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Evolution and infant sleep: an experimental study of infant–parent co-sleeping and its implications for SIDS

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Human infant sleep evolved under conditions of continuous parental contact (1). In fact, for the vast majority of non-Western contemporary people, infant–parent co-sleeping remains the predominant sleeping arrangement for parents and children (2). A perspective which considers the evolution and natural history of infant sleep, combined with current developmental data, leads to the conclusion that the healthiest form of infant sleep should be expressed most frequently within a sensory-rich, social or co-sleeping environment, and not in a solitary one as Western sleep researchers assume (3).

Infant sleep and SIDS studies are focused exclusively on solitary sleeping infants. This means that infant sleep and SIDS researchers continue to miss opportunities to study the extent to which parental and infant sleep physiology are entwined. For millions of years of human evolution, infants have successfully adapted to sleeping with at least one care-giver. The idea that infants sleeping alone is "normal", or always preferable to co-sleeping, is historically recent; until now, possible negative consequences of this sleeping arrangement for infants have never been experimentally explored. We do not suggest that infant–parent co-sleeping studies can elucidate primary causes of SIDS, but rather that these studies may offer additional insights into some of the diverse types of co-factors which conspire with a range of primary deficits to increase SIDS risks, among some infants (3).

Recall that SIDS remains enigmatic, but most researchers agree that multiple etiologies are involved, and that no single explanation will likely prove sufficient to explain all SIDS deaths. The fact that the SIDS population is so remarkably heterogenous, and the syndrome itself is thought to be multifactorial (4), further justifies careful attention being paid to the nature of the sleep environment within which the syndrome finds expression.

The co-sleeping hypothesis offered here must be considered alongside other co-factors, too; and it is not necessarily relevant to all SIDS, or potential SIDS victims. Exactly *how* co-sleeping is practiced will determine whether, or if, the proposed benefits of co-sleeping can be experienced by the infant. For example, in New Zealand, bed sharing is associated with increased SIDS risk, which certainly raises questions about the perspective offered here. We begin our work realizing that no environment for an infant is risk free, including a co-sleeping one. We also know that epidemiological studies delineate associations between variables in large populations and do not, for any given SIDS event, reveal anything about the underlying mechanisms, or specific conditions under which particular deaths of *individual infants* occurred.

As is the case in New Zealand, bed sharing is mostly practiced among socioeconomically disadvantaged groups (indigenous Maori) who exhibit almost all of the known SIDS risk factors (5). Moreover, in New Zealand, co-sleeping can take place under adverse and/or dangerous conditions such as when adults and infants sleep together on sheepskin bedding material, or when one or both parents have used alcohol, or other drugs, or are depressed (E Mitchell, personal communication). Given the subtle and complex co-factors suspected to be relevant to each SIDS death, it is not appropriate to use these data to conclude that co-sleeping is dangerous across all family circumstances, across all cultures, or that it cannot help protect some infants from SIDS.

The evidence supporting the potential protective benefits of co-sleeping, is, admittedly, indirect and circumstantial; but consider here the diverse lines of evidence from which this hypothesis emerges. The lowest rates of SIDS in the world occur in Asian cultures, including industrial ones such as Japan, where infant–parent co-sleeping is the norm (6, 7). Exceedingly low SIDS rates have been verified in Hong Kong, even when Western autopsy protocols identifying SIDS victims are employed (8, 9). These low SIDS rates continue in Asian ethnic groups even after they immigrate to Western (non-co-sleeping) cultures, where most continue their traditional care-giving practices which include co-sleeping (10). One study reports that among five Asian-American subgroups living in California, the incidence of SIDS ranged from a low of 0.9 deaths per 1000 live births to a high of 1.5 per 1000. The variability was related directly to the duration of residence in the USA: the longer the group lived in the USA, the higher the SIDS rates (11), leading us to ask if the trend toward higher SIDS rates reflects the adoption of more "American" patterns of infant sleep management, i.e. solitary infant sleep, among other things.

Another line of supportive, albeit indirect, evidence is drawn from psychobiological studies. For example, even short-term, intermittent separation from a care-giver is now known to have deleterious physiological consequences on a variety of "altricial" or undeveloped mammal infants, including the human infant who is the

Table 1. Immediate short-term consequences of parent-infant separation in monkeys and rats (from (3)).

Physiological consequences of separation	Investigator(s)
Bonnet or pigtail monkeys	
Initial period: increase in heart rate and body temperature	Reite & Snyder (1982)
Subsequent period of depressed behavior: decrease in heart rate and body temperature	Reite et al. (1978a, 1978b)
Increase in cardiac arrhythmias	Seiler et al. (1979)
Alterations in heart rate, body temperature and circadian rhythms	Reite et al. (1982)
Disturbances in sleep: increased arousals; increase in REM latency; decrease in time in REM	Reite & Short (1978)
Changes in regulation of EEG activity	Short et al. (1977) Reite et al. (1982)
Alterations in cellular immune response accompanying mother-infant or peer separation	Reite et al. (1981) Laudenslager et al. (1982) Other references: McKenna (1979, 1982) Reite & Capitanio (1985) Coe et al. (1985) Hofer (1981, 1978, 1983)
Squirrel monkey (*Saimiri sciureus*)	
Increase in adrenal secretion and plasma cortisol levels	Coe & Levine (1981) Coe et al. (1978, 1985)
Serum levels of immunoglobulins: decline after 7 days; back to normal in 14 days	Coe et al. (1985)
Complement proteins to cortisol diminish	Coe et al. (1985)
Lower level of antibody production in response to bacteria (*Escherichia coli*)	Coe et al. (1985)
Rats, 2 weeks old	
Bradycardia	Hofer (1981, 1978, 1983)
Increased sleep latency	
Augmented sleep	
Decrease in REM sleep	
Rats, 10 days old	
Fifty percent reduction in brain and heart enzyme (ornithine decarboxylase) due to separation-induced suppression of growth hormone	Butler et al. (1978) Kuhn et al. (1978)

From McKenna 1986.

most vulnerable and slow developing mammal infant of all (12). For example, body temperature, cardiac patterns, hormonal and immune status, growth rates and sleep architecture are significantly affected by short-term separations of infant monkeys from their mothers, as much research demonstrates (Table 1). Moreover, experimental work on the effects of particular sensory stimulii on specific physiological parameters continues to reveal that among human and other infant mammals, even the most fundamental systems, such as breathing, arousal patterns, heart rate, sleep architecture and thermoregulation, parameters important in the investigation of SIDS, are affected by the presence or absence of parental contact (13–16).

Such external physiological regulation and support by a primary care-giver is a critical and special dimension of the human infant's unique evolutionary history. It is millions of years old. Paleoanthropological and archaeological data indicate that by four million years ago, upright posture (bipedalism) was already being favored by natural selection (17). Freeing the hands for tool use had significant reproductive value. But a serious drawback to these adaptations was the necessary structural accommodations required of the pelvis. Bipedalism reduced the size of the birth opening, at the very same time that the average cranial capacity of our ancestors was becoming substantially larger, presumably to permit complex learning and sociality. The adaptive solution to this evolutionary conflict was (and continues to be) the birth of exceedingly neurologically immature infants (small brained infants) for whom the majority of brain growth (about 75%) occurs postnatally, and not in the womb (18, 19). Co-sleeping became a necessity early in the evolution of our hominid

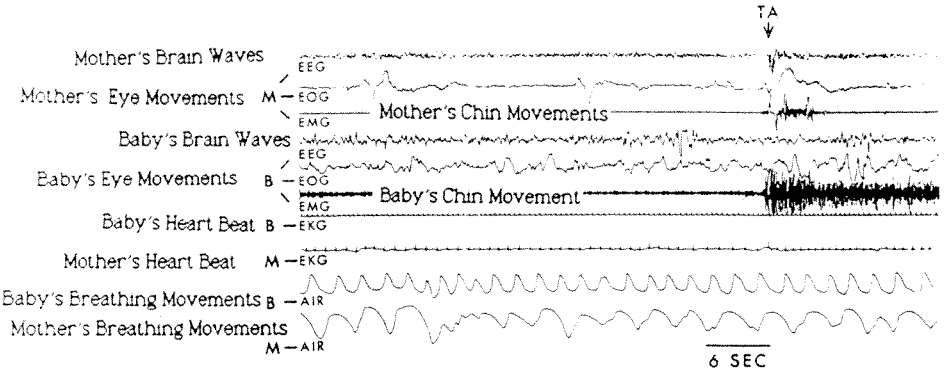

Fig. 1. Polygraph recording of a co-sleeping mother and her three-month-old infant. In this 6-s segment of their sleep time the mother has a small physiologically recognizable transient arousal (TA), which almost simultaneously induces a change in the baby's physiological status. Such natural interactions occur frequently throughout the night while mothers and infants co-sleep. We ask whether or not these small interruptions to the infant's sleep provide the infant with practice in arousing, and whether this practice may assist infants eventually to arouse more efficiently on their own during some form of respiratory crisis.

ancestors to assure the survival of exceedingly slow developing and non-ambulatory infants.

The composition of human milk also supports the idea of a long evolutionary history of human infant–parent co-sleeping. Compared with other mammals human milk is low in fat and protein and relatively high in carbohydrates, especially lactose, a key nutrient needed, among other things, for brain growth. The concentration of lactose in milk is highest among primates whose infants are the least neurologically developed at birth. Other mammals such as lions and several species of deer, leave their young in nests or burrows and return to them at intervals of 6–12 h; they are called the "cache species". Their milk, unlike human milk, is high in fat and protein, allowing the young to be satiated for longer periods of time. The composition of human milk which provides less calories per feeding suggests that human beings evolved "on demand" feeding patterns, where infants remain in close contact with their mothers and can nurse at any time during the night (as they co-sleep) and day as they are carried by body shawls of some sort (1, 20).

We do not suggest that solitary infant sleep "causes" SIDS, or that SIDS deaths can be eliminated simply by co-sleeping, or that all parents by virtue of our evolution, should co-sleep. Parental lifestyles and expectations of Western industrial people make this issue very complex. But we do argue that not all infants are as biologically equipped to respond equally well to solitary infant sleep, and it is to these infants that these research questions are directed. Three different assumptions underlie our research: (1) human infant–parent co-sleeping represents the species-wide (universal) and biologically stable pattern; (2) infant–parent co-sleeping was favored by natural selection specifically to confer a range of physiological, social and psychological survival benefits to the vast majority of infants and; (3) infant–parent co-sleeping evolved in conjunction with, and to

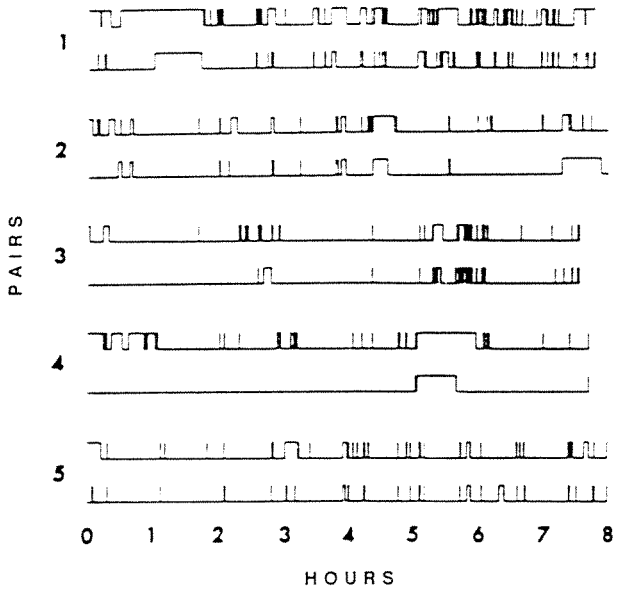

Fig. 2. This computer generated illustration shows the high amount of synchrony of awakenings of five co-sleeping mother–infant pairs. Each pair (1–5) is a co-sleeping mother and infant. The top line of each pair shows the sleep-wake transitions of the infant, the bottom line of each pair shows the sleep-wake transitions of the mother. The spikes represent 1 min of wakening. When the line travels along the bottom, the individual is asleep; when it moves to the top, the individual is awake. Notice the number of times that mothers and infants arouse or awaken together over the 8-h period of recording (from (21)). (From McKenna et al., 1991.)

offset, the human infant's neurological immaturity. With respect to SIDS research, our view is that parental sleep contact promotes patterns of infant sleep, breathing and arousal patterns which are most compatible with the human infant's unique developmental vulnerabilities, as described below. We ask: does solitary infant sleep contribute in any way to the pathophysio-

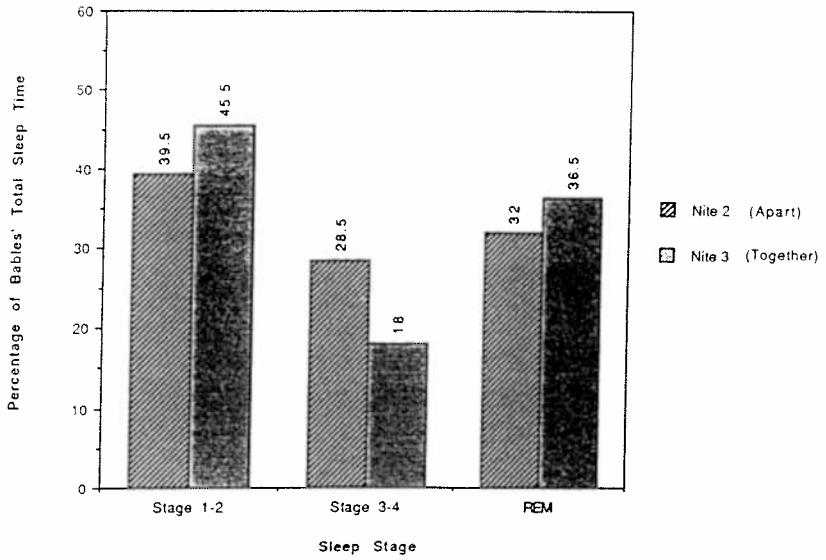

Fig. 3. Mean percentage of baby's total sleep time spent in each sleep stage as a function of environment. These data come from a study in which three mother-infant pairs spent three consecutive nights in the sleep laboratory. The first two nights mothers and infants slept alone, in adjacent rooms; the third night they slept in the same bed. Each night mother and baby were physiologically monitored using standard polysomnography. The recordings were fed into the same polygraph. Notice that the infant's stage 3 or 4 (which were combined to be able to compare with mother's sleep) dropped dramatically in the co-sleeping situation. We speculate that at younger ages, lighter sleep may be more likely, and possibly safer, for infants, and is induced by contact with the parent (from (21)). (From McKenna et al., Sleep 1993;16:269.)

logy of some SIDS, even if this environmental factor is only relevant to a very few number of SIDS, or potential SIDS events (3, 19, 21).

Materials and methods

We have completed two preliminary physiological studies of infant-parent co-sleeping in the sleep laboratory. In our first study of five mother-infant pairs, we monitored, simultaneously, each mother and infant as they slept in the same bed. EEG, EKG, chest movements, airflow and EOG of the mother and infant were recorded and written out simultaneously on a 12-channel polygraph (21–23). The infants were between two and four months of age, the peak age for SIDS. During a second study we examined three mother-infant pairs over three consecutive nights using the same techniques. The first two nights mothers and their infants slept within auditory range in adjacent rooms while all standard physiological parameters were recorded simultaneously, including oxygen saturation levels of the infants. On the third night we continued the recordings as mother and infant shared the same bed (23, 24).

Results

The preliminary results indicated that: (1) co-sleeping mothers and infants exhibit high levels of arousal overlap, both longer epochal, and smaller physiologically defined transient arousals (Figs 1 and 2); (2) infants exhibit more frequent state transitions while co-sleeping; (3) co-sleeping mothers and infants spend more time, at the same time, in the same state of sleep and wakefulness while in the same bed; (4) compared to the solitary sleep environment, on average, co-sleeping infants spent less time in deep stages of sleep (stage 3 or 4) (Fig. 3); (5) co-sleeping mothers intervened during the arousals of their infants, possibly prolonging them; (6) using standard criteria, neither the mother's nor the infant's sleep was clinically disturbed in the co-sleeping environment: mothers reported having a normal, if not better, sleep than she did at home; (7) infants were responsible for positioning and repositioning themselves with respect to their mothers, and mostly slept on their sides, diagonally, facing their mother's face; and (8) co-sleeping mother-infant pairs spent more time, at the same time, in the same sleep or awake status while co-sleeping (21–24).

Discussion

We realize that our preliminary findings are extremely limited, and that our research can prove nothing about the possible benefits of co-sleeping, or whether or not it is protective of some SIDS. However, the potential

value of continuing and expanding co-sleeping studies is made clear by these data, particularly since the ways in which the physiological status of the infant is changed during co-sleeping is relevant to several pertinent issues and/or hypotheses about SIDS. For example, the finding that co-sleeping mothers and infants exhibit overlapping physiological (partner-induced) arousals are potentially important because of the suspected relationship between infant arousal deficiencies and some cases of SIDS. We can speculate that co-sleeping may provide the infant with increased opportunities to learn how to arouse. That is, by inducing arousals at times when the infant might not otherwise arouse had the infant been sleeping alone, a co-sleeping partner's interruptions may provide the infant with practice in arousing (21–24).

Partner-induced arousals which occur throughout the night in a co-sleeping situation increase the overall amount of physiological variation as defined by the number of transitions infants make from one stage of sleep to another, or from sleep to momentary wakefulness. We also speculate that co-sleeping-induced arousals may facilitate more synchronous maturity of the various subsystems involved in arousal (heart rate, a change in breathing rate, for example) as well as the mechanisms responsible for the ease by which infants shift from one stage of sleep to another, or from sleep to wake status. These linkages among the infant's physiological subsystems which interact during arousals may not occur as easily, as often, or as quickly, if infants regularly sleep alone.

Finally, ethological (minute-to-minute) behavioral analysis of our video tapes of mothers and infants sleeping together and alone reveal that while together, infants spend more time on their sides facing their mothers' faces, often diagonally; they do not spend much time on their backs. The infant plays an active role in positioning itself relative to its mother, it moves more, and the mother, likewise, plays an active role in aerating bedding, moving the sheets, and in keeping the space between the infant's head clear of any potential obstruction. Our studies, which are being expanded, will eventually permit us to make statements about the possible dangers of co-sleeping, too, including whether or not, as Mitchell et al. suggest, co-sleeping can overheat infants, thereby increasing SIDS risks (21–24).

Conclusions

In summary, human infants are different from other mammals insofar as the central nervous system is exceedingly undeveloped at birth. It is reasonable to assume, and developmental studies support this contention, that their bodies have been designed by natural selection to be highly responsive to contact with a caregiver on whom, and for a considerable period of time, its survival depends. Not even 1000 years of separate sleeping (let alone 100 to 200 years) can have any appreciable, if any, effect on making the infant's biological system more fine tuned to the recent cultural innovations of sleep isolation.

In our enthusiasm to view the human infant in accordance with industrial Western European values which favor early autonomy and individualism over familial independence, researchers inadvertently may have pushed too far the notion of the infant's physiological independence from its care-givers, confusing the infant's preparedness to adapt, with actual adaptation (3).

We have put forth several different but interrelated proposals concerning the evolutionary history of parent–infant sleep and hypothesized that for some possibly small subclass of SIDS vulnerable infants, parent–infant contact throughout the night may help them to override deficits involved in some cases of SIDS. Human evolutionary studies integrated with cross-cultural data on human behavior, and evolutionary theory itself, can serve as an unbiased starting point for conceptualizing biomedical problems, especially those like SIDS which resist our understanding.

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