Sleep and Arousal Patterns of Co-Sleeping Human Mother/Infant Pairs: A Preliminary Physiological Study With Implications for the Study of Sudden Infant Death Syndrome (SIDS)

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KEY WORDS Mother-infant co-sleeping, Sleep stage synchrony, Arousal synchrony, SIDS, Infant breathing, Evolution

ABSTRACT The prevailing research design for studying infant sleep erroneously assumes the species-wide normalcy of solitary nocturnal sleep rather than a social sleeping environment. In fact, current clinical perspectives on infant sleep, which are based exclusively on studies of solitary sleeping infants, may partly reflect culturally induced rather than species-typical infant sleep patterns which can only be gleaned, we contend here, from infants sleeping with their parents—the context within which, and for well over 4 million years, the hominid infant's sleep, breathing, and arousal patterns evolved. Our physiological study of five co-sleeping mother-infant pairs in a sleep lab is the first study of its kind to document the unfolding sleep patterns of mothers and infants sleeping in physical contact. Our data show that co-sleeping mothers and infants exhibit synchronous arousals, which, because of the suspected relationship between arousal and breathing stability in infants, have important implications for how we study environmental factors possibly related to some forms of the sudden infant death syndrome (SIDS). While our data show that co-sleeping mothers and infants also experience many moments of physiological independence from each other, it is clear that the temporal unfolding of particular sleep stages and awake periods of the mother and infant become entwined and that on a minute-to-minute basis, throughout the night, much sensory communication is occurring between them. Our research acknowledges the human infant's evolutionary past and considers the implications that nocturnal separation (a historically novel and alien experience for them) has for maternal and infant well-being in general and SIDS research strategies in particular.

Unlike old wives and baby books, developmental researchers have greatly underestimated the overwhelming complexity and social importance of infants' sleep-wake behavior. It is time for us to give it the serious attention it warrants (Sostek and Anders, 1981:114).

Little is known about the natural ecology of human social sleeping. By 'natural ecology' we mean an understanding that emerges from an integrated evolutionary, developmental, and cross-cultural perspective. Our...
Although research that shows specifically why social and solitary sleeping infants should differ in their pattern of nocturnal arousals has not yet been done, physiological studies of the potential effects of parent-infant sensory contact may offer some insight. Numerous studies reveal that among mammals in general (see Goodall, 1981) but especially among monkeys, apes, and humans, all of whom are born neurologically quite immature and develop slowly, parent contact is associated with a variety of defensive effects on the infant. For example, Fardig (1980) found that even radiant-heated cribs could not maintain newborn human infants' skin temperatures at levels achieved by placing the infants on their mothers' chests. In rhesus, pigtail, bonnet macaques, and squirrel monkeys, even relatively brief separations from parental ventral contact can induce dramatic short-term as well as some long-term physiological changes in sleep, cardiac stability, stress (ACTH) hormone levels, temperature, and immunological efficiency (McKenna, 1986; Ricke and Capitanio, 1985; Ricke and Short, 1978). Among other mammals, such as rat pups, it has been established that particular kinds of maternal contact regulate the production of growth hormones and enzymes and, hence, growth hormone cease altogether when pups are deprived of contact with their mothers (Kush et al., 1978).

Even though cross-cultural and cross-species data collected during the past 20 years clearly suggest that the separation of the infant from the parent for nocturnal sleep is a relatively recent historical and evolutionary phenomenon, current research is nearly exclusively focused on patterns of solitary sleeping infants. This research orientation represents a dubious example of Western ethnocentrism, even more critically focused on patterns of solitary sleeping infants. The latter, we suggest, can best be discovered in social rather than in solitary infant sleeping patterns. The variety of sensory stimuli is probably provided by a caregiver. (See Anders and Zeanah, 1984; Hinde, 1984; Sanders, 1969 for related discussions.)

This paper has three primary goals: first, to describe preliminarily the continuous nocturnal sleep and arousal patterns of co-sleeping infants and their infants by using standard physiological measure recorded polygonically; second, to investigate the degree of synchrony in mother-infant arousals and sleep stages; and third, to consider the possibility that synchrony in sleep and arousal patterns may be important from an evolutionary perspective in light of the suggestions that failure to arouse may be a precursor to some forms of respiratory collapse, thereby predisposing some infants to SIDS (see Davies, 1985; Gutenruth, 1977, Hoppenbrouwers and Hodgman, 1986; Konner and Super, 1987; McKenna, 1986; Sterman and Hodgman, 1988).

METHODS
Subjects and procedure

Ten healthy subjects (five mothers and five infants, 2 to 6 months of age) reported to the Sleep Disorders Center at the University of California Medical Center at approximately 8:00 p.m. for continuous all-night recording of sleep, using standard methodology (Rechtschaffen and Kales, 1968): electroencephalogram (EEG) at points C3/A2 on the skull, electro-oculogram (EOG) to record eye movements, chin electromyogram (EMG) to measure skeletal muscle tone, and respiratory effort (chest strain gauge). All of these procedures entail surface recordings, are noninvasive, and were approved by the University of California Irvine Human Subjects Research Committee.

Each mother-infant pair shared a single-sized bed in a darkened, sound-attenuated room. One purpose of this study was to allow for the post hoc analysis of maternal-fetal physiological interactions, since they are less direct and take different forms (see McKenna, 1986; Prechtl, 1984). Had we used only mothers and infants who regularly slept together, there is at least indirect evidence from studies of nonhuman primates and other mammals that the likelihood of documenting mother-infant interactions would have been enhanced (see Capitanio et al., 1985; Field, 1985; Galef, 1981; Hofer, 1981; Schwartz and Rosenblum, 1985). For example, even when mothers and infants are not sleeping together in the same bed, there is a general temporal trend toward behavioral synchrony in sleep-wake patterns and other behaviors (Anders, 1973; Kaye and Wells, 1978).

Our small sample size (five mother/infant dyads) becomes less problematic when the number of minutes of continuous maternal-infant co-sleeping, (440 minutes) is considered. The technological challenges of monitoring both mother and infant simultaneously as they slept in the same bed were significant and, to our knowledge, had never previously been attempted. Parameters recorded in each mother-infant pair included:
to be written out simultaneously on a single 12-channel polygraph. Moreover, to recruit mothers willing to subject themselves and their infants to the rigors of all night recordings proved to be a formidable challenge—especially when the age restrictions of the infants are considered.

Scoring

Polygraph recordings were scored for sleep stages in 30-second epochs according to accepted criteria. The Rechtschaffen and Kales (1968) system for young adults was utilized for the mothers while the scoring system for 3-month-olds developed by Guilleminault and Souquet (1979) was used for the infants. Identification of sleep-wake states in both scoring systems depends on three simultaneous parameters: EEG, EOG, and EMG.

Five sleep stages are defined in adults: Stage REM (rapid eye movement sleep) plus four stages of non-REM sleep defined as Stages 1, 2, 3, and 4. Stages 1 and 2 are often referred to collectively as light N-REM sleep, whereas Stages 3 and 4 together constitute slow-wave or delta sleep (also called deep sleep) because of the presence of slow, high-voltage (>75 μV) brain waves. In the 3-month-old infant, only three sleep stages are defined: Stage REM, Stage 1, and Stage 2. A major difference between the infant and adult system (besides the lack of differentiation between Stages 1 and 2 and also 3 and 4 in the infant) is the higher voltage criterion for delta waves (>15 μV) in the infant. In the process of data reduction for our study, Stages 1 and 2 in the adult were sometimes combined to obtain total light N-REM sleep, and likewise Stages 3 and 4 were combined to obtain total slow-wave sleep.

The "epochoal" system of sleep stage scoring assigns to each 30-second epoch either Wakefulness (W) or one stage of sleep based on the predominant (>50%) sleep-wakefulness pattern occupying that epoch. Although awakenings of 15 seconds or longer that meet these criteria (i.e., epochal awakenings [EAs]) are automatically identified by the epoch system, shorter-duration sub-epochal arousals, occupying less than 50% of an epoch (e.g., less than 15 seconds in duration), are not recognized by this system. Because of our interest in all arousal phenomena in sleep, we also quantified these sub-epochal or transient arousals (TAAs), modifying the criteria for TAs provided by Carakdon et al. (1982). They define a transient arousal as any clearly visible EEG arousal lasting at least 2 seconds but not associated with any sleep stage change in the epochal scoring system. In our scoring of TAs we have omitted the latter exclusion criterion to permit identification of all brief EEG arousals during sleep, irrespective of whether there is a return to the same or a change to a different stage of sleep. Transient arousals among infants were scored when there was typically either an abrupt increase in the predominant EEG frequency or a sudden burst of distinctly higher-voltage slow waves. In the mothers, TAs were evidenced by an increase in EEG frequency (to alpha or beta) frequently accompanied by bursts of K-complexes or sharp waves. Although it was not a requirement (see exception below), by far the majority of TAs in all infants and mothers were accompanied by signs of arousal on other channels, i.e., a change in EOG pattern (to slow rolling eye movements or blinking), an increase in chin EMG amplitude, and/or a change in pattern of respiration (Fig. 1). For two of the mothers exhibiting alpha intrusion in sleep, abrupt increases in EEG frequency to an alpha rhythm were not scored as TAs unless accompanied by clear evidence of arousal on at least one other channel.

All epochal sleep-stage scoring and quantification of EWS and TAs were performed by an accredited clinical polysomnographer (Mosko) for each mother or infant independently of the other dyad member.

RESULTS

Co-sleeping patterns of mothers

Tables 1 and 2 present means, standard deviations, and ranges for standard descriptions of nocturnal sleep for mothers and infants. Mothers sleeping with their infants spent the majority (69.9%) of their TST in light non-REM sleep (Stages 1 and 2). Stage 1 sleep is a drowsy condition often experienced subjectively as wakefulness rather than sleep, whereas in Stage 2 sleep, consciousness is altered to the extent that "if awakened most people usually recognize having been asleep" (Riley, 1985-85). On the average, 15.8% of mothers' total sleep time was spent in slow-wave (or deep) sleep. In Stages 3 and 4 there was substantial intra-subject variation, ranging from 12 to 22% across mothers. Slow-wave sleep is subjectively experienced as deep sleep, and arousal thresh-
TABLE 1: Standard descriptors of nocturnal sleep

<table>
<thead>
<tr>
<th></th>
<th>Mothers</th>
<th></th>
<th>Infants</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>Total recording time (TNT) (minutes)</td>
<td>410.7 ± 14.4</td>
<td>454-490</td>
<td>410.7 ± 14.4</td>
<td>454-490</td>
</tr>
<tr>
<td>Total wake time (TWT) (minutes)</td>
<td>62.2 ± 37.9</td>
<td>41-221</td>
<td>50.5 ± 26.6</td>
<td>28-88</td>
</tr>
<tr>
<td>Total sleep time (TST) (minutes)</td>
<td>367.7 ± 75.7</td>
<td>248-421</td>
<td>419.2 ± 25.6</td>
<td>375-451</td>
</tr>
<tr>
<td>Sleep period time (SPT) (minutes)</td>
<td>459.0 ± 165.5</td>
<td>447-485</td>
<td>470.2 ± 14.2</td>
<td>454-489</td>
</tr>
<tr>
<td>Sleep efficiency (%)</td>
<td>78 ± 14</td>
<td>53-91</td>
<td>89 ± 57</td>
<td>81-94</td>
</tr>
<tr>
<td>Wake after sleep onset (WASO) (minutes)</td>
<td>88.8 ± 27.2</td>
<td>39-196</td>
<td>30.4 ± 12.3</td>
<td>25-48</td>
</tr>
<tr>
<td>Sleep LAT (minutes)</td>
<td>8.8 ± 5.5</td>
<td>2-14</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>REM LAT (minutes)</td>
<td>162.8 ± 94.7</td>
<td>64-279</td>
<td>113 ± 13.3</td>
<td>1-345</td>
</tr>
<tr>
<td>REM periods</td>
<td>1.2 ± 1.0</td>
<td>1-2</td>
<td>0.9 ± 0.7</td>
<td>1-2</td>
</tr>
<tr>
<td># Stage shifts</td>
<td>1.2 ± 1.0</td>
<td>1-2</td>
<td>0.9 ± 0.7</td>
<td>1-2</td>
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</tbody>
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TABLE 2: Mean stage time as % TST

<table>
<thead>
<tr>
<th>Stage</th>
<th>Mothers</th>
<th></th>
<th>Range (%</th>
<th>Infants</th>
<th></th>
<th>Range (%)</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td></td>
<td>Mean</td>
<td>SD</td>
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<tr>
<td>1</td>
<td>15.2 ± 5.5</td>
<td>9-24</td>
<td>49 ± 11</td>
<td>31-62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>54.4 ± 6.0</td>
<td>46-62</td>
<td>21 ± 10</td>
<td>14-36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8.0 ± 3.0</td>
<td>2-10</td>
<td>21 ± 15</td>
<td>8-43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>9.8 ± 5.2</td>
<td>3-18</td>
<td>21 ± 4.8</td>
<td>26-39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>REM</td>
<td>15.1 ± 1.6</td>
<td>3-24</td>
<td>21 ± 4.8</td>
<td>26-39</td>
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Olds are highest in Stages 3 and 4 (Riley, 1985).

One of the most comprehensive studies of solitary sleeping females to which our co-sleeping mothers were compared was conducted by Williams et al. (1974). Our small sample size contrasts with their large sample of more than 200 subjects, and the different laboratory and testing conditions prevent us from making statistical comparisons. Nevertheless, it is clear that our co-sleeping mothers experience more sleep fragmentation than do solitary sleepers. For example, on the average our co-sleeping mothers experienced one less REM cycle than did the solitary sleeping females of comparable age reported by Williams et al. (1974) and thus spent much less average total time in REM sleep. Moreover, the time it took our co-sleeping mothers to fall asleep, i.e., sleep latency (Table 1), was more than twice the amount of time reported for solitary sleepers, and co-sleeping mothers had more WASO (waking after sleep onset) and lower SE (sleep efficiency). The number of stage shifts among co-sleeping mothers was more than four times the mean frequency reported for solitary sleepers, and sleep efficiency (which ranged from 53 to 91 among our co-sleepers) was lower for solitary sleeping females.

Infants

Compared with their mothers with whom they sleep, our infants averaged higher SE (sleep efficiency) (Table 1) because of shorter sleep latencies and less WASO (waking after sleep onset). Our co-sleeping infants spent an average of 39.6% of their total sleep time in Stages 1-2, 21% of their time in Stages 3-4, and 31% of their total sleep time in REM (Table 2). Moreover, infants spent twice as much total sleep time in REM sleep as their mothers did, 31 ± 4% and 15 ± 5%. Compared with solitary sleeping infants studied by Riley (1985) and Orr (1985), our co-sleeping infants generally averaged less time in delta sleep (Stages 3-4) and aroused for periods shorter than a minute more frequently. But overall these five infants exhibited remarkably similar sleep profiles to those of solitary sleeping infants studied by Hoppenbrouwers et al. (1982), at least as close as one can tell through inferences drawn from the much larger data set.

When all mothers and all infants are ranked independent of their co-sleeping partner according to total wake time, with rank 1 indicating the most wake time and rank 4 the least, there is a trend toward co-sleepers sharing the same rank. But while one mother had the second highest percentage of TWT (total wake time), her infant ranked third in percentage of TWT—below an infant whose mother ranked third. In other words, six out of ten co-sleeping individuals shared the same rank as their co-sleeping partner in TWT.

Overlap in sleep wake stages of co-sleeping mothers and infants

Using the 30-second epochal scoring system for sleep wake stages, we computed for each co-sleeping mother and infant the percentage of that individual's sleep period time spent simultaneously in the same stage of sleep or wakefulness as the other member of the pair. We called these times of corresponding sleep wake stages Simultaneous Activity Times (SAT) as shown in Figure 2. Total SAT averaged 46% for the mothers (range 43-48%) and 44% for their infants (range 42-45%).

Since the progression of sleep stages through the night has an inherent organization that could contribute to these high percentages of SAT, and since we were interested in determining whether co-sleeping would influence the amount of synchrony in sleep wake stages, we also computed SATs produced by pairing each mother with every other infant with whom she did not sleep, i.e., 20 randomly matched pairings. Starting with the first epoch of recording time of each mother and infant to be compared, we determined the mean of these 30-second epochs (matched page by page of recorded data) during which they were in the same sleep or wake stage at the same moment—just as we compared each to their "real" co-sleeping partner (see Figure 3 and 4). We then calculated an SAT (simultaneous activity time) score for each by dividing their total combined minutes of sleep stage or arousal overlap by their SPT (sleep period time, i.e., the time from initial sleep onset until the final morning awakening). Figure 2 shows the mean SAT in mothers paired with other infants (randomly matched) averaged 29% (range 18-30%) and for infants randomly paired with other mothers the average SAT was 28% (range 17-43%). The increase in SAT in mothers paired with their own infant vs. with other infants is significant (P < 0.0004; two-tailed test). SAT is also greater in SAT in infants paired with their own vs. with other mothers (also P < 0.0004).

To investigate the increase in SAT seen in co-sleeping mothers and infants further, we calculated the percentage of simultaneous
Relationship between mothers' and infants' arousal patterns

We also investigated the temporal relationship between arousals in co-sleeping mothers and infants. We examined EWS and TAs in each member of a pair for overlap with EWs (epochal awakenings) and TAs (transient awakenings, >2 seconds but <15 seconds) in the other. That is, for each dyad member, EWS and TAs were first identified separately and then categorized according to the corresponding state of the other dyad member. Specifically, for each dyad member EWS were categorized according to whether the other dyad member a) also had an epochal arousal in the same 30-second epoch; b) was already awake when the other had the arousal; that is, had an EW in a previous epoch and remained awake; or c) stayed asleep, i.e., the other dyad member remained asleep throughout the EW. Each TA was categorized according to whether the other dyad member a) had a concurrent or simultaneous TA within ±5 seconds; b) had an overlapping epoch of waking where already awake); i.e., had an EW in the same epoch or a previous one and remained awake; or c) stayed asleep, i.e., had neither a concurrent TA nor an epoch of waking. We were not able to categorize EWS and TAs further in terms of which dyad member aroused first because of the nearly simultaneous appearance of the onset of arousals in a large percentage of instances.

The temporal correspondence in pattern of EWS (epochal awakenings) is shown in Figure 5, which graphs for each mother-infant pair the entire recording period in 30-second epochs and shows all transitions into and out of sleep and wakefulness without regard to particular sleep stage. These graphs not only show the simultaneity of a large percentage of EWS mothers and infants, but also correspondence in periods of consolidated sleep.

Mothers averaged 33±2 EWS (range 29–48) during the night. Of the mothers' combined total of 167 EWS, their infants had an overlapping EW in 45±75 of the cases (Fig. 6a): in most of these cases (67 EWS) the infants awoke in the same epoch, and in the remaining eight maternal EWS, the infant was already awake from a previous EW, ignoring mother-infant pair #2 (because the infant had only two EWS all night compared to 12–36 EWS in each of the other four infants, the percent of EWS in individual

overlap for each sleep-wake stage separately. The percent of simultaneous overlap was higher for every sleep-wake stage when compared for mothers paired with their own vs. with other infants (Fig. 3), although the increase reached statistical significance only for WASO (P < 0.001). The same was true when infants paired with their own mothers were compared with infants in randomly matched pairs (Fig. 4). Stage 1-2 showed the smallest increase in simultaneous overlap with co-sleeping for mothers and infants alike. Our small sample size may explain the lack of statistical significance in the face of an apparent trend in co-sleepers toward greater simultaneous overlap in all sleep stages (but especially Stage 3-4 and Stage REM).

mothers which overlapped an EW in their infant ranged from 50 to 60%. Averaging across all infants, infants remained asleep through 55% of their mothers' EWS.

In contrast, mothers remained asleep through an average of only 11% of their infants' EWS, revealing perhaps greater maternal sensitivity to infant arousals (Fig. 6b). Infants averaged 20±10.1 EWS (range 2–36) of the 101 combined total EWS recorded across infants, 90 (89%) overlapped with a maternal EW. Of those 90 infant EWS, the mother most often (67 cases) had an EW in the same epoch, whereas in 23 cases the mother was already awake from a previous EW. Again ignoring mother-infant pair #2, for individual infants 83 to 97% of infant EWS overlapped an EW in the mother. (For infant #2 with only 2 EWS, this value was 100%).

These temporal relationships in EWS far exceed chance. When records of mothers were paired with those of infants with whom they did not overlap the percent of maternal EWS overlapping EWS in the infant was only 9.2%, and for total infant EWS this value was only 23%. When compared to values obtained in co-sleeping pairs, the differ-
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Fig. 7. Transient arousal rates.

Fig. 8. Episodic arousal rates.

DISCUSSION

This study provides the first preliminary data demonstrating that co-sleeping mothers and infants influence each other's sleep and arousal patterns, and specifically that there is a very high temporal correspondence between shorter TAs and, especially, longer EWs in co-sleeping pairs different than what is expected by chance. Ours is the first study to use standard polysomnographic techniques to document what should be fairly obvious. Because human infants are neurologically immature at birth and slow to develop, and parental investment is generally high among human mothers, it is to be expected that natural selection should favor increased maternal sensitivity across a range of environmental contexts, including co-sleeping. From the infant's perspective, natural selection should favor not only caregivers capable of responding quickly and
effectively to their needs, but also infants who successfully respond in kind to the variety of sensory cues conceptually provided by the mother upon whom, and for a relatively long time. Their overall survival depends on whether bowlby, 1969; chialom, 1983; Hinde, 1984; Konner, 1981; Sanders, 1969; Stern, 1965, and Thravathan, 1967, for discussion.

While the infant's overlapping and sometimes simultaneous arousals with the mother occur at rates different than what is expected, it is clear that mothers respond more frequently to their infants' arousals than vice versa, and, hence, appear to be the more sensitive partner in the co-sleeping dyad. This may reflect an inability of the infant to monitor sensory cues as efficiently as the more mature partner. According to Gele (1931), slow maturing and highly dependent mammals move toward efficient physiological re-engagement with their "host" mother only after first losing some structural and functional integrity. This may be true for human infants because it is the parent who, according to Andrea, literally regulates behavioral, nutritional, and hormonal functions of the infant by different aspects of the relationship: motivational, autonomic, and "rhythmic responsiveness" (1984, 65).

We did not attempt to classify arousals with regard to which individual, mother or infant, aroused first. We agree with Orr when he states that "the arousal response is clearly a complex neurological event that transcends the normal boundaries of medical specialties and subspecialties (1985: 175). The directionality of arousals, i.e., who initiates but can be exceedingly subtle and difficult to detect, especially for transient arousals. It appears that subtle, reciprocating physiological events lead to a measurable transient arousal that cannot be counted as a true arousal, but these cues may be important to the partner who does show true arousal according to our criteria. Hence, the question of who actually "causes" an arousal may be the wrong question since both partners may feed off of the other's indication of some physiological setting in motion a sequence of EEG, EOG, or EMG responses that may in each lead to a true "measurable" arousal. Mutual infant-arousal overlap (within ± 5 seconds) before both settle down for more restful sleep.

The extent to which co-sleeping mothers and infants can be said to be in synchrony or some kind of physiological entrainment, either in terms of the temporal organization of sleep-wake patterns or in terms of several phenomena, is a difficult but important question (see Anders and Seash, 1984; Sanders, 1969). Rosenfeld (1986) offers a thoughtful concept of both synchrony and entrainment, suggesting that synchrony is recognizable when "relatively persistent patterns of response in the mother's rhythmic and episodic behavior of at least one participant in a social encounter occurs as a time clock to whose beats of behavior the other is responsive and entrained" (Rosenfeld, 1961:90). If one adopts Rosenfeld's conceptualization of synchrony, much of the time mother-infant arousals and awakenings (rerecall Figs. 5, 6a,b) meet the criterion; however, the data presented here reveal a great deal of mother and infant independence as well. White arousals are "persistent" and often (but not always) function as a "time clock to whose beat of behavior the other is responsive or entrained." Whether infant arousals are perfectly correlated and, thus, arousals are "asynchronous" all of the time.

Our data suggest some temporal synchrony in occurrence of specific sleep stages and periods of wakefulness within the sleep period that cannot be explained solely by the inherent organization of sleep stages. Since we were not able to test each mother and each infant separately and under varying environmental conditions, as would be ideal (i.e., compare their solitary patterns of sleep with their social sleep patterns), we did the next best thing. We matched and compared, epoch to epoch, the sleep profiles of every infant with every mother with whom it did not sleep in the study, and similarly every mother with every infant. By doing so, we could partially isolate particular social or environmental influences on sleep morphology from autonomous or circadian ones. That is, if mothers or infants had no particular behavioral or physiological influence on each other as they co-slept and, thus, ultradian or circadian rhythms were responsible for any of their behavioral or physiological differences, the resulting synchrony emerged out of strictly behavioral studies, and not the kind of combined behavioral and random factors conducted here. Recall the classic study on infant gaze and attention avoidance by Brazelton et al. (1974) and on mother-infant "attempts" and turn-taking behavior by Field (1985), as well as the studies of the emergence of empathy and shared attention by Sanders, Emde, and Campos (see reviews in Kagan, 1984; Reite and Field, 1985; and Stern, 1985). All of these studies illustrate important forms of maternal-infant complementarity and the development of forms of synchronicity in the first year or 2 of life. It may well be that all of these behavior patterns emerge from the maternal-infant physiological interdependence of a kind. Pritchett (1984), Hofer (1981), Hoppenbrouwers and Hodgman (1986), and McKenna (1986) endorse. Surely it is difficult and, indeed, probably inappropriate to attempt to extract an "educational" environment from the "innate" evolutionary environment of adaptedness (after Bowlby, 1969).

Our findings that mothers and infants overlap in social and temporal arousals in each other provide a rationale for conducting further research by using larger samples to answer several questions relevant to the study of the sudden infant death syndrome (SIDS). This infant malady kills about two out of every 1,000 infants each year and is the leading cause of nonaccidental death in the United States for infants under 1 year of age. (See Hoffman et al., 1988, for an overview.) It is not presently understood and it is not yet producible. Using an anthropological framework integrated with clinical data, McKenna (1986; McKenna and Mosko, 1990) reviewed SIDS research and proposed that a human infant may be more susceptible than other species to breathing control errors in some SIDS cases because of our species-specific anatomical and neurological requirements for such breathing and the environment is not at all compatible with such breathing. In SIDS, and at normal breathing, the corollary controlled prerequisite for language mastered by an infant around 7 months of age, well before they speak at the SIDS age, may only match that of a typical infant different from normal breathing and not compatible with SIDS, and 2) no parent-child sensory breathing cues and general proxim-
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Co-sleeping infants as reported here may prove to be significant in helping infants to override potentially fatal breathing control errors by way of continuous streams of both rhythmic and aperiodic alveolar stimuli. Under what kinds of sleep conditions do infants arouse the most and to what extent is there an interaction between breathing rate and arousals? This question is especially important and needs to be pursued since neurophysiological structures and processes underpinning arousals are suspected of playing a role in either helping or hindering infants to breathe from prolonged breath pauses or prolonged apneas. For example, Lindsell and Rijksen (1985) reported that infants sleeping in a supine position with no head support were at greater risk for breath pauses if the infant was previously aroused. These findings are consistent with the hypothesis that infants who are prone to arousals have a higher likelihood of experiencing breath pauses.

In summary, sleep research indicates that sleep is associated with changes in cerebral metabolic rate, blood flow, and oxygen consumption, and that these changes are related to the process of sleep itself. The role of sleep in the development of the brain and the central nervous system is also being studied. Sleep research has contributed to our understanding of the neurophysiological processes underlying sleep and wakefulness, and has implications for the treatment of sleep disorders such as sleep apnea and narcolepsy.

ACKNOWLEDGMENTS

The authors wish to acknowledge especially Dr. Mark Mosko for his constant support of the research. We also wish to acknowledge the contributions of the following individuals for their time and effort in the collection and analysis of the data: J. J. McKenna, P. S. Gordon, and P. J. Hough. We also wish to acknowledge the support of the National Institute of Child Health and Human Development for their financial support of this research.

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