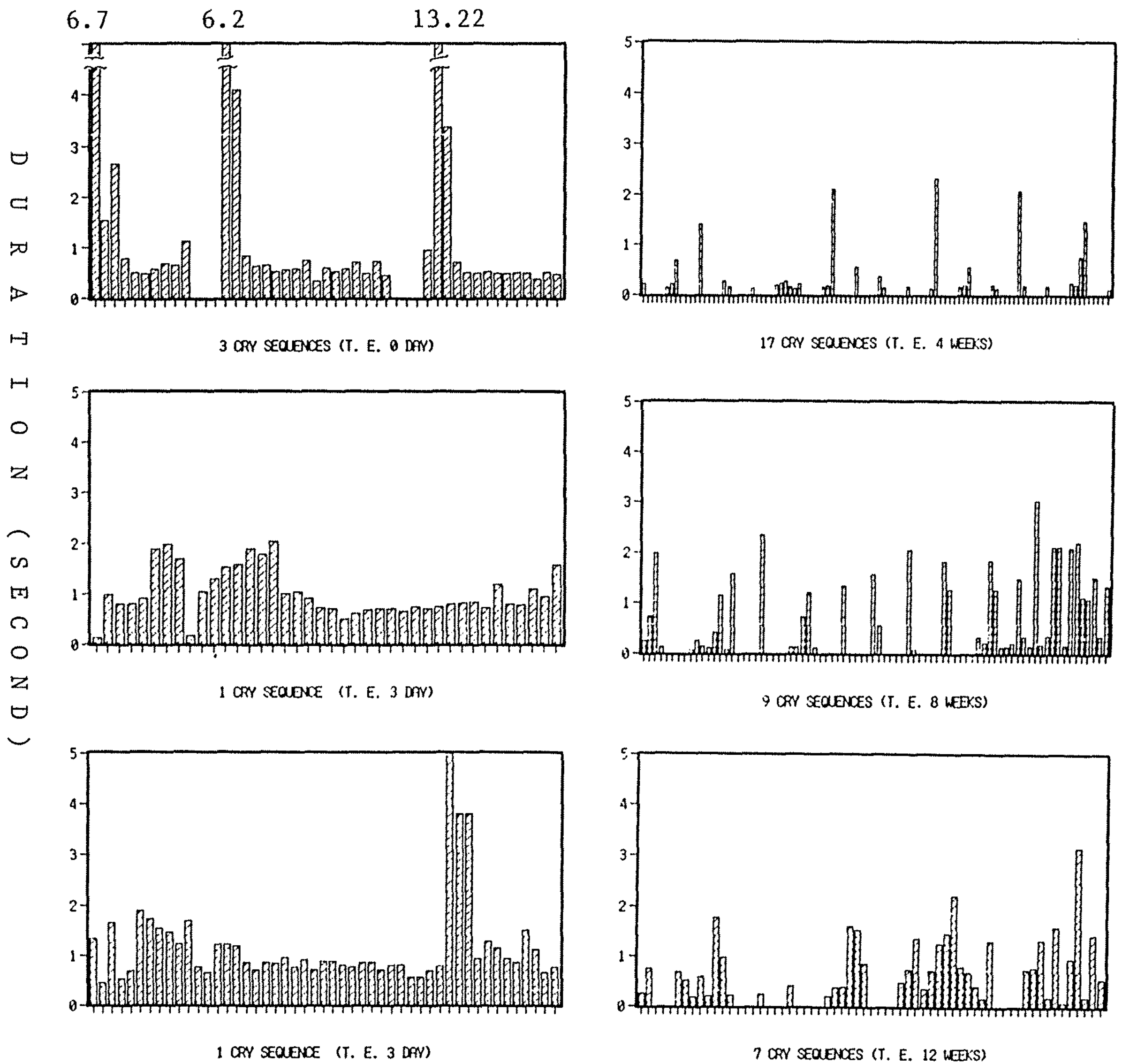


Figure 3.3.A Schematic Representations of Cry Sequences at Various Ages. Except for 3 days (left middle and lower) when only one single sequence was shown, other periods were observed with 3 to 17 sequences.

Table 3.3 Cry Sequences of Infant I. S.

0 DAY

1 (Pa1)(Pb2)(Db5)(Pb2)(Db1)(Pb1).
2 (Da1)(Db10).
3 (Pa1)(Da1)(Db1)(Pb3)(Db1).
4 (Pb1)(Db3)(Pb2)(Db5)(Pb1)(Db1)(Pb1)(Pc1)(Ka1).
5 (Pa1)(Db1)(Lc1)(Db3)(Lc3).
6 (Fd1)(Ld1)(Pa1)(Db1)(Dc2)(Db2)(Pb7)(Ld1).
7 (Lc2)(Pa1)(Da1)(Db3)(Dc5)(Db1)(Dc4)(Db2)(Pb1)(Pc1).

3 DAYS

1 (Fc2)(Pa1)(Fc1)(Fb1)(Fc1).
2 (Fd3)(Lc1)(Fc1)(Fd1)(Fd5)(Fc1)(Pb1)(Fc1)(Pc1)(Pb1)(Sc1)(Sb1)(Fb1)(Fc1)(Pb5)(Pc2).

4 WEEKS

1 (Lc1)(Pc2)(Fa2)(Pa2)(Lc1)(Lb1)(Ld1)(Pc1)(Pa1)(Lc1)(Pc2)(Lc1).
2 (Fa1)(Fc1)(Pb1)(Fb1)(Lc1)(Ld1)(Pc2)(Pa1)(Pc4)(Pa1)(Pc1).
3 (Sa1)(Sc1)(Sa1)(Lc2)(Ld1)(Lc2)(Ld1)(Lc2)(Sa2)(Pc1)(Ld1)(Lc1)(Ld1)(Lc1)(Ld4)(Lc1)(Sb1)(Sc2)(Sb1)(Ld1)(Lc1)(Sc1)(Lc1)(Sc1)(Sa1)(Pa1)(Pc2)(Ld1)(Sc1).

14 WEEKS

1 (Ba1).
2 (Fc7).
3 (Fc5)(Fb1)(Fc2)(Pa1)(Lc1).
4 (Sd1)(Pc1)(Fc1)(Fd5).
5 (Fc1)(Fd1)(Fc1)(Fd2)(Fc1)(Fd1)(Ba1)(Fd2).
6 (Fc1)(Fd2)(Sb1)(Fc1)(Fd2)(Sd1)(Fd1).
7 (Fb2)(Fc1)(Pc1)(Sa1)(Pd1)(Sd1)(Fa1)(Fd1).
8 (Fc12)(Pa1).

	a 1600msec up	b 1599-800 msec	c 799-250 msec	d under 249 msec
P (phonation)	•••••	•••••••••• ••••••••••	••	
D (dys-phonation)	•••	••••••••••• ••••••••••• ••••••••••• •••••••••••	•••••••••• •	
H (hyper-phonation)				
F (glottal plosive)				•
S (glottal stop)				
L (low intensity)			••••••	••
X (complex: P + H + D)	•			
B (babble)				

	a 1600msec up	b 1599-800 msec	c 799-250 msec	d under 249 msec
P (phonation)	•	•••••••	•••	
D (dys-phonation)				
H (hyper-phonation)				
F (glottal plosive)		••	••••••••	•••••••••
S (glottal stop)		•	•	
L (low intensity)			•	
X (complex: P + H + D)				
B (babble)				

	a 1600msec up	b 1599-800msec	c 799-250 msec	d under 249 msec
P (phonation)	••••••	•	•••••••••• •••••	
D (dys-phonation)				
H (hyper-phonation)				
F (glottal plosive)	•••	•	•	
S (glottal stop)	•••••	••	••••••	
L (low intensity)		•	•••••••••• ••••••	•••••••••• ••
X (complex: P + H + D)				
B (babble)				

	a 1600msec up	b 1599-800msec	c 799-250 msec	d under 249 msec
P (phonation)	••		••	
D (dys-phonation)				
H (hyper-phonation)				
F (glottal plosive)	•	•••	•••••••••• •••••••••• •••••••••• •••	•••••••••• •••••••
S (glottal stop)	•	•		••••
L (low intensity)			•	
X (complex: P + H + D)				
B (babble)	••			

Figure 3.3.B Developmental Change of Patterns of Cry Vocalizations

0 day	3 days
8 wks	14 wks

selected were plotted using the classification scheme(Figure 3.3.B.). In terms of the structural dimension, while phonation and glottal plosive were observed in all 4 age periods (glottal plosive occurred only once in 0 day), dysphonation, complex, and babble-like vocalizations were observed in only one of the age periods, with dysphonation and complex vocalizations characterizing the crying of the 0 day, and the babbling-like vocalization characterizing the crying in 14 weeks. Cry vocalization involving glottal stop occurred only after 3 days.

When examined from the point of view of duration, the cry vocalizations in 0 day were represented by longer phonations and dysphonations, whereas shorter glottal plosive cry vocalizations were observed to be frequent in 14 weeks.

In general, the patterns and characteristics observed here tend to agree with those observed in the previous section. The orders of cry vocalizations in 24 sequences from Subject T. E. are shown in Appendix B-2.

Part 2.

3.4 Crying and Concurrent Behaviours

1)Developmental change of the mean frequencies of the 5 categories

Figure 3.4.1(a),(b) and Table 3.4.1 show the developmental trends of the frequencies of the 5 categories of behaviours.

As can been seen from Table 3.4.1, while vocalization was observed around 41 % to 79% during the 5 age periods with the peak occurring at 4 weeks and 8 weeks, visual exploration and eyes open were seen to increase from 10 % and 16 % to 70 % and 86 % at 12 weeks. The category "movement" showed a variation between 31 % and 71 %, with 3 days and 12 weeks showing the lower levels. The low rate seen in 3 days was due to the long and continuous crying typically observed at this age (as also partially evidenced by 56 % of vocalization) when the infants maintained a quite intense level of crying for an extended period of time during which the body and the limbs were stiff and motionless. This result is in agreement with that of Stark & Nathanson (1974). The low rate of movement in crying observed at 12 weeks was, however, related to the lower rate of vocalization (41 %) at this age. The intensity of crying was also indicated by the appearance of a higher rate of "grimace" at 3 days and 4 weeks (60 % and 55 % respectively) as compared with the last two age periods (25.9% and 20 %, respectively).

At this level of data reduction, the results provided us

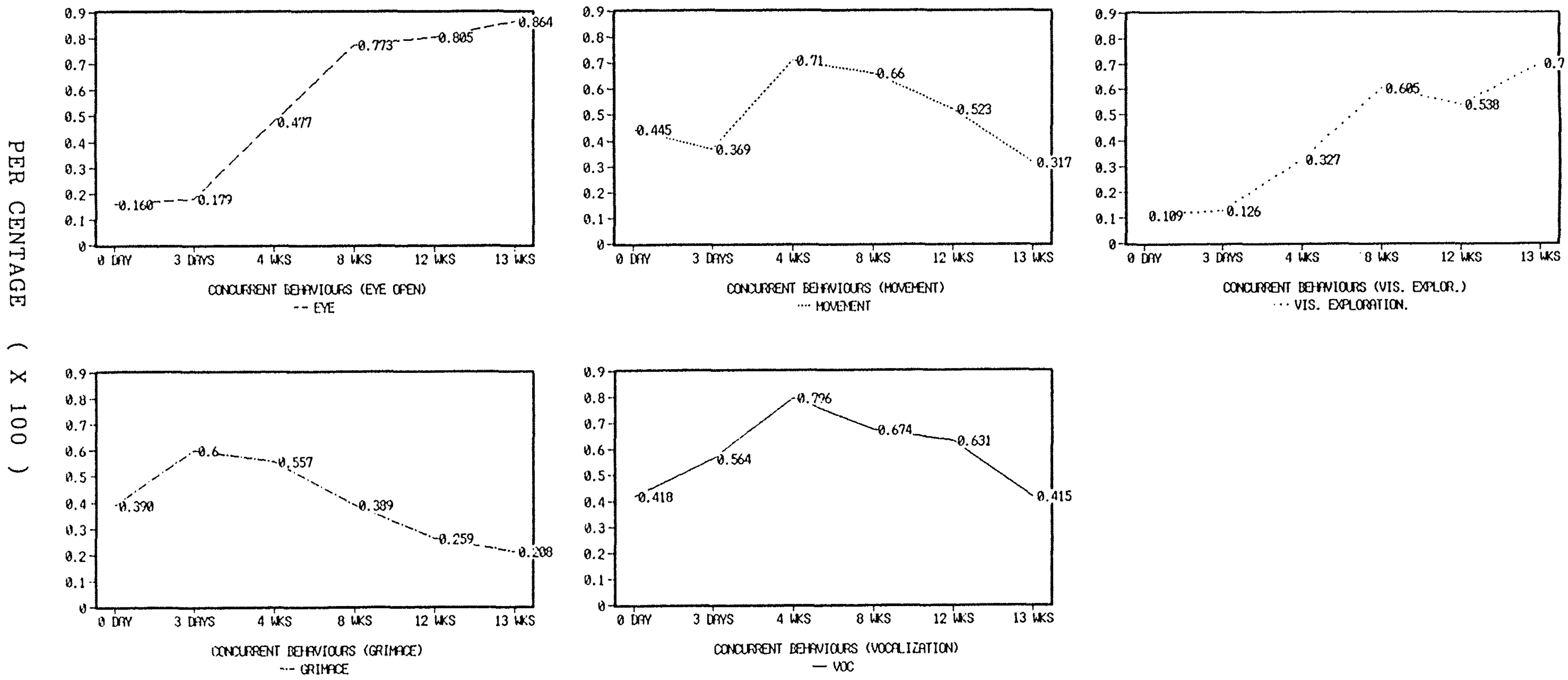


Figure 3.4.1(a)Developmental Change of Five Concurrent Behaviours Shown Separately.

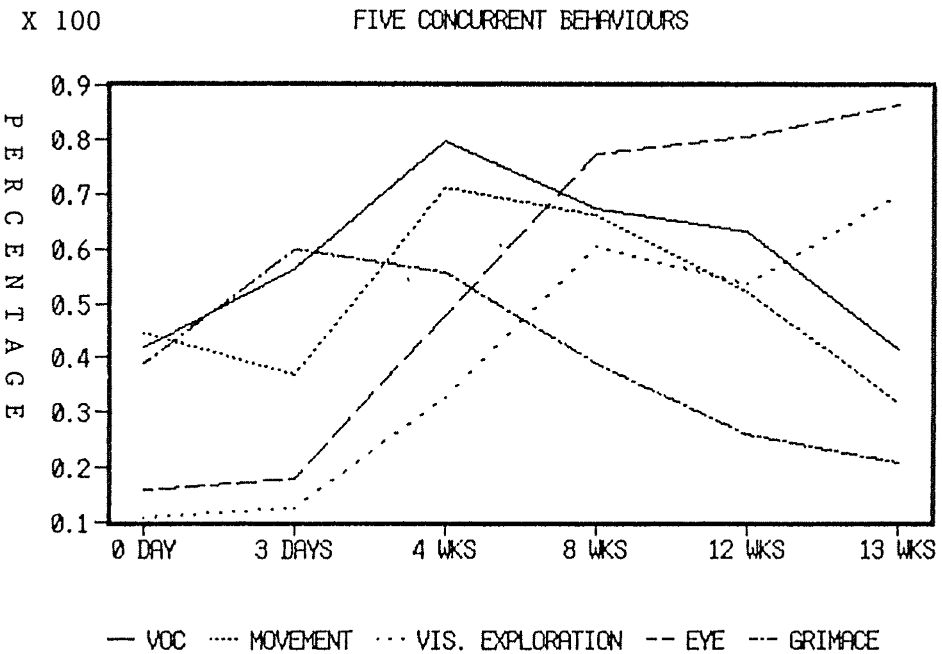


Figure 3.4.1 (b) Developmental Change of Five Concurrent Behaviours.

This figure compares the five developmental curves which are shown separately in Figure 3.4.1 (a).

Table 3.4.1 Developmental Change of 5 Concurrent Behaviours

age	V	M	X	E	G
0 DAY	41.8	44.5	10.9	16	39
3 DAYS	56.4	36.9	12.6	17.9	60
4 WKS	79.6	71	32.7	47.7	55.7
8 WKS	67.4	66	60.5	77.3	38.9
12 WKS	63.1	52.3	53.8	80.5	25.9
13 WKS	41.5	31.7	70	86.4	20.8

V: Cry or fuss vocalization

M: Movement of limbs

X: Visual exploration

E: Eye open

G: Grimace

Numbers are percentages of the number of units of behaviours observed. The unit employed was one second.

with some quantitative basis for understanding the relative relationship between and among different categories in infant crying and their developmental trends. However, since each category was treated independently, the picture resulted was not sharp enough to enable us to say exactly what happened when an infant cried, at different age periods. In the following sections, two more analyses will be performed to do just this. It is hoped that, by the end of our analyses, a clearer picture of the development of crying as a behaviour system for action will emerge.

2)Co-occurrence of vocalization and visual exploration

Based on data obtained from the first order reduction as described above, the aim of our next anaysis was to examine the co-occurrence of cry vocalization and visual exploration. The analysis was based on the hypothesis that although the different components of the behaviour system for action were present at birth (connecting serially with each other in time), they were integrated and became coupled with one another later during the course of the first few months. If this hypothesis is true, we would expect cry vocalization and, for example, visual exploration, to occur not at the same time, but independent of each other in the beginning days, and only later when the coupling occurred would they be observed to occur together.

The procedure was first to identify the co-occurrence of visual exploration and vocalization and to calculate the number of seconds that such a condition lasted, for each episode. The value obtained was to be divided by the total numbers of duration of vocalization and of visual exploration. Two values, represented as a proportion or percentage, were obtained as indecies of the porpotion of time when vocalization was actually observed to occur together with visual exploration, and vice versa. The results are shown in Figure 3.4.2.

As can be seen in Figure 3.4.2, a shift was observed to occur between 3 days and 4 weeks. While the portions of co-occurrence of visual exploration and vocalization at 0 day and 3 days were less than 3 per cent, they rose to 23 and 45 percent for vocalization observed together with visual exploration and for visual exploration observed with vocalization, respectively, at 4 weeks.

Like phenomenon in other domains of development, the co-occurrence of vocalization and visual exploration also showed individual difference in the timing of the first appearance. A closer look at the results indicates that among 13 episodes

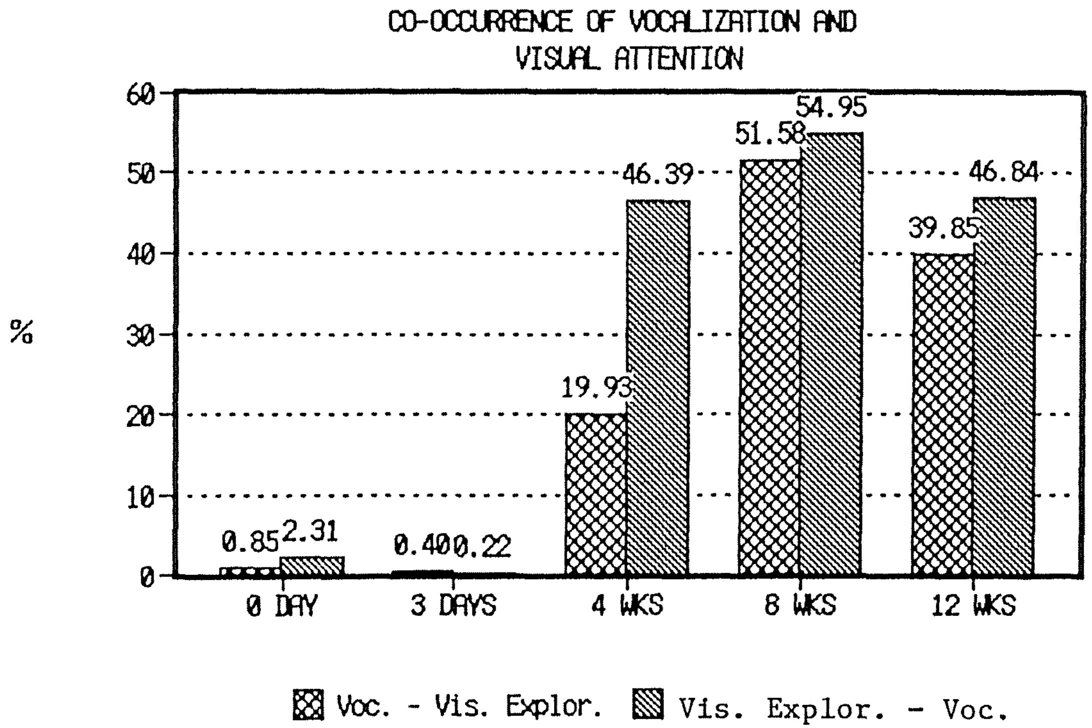


Figure 3.4.2 Developmental Change of Co-occurrence of Vocalization and Visual Exploration.

obtained through procedure described above, only one episode showed a rate of co-occurrence other than 0 percent, 3 seconds, to be exact. Among 10 episodes from 4 weeks, however, 2 episodes recorded 0 percent of co-occurrence. After 4 weeks, among the 26 episodes analysed, all showed some degree of co-occurrence of the categories of behaviours in question. Figures 3.4.3 and 3.4.4. show the developmental trends of co-occurrence of vocalization and visual exploration in individual episodes.

3)Behaviour sequences: Before, during and after cry vocalization

In order to find out what an infant does before, during and after cry vocalization, another analysis was performed. This analysis was based on the data sheets obtained for the previous two analyses. Coders were instructed to, first, locate the appropriate sequence by applying three criteria:

i) A vocalization sequence should be preceded and followed by a "blank" period during which no vocalization was observed for 5 seconds or more;

ii) The vocalization selected should last more than 3 seconds;

iii) Within the boundaries, periods of no vocalization

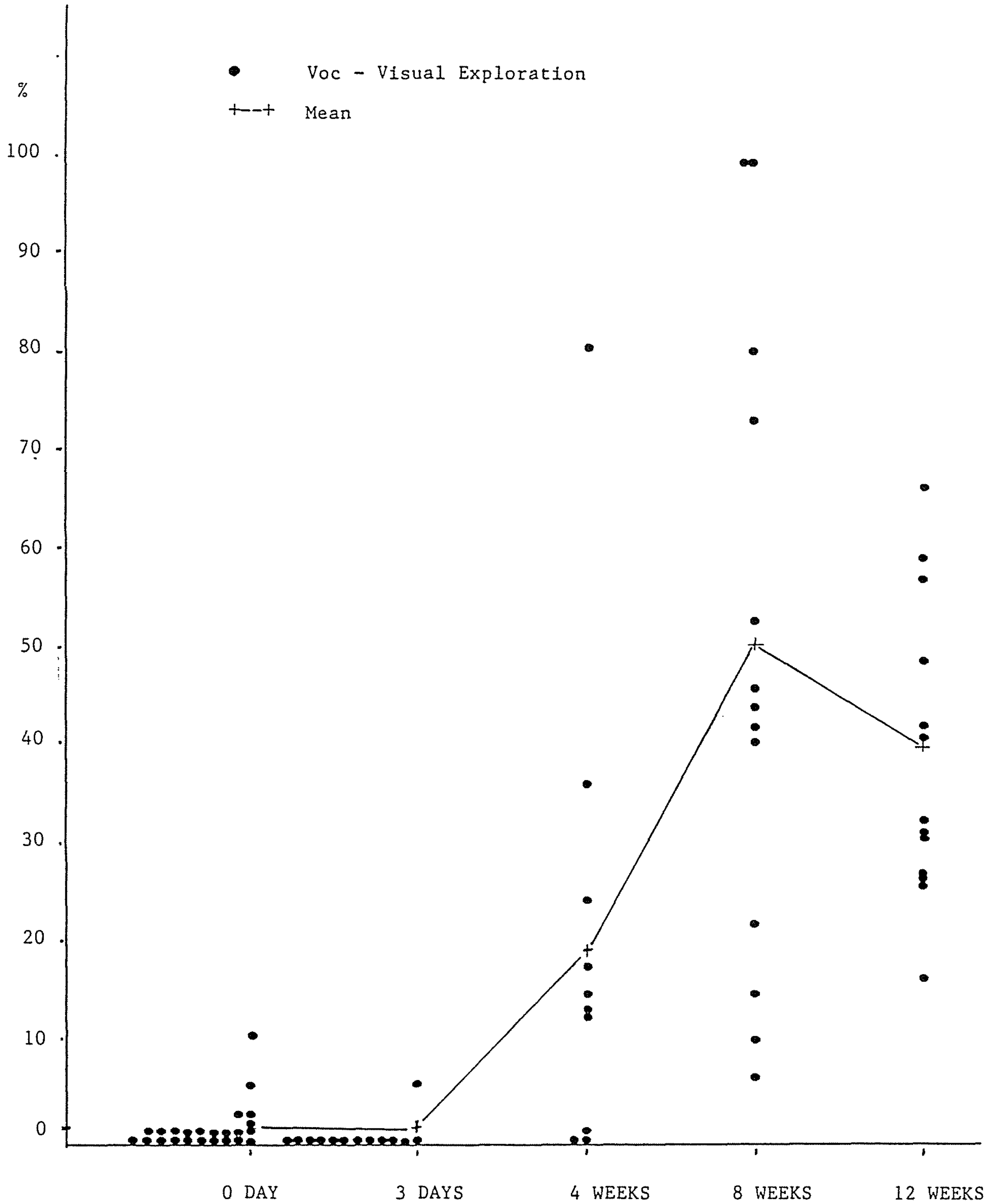


Figure 3.4.3 Developmental Change of Co-occurrence of Vocalization and Visual Exploration As Based on Individual Observations.

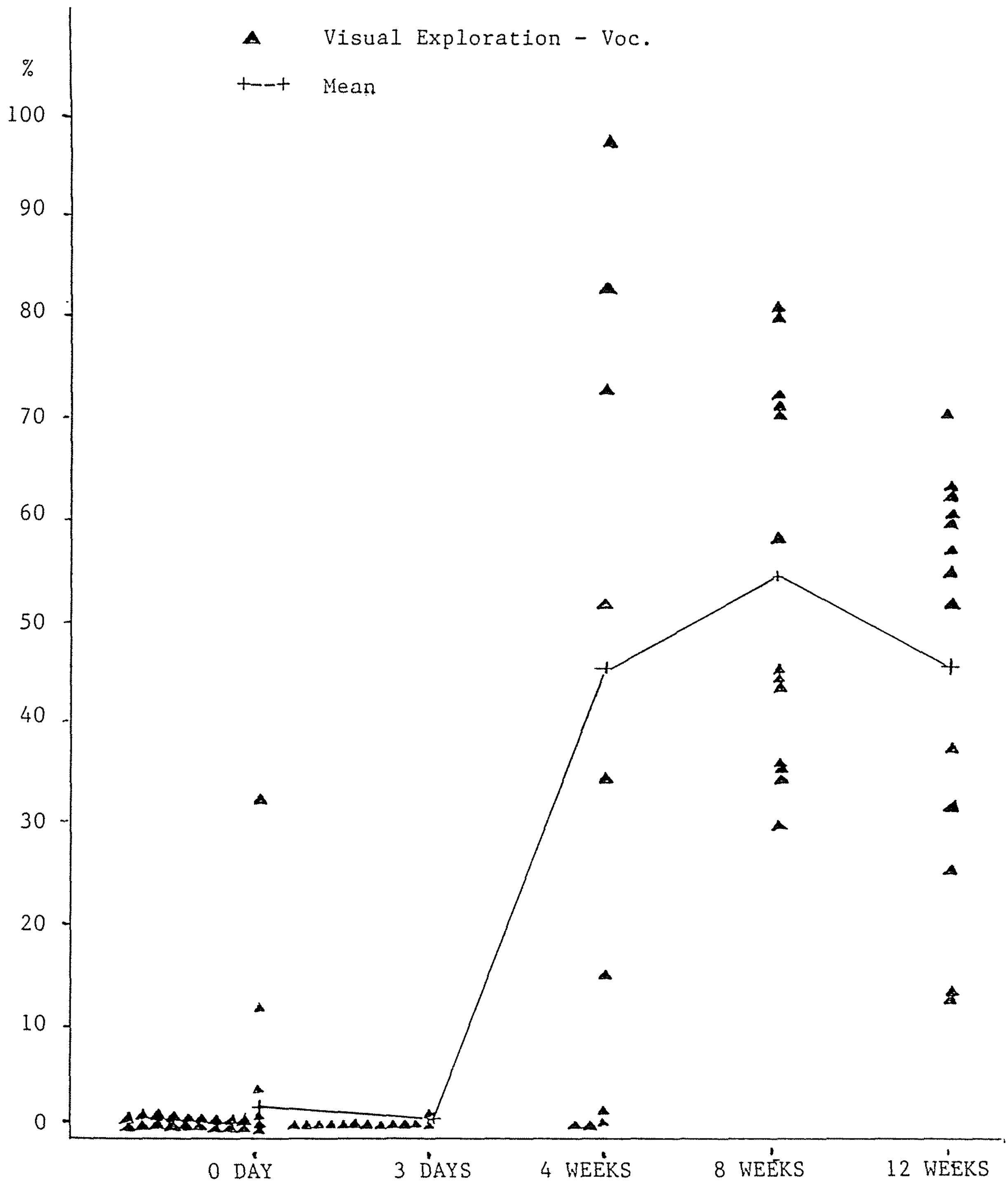


Figure 3.4.4. Developmental Change of Co-occurrence of Visual Exploration and Vocalization As Based on Individual Observations.

were disregarded, and the whole sequence of vocalization was treated as continuous.

Secondly, the coders were instructed to record the presence of 4 other categories of behaviours during the vocalization period, as well as 5 seconds before and after the sequence. Hereafter, the selected episodes will be referred to as "sequences".

As a result of selection according to these criteria, a total of 228 sequences were obtained. All age periods were represented, although the period of 4 weeks was slightly under-represented (7.5 %, 17 sequences), for it was a period when crying tended to be long and continuous, that the mothers had to intervene, and thus created more sequences ending without enough "blank" period. However, these sequences showed clear patterns, as described below.

Table 3.5 and Figures 3.5.a, 3.5.b, 3.5.c showed the percentages of behaviour categories observed before, during, and after cry vocalization at different age periods.

At 0 day and 3 days, both before and after cry vocalization, the category N (N for none of the 5 categories employed) accounted for more than 13%. Since this category implies that the infants were either in a sleepy or drowsy state, this result indicated that at these periods, cry

Table 3.5 Concurrent Behaviours Before, During, and After Cry Vocalization

A. PRE-VOC

	0 DAY	3 DAYS	4 WEEKS	8 WEEKS	12 WEEKS
N	13.00	27.59	0.00	0.00	1.64
M	45.00	6.90	0.00	8.00	1.64
E	0.00	0.00	0.00	0.00	1.64
X	2.00	0.00	0.00	0.00	1.64
G	5.00	6.90	0.00	4.00	0.00
ME	1.00	0.00	0.00	0.00	1.64
MX	5.00	0.00	7.69	4.00	6.56
MG	8.00	20.69	0.00	0.00	1.64
EX	4.00	17.24	15.38	24.00	32.79
EG	0.00	0.00	0.00	0.00	0.00
XG	1.00	0.00	0.00	0.00	0.00
MEX	8.00	6.90	61.54	56.00	47.54
MEG	0.00	0.00	0.00	0.00	0.00
MXG	7.00	3.45	0.00	0.00	1.64
EXG	1.00	6.90	7.69	4.00	0.00
MEXG	0.00	3.45	7.69	0.00	1.64

B. IN-VOC

	0 DAY	3 DAYS	4 WEEKS	8WEEKS	12 WEEKS
N	0.00	0.00	0.00	0.00	0.00
M	2.04	0.00	0.00	5.71	0.00
E	0.00	0.00	0.00	0.00	0.00
X	0.00	0.00	0.00	0.00	1.47
G	12.24	13.33	0.00	0.00	0.00
ME	0.00	0.00	0.00	0.00	0.00
MX	1.02	0.00	0.00	0.00	4.41
MG	71.43	60.00	0.00	0.00	0.00
EX	0.00	0.00	0.00	5.71	2.94
EG	0.00	0.00	0.00	0.00	0.00
XG	0.00	3.33	0.00	0.00	0.00
MEX	0.00	0.00	7.69	22.86	33.82
MEG	0.00	0.00	0.00	0.00	0.00
MXG	10.20	20.00	7.69	2.86	4.41
EXG	0.00	0.00	0.00	0.00	2.94
MEXG	3.06	3.33	84.62	62.86	50.00

C. POST-VOC

	0 DAY	3 DAYS	4 WEEKS	8 WEEKS	12 WEEKS
N	23.66	23.08	0.00	0.00	0.00
M	21.51	0.00	0.00	0.00	0.00
E	0.00	0.00	0.00	0.00	1.67
X	0.00	7.69	0.00	3.45	1.67
G	23.66	38.46	0.00	0.00	0.00
ME	0.00	0.00	0.00	0.00	0.00
MX	4.30	0.00	9.09	6.90	13.33
MG	22.58	11.54	0.00	0.00	0.00
EX	3.23	0.00	9.09	51.72	31.67
EG	0.00	0.00	0.00	0.00	0.00
XG	0.00	3.85	0.00	0.00	0.00
MEX	1.08	3.85	54.55	27.59	35.00
MEG	0.00	0.00	0.00	0.00	0.00
MXG	0.00	0.00	0.00	0.00	0.00
EXG	0.00	11.54	18.18	3.45	6.67
MEXG	0.00	0.00	9.09	6.90	10.00

Numbers indicate percentages of the number of units of behaviours observed.

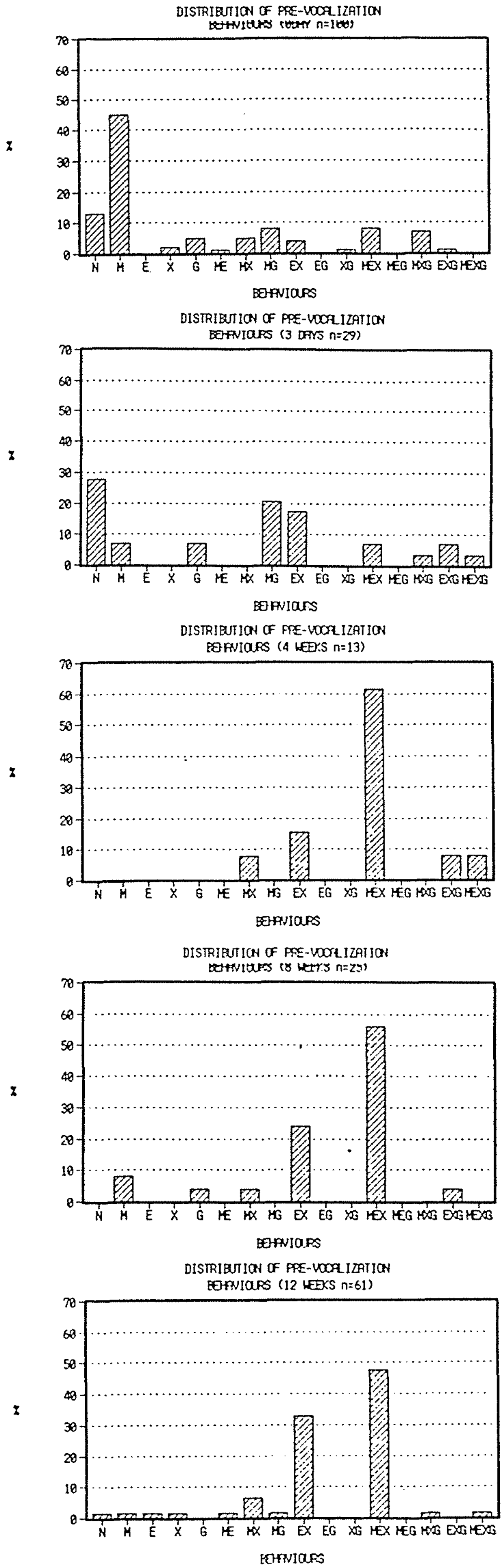


Figure 3.5.a Developmental Change of Pre-vocalization Behaviours.

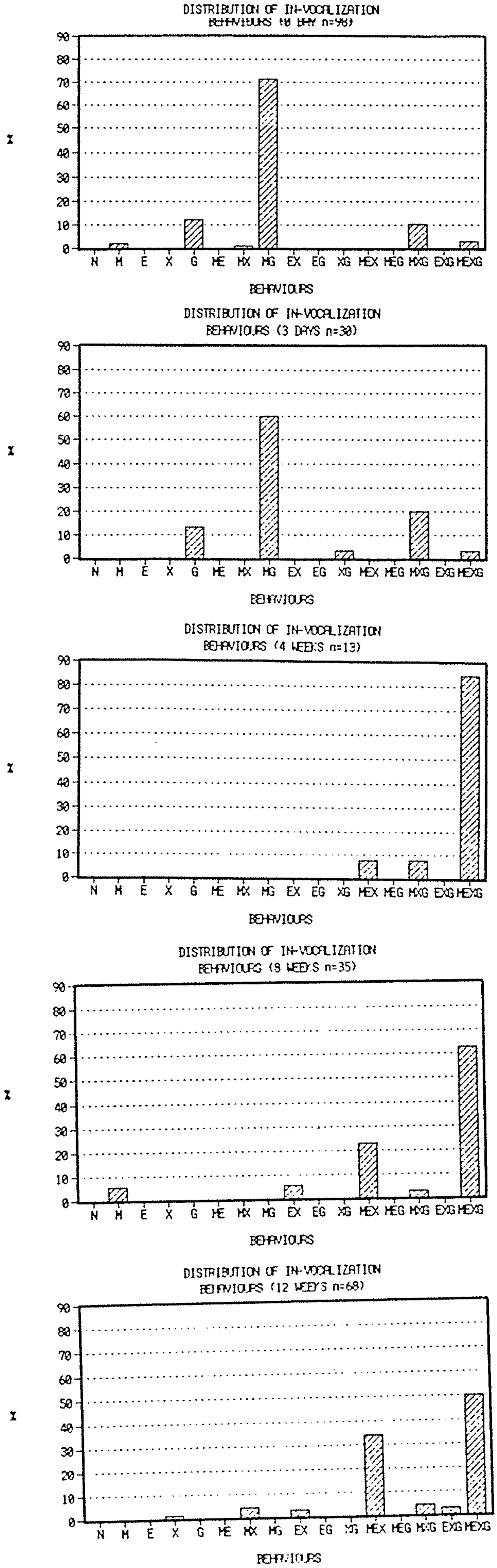


Figure 3.5.b. Developmental Change of Behaviours During Vocalization.

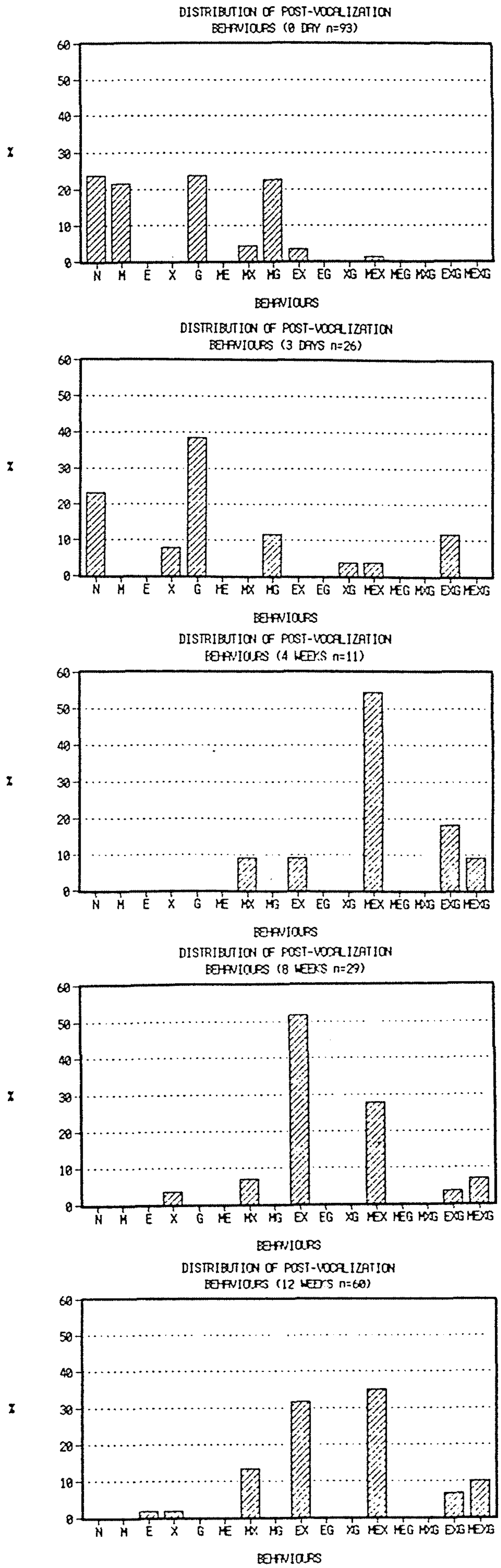


Figure 3.5.c Developmental Change of Post-vocalization Behaviours.

vocalizations tended to appear suddenly, and after crying, infants tended to go back to a drowsy or sleepy state.

Another feature commonly observed in these figures was that in all situations (i.e., before, during and after cry vocalization), 4 weeks seemed to serve as a dividing point; with the previous periods (0 day and 3 days) showing one pattern, and the subsequent periods (4 weeks, 8 weeks and 12 weeks) showing another pattern. Thus, in the case of pre-vocalization (Figure 3.5.a), movement of the limbs was observed at 45% in the first day. MG and EX were the only categories observed to appear over 10% (20.69% and 17.24%, respectively). At 4 weeks and after, the most frequently observed categories were the MEX and EX, with the former showing gradual increase from 15.38% to 24% to 32.79%, and the latter maintaining around 50%(61.54%, 56%, and 47.54% respectively). In the case of concurrent behaviours during cry vocalization (Figure 3.5.b), MG, G, and MXG were three categories that were most frequently observed in the first week. Beginning at 4 weeks, MEXG and MEX were more prominent, implying that visual exploration(X category) was frequently observed during crying.

Finally, in the case of concurrent behaviours after cry vocalization(Figure 3.5.c), M, G, or their combination were most frequently observed in 0 day. In 3 days visual exploration(category X) was added to the list, implying that when the infants were not sleepy at the end of a cry sequence, they began to explore the environment. At 4 weeks, no cry sequence was observed to be followed by a sleepy or drowsy state. Instead, MEX and EXG were dominant. At 8 weeks and 12 weeks, the pattern was similar, with EX and MEX being the most frequently observed categories for both age periods.

In different forms, Appendix C-1 and Appendix C-2 present a summary of the developmental changes of the concurrent behaviours before, during, and after the onset of cry or fuss vocalization.

Chapter IV. CONCLUSION

4.1 Conclusion

In this dissertation the expression of the infants' spontaneous crying during the first three months of life was analysed from the point of view of the development of an action system. In terms of the data employed, the analyses were based on two classes of observations; the cry vocalization and the concurrent behaviours. The analyses were aimed at providing an outline of the reorganization of the cry expression action system at or around the end of the first month. It was demontrated that around this time the system changed from one that can be characterized as being a simpler and mainly closed system with one mode of activation and inhibition to one that was a more differentiated (two modes of activation and inhibition) and open system. Among the multiple changes that constituted the reorganization, it was demonstrated that the short glottal plosives most often observed in the beginning phase of a cry sequence after the first days and the visual exploration concurrent with cry vocalization were playing important roles. In particular, the appearance of visual exploration during cry vocalization around 4 weeks provided the cry expression action system with a behavioural basis for coordinating the infant's ongoing action (i.e., cry vocalization) with the environment, thus making the system a more goal-directed action system. This interpretation is in accordance with the action systems theory which rests on the assumption that infants are built to seek and receive information from the periphery and, in turn, can modify their actions in accordance with these perceptions (Reed, 1982, Thelen, 1989).

4.2 Theoretical Implications

In this section three issues will be discussed; the developmental process of the cry expression action system, the mode of control of the cry expression action system, and the implications of the findings of the present study. From an action systems point of view, the analyses carried out in this study illustrated several important aspects of the development of the cry expressing action system in the first three months. Two aspects will be taken up; the first concerns the components of the system and their developmental change; the second addresses the mode of control of the action system, namely the activation and the inhibition of crying.

1) The Cry Expression Action System

Infant crying begins as a reflexive response which can be activated with minimum stimulation(Lester, 1985, Torda, 1976). Although even this reflex-based response seems to require an extended degree of coordination among the respiratory, vocalizing and other motor systems (Golub, 1980, Golub & Corwin, 1985), the system is relatively simple. As was shown in the analyses concerning concurrent behaviours conducted in this study, the visual exploration behaviour, an important distinguishing feature observed in the cry expression of an older infant, was observable in the first week (0 day and 3 days). However, when examined closely, the occurrence of this and the eye opening state were only observed when there was no crying or fussing. The coupling of these behaviours with the uttering of cry or fuss sounds begins to be observable in this set of data at 4 weeks. Thus, the simple system consisting of respiration, vocalization, and other motor components, expands to include an important cognitive or perceptive component, making the expression system a more effective action system. Beginning as an intra-organismic process in the first days, the crying of the infant develops into an inter-organismic process that involves the infant's active search for information and the infant's active participation in regulating the process.

2) The Activation and Inhibition of Crying

The results of analyses in this study show that not only the quantity and the quality of cry sounds, but also the behaviours concurrent with the utterance of cry vocalization, change over the first three months. They suggest changes in the manner of activation and inhibition in the cry expression system of the young infants. The newborn baby is usually observed to cry reflexively and profusely, as was demonstrated in the first cries of Subject T. E. Furthermore, in this study, except for Subject H. H. who was born with a Caesarean section, all the subjects were observed to have at least one cry bout every three minutes on average in 0 day. The first cries of Subject H. H. also showed the typical characteristics, although only 3 sequences were observed during the 54 minutes observation. During the first hours, all of the subjects were observed to show cry sequences that were preceded by convulsive inspirations and/or startles, which are known to occur frequently in newborns.

The cries of infants on the second or third day showed basically the same pattern as that of the newborn infants, with additional characteristics appearing for the first time:

longer sequence (double or triple that of the first cries), variation in cry duration, and the appearance of short glottal plosives in the beginning of a sequence. The intense, intermittent cries of the newborn were not seen in the observations after the first day.

During the first week, the infant may have opened his/her eyes before crying, but since the cry was very intense, the eyes were tightly closed during the cry sequence. Similarly, although infants at this age were able to orient to auditory or visual stimulus when in the awake and alert state (Brazelton, 1984), they were not susceptible to the same stimuli once the cry sequence started.

These observations seem to suggest that the controlling mechanisms of crying behaviour during the first days and thereafter were different. The intense and intermittent newborn type of cries seemed to be under the control of a mechanism which operated on a "maximum output with minimum input" principle. After the first hours, when infants became less irritable, they were more likely to sustain longer sequences of cry, once the cry sequence was started with stimulus above a certain intensity. Partially because of the intensity of the cry during the first days, interruption of crying requires stronger stimulation, such as sucking (nutritive or non-nutritive), tactile and/or vestibular stimulus (swaddling or holding up vertically). The cessation of cry vocalization at this age was considered as resulted from fatigue or the depletion of energy, as suggested by the appearance of the sleep state (indicated by category N, i.e,. none of the 5 categories) immediately after a cry sequence.

At four weeks, not only did the type of vocalization change (increasingly frequent use of glottal plosives, glottal stops), but also the infants were able to maintain an awake state during which visual exploration and cry vocalization were carried out together. Unlike in the previous age, the crying appeared to begin to come under two modes of control. Beginning with glottal plosives uttered in low intensity while the infant was also visually exploring the environment, the crying could be escalated or inhibited depending on the result of the infant's perception or appraisal of the situation in terms of the current status of goal-attainment. Only when either the fussing was neglected for too long, or the existence of an undesirable state of affair (e.g., pain, uncomfortableness, and the absence of signs of the caregiver, etc.) was perceived, did the crying shift to a more intense mode as observed in an earlier age when the inhibition of the crying required stronger stimulus such as sucking or vestibular stimulation. With further development of cognitive and other motor skills, the activation and inhibition of crying became more tightly linked with the process of appraisal in terms of the infant's currently perceived goal.

3) Implications for the Development of Inter-personal Interaction

The appearance of the visual exploration behaviour concurrent with fussing and/or crying has important implications for the development of inter-personal interaction. When crying can only be more effectively calmed down by feeding or physical contact or intervention that induces vestibular stimulation, the mode of interaction between the infant and the caregiver tends to be carried out in the proximal mode. However, when the infant's crying shows the first sign of being susceptible to the influence of verbal or visual stimulus produced distally, as eye opening and visual exploration behaviours concurrent with crying in older infants seem to suggest, the distal mode of interactions will be greatly facilitated. The advent of this new mode of interaction seems to mark a critical period in the development of the infant's inter-personal relationship.

Observations made, but not formally reported, in the course of this study seem to suggest that the new mode of interaction between the infant and the caregiver serves as a mixed blessing, in the sense that, although the "new skill" is usually considered as an "achievement", the newly integrated skills of the infant can lead to undesirable results, depending on the converged effects of a number of factors such as infant's temperamental characteristics and the caregiver's psychological status and reaction tendency.

In the course of data collection, the caregivers (the mothers in all cases) were asked to assess the cause or nature of their infant's crying. After the appearance of the coupling of crying, eye opening and visual exploration was recognized by all the mothers, their opinions were solicited. Three types of attitudes or attributions were expressed by the mothers:

a. That the child has become capable of being understood and treated as a fellow human being (*ningenteki, tsujiaeru*).
b. The child is shrewd or mean (*zurui*) or spoiled (*amaeru*).
c. That the accompanied gaze makes the crying difficult to ignore.

If these expressed opinions or attitudes were anything to rely on concerning future parental behaviour in response to infant crying, the following tendency can be hypothesized to occur, namely, for proximal mode of response, increase in latency to respond and decrease in response rate; for distal mode, decrease in latency to respond and increase in response rate. While empirical testing of these hypotheses awaits future research, it is to be pointed out that the findings obtained in this study provide some clues for future empirical studies.

Recent research in motor development has demonstrated the usefulness of the approach variously labelled "dynamic systems approach", or "theory of action systems" (Hofsten, 1989, Pick, Jr. 1989, Reed, 1982, Thelen & Fogel, 1989, Thelen, 1989). In this dissertation is another application of this approach. Furthermore, it was suggested in recent theorizing that the dynamic systems approach would be useful for understanding and guiding research in other aspects of behavioural development (Thelen, Kelso, & Fogel, 1987). It is believed that one direction of future research will be to apply this approach to the development of the infant's inter-personal relationship as mentioned above. Based on what has been obtained concerning the developmental process of an action system from the point of view of the infant, our next steps will be to identify the elementary components of the system in question and the relationship among them, and then to search for the possible "organizers", or, in the term of dynamic systems, the "control parameter" (Fogel & Thelen, 1987, Thelen et al, 1987). It is believed that such an approach will be able to do justice to the complexity of human development.

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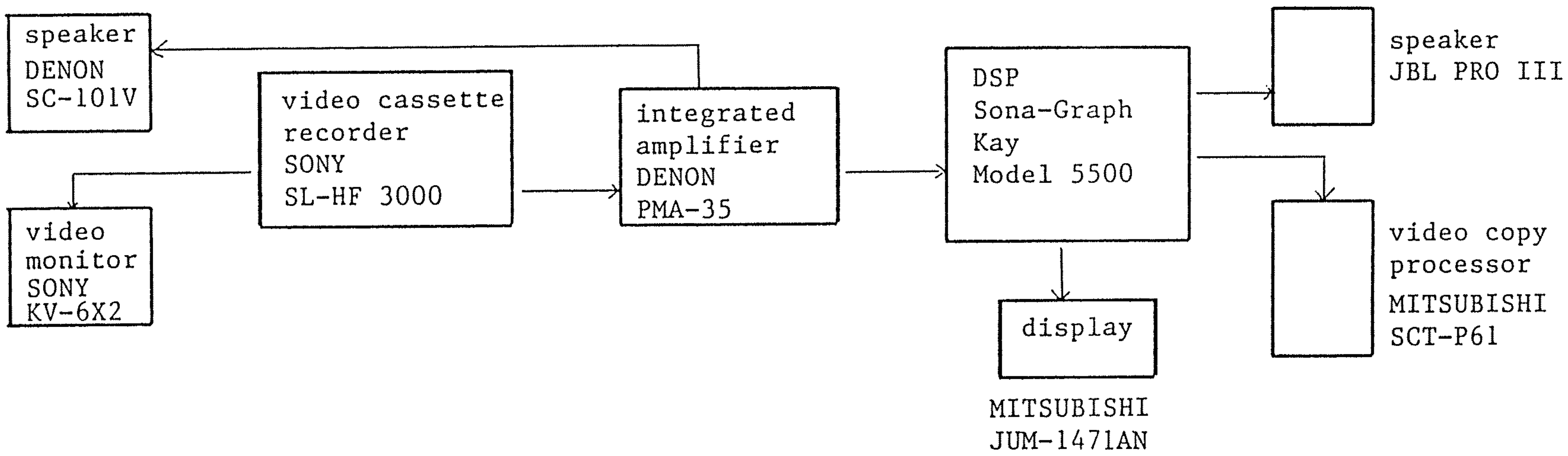
APPENDIX A Block Diagram of Devices Used in Data Analysis



APPENDIX B-1 Results of Statistic Tests

a. Mean Duration of Cry Vocalizations (n=2516)

	Day 0	Day 3	4 Wks	8 Wks	12 Wks
Day 0		ns	t=4.309 df=1146 $p<0.001$	t=5.185 df=1125 $p<0.001$	ns
Day 3			t=4.12 df=928 $p<0.001$	t=5.124 df=905 $p<0.001$	ns
4 Wks				ns	t=2.829 df=812 $p=0.005$
8 Wks					t=3.652 df=802 $p<0.001$

b. Mean Duration of Cry Interval (n=2209)

	Day 0	Day 3	4 Wks	8 Wks	12 Wks
Day 0		t=4.376 df=1113 $p<0.001$	t=2.794 df=1120 $p=0.005$	t=5.766 df=765 $p<0.001$	t=5.986 df=360 $p<0.001$
Day 3			t=7.494 df=863 $p<0.001$	t=9.783 df=593 $p<0.001$	t=8.775 df=306 $p<0.001$
4 Wks				t=3.401 df=725 $p=0.001$	t=4.230 df=359 $p<0.001$
8 Wks					ns

APPENDIX B-2 Cry Sequences of Subject T. E.

0 Day

1. (Lc1)(Pa1)(Da1)(Dc7)(Pc4)(Lc1)
2. (Pa1)(Db1)(Da1)((Dc1)(Pc2)(Dc3)(Db1)
3. (Pa1)(Da1)(Db1)((Dc9)(Pc1)(Dc1)(Pc1)(Dc1)(Pc1)

3 Days

1. (Sb1)(Sc1)(Fa1)(Fc2)(Pa2)(Pb3)(Pa1)((Pc2)((Pb4)(Pc1)(Pb3)(Pc1)(Pb1)(Pc1)(Pb3)(Pb1)(Db2)(Pc1)(Pb2)(Pc3)(D+Fc1)(Da1)(Ka1)(Db3)(Pb3)(Db2)(Pc2)....(interrupted)
2. (Sd1)(Sb1)(Fb1)(Fc1)(Fa1)(Pa3)(Sd1)(Pb4)(Pa3)(Pb3)(Pc10)(Dc1)(Db2)(Pb1)(Pc1)(Pb1)(Dc2)(Da1)(Db1)(Pb1)....(interrupted)
3. (Fa1)(Pa3)(Db2)(Pb1)(Pc3)(Pb5)(Db2)(Pb1)(Pc5)(Pb1)(Pc3)(Db1)(Pc5)....(interrupted)

4 Weeks

1. (Sd1)/5.64 sec/*
2. (Sd1)(Fd1)(Sc1)/17.56 sec/
3. (Sb1)/3.01 sec/
4. (Fd2)/33.81 sec/
5. (Fd1)/7.24 sec/
6. (Sd1)(Fd2)(Ld3)/5.82 sec/
7. (Fd2)(Pa1)/5.39 sec/
8. (Fc1)/6.26 sec/

8 Weeks

1. (Sc2)(Sa1)(Ld1)/4.22 sec/
2. (Ld1)(Lc1)(Sd1)(Ld1)(Bc1)(Sb1)(Ld1)(Pb1)/3.98 sec/
3. (Ld2)(Sb1)(Bb1)(Sd1)/5.08 sec/
4. (Fc1)(Fd1)(B+Fa1)(Sb1)(Sd2)(Fd1)(Pb1)(Pc1)(Pd1)(B+Sa1)(Fd1)(Fc1)(B+Sa1)(B+Fa1)(Fc1)(Pa1)(S+Ba1)(S+Bb1)(S+Fb1)(Bb1)(Pc1)(Bb1)

12 Weeks

1. (Fc1)(Pc1)/24 sec/
2. (Fc2)(Ld1)(Fc1)(Fd1)(Ba1)(Bb1)(Sd1)/3.43 sec/
3. (Sd1)/3.03 sec/
4. (Lc1)/5.53 sec/
5. (Fd1)(Fc2)(Ha1)(Bb1)(Bc1)/12.14 sec/
6. (Sc2)(B+Sb1)(Sc1)(Fc1)(Fb2)(Ba1)(Bb1)(Bc1)(Lc1)(Fd1)(B+Sb1)/3.13 sec/

* Number between slashes indicates time lapse until next vocalization was heard.

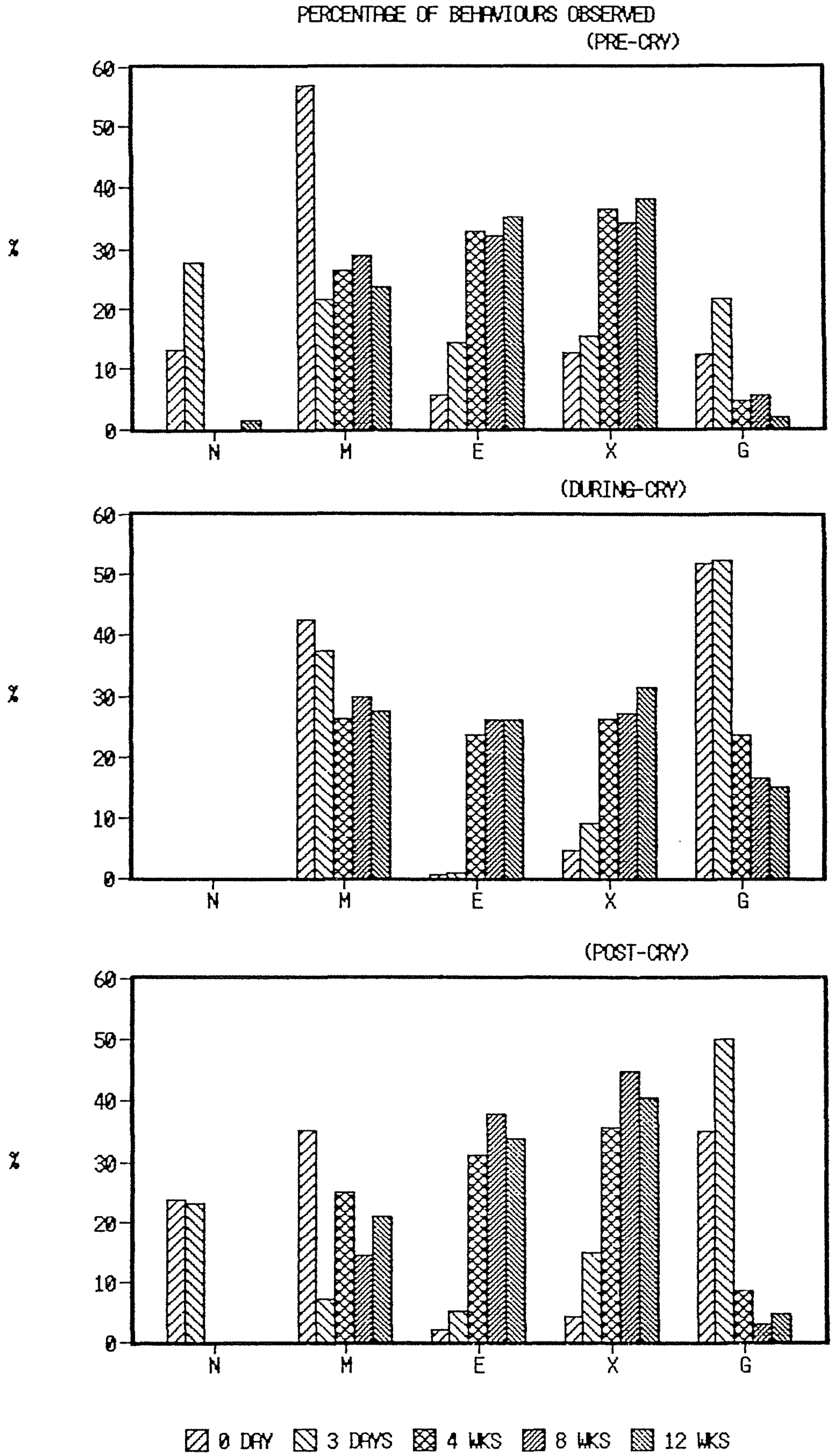
APPENDIX C-1 Summary of Concurrent Behaviours Before, During, and After Cry Vocalization.

	0 day	3 days	4 wks	8 wks	12 wks
PRE-VOC					
N	13.00	27.59	0.00	0.00	1.64
M	56.99	21.56	26.28	28.70	23.37
E	5.49	14.08	32.68	32.03	35.12
X	12.32	15.23	36.53	34.03	38.13
G	12.16	21.56	4.48	5.33	1.78
IN-VOC	0 day	3 days	4 wks	8 wks	12 wks
N	0.00	0.00	0.00	0.00	0.00
M	42.44	37.50	26.28	30.00	27.45
E	0.77	0.83	23.72	26.19	26.22
X	4.68	9.17	26.28	27.14	31.37
G	52.13	52.50	23.72	16.67	14.95
POST-VOC	0 day	3 days	4 wks	8 wks	12 wks
N	23.66	23.08	0.00	0.00	0.00
M	35.31	7.05	25.00	14.37	20.84
E	1.98	5.13	31.10	37.93	33.90
X	4.13	14.75	35.61	44.83	40.56
G	34.95	50.00	8.33	2.88	4.72

N : None of the behaviours observed
M : Movement of the limbs
E : Eye open
X : Visual exploration
G : Grimace

Numbers indicate percentages of the number of units of behaviours observed.

APPENDIX C-2 Summary of Co-occurrent Behaviours Before, During, and After Cry Vocalization.



N: No category observed M: Movement of limbs E: Eye open
X: Visual exploration G: Grimace