CRYING AND BEHAVIOURAL STATE ORGANIZATION IN SIX- TO EIGHT-WEEK OLD INFANTS

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Crying and Behavioural State Organization in Six-

to Eight-week old Infants

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ABSTRACT

The purpose of this investigation was to explore the hypothesis that excessive crying or "colic" in infants is the result of functional disorganization of neurological systems. Behavioural state was used as a window on nervous system functioning, and a previously researched questionnaire was used to obtain parental reports of the infants' levels of crying and levels of activity.

Forty-one six- to eight-week-old infants were videotaped as they lay in a crib in a lab room. Caretakers were asked to intervene only as they would normally (e.g., if the infant cried). Recording continued until sixty minutes of the infant lying undisturbed had been collected.

Video records were scored for predominant state in 10 s intervals, by an observer blind to the level of crying reported for each infant. Behavioural state was rated in seven categories: quiet sleep, active sleep, drowsy, quiet awake, active awake, fussing, and crying. An eighth state, caretaker intervention, was scored whenever the parent intervened with an infant during the recording.

Measures derived from the behavioural state records included frequency of state changes, direction of state changes, proportions of sleep and waking spent in the active states, and the proportion of the observation spent crying. The relationships between crying and indices of state organization were assessed through use of correlations between continuous measures, and t-tests for dichotomous questionnaire items.

The hypothesized pattern of relationships emerged. Crying was associated with greater proportions of active sleep, greater proportions of active awake, lesser proportions of sleep, and greater frequencies of state change.

The findings were discussed in terms of their implications for the problem of excessive crying in infancy.

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INTRODUCTION

Crying

Excessive crying, or "colic", is among the most common pediatric problems in early infancy. Crying is a cause of much concern among parents of young infants. M. Brown (1979) compared two groups of parents of preterm infants, grouping the parents according to how often they sought professional advice about their infants. The only difference between the groups was that parents requiring much professional support perceived greater problems with their infants' level of crying, and their infants' sleep and wake states.

Popular and medical explanations of colic relate excessive crying to gastrointestinal distress or feeding problems. Empirical study does not support this relationship. Ames (1982) reported an extensive review of the research, in which no strong evidence was found to support the popular view. Ames, Gavel, Khazaie, and Farrell (1984) did a factor analytic study of mothers' reports of crying and soothing. Their principal components analysis showed gastrointestinal symptoms and amount of crying to form two separate and unrelated factors. No evidence is available to support the view that excessive crying is caused by gastrointestinal distress in the majority of cases.

Abandoning the gastrointestinal distress explanation of excessive crying, some researchers have suggested an alternative. Weissbluth (1984) suggested that "colic appears to be much more of a neurological developmental condition than a gastrointestinal problem, or a parental problem" (p. 72). Weissbluth focused on the relationship between problems with the sleep-wake rhythms and the synchronization of these rhythms with other biological rhythms. He stated that "the more disorganized these rhythms are the more severe the colicky behavior" (p. 74). Parallelling Weissbluth, Lester (1985) has put forward a similar hypothesis about excessive crying: "Periods of so-called unexplained fussiness and sudden increases in crying that occur in the first few months are probably related to maturational changes in brain structure and shifts in the organization of the CNS" (p. 18). Finally, Brazelton (1985) has reported that "it was an accepted fact that colic lasted only 3 months," (p. 330) and that "the end of this predictably regular, daily crying was bounded by a maturational shift [the so-called "biobehavioural shift"; Emde & Robinson, 1979] in the developing central nervous system and in the psychophysiological organization of the baby" (p. 331).

In the present study, an attempt was made to operationalize nervous system organization and thereby examine the relationship between amount of crying and neurological organization. Neurological organization was operationalized as behaviourally defined state. In the following section, the history and meaning of the state concept will be reviewed briefly. An argument will then be made that the organization of state parameters reflects the underlying functioning and organization of neurological systems. Finally, the specific relationships between amount of crying and behavioural state that are suggested by the theorizing and observations of Weissbluth, Lester, and Brazelton will be made explicit.

History and Meaning of the State Concept

In 1959, Peter Wolff published "Observations on Newborn Infants". Wolff's subjects were four newborn infants, and each was observed for an average period of seventeen hours per day over their first five days of life. Wolff was looking for "stable and distinguishable patterns of behaviour" (p. 2). He found six such patterns. Regular sleep and irregular sleep were distinguished by differences in respiration and in the amount of movement by the infants. Drowsiness was identified by periodic opening and closing of the eyes. Alert inactivity, alert activity and crying were three patterns of waking behaviour that he described. Thus, Wolff became the first infant researcher to provide a descriptive categorization of states in infants.

The most frequently-cited definition of state in this context comes from Ashby (1957, p. 25) who described a state as "any well-defined condition or property that can be recognized if it occurs again." An infant is a biological system, and an infant's behavioural state is identified by one or more behavioural criteria that can be recognized by an observer.

The importance of the state concept was quickly recognized by infancy researchers. At first, state had a wide diversity of meanings. Escalona (1962) wrote about state in the context of the methodology of developmental research. She saw behaviour as a function of the "state" of the organism, the stimuli acting on the organism, and the broader environment in which these forces interact. Escalona considered state to include a wide range of variables including position, time since feeding, and time since last startle response. Pointing to such a wide variety of factors, Escalona stated that she could "see no way of sufficiently controlling the multiple state variables in order to make research conclusive..." (p. 36). It seemed more useful, then, to restrict the connotation of state to the various classes of wakefulness and sleep. Such a connotation was accepted in the field and this more limited state concept was quickly and widely seen as a factor to be considered in the study of newborns (Bell, 1963; Prechtl & O'Brien, 1982).

After the concept was initially accepted, the problem of state became one of describing what these patterns of behaviour represented. Early researchers considered the states to represent a continuum of arousal from the most quiescent sleep to the most highly aroused crying (Wolff, 1959). Bell (1963) used the terms state and arousal interchangeably, and J.L. Brown (1964) considered state to represent variations in tension.

The notion of states as forming a continuum of arousal has since been generally discarded (Anders, 1974), for both logical and empirical reasons. Ashton (1973a) outlined a logical problem concerning the multi-dimensional nature of ratings of both state and arousal. Since neither state nor arousal could be rated along any unidimensional scale, no one-to-one correspondence between state and arousal could be claimed.

There were more empirically based reasons for rejecting the arousal continuum notion. Some of these reasons came from studies of sleep. Very early conceptualizations of sleep were of a unitary state of restitution. Sleep was described by a simple parallelism with rest (Roffwarg, Muzio, and Dement, 1966). However, at least two sleep states are now recognized. They are popularly described by the presence or absence of rapid eye movements (REMs) under closed eyelids. During REM sleep, a fast, low-amplitude EEG pattern is present and this pattern is very similar to that seen in awake states (Prechtl and O'Brien, 1982). Furthermore, despite lowered response to stimuli, there is greater spontaneous activity in infant REM sleep as compared to non-REM sleep (Roffwarg et al., 1966). In fact, infants' activity during REM sleep is such that if it is measured by means of a sensitive air-filled mattress, the level of activity has been shown to exceed that manifest during non-crying wakefulness (Emde, Gaensbauer, & Harmon, 1976). The fact that one of the sleep states could be seen to be a state of "greater arousal" than one of the wake states was contrary to the notion of an arousal continuum.

The study of reactivity also yielded results conflicting with the arousal continuum description. Researchers assumed that a continuum of arousal would be reflected in a continuum of reactivity to stimulus. This assumption was not borne out. Bell and Haaf (1971), for example, studied infants' reactions to such situations as the removal of a pacifier or being placed face down. These researchers were searching for the order of the state continuum, reasoning that "if states affect other behaviours, the best order would be that best correlating with other behaviours" (p. 72). Bell and Haaf were unable to find any ordering that was well correlated with reactivity. Ashton (1973a) was also among those examining the relationship between state and reactivity. He found reactivity to be an interactive function not only of state, but also of stimulus intensity, time since feeding, and the response parameter noted.

For the reasons outlined, the conceptualization of states as forming a continuum was generally discarded. Even Wolff (1984), an original proponent of the continuum concept, has accepted this point. After arguing against the notion of an arousal continuum Ashton (1973b) went so far as to suggest that the state concept should itself be discarded. In addition to his review of the arousal continuum and reactivity ideas, Ashton examined various state rating scales used up to that point. Noting small discrepancies between systems, Ashton decided that the state variable was usually idiosyncratic to each separate team of researchers. From this, he came to interpret state as nothing more than a convenient abstraction. Ashton suggested that researchers were using state only because it was easier than noting all the separate aspects of infants' behaviour. Ashton's position was not widely adopted. Instead, researchers came to see states not as forming a continuum but as discrete patterns of behaviour representing discrete modes of neurological functioning.

Behavioural State and CNS Functioning

Since Wolff's (1959, 1966) original presentations of the concept, state has come to be seen as a direct reflection of nervous system functioning. The following are some short, representative quotes:

> One of the last domains where higher cortical function remains the dominant view is that of state regulation. (Amiel-Tison, 1985, p.368);
>
> The capacity to synchronize internal rhythms with each other ... appears to involve higher central nervous system activity (Anders, 1974, p.36);
>
> States represent sustained levels of organization of brain function that occur spontaneously (Parmelee & Stern, 1972, p.200); and finally,
>
> States are assumed to be expressions of fundamental processes in the central nervous system which can be studied by behavioural ... procedures (Thoman, Denenberg, Sievel, Zeidner, & Becker, 1981, p.46).

A relationship between neurological functioning and state is widely and explicitly assumed. There are several classes of evidence to support the assumption of states as a reflection of CNS functioning. Some of the evidence is strong and some is weak, but taken together, the various pieces of evidence form a good case.

A necessary first step is to demonstrate through naturalistic observation of neonates that there is something worth studying. Since Wolff's pioneering studies, several researchers have formulated state-rating schemes. There are small differences between these schemes, and as described earlier, Ashton (1973b) focused on the variations and saw state as idiosyncratic to individual researchers. In contrast, Korner (1972) focused on the smallness of the discrepancies and wrote that "it is striking that the overlap of criteria far exceeds the differences" (p. 79). Emde and Robinson (1979) have pointed out that almost all state rating schemes include at least two sleep states (active and quiet), at least two waking states (active and quiet), and at least one crying state. Considered together, the various state rating schemes demonstrate that there is substantive agreement regarding state indices useful in understanding infant behaviour (Korner, 1972). Prechtl and O'Brien (1982) have argued that this high level of agreement is important for strengthening the proposition that "states are a priori patterns of activity and not simply constructs of the observer's mind" (p. 62).

Naturalistic observation offers nothing to connect behavioural states to nervous system functioning. Rather, it brings the study of the assumed relationship to its natural starting point. One can now be sure that there is something to study. State is not simply a convenient abstraction; there is some phenomenon that researchers commonly observe.

The study of sleep has provided important information about the relationship of state to neurological functioning. Several researchers have described the development of state patterns in fullterm and preterm infants. The findings are generally consistent from one study to another. Parmelee, Wenner, Akiyama, Schultz and Stern (1967) found that premature infants of less than 34 weeks gestational age (GA) showed only a single sleep state, an ill-defined active sleep. By 36 weeks GA, the active sleep state was better defined and had come to resemble Stage I REM sleep of adults. As well, the premature infants had begun to spend a larger and larger proportion of their total sleep time in quiet sleep, although still spending much time in an active sleep state. In contrast, fullterm neonates spend about equal proportions of their sleep time in active and quiet sleep (Berg & Berg, 1987). By three months past term, all infants spend about twice as much time in quiet sleep as in active sleep (Emde & Robinson, 1979). The changing ratio of the sleep states is a function of decreasing amounts of active sleep, not increases in quiet sleep (Berg & Berg, 1987).

Coons and Guilleminault (1984) observed thirty infants over the period between 3 weeks and 6 months of age. They found that at three weeks of age, the longest single period of sleep was an average of 23% of total sleep time. By six months of age, the longest single sleep period had increased to an average of 48%

of total sleep time. They also found that by 6 weeks, the longest single sleep period usually followed the longest single awake period. By six weeks this sequence, the longest sleep following the longest wake, would tend to occur at a non-random time and by three months of age this sequencing effect was quite robust.

Another facet of the organization of sleep reported by Coons and Guilleminault was the direction of sleep onset. In contrast to the adult pattern, young infants usually begin sleep in an active sleep state, then move into quiet sleep. Coons and Guilleminault showed that over the first six months of life the proportion of active sleep onsets decreases dramatically, to be replaced by quiet sleep onsets.

Coons and Guilleminault reported that the ordering of states and the consolidation of sleep occurred prior to a swing to circadian rhythms (i.e., the longest sleep period occurring at night). That is, they suggested that the various states develop and become organized independently of one another, and that "it is only once such organization has been established that the influence of environmental stimuli can bring about a day/night state distribution" (p. 175). By this interpretation, sleeping or waking cycles develop independently of circadian rhythms, only entraining to day and night rhythms after becoming independently organized. This strengthens the proposition that state patterns are fundamental expressions of neurological development.

The most significant fact about developing sleep patterns vis-a-vis nervous system functioning is the increasing proportion of quiet sleep. McGinty (1971) expressed the accepted view that "during development the neural control of sleep appears to shift from a mechanism organized within the brainstem to forebrain mechanisms" (p. 343). McGinty referred to this as the encephalization of sleep (cf. Stern, Parmelee, Akiyama, Schultz, & Wenner, 1969; Booth, Leonard, & Thoman, 1980; Emde & Robinson, 1979). The exact formulation of this view has been slightly revised (e.g., Berg & Berg, 1987), but the principle remains sound.

There is some empirical evidence to support this view. McGinty (1971) reported that there are similar patterns of ontogeny of sleep across species and that, therefore, cats are often used to illuminate neural processes of human sleep. Using cats as subjects, Sterman and Clemente (1962) showed that electrical stimulation of the forebrain induced a quiescent sleep state. This finding, they said, supported the interpretation that processes of suppression (e.g., quiet sleep) are active, basic functions of the central nervous system. Jouvet (1962) found that removal of all neural tissue above the rostral pons (at the top of the brainstem) resulted in an active sleep-like state in cats, whereas some lesions of the forebrain brought about an abolition of both active and quiet sleep. Electrophysiological data provided by Prechtl (1974) supported the role of the forebrain in quiet sleep. He utilized the concept of EEG coherences. When recording from two points on the scalp, a coherence is a type of correlation between the two recordings. Such a correlation is assumed to represent some common organized activity between the two points. Prechtl (1974) reported that during state 1 (quiet sleep), high coherences occurred during fronto-central recording, and these continued to the end of the quiet sleep episode. The same sort of coherences were not present during state 2 (active sleep). In addition, this pattern of results was not present during centro-parietal recording.

These studies illustrated an important idea. Quiet sleep is under cortical control or influence. In contrast to the older, more simplistic view that quiet sleep is a function of the forebrain, and active sleep a function of brainstem mechanisms, quiet sleep is seen to be influenced by both forebrain and brainstem mechanisms. Nonetheless, the development of quiet sleep awaits the development of forebrain mechanisms, the exact nature of which remains unclear. Over the first few months of life, sleep changes from being principally regulated by the brainstem to being regulated by both brainstem mechanisms and cortical mechanisms (Berg & Berg, 1987). Therefore, the supposition that changes in various state characteristics reflect the infant's neurological maturation (Booth et al., 1980) seems to be a reasonable one.

Another area of research that suggested that the various states represent different modes of CNS functioning is the study of reflex responses. An illustrative study is that of Vlach, Bernuth, and Prechtl (1969), who stimulated twenty 4- to 8-week-old infants to elicit a variety of exteroceptive skin reflexes. They were able to subdivide the twelve reflexes they examined into three groups. Finger and toe reflexes were highly state dependent, absent in quiet sleep and easily elicited during wakefulness. The second group of reflexes, including the pubic, axillary, and inguinal reflexes, showed no state dependency. A third group of reflexes showed a moderate degree of state dependency.

The different patterns of reflex responsiveness reported in Vlach et al.'s study and elsewhere (e.g., Beintema, 1968) provided some evidence that the functional properties of the nervous system differ in the different states. That is, if response patterns are different in different states, then the underlying neural functions that mediate these responses are likely different.

Prechtl (1974) has presented a strong piece of evidence to suggest that states reflect the functioning of the nervous system. Using statistical procedures, he showed that the functional properties of the nervous system differ in the different states. He took seven different measures of physiological functioning (respiratory and heart rates, their interquartile ranges, EEG mean squared amplitude, number of REMs, and time with EMG present). He then compared the physiological measures with independently assessed behavioural state ratings. Using discriminant analysis, Prechtl found the polygraphic variables reliably clustered into the different states. Similar results using other techniques were reported by Stern et al. (1969). Behaviourally defined states were shown by this method to reflect underlying physiological variables which in turn reflected neurological function.

A final class of evidence for the relationship of behavioural state to CNS function is found in the study of neurologically disordered infants. It was in this area that the relationship between underlying neural systems and state organization was first suggested. Beintema (1968) introduced behavioural states into his neurological examination of newborns in order to control for differing levels of reflex responsiveness in the different states. What was noticed, however, was that babies with neurological problems showed unusual sequences of behavioural states throughout the examination (Prechtl and O'Brien, 1982). Since then there have been many studies and case reports to support their observation.

A comparison of the organization and stability of sleep states in fullterm, preterm, and small-for-gestational-age (SGA) infants was undertaken by Watt and Strongman (1985). These researchers found that preterm infants at forty weeks GA, "who might be expected to reflect a degree of compromise in their neurological organization" (p. 160), showed more frequent state changes, and therefore less state stability, than did fullterms of forty weeks GA. As well, the SGA infants showed higher proportions of active sleep at forty weeks GA than either the fullterms or the preterms.

Watt and Strongman also reported that while preterms were less organized with respect to stability, these infants did demonstrate a higher proportion of quiet sleep at term than did fullterm infants. This somewhat paradoxical finding, which has been reported in other studies (e.g., Booth et al., 1980; Michaelis, Parmelee, Stern, & Haber, 1973), can be reconciled with the assumed CNS/state relation. Amiel-Tison (1985) has reported that under unfavourable conditions, CNS maturation may in fact be accelerated. One would not expect that this accelerated maturation would match a more "normal" course of maturation. In this way, one might be able to reconcile the unusual pattern of premature infants' states, more and less mature, depending on the parameter noted.

In 1976, Monod and Guidasci studied a group of twenty newborns displaying various neurological pathologies including trisomy 21, hydrocephaly, and microcephaly. They compared the behavioural state records of these infants with the behavioural state records of twenty-nine normal infants. The pathology group showed much less sleep in general, and their sleep was difficult to classify as quiet or active. In extreme malformations of the brain, only a single state was observed, and this state could not be classified as either awake or asleep. This is similar to the pattern shown by premature infants of less than 29 weeks GA. In a separate study, Dreyfus-Brisac (1979) reported that infants with neurological pathologies often showed periods of indeterminate sleep, classifiable as neither active nor quiet.

Monod and Guidasci used four different methods of classifying sleep states. For normal babies, the different procedures resulted in similar profiles for each infant. In contrast, "assessment of sleep states ... can be very difficult in abnormal babies and give different results if different methods of sleep assessment are used." (p. 232). Prechtl (1974) reported the results of discriminant analyses of abnormal infants' state profiles showed much dissociation and wide overlaps of state clusters compared to the same analyses of normal babies' profiles.

Aylward, Lazzara, and Meyer (1978) reported a case study of a hydranencephalic infant. This infant had virtually no cerebral hemispheres. In their report, Aylward et al. focused on more traditional neurological and cognitive signs (e.g., the baby did display an habituation response to loud noise), but they gave some mention to states. The infant displayed much inconsolable crying and a very high rate of state shifts. This poor state regulation, they reported, "suggests cortical mediation" (p. 216) of state behaviours.

Related to the studies of neurologically impaired infants are studies of the predictive nature of measures of state organization. Thoman (1975) wrote a fairly general report of her research on the development of behavioural states in infants, and one measure that she reported was rate of state changes. For thirty-nine of the forty infants she studied, the rate of state changes clearly decreased over the first month of life. Only one infant showed an increasing rate of state changes over time. That infant was later a victim of Sudden Infant Death syndrome. This finding is not at all conclusive but it is often quoted, and Thoman and her colleagues were spurred on to explore the correlates of state development.

Thoman, et al. (1981) developed a measure of state stability. For this measure, records of the relative amounts of time spent in each state are produced for each of two observations. The records are compared and an index number produced. If the profiles are similar, states are described as stable and a high number results. In the first study using the state stability index, twenty-two healthy fullterms were subjects. The four infants with the lowest stability scores each developed major problems by thirty months of age. One developed aplastic anemia, a second had hypsarrhythmia (an unusual EEG pattern associated with infantile spasms), another died of SIDS and a fourth was hyperactive. None of the infants at the high end of the continuum showed any evidence of developmental dysfunction at thirty months of age.

Becker and Thoman (1982) found a strong negative correlation between the frequency of REM storms (sudden, brief bursts of high frequency REM) at six months and state stability scores in the first month. They also found that high rates of REM storms predicted significantly lower scores on the Bayley scales of infant development at one year. A year later, in 1983, Becker and Thoman compared state stability scores for the times infants were alone to state stability scores for the times infants were with their mothers. State stability scores calculated during the two situations were well correlated for the individual infants. This was evidence for individual consistency in state organization. Becker and Thoman interpreted this finding "as evidence for overall integration of the central controls for both sleep and wakefulness" (p. 408), regardless of environmental contingency.

Finally, Tynan (1986) used the state stability index to assess thirty-seven infants in a neonatal intensive care unit. Once again the measure was very powerful in predicting outcome. He reported that there were no known false positives or false negatives using the measure. For example, he reported a case of an infant not expected by medical staff to do well. The infant's stability index was high and he thrived. Another infant showed normal signs for a premature infant and had a positive prognosis. His low state stability index was the only measure that predicted his later, severe problems.

To summarize, behavioural state is a relatively new concept in the study of infancy. Anders (1974) has referred to behavioural state as a window on CNS functioning, and the evidence presented makes a fairly strong case for this contention. States can be assumed to reflect neurological functioning based on several classes of evidence. Development of state parameters and state organization accompanies maturation of the nervous system as shown by studies of the ontogeny of sleep. Physiological measures correlate well with behaviourally-defined state. Neurological defects are manifest in abnormal state patterns. Finally, at least one measure of problems with the organization or stability of states has been shown to be very powerful in the prediction of later physiological problems.

Crying and Behavioural State

No explanation for excessive crying in infants is well supported by currently available data. Explanations based on gastrointestinal distress are without empirical support, despite efforts of researchers to find such evidence. The newest proposed explanations focus on excessive crying or "colic" as a neurological problem; colic is seen as being the result of neurological disorganization. The proposed colic/nervous system relation is based on the coincidence of the timetable of colic, beginning at about 3 weeks and ending at about 3 months, and the timing of the often-referred-to "biobehavioural shift" completed at about 3 months (cf. Emde, et al., 1976; Clifton, Morrongiello, Kulig, & Dowd, 1981; Davis & Rovee-Collier, 1983; Brazelton, 1985), and on the clinical perceptions of Weissbluth, Lester, and Brazelton. This hypothesis is provocative, but it too is largely without strong, empirical support.

Behavioural state has been seen as a vehicle for the study of infants' neurological development. This view is well supported by empirical study, as indicated by the foregoing review.

If neurological disorganization causes crying, and if behavioural state reflects neurological functioning, then infants with higher levels of habitual crying should display greater disorganization of behavioural state parameters. There are two studies that gave some very tentative support to the proposed general relationship between amount of crying and state organization. First, the study by M. Brown (1979) revealed that parents showed high levels of concern over both infants' crying and their sleep-wake states. This was suggestive at best, but the result did point to a relationship between behavioural state and crying in the eyes of parents. Second is a study by Ames and Bradley (1983). These researchers compared groups of infants classified by mothers as being either colicky or not colicky. Colicky infants had scored more poorly as neonates on a scale named "state regulation" that included items relating to consolability and ability to self-quiet. This evidence is not strong, but it is consistent with a proposed relationship between amount of crying and behavioural state organization.

The present study was designed to determine more directly the relationship between amount of crying and behavioural state organization. Parental reports of the length and frequency of crying episodes and of whether an infant had been described as colicky formed the measures of habitual amount of crying, along with an observational measure of crying. Infants were videotaped and the videotape records scored for behavioural state. The behavioural state records and parental reports of infants' behaviour provided the measures of behavioural state organization.

The specific relationships hypothesized in the present study had been clearly suggested in the writings of Brazelton (1985), Lester (1985), and Weissbluth (1984). Weissbluth speculated that excessive crying was related to sleep difficulties, and Lester, Weissbluth, and Brazelton appeared to share the view that excessively crying infants are less able to suppress the "ever present background restless, random fidgety behaviors" (Weissbluth, 1984, p.72). Weissbluth specifically stated that colicky infants "always seem to sleep in an active fashion" (p. 72). As well as differences in the nature of sleep, Weissbluth reported that excessive criers "usually behaved as if they suffered from... not enough sleep," (p.72) and that "briefer sleep durations were observed among infants with colic" (p.73).

There is some empirical support for a relationship between sleep patterns and amount of crying. Using parental reports, Snow, Jacklin, and Maccoby (1980) reported positive correlations between the number of sleep-wake transitions and amount of crying over the first two years of life. Bernal (1973) also used parental reports, and she showed a positive relationship between amount of crying during the first ten days of life and sleep problems reported at fourteen months. Other studies (Weissbluth, Davis, & Poncher, 1984; Blurton-Jones, Ferreira, Brown, & MacDonald, 1978) have reported similar relationships, using retrospective parental reports. No direct observational studies of the relationship between amount of crying and sleep variables has been reported.

Further to the crying/sleeping relationship, the proportion of sleep time an infant spends in active sleep clearly has been seen to be an indicator of regulatory difficulties. J.L. Brown (1964) noted that infants "who spend a large amount of time in disturbed sleep are manifesting homeostatic difficulties that make it hard for them to attain a quiet awake state" (p. 319). Conversely, Thoman (1975) considered an infant to be well-organized if "he spent a relatively large amount of time in quiet sleep" (p. 302).

Based on the proposed relationship between sleeping and crying, two hypotheses were advanced. The first hypothesis was that the habitual amount of crying reported by parents and the amount of crying observed would be positively related both to parental reports of restless sleeping and to greater proportions of total sleep time spent in an active sleep state during the observation. Hypothesis 2 was that there would be negative relationships of both reported amount of habitual crying and observed amount of crying with proportion of an observation period spent in a sleep state.

Focusing on the proposed inhibitory difficulties of excessive criers, Lester, Weissbluth, and Brazelton each pointed to generally increased activity levels in these infants. Weissbluth noted that the waking behaviour of excessive criers is more active and vigorous, and Brazelton (1985) reported that it was "active, intensely driving babies [who] were likely to have long periods of crying" (p. 331). The third hypothesis was that amount of crying, reported and observed, would correlate positively both with parental reports of waking activity and with proportions of awake time spent in an active awake state.

The fourth and fifth hypotheses concerned state changes. Coons and Guilleminault (1984) suggested that the ability to maintain a state efficiently was a reliable indicator of CNS organization and maturation, and Thoman (1975) stated that when infants are seen "who deviate markedly in terms of state durations, frequency, and nature of transitions, their state organization can be considered to be aberrant" (p. 302). Brazelton (1985) has suggested that the extreme patterns seen in excessive criers are correlated with "other types of activity such as their abilities to control state shifts" (p. 332). Therefore, hypothesis 4 was that both reports and observations of amount of crying would be positively correlated with number of state transitions per unit of time.

The fifth hypothesis was related to the nature of state changes. Thoman (1975) and Prechtl (1974) have each noted that any infant can move from any one state to any other state. Some transitions, however, are more likely than others. Thoman (1975) referred to unusual state changes, Prechtl and O'Brien (1982) had noted the unusual state changes of neurologically damaged infants, and Brazelton (1985) reported that it is excessive criers who are seen "shooting from quiet state to crying and back again to an exhausted state" (p. 335). Therefore, the fifth hypothesis was that amount of crying would be positively correlated with the proportion of an infant's state changes that occurred with low frequency, based on the patterns of state changes made by infants in the present study.

METHOD

Subjects

Forty-seven 41- to 56-day-old infants and their parents participated in this study. This age range was chosen because 40 to 56 days is the period when crying is at its peak for both normally and excessively crying infants (Illingworth, 1954; Meyer & Thaler, 1971; Rebelsky & Black, 1972). Records for six infants were not used: three were pre-test infants and their videotapes were used for training coders; two infants were withdrawn by their parents because of excessive crying during the observation, and one videotape was unusable because of equipment failure.

The mean age of the 41 infants retained was 48 days, ranging from 41 to 54 days. Twenty of the infants were male and 21 were female. All had been fullterm births, and their mean birthweight was 3360 g, with a range of 2300 g to 4200 g. Of the 41 infants retained in the study, two were exclusively bottlefed while the other 39 were breastfed. Four of the pregnancies were reported to have had complications. One mother reported chronic nausea for the first four months, a second reported a breech presentation, a third recalled three episodes of premature labour, and finally, one mother reported gestational diabetes (that infant's birthweight was 3300 g). All of the infants were reported to be healthy at the time of the observation. Mothers' and fathers' mean ages were 30 and 33 years, respectively, with a range from 19 to 44 years both for fathers and mothers. The mean number of years of education completed was 14 for both fathers and mothers, with fathers' education levels ranging from 9 to 20 years completed, and mothers' ranging from 10 to 23 years education completed.

Parents interested in having their infant participate in studies at Simon Fraser University were contacted through the maternity wards of four Greater Vancouver hospitals where they received a postcard with an explanatory covering letter. Parents returned the postcard to register their infant in the University Infant File.

Parents of infants of the appropriate age were contacted by telephone and a mutually convenient time set. Parents were asked to bring their infants to the university in either the late morning or early afternoon. Early mornings were excluded for the convenience of the parents and late afternoons were excluded after the only two infants to be scheduled in the late afernoon were the only two infants to be withdrawn from the study.

All of the infants were fed after arriving at the university but prior to the beginning of the observation. This was requested to control any possible effects due to variations in time since feeding (cf. Ashton, 1973b; Bell, 1963).

Apparatus

The observation sessions were conducted in a 3 m x 3 m carpeted room dedicated to the study. A 73 cm x 110 cm wooden crib with 10 cm high sides was placed midway between the sides of the room and against the back wall. A commercially available crib pad formed the mattress and a commercially available crib bumper was placed about the sides. Sanyo videotape cameras, model #VC 1620X, were placed on either side of the crib. The signal was fed through a Viscount switcher, model #2VISK, so recording was from only one camera at a time. From the switcher, the signal was fed through an RCA video time-date generator, model #TC1440A, to superimpose the date and time of the recording along the top edge of the image. The signal was recorded on a Panasonic videotape recorder, model #AG-6200, and monitored on a small black and white television. Infants' vocalizations were recorded with a small Sony microphone, model #ECM16, suspended 40 cm above the crib and connected to the videotape recorder. Later coding of the videotapes was done using the same videotape recorder, and a Sony television monitor, model #KV1207, with a small locally designed and manufactured electronic timer used to signal ten-second segments.

Procedures

Videotape Observations

Before the observation period began, parents were told that the study was an investigation of the possible relationship between infants' crying and sleeping and waking patterns. After the baby was fed and settled to the parent's satisfaction the parent was asked to place the infant in the crib in the infant's usual position. The cameras were focused and aligned so as to have as much of the infant's body in the picture as possible, always including the entire head. All but the infant's feet was usually on screen.

The parent and researcher remained in the room with the infant, out of the infant's sight. The researcher monitored the television screen, and switched from one camera to the other to keep the infant's face in the picture. The parent was asked to leave the baby undisturbed except for routine caretaking (e.g., wiping away small spills), or intervention in crying or fussing. Parents were told that if the infant fussed or cried, the situation should be handled as it normally would at home. Thus, infants were left to cry or they were soothed, as the parent preferred. Becker and Thoman (1983) described state as "an integrated outcome of infant-environment interaction" (p. 405). Therefore, to have altered or controlled the parent's usual responses to the infant's crying and fussing would have been to alter the infant's usual state behaviours, more than could have been justified in this study. If an infant was picked up by the parent, the videotape was paused, recording the occurrence of the intervention, and the taping resumed as soon as the infant was returned to the crib.

During the observation session, parents were asked to complete a questionnaire This questionnaire had been used in previous studies (e.g., Ames et al., 1984), and contained several questions about the infant's usual sleeping and waking behaviours, amount of crying, and some basic demographic information. Responses formed the basis of all parental self-report measures.

The session was ended after at least sixty minutes of the infant undisturbed had been videotaped, exclusive of the time spent in caretaker intervention. This duration was chosen following Thoman (1975), who demonstrated that one hour of observation is sufficient time to reveal infants' individual differences in behavioural state measures. This duration also compared favorably to Brazelton's Neonatal Assessment Battery, a 20 to 30 minute exam that includes a "state regulation" scale (Brazelton, 1985). Infants spent a mean time of 85.6 minutes in the observation period, with a range of 62 minutes to 134 minutes.

Behavioural State Coding

The videotape records were rated for predominant state in 10 s segments, beginning with the first second of the video record, and ending with the last complete 10 s segment. An electronic timer which emitted a tone every 10 s was coordinated with the time record superimposed on the video record. The audio signal of the timer was used so that coders could visually monitor the infant at all times, not having to visually monitor the timing of the segments. At the end of each 10 s segment the coder rated the predominant state during the segment. For example, if an infant spent 4 s of a segment in one state and 6 s of that segment in a second state, the second state would be rated as the predominant state for that segment. Exact timing of these segments was not required; coders made a judgement as to the predominant state.

Coding was done using a seven-point scale of behavioural state categories, adapted from Prechtl (1974), with modifications similar to the scale used by Wolff (1966). The modifications were made principally to give the behavioural state scale continuity with other research done at Simon Fraser University (e.g., Mackinnon, Ames, Davis, Carfantan, Pierlot, & Lemke, 1986; Fisher, 1986). The modifications consisted of adding a fussy state and a drowsy state to Prechtl's original five. Also, the respiration criterion was dropped from Prechtl's scale because it would have been difficult to score reliably from videotape records. The scale's seven states were: quiet sleep, active sleep, drowsy, quiet awake, active awake, fussing, and crying. The states were numbered 1 through 7, respectively, to speed coding. An eighth state, caretaker intervention, was added, and this state was scored whenever the parent engaged in any sort of behaviour with the infant. Table 1 contains a description of the criteria for coding each state.

Coding of all of the videotape records was done by one individual, who was blind both to the habitual amount of crying reported for each infant and to the exact hypotheses of the study. A second coder, also blind to amount of crying and the exact hypotheses, scored a randomly selected eleven videotapes, so as to establish the reliability of the ratings. The two coders were trained together, using the first three videotapes made. After the initial training, coders made their ratings independently. The mean kappa (Cohen, 1960) for the coding was 0.82 with a range from 0.53 to 0.95. The individual kappas are presented in Appendix A.

TABLE 1

STATE CODING CRITERIA

STATE	EYES	MOVEMENT	VOCALIZATION
Quiet Sleep	Closed	Absent	None
Active Sleep	Closed	Present	None
Drowsy	Opening/Closing	Absent	None
Quiet Awake	Open	Absent	None
Active Awake	Open	Present	None
Fussing	Open/Closed	Absent/Present	Whimpering
Crying	Open/Closed	Absent/Present	Continuous Crying

RESULTS

Pearson correlation coefficients were calculated to assess the relationships between continuous measures, and t-tests were used to evaluate the difference between means of groups formed by dichotomous measures. One relationship, between two dichotomous measures, was examined by Fisher's exact test for a 2 x 2 contingency table. Groups formed by dichotomous measures were very disparate in size, so t-tests were based on the more conservative strategy of using separate, rather than pooled, variance estimates, except for the exploration of sex differences, which was based on comparably sized groups. Each hypothesis was considered to be a separate "family" for the Bonferroni correction, the adjustment of probability levels used to test the statistical significance of the results. All significance tests of the correlations and the t-tests were two-tailed.

Cry Measures

For each hypothesis, three different measures indexed crying.

1. Observed crying was the proportion of the observation that an infant spent crying. It was derived by dividing the total number of segments rated crying by the total number of segments scored for the infant. The mean proportion of the observation that infants spent in a crying state was 0.03

(<u>SD</u> = .07) with a range from 0 to 0.36.

2. The <u>cryscore</u> was obtained by summing the responses to three questionnaire items:
   a. "Approximately how many times per day does your baby cry?", scored on a 4-point scale (0 to 3);
   b. "How long does the single longest crying episode last each day?", scored on a 5-point scale (0 to 4); and,
   c. "How long does the average crying episode last?", also scored on a 5-point scale (0 to 4).

   This measure was first described and used by Wilkie (1983). The cryscore has a potential range of 0 through 11, with infants reported to cry more receiving higher scores. Mean cryscore in the present study was 3.3 (<u>SD</u> = 2.1).

3. The third cry measure, another parental report item, was the simple dichotomous question "Has anyone ever said your baby has colic?". Ten parents answered "yes", 29 answered "no", and two did not respond.

<u>Relations Among Cry Measures</u>

There was a weak, positive relation between the cryscore and observed crying that did not approach statistical significance ($r(41) = .18$, $p = .265$). T-tests between groups formed by the colic item only approached statistical significance. The mean of the colic group on observed crying ($M = .08$, $SD = .12$) was higher than the non-colic group ($M = .02$, $SD = .04$), but the difference was not statistically significant ($t(9.6) = 1.77$, *p* = .109). Similarly, while the mean cryscore for the colic group (*M* = 5.0, *SD* = 2.6) was higher than the mean cryscore for the non-colic group (*M* = 2.9, *SD* = 1.6), the difference was not statistically significant ($t(11.5) = 2.4$, *p* = .033) if correction for three tests was considered (i.e., if alpha family-wise is set at *p* = .05, alpha per test is .05/3 or *p* = .016).

Sex Differences

No evidence of sex differences has been reported for any of the state measures used in this study, and there are no sex differences that have been reported in the incidence of colic.

For each of the continuous measures used in the present study, t-tests were performed to test male/female differences, and Fisher's exact test was used to test for differences in the distribution of reports of colic. There were no statistically significant sex differences in any of the measures.

Caretaker Intervention

In the present study, parents were told that when an infant cried, the infant should be attended to or left alone, as the parents saw fit. Thus, observed crying by the infant was partly under the control of the infant, and partly under the control of the parents. Therefore, an examination of the relationship between caretaker intervention variables and crying variables was considered to be necessary.

A first measure was the number of times the parent intervened during the observation period (*M* = 4.8, *SD* = 4.6). This measure appeared to be positively correlated with observed crying ($r(41) = .20$, $p = .203$), appeared to show a negligible correlation with cryscore ($r(41) = .02$, $p = .875$), and had a higher mean for the colic group (*M* = 7.0, *SD* = 5.9) than for the non-colic group (*M* = 4.3, *SD* = 3.9; $t(11.8) = 1.32$, $p = .213$). None of these relationships approached statistical significance.

The second measure of caretaker intervention was the proportion of the entire observation period that the infant spent in segments scored caretaker intervention (*M* = .22, *SD* = .16). This measure showed no statistically significant correlation with observed crying ($r(41) = .22$, $p = .168$) or with cryscore ($r(41) = .07$, $p = .675$), and the difference between the colic group mean (*M* = .25, *SD* = .16) and the non-colic group mean (*M* = .22, *SD* = .16) was not statistically significant ($t(16.3) = .59$, $p = .566$).

In summary, caretaker intervention variables showed no significant relationships with the crying measures. Reference to caretaker variables, therefore, is not necessary for the interpretation of relationships between state variables and the crying variables.

Hypothesis 1: Active sleep

There was one observational measure of active sleep, and one questionnaire measure. Thus, six tests were required to evaluate the first hypothesis. Therefore, the corrected probability level for tests of this hypothesis was $p = .008$.

Proportion of active sleep was calculated by dividing the number of segments scored active sleep by the total number of segments scored as sleep, either active or quiet. The overall mean for proportion of sleep spent in active sleep was .12 ($SD = .13$), based on the 39 infants observed to sleep in the study period. This measure was positively correlated with observed crying ($r(39) = .56$, $p < .001$). The mean proportion of active sleep was higher for the colic group ($M = .18$, $SD = .21$) than for the non-colic group ($M = .10$, $SD = .06$), but the difference was not statistically significant ($t(8.4) = 1.2$, $p = .566$). The correlation between cryscore and proportion of active sleep was virtually naught ($r(39) = -.09$, $p = .566$).

A dichotomous parental report item asked whether the infant slept restlessly or quietly. For the group reported to sleep restlessly ($n = 7$), the means for both cryscore ($M = 4.6$, $SD = 2.4$) and for observed crying ($M = .05$, $SD = .08$) were higher than for the group reported to sleep quietly ($n = 33$; cryscore $M = 3.1$, $SD = 2.0$; observed crying $M = .03$, $SD = .07$). The differences, however, were not statistically significant (cryscore: $t(7.9) = 1.54$, $p = .163$; observed crying:

$t(8.1) = 0.9$, $p = .408$). No relationship was found between the restless sleep and the colic question (Fisher's exact test, $p = .257$).

Hypothesis 2: Amount of Sleep

One measure was used to evaluate hypothesis 2. Three tests were performed yielding a required probability level per test of $p = .016$. The proportion of the observation period spent in a sleep state was calculated by dividing the number of segments scored as sleep, either quiet or active, by the total number of segments observed, exclusive of those spent in caretaker intervention. The overall group mean for the proportion of the observation period spent sleeping was .45 ($SD = .26$).

As hypothesized, a negative correlation between proportion of sleep and observed crying was found ($r(41) = -.39$, $p = .012$), and the colic group ($M = .25$, $SD = .18$) showed significantly lower proportions of sleep than the non-colic group ($M = .51$, $SD = .26$; $t(22.5) = 3.39$, $p = .003$). The correlation between cryscore and proportion of sleep was negative, but not statistically significant ($r(41) = -.24$, $p = .490$).

Hypothesis 3: Active Awake

Two measures indexed active awake, the focus of the third hypothesis. Given two measures of active awake compared with three measures of crying, the required probability level for tests of hypothesis 3 was $p = .008$.

A measure of the proportion of wake time spent in an active awake state during the observation was calculated by dividing the number of segments scored active awake by the total number of segments scored awake, either active or quiet. Proportion of active awake ($M = .84$, $SD = .20$) showed correlations in the expected direction with observed crying ($r(41) = .18$, $p = .265$) and with cryscore ($r(41) = .11$, $p = .485$), but these correlations were very small and not statistically significant. The colic group mean ($M = .93$, $SD = .05$), however, was significantly higher than the non-colic group mean ($M = .80$, $SD = .23$; $t(34.3) = 2.9$, $p = .006$).

A parental report of waking activity was based on a single questionnaire item, "While awake, how much of the time does your baby move his/her arms and legs?". This item was scored on a four-point scale, with responses ranging from 0 for "very little of the time" to 3 for "almost all the time". Mean score on this item was 2.0 ($SD = 0.8$).

The parental report of waking activity showed the hypothesized positive correlation with observed crying ($r(41) = .33$, $p = .035$), but the correlation was not statistically significant. With cryscore, the correlation was practically naught ($r(41) = .05$, $p = .761$). As with the observational measure, the colic group mean ($M = 2.7$, $SD = 0.48$)

was significantly higher than the non-colic group mean (*M* = 1.8, *SD* = .80; $t(26.6) = 4.08$, $p < .001$).

Hypothesis 4: Rate of State Changes

One measure, number of state changes per unit time, was used to test the fourth hypothesis. With one measure yielding a total of three tests of hypothesis 4, the probability level required was $p = .016$. A state change was counted whenever one 10 s segment was scored as a different state than the immediately preceeding 10 s segment. The measure was calculated by dividing the total number of state changes noted, exclusive of those changes either to or from caretaker intervention, by the total number of segments observed, omitting those scored caretaker intervention. By performing this division, the problem that an infant observed for a greater length of time will show more state changes was controlled. The mean rate of changes thus calculated was .16 (*SD* = .06).

Observed crying was significantly positively correlated with number of changes ($r(41) = .40$, $p = .010$), and the relationship with cryscore was in the hypothesized direction, but it did not meet the required probability level ($r(41) = .14$, $p = .375$). Similarly, the colic group mean was higher (*M* = .18, *SD* = .08) than the non-colic group mean (*M* = .15, *SD* = .06), but the difference was not statistically significant ($t(12.3) = 0.96$, $p = .357$).

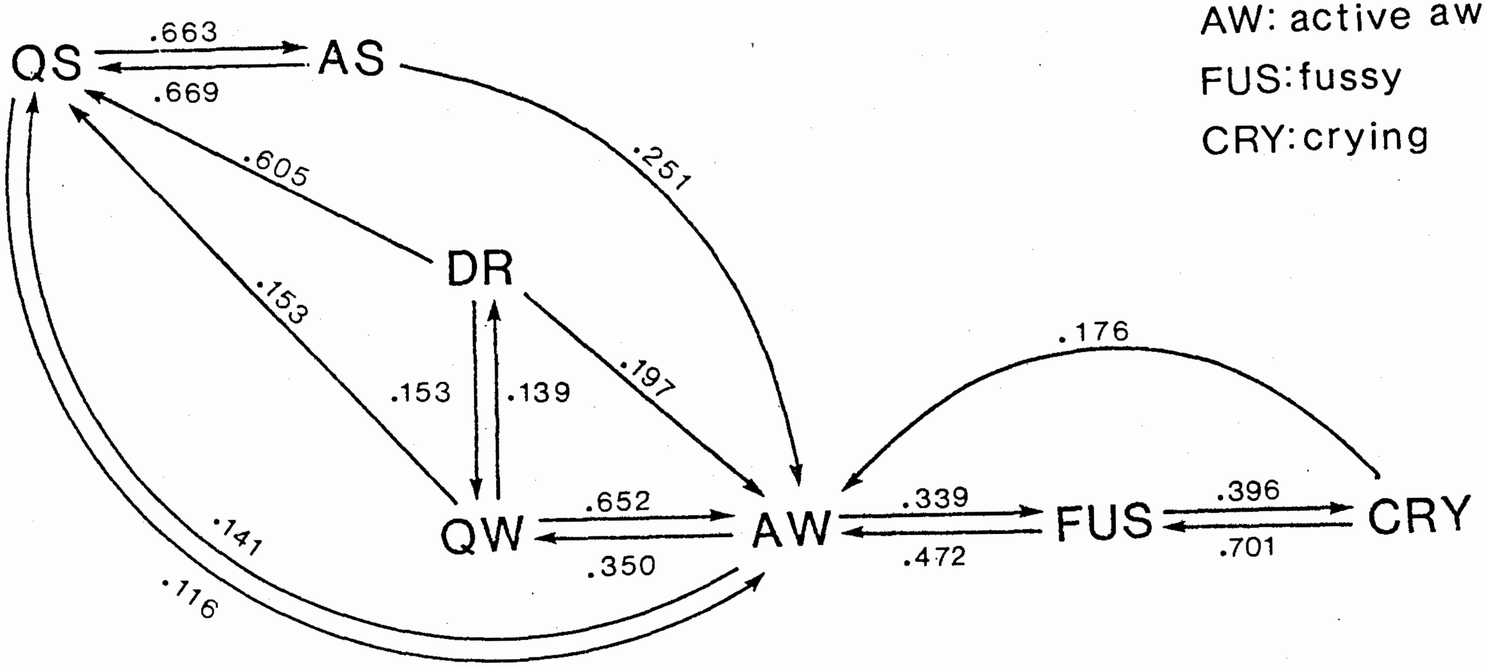
Hypothesis 5: Unusual State Changes

Evaluation of hypothesis five was based on one state measure. Thus there were three tests and the corrected probability level was $p = .016$. The pattern of state transitions for infants in the present sample is displayed in Figure 1. Especially noteworthy in Figure 1 is the direction of sleep onsets. Infants in the present sample moved to and from sleep by way of quiet sleep, while younger infants are reported to move to sleep via active sleep (cf. Thoman, 1975; Coons & Guilleminault, 1984).

To determine what state changes occurred with the lowest frequencies, a 7 x 7 matrix was assembled listing all of the states scored, except caretaker intervention. The proportion of changes from any one state to any other state was computed for each infant. For example, the proportion of changes from quiet sleep to drowsy was calculated by dividing the number of quiet sleep to drowsy transitions by the total number of transitions made from quiet sleep to all other states. This operation was done for each possible state change for each infant. Table 2 reproduces the matrix of transition probabilities. These proportions were averaged across the forty-one infants. Any state transition that accounted for less than 10% of the changes from a given state was considered to be a low frequency change. To calculate the rate of low frequency changes for each infant, the number of changes designated low frequency made by an infant

Figure 1

Observed Patterns of State Transition.



QS: quiet sleep
AS: active sleep
DR: drowsy
QW:quiet awake
AW: active awake
FUS:fussy
CRY:crying

Table 2

Matrix of State Transition Probabilities

FROM:

TO:	QS	AS	DR	QW	AW	FUS	CRY
QS	X	.663	* .093	* .075	.141	* .015	* .014
AS	.669	X	* .030	* .016	.251	* .022	* .011
DR	.605	* .044	X	.153	.197	* .000	* .000
QW	.153	* .016	.139	X	.652	* .038	* .003
AW	.116	* .076	* .085	.350	X	.339	* .034
FUS	* .029	* .045	* .000	* .058	.472	X	.396
CRY	* .053	* .049	* .003	* .018	.176	.701	X

* low frequency changes

X non-transitions

QS: quiet sleep
AS: active sleep
DR: drowsy
QW: quiet awake
AW: active awake
FUS: fussy
CRY: crying

was divided by the infant's total number of changes, yielding a proportion measure.

Comparisons with cry measures did not support hypothesis five. Proportion of low frequency changes (M = .11, SD = .08) showed a weak positive correlation with observed crying ($r(41) = .21$, $p = .194$), and a weak negative correlation with cryscore ($r(41) = -.18$, $p = .250$), neither of which was statistically significant. The difference between the non-colic group mean (M = .12, SD = .09) and the colic group mean (M = .09, SD = .09) was not statistically significant ($t(14.7) = 1.05$, $p = .312$).

In summary, all hypotheses except hypothesis five received some support based on the tests performed. Except for hypothesis five, all hypotheses were supported by all results being in the expected direction, save one virtually zero correlation between cryscore and proportion active sleep, and one naught correlation between cryscore and proportion wake time spent in an active awake state. No hypothesis, except hypothesis five, was without at least one statistically significant relationship being in the hypothesized direction, and no hypothesis was refuted by statistically significant relationships opposite to hypothesis.

DISCUSSION

The results of this study support the general proposition that excessive crying in young infants is related to disorganization of infants' neurological systems. The support given this general hypothesis, however, is not unequivocal. In order to strengthen confidence in the conclusions, the nature of the sample and the measures used will be critically evaluated.

The sample represented a reasonable range of both age and educational level for both mothers and fathers, and there were no biasing qualities of the infants. Ames (1982) reported that in studies providing estimates of the incidence of colic, the median incidence was 21%, with a range from 12% to 36%. In the present study, 26% of respondents reported that their infants had been described as colicky, a rate that was within the normal range.

Two of the cry measures, observed crying and the colic question, showed the expected relationships to the state variables. These two measures also showed some tendency to be related to one another, but the third measure, the cryscore, did not relate well to the other cry measures or to the state variables. The cryscore was a composite of three questions, each asking for an accurate estimate of the duration or frequency of crying episodes. One suspects that parents do not have such exact estimates readily available. Parents were presented with a lengthy questionnaire, and asked several questions about their infants. Many of these parents would not have ever stopped to think about some of these variables. For example, a parent for whom crying was not an issue would not likely have a ready, accurate estimate of the length of an infant's longest crying episode.

Although it may not be a strictly veridical measure of infant crying, the cryscore does represent some qualities of the infant, but only as filtered through the expectations and beliefs of the parents. That presented a problem in this study. The moderate sample size was not sufficient to overwhelm large variance components in any of the measures. The cryscore's many sources of variance attenuated its usefulness in the present study, and it will not be discussed further.

In contrast to the cryscore questions, a parent probably can recall with ease whether or not the infant has been described as colicky. Similarly, the observed crying measure does not have the obvious weaknesses of the cryscore. One must consider, however, that in the present study crying episodes could be interrupted by parents. Therefore, infants observed to cry were infants who were allowed to cry. Although this might complicate interpretation of the measure, it does not implicate the veracity of the measure.

Observed crying and parental report on the colic question were each useful measures. The colic group showed more, but not statistically significantly more, observed crying than the non-colic group. This suggests that while the measures are not wholly independent of one another, each contributes uniquely to the study.

The two observational measures compared for the first hypothesis were strongly correlated. Infants who were observed to cry more also spent a greater proportion of their sleep time in active sleep. The strongest correlation found in this study was between these two measures. Weissbluth (1984) in particular focused on the relationship between crying and sleep difficulties. The only evidence in support of Weissbluth's hypothesis prior to this study (e.g., Snow, Jacklin, & Maccoby, 1980; Bernal, 1973) was based on parental reports. This study is the first observational validation of the hypothesized relationship.

The second hypothesis received the most consistent support of any in this study; both cry measures showed statistically significant relationships with the proportion of observed sleep. Infants observed to cry more slept for a lesser proportion of the observation period. This is not a necessary relationship; increases in the proportion of the observation spent in any single state would be negatively correlated with the total proportion spent in all other states, but would bear no necessary relationship with proportion spent in any one or two of the other seven states. It is significant, then, that infants increase their crying time at the expense of sleep time. This relationship is also reflected in the difference between the colic and non-colic groups. Infants described as being colicky slept less. No other studies to lend empirical support to the clinical perceptions of Weissbluth, Lester, and Brazelton have been found.

It appears that crying is negatively related to both the amount of sleep and to the proportion of sleep spent in active sleep. The quotes by Brown (1964) and Thoman (1975) cited earlier support the notion that greater proportions of sleep spent in an active sleep state and lesser amounts of sleep in general indicate regulatory difficulties.

The third hypothesis was also supported. While the positive correlation between proportion of wake time spent in the active awake state did not reach the required level of statistical significance, the colic group mean for proportion of wake time spent in an active awake state was higher than the non-colic group mean. As Brazelton, Lester, and Weissbluth have each suggested, colicky infants do seem to be overly active in general. Parental reports of infants' waking activity also showed the hypothesized relationship. Once again, while the reports of each of the three theorists suggest that in clinical circles it is an accepted fact that colicky infants are generally more active, this is the first empirical demonstration of the fact.

The fourth hypothesis was that crying would positively correlate with the rate of state changes. While the colic item did not differentiate infants on this measure, observed crying did show a strong positive correlation with rate of state changes. The observations of Lester, Weissbluth, and Brazelton hinted at this relationship, but it has not been previously demonstrated empirically. According to the interpretations of Coons and Guilleminault (1984) and Thoman (1975) a high rate of state changes indicates some problem with neurological organization.

The fifth hypothesis was that crying would be positively related to the rate of low frequency state changes. This hypothesis was based on the speculations of Thoman (1975), the clinical observations of Brazelton (1985), and the studies of neurologically damaged infants done by Beintema (1968). Nonetheless, hypothesis 5 was the only one not to receive support. Observed crying showed no significant correlation with the measure of low frequency changes, and the relationship between the means of the colic and non-colic groups was not as hypothesized. Perhaps the unusual state changes referred to by Thoman and Beintema may be more extreme than those seen in this study, and as such these unusual changes may be seen only in neurologically damaged infants (i.e., those with structural problems).

The data from the present study support the observations of Coons and Guilleminault (1984) who reported the changing direction of sleep onsets accompanying the maturation of sleep patterns. Over the first few months of life, there is a change from predominantly active sleep onsets to the adult pattern of quiet sleep onsets. This changing pattern is obvious if Figure 1 is compared with data provided by Thoman (1975). In Thoman's sample, 40 1-day olds, some observed at home, some at the hospital, the modal pattern was to move to sleep by way of active sleep. In the sample of 6- to 8-week olds of the present study sleep onsets were predominantly by way of quiet sleep. Thus, the previously noted development shift in sleep patterns is illustrated.

In summary, the proposal that excessive crying is related to functional disorganization of infants' nervous systems was supported in this study. Each of the hypothesized relationships that were observed are subject to alternate explanations, as is always the case in correlational studies. The results viewed as a whole, however, form a strong case for the proposed relationship between neurological disorganization and excessive crying.

There are cautions that must be expressed in the interpretation of this laboratory study. Sostek and Anders (1975) have shown that infants' sleep patterns can be different in the laboratory as compared to the home. The sample size is moderate, and the observation period is relatively short. Ideally, the study would be repeated with home measures, and with longer observation periods. These cautions notwithstanding, the hypothesized relationships between indicators of neurological organization and amount of crying emerged in the expected pattern.

The largest problem in interpretation of these results is that of causal direction. Lester (1985), Brazelton (1985), and Weissbluth (1984) have intimated that the causal path runs from neurological disorganization to crying, but the interpretation of the results supporting the first four hypotheses must be tempered with the usual cautions regarding correlational data. It is possible that there is some third factor (e.g., painful stimuli) that leads both to crying and to disorganized states, or it may be that the final causal path is from crying to disorganization of state indicators. In the case of the latter, for example, the increased motor activity that accompanies crying might persist into sleep, producing a higher proportion of active sleep. Such alternate explanations cannot be rejected on the basis of the data presented in this study, but the significance of the observed relationships is not diminished. Whatever the causal route, attempts at alleviating the effects of excessive crying would ideally include attempts at increasing the amount of sleep infants get, quieting what sleep they do, and somehow reducing their overall activity level.

The question of the causal direction does not lend itself to empirical study. Any intervention, especially non-pharmacological intervention, that reduces crying also tends to organize the state paramaters. It is difficult to directly manipulate the amount of crying without also directly manipulating state variables. For example, rocking infants reduces crying, but it also seems to increase sleeping. One cannot easily tease apart the two effects.

Rovee-Collier and Lipsitt (1982) have presented a picture in which "newborn behaviours cannot be interpreted independent of their regulatory functions" (p. 149). In this view, the job of the young infants is to learn to regulate their physiological systems. The self-regulatory strategies available to the infant are behavioural as well as physiological. One principal behavioural strategy is crying.

An infant who displays signs of functional disorganization of neurological systems demonstrates a difficulty in self-regulation of these systems. In this framework, colicky infants are manifesting regulatory difficulties, and their crying is a behavioural strategy for enlisting the assistance of caregivers in the regulatory task.

Hunziker and Barr (1986) have shown that if infants are carried in someone's arms or in a carrier for three hours a day, they cry less than infants not carried as much. Carrying gives infants assistance with thermal regulation, provides respiratory regulation (MacKinnon, et al.,1986), and provides for hunger regulation (i.e., the researchers reported that increased carrying is associated with increased feeding frequency). Thus, carrying assists infants in maintaining physiological regulation. All of the soothing strategies mentioned by Ames (1982) can be interpreted as providing either some sort of rhythmic stimulation and thereby restoring organization, or some constant stimuli preventing the breakdown of organization. Therefore, it seems to me that the key to understanding crying is to understand the development of infants' self-regulatory abilities.

A first step to be taken in future research on excessive crying is to determine whether it is better conceptualized as a developmental delay or as a problem of individual differences. McCall (1979) has discussed the differences between the concept of a developmental function and the concept of individual differences. A developmental function represents the process of change over time in some attribute of the individual. Individual difference refers to an individual's place in the distribution of some attribute. The same attribute of an individual is interpreted differently, depending upon the concept through which one views the attribute. If one uses a spatial metaphor, one might visualize an entire normal distribution (representing individual difference) moving along a path of change (the developmental function). Individuals may be re-positioned within the distribution, and individuals may move at different rates along the path. The latter effect represents delay or advancement along the developmental function.

With regards to crying and state organization, the question is whether colicky infants are infants who are likely to remain at the extreme end of a normal distribution of state organization, or whether they are temporarily delayed in their acquisition of the ability to self-regulate, but have the potential to catch up and thus change their position within the distribution at some later date.

The normative picture is that state organization increases over time. Thoman (1975) showed that most infants' rate of state changes declined over time. Coons and Guilleminault (1984) showed that infants spend lesser and lesser amounts of time in an active sleep state, making for greater proportions of sleep time spent in active sleep. If colic is the extreme end of a normal distribution, which moves unchanging through time, colicky infants should always show more active sleep than non-colicky infants, for example. If instead colic represents a developmental lag, colicky infants will most likely come to be evenly distributed within the normal distribution of sleep patterns.

The only method by which the individual difference versus developmental function question can be addressed is by way of longitudinal study. Thus the study of crying in infancy should follow the road of all developmental research. First, study of what occurs at various ages is undertaken to provide normative pictures and hypotheses. Then, longitudinal research is undertaken to illuminate the mechanisms by which the pictures taken at the various ages are related to one another. This research has begun to paint a picture of excessive crying and its relationship to infants' abilities to self-regulate their physiological systems. Future research should focus on the relationship of excessive crying to later indicators of physiological self-regulation.

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APPENDIX A

BEHAVIOURAL STATE CODING: RELIABILITY

PERCENT AGREEMENTS AND KAPPAS

INFANT	% AGREEMENT	KAPPA
BA	85.0	.81
CH	89.4	.87
CS	75.0	.65
LL	98.3	.88
MS	92.4	.89
NT	88.8	.84
RH	88.5	.83
RM	97.7	.95
SD	91.5	.87
SL	89.0	.53
SP	94.5	.90