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by

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ABSTRACT

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This study contributes to the growing understanding of social sleep environments and their relationship to parent and infant behaviour and physiology by exploring the ways proximity and/or regularity of bed-sharing practice affect the physiology of parents and infants during triadic social sleep. The study explores the sleep physiology of 15 regularly and occasionally bed-sharing families, testing previous claims of shared sleep and arousals amongst breastfeeding mother infant dyads, and presents a new examination of the effects of proximity on mother infant physiology, and for the first time father infant physiology during bed-sharing compared to rooming-in.

Fifteen families considered low-risk for SIDS with breastfed infants less than 3 months of age were recruited from N. Tees region. Families either regularly slept their infant in a cot by the side of the parent's bed, or with the infant in the parent's bed. Circumstances under which co-sleeping was practised, and its frequency were assessed from sleep diaries, together with interview.

Data were acquired by physiological monitoring via respiratory plethysmography bands, temperature probes (axillary and rectal), pulse oximeter probe (rubber type, not clip) and infra-red video capture over three nights (one adjustment night and two test nights) in the Durham University Sleep Lab. The two test night conditions were 1) infant sleeping in the parental bed 2) infant sleeping in a cot positioned next to the parental bed.

Infant sleep/wake states were determined using cardio-respiratory video method. Sleep stages were subjectively assigned to 4 sleep state categories, awake (AWK), active asleep (REM), quiet sleep (QS) and indeterminate (IND), according to the characteristics predominant in any 1 minute epoch.

Data from this study identified that mothers and infants experienced less time awake on bed-sharing nights and infants spent less time in Quiet sleep on the bed-sharing night; that regular bed-sharing infants experienced disruption to their sleep when separated from their mothers, but greater stability in their sleep physiology between by-the-bed sleeping and bed-sharing than occasional bed-sharing infants; that regularity of normal sleep condition only affected the shared sleep of regular bed-sharing mothers and infants on the bed-sharing night; and that sleep state synchrony and arousal synchrony were present amongst breastfeeding bed-sharing mothers and infants. Neither sleep condition nor regularity of normal bed-sharing practice made a discernable difference to paternal sleep state distribution and fathers did not demonstrate sleep state synchrony with their infants during social sleep. Paternal arousal behaviour was entirely unaffected by the location of the infant or their regular sleep location. Two noteworthy trends from the paternal data were that the absence of the father on the cot night affected both infant and mother sleep and that paternal habituation to sleeping practice was observed.

TABLE OF CONTENTS

LIST OF FIGURES

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the Regulations of Durham University.

No part of this thesis has been submitted for any other degree. This thesis has not been presented to any other University for examination either in the United Kingdom or overseas.

GLOSSARY

This review frequently employs terminology reflecting those used by the authors being reviewed. The lack of consistency in these terms reflects the discursive flow within the field and cannot be avoided. However, the following definitions are employed to terms used within the analysis and discussion of this thesis.

- **Apparent life-threatening event (ALTE)** - a prolonged infant apnoea spell, which may have severe physiological consequences including respiratory arrest.
- **Bedding in** – Sleeping an infant with a parent or parents on a contiguous sleep surface, which has been designed for sleep.
- **Bed-sharing** -"Parents and infants are deemed to bed-share if the infant slept in the parental bed with one or both parents (at the same time the parent(s) slept), for any portion of a night or nights." (Ball, 2002)
- **Behavioural synchrony** – "relatively persistent patterns of responsiveness in which periodic and episodic behaviour of at least one participant in a social encounter serves as a time clock to whose beats of behaviour the other is responsive and entrained" (Rosenfeld. 1981: 90).
- **Combination bed-sharers** – Families who use a range of sleep locations for their infants including sleeping their infants in the parental bed with one or both parents (at the same time the parent(s) slept), for any portion of a night or nights
- **Co-sleeping** – "Parents and Infants sleeping within sensory interchange of one another – be that involving touching, gas exchange, etc. but does not involve an adult and infant necessarily sleeping on the same surface or in contact with one another" (Ball 2002).
- **Cot Death** - The common name for SIDS, where infants who were previously well or suffering from an apparently minor ailment die suddenly and unexpectedly in their sleep with no identifiable cause at post-mortem examination.
- **Habitual bed-sharers** – Parents who, with very few exceptions, sleep their infant in the parental bed with one or both parents (at the same time the parent(s) slept), for any portion of a night or nights
- **Near miss SIDS** - a prolonged infant apnoea spell, which may have severe physiological consequences including respiratory arrest [more recently designated as apparent life-threatening event (ALTE)]
- **Rooming-in** – Sleeping an infant in the same room as a parent, or parents but not on a contiguous sleep surface.
- **Shared arousal achieving parental consciousness (SAAPC)** – Referring to occasions when a parent arouses within the same or

following minute to their infant and achieve a state where they are able to make a conscious intervention in their infant's situation

- **Social sleeping** – A general term referring to the act of two or more individuals sleeping within the same space [room], whether on the same or different sleep surfaces.
- **Sudden Infant Death Syndrome (SIDS)** - "The sudden death of an infant under 1 year of age which remains unexplained after a thorough case investigation, including performance of complete autopsy, examination of the death scene and a review of the clinical history". (Willinger et al 1991).

Chapter 1

INTRODUCTION

"Recently, scientific studies have demonstrated that bed-sharing between mother and infant can alter and synchronize sleep patterns of mother and infant. These studies have led to speculation in the lay press that bed-sharing, sometimes referred to as co-sleeping, may also reduce the risk of SIDS. While bed-sharing may have certain benefits (such as encouraging breastfeeding), there are no scientific studies demonstrating that bed-sharing reduces SIDS. Conversely, there are studies suggesting that bed-sharing, under certain conditions, may actually increase the risk of SIDS. Also, it should be noted that no benefits have been shown for infants sleeping with individuals other than the mother." (Kattwinkel et al. 1997)

Sleeping an infant in the same room as a parent, or parents, has been found to be beneficial to an infant less than six months of age; a parent's presence in the same room has been statistically demonstrated to protect against Sudden Infant Death Syndrome (SIDS) (Fleming. 1996; Carpenter. 2004). However, sleeping an infant with a parent or parents the same sleep surface (designed for sleep) is often considered undesirable and may confer a risk of accidental death or increase the risk of SIDS (Mitchell et al. 1993; Nakamura, Wind et al. 1999; Kemp, Unger et al. 2000).

The mechanism that makes rooming-in protective is unclear. Unfortunately, whilst population studies such as the Confidential Enquiry into Still-births and Deaths in Infancy and Sudden Unexpected Death in Infancy (CESDI SUDI) study (Fleming, Blair et al. 1996) and more recent European Concerted Action on SIDS (ECAS) study (Carpenter. 2004) can provide data on the strength and direction of relationship between sleep environment and SIDS they cannot identify causal mechanisms. This means that explanations for why sleeping a young infant in the same room as a parent can reduce the risk of unexplained infant death are speculative.

The predominant candidate for explaining the protective mechanism is sensory exchange, a theory resulting from Mosko and McKenna's 'arousal deficiency' theory; this suggests that rooming-in allows sensory exchange between parent(s) and infant. The exchange of sensory information acts as an 'auto-cue' for the infant's physiology and offers the potential for parental intervention at an earlier stage during episodes of infant distress (McKenna, Mosko et al. 1990). This theory is derived from exploring the parent infant sleep relationship as an evolved mechanism that optimises fitness.

However, the theory that sensory exchange can protect against SIDS or accidental death when infants share a room with a parent ought to extrapolate to infants sharing a sleeping surface with a parent; if sensory exchange is associated with proximity (Mosko, Richard, et al. 1997) then surely a closer infant is a safer infant. The same would theoretically apply to any protective value gained from an increase in parental monitoring of the infant. This seems at odds, however, with data suggesting that bed-sharing is disadvantageous (Byard, Beal et al. 1994; Bass, Kravath et al. 1986; Thogmartin. 2001; Carpenter. 2004).

Combined with clear indications that bed-sharing for at least a part of the night on a regular or occasional basis is widespread in the UK (Ball 2002) and US (McCoy, Hunt, et al. 2004), and established links between bed-sharing and the uptake and continuation of breastfeeding (McKenna, Mosko, et al. 1997) (known to be highly beneficial to newborn infants (Cunningham, Jeliffe, et al.1991)) the situation creates confusion as to what advice should be given about bed-sharing and leaves parents with conflicting messages on night time care giving. In order to address this situation a systematic investigation of all aspects of social sleep, both rooming-in and bedding-in, is required. One way to progress toward this goal is by mapping physiological relationships between parent and infant during night time sleep and exploring if and when sensory exchange is occurring and how social sleep variation affects it.

Physiological studies of both parents and infants during sleep are rare. Those that have been conducted state that shared sleep state and arousal synchrony have been observed in mother infant dyads during bed-sharing (McKenna and Mosko. 1990) and some mothers with infants under 3 months old who bed share have been observed to undergo a variation in their sleep cycles from around 90 minutes (apparent in adult females) to become closer to 60 minutes (apparent in infants less than 3 months) (Fleming, Sawczenko, et al. 1998). They also suggest higher infant temperature during bed-sharing than cot sleeping (Tuffnell et al. 1996, Baddock et al. 2004, Ball 2002) though this did not appear to impair thermoregulation (Baddock et al. 2004, Ball 2002) and that the warmer bed-sharing infants were more likely to wake and feed (Baddock et al. 2004).

It is possible that increased infant waking, synchronous arousals and shared sleep state may be indicators of sensory exchange, where physiological and behavioural characteristics of the mother influence the infant, or vice-versa, during sleep. Such observable characteristics may provide a proxy measure of sensory exchange and help determine whether sleep synchrony exists in sleep conditions other than just bed-sharing. It is also unclear whether all bed-sharers or only those who regularly bed-share can become 'attuned' to their infant's sleep. Further, it is unclear whether both mothers and fathers can become 'attuned' to their infant's sleep. Such data would assist in building a better understanding of sensory exchange in social sleep.

The primary goals of this research are to determine whether both shared sleep state and arousal synchrony are related to proximity, and/or the regularity of bed-sharing, for both mothers and fathers. For this (preliminary) study 21 breastfeeding mother infant pairs with infants aged 1-4 months and their partners were recruited (10 regular bed-sharing and 11 occasional bed-sharing families) to participate in a two condition trial of infant sleep location. Data were collected using physiological monitoring by respiratory plethysmography and pulse oximetry, combined with simultaneous video observation using a ceiling mounted low-light intensity camera to identify transient movement arousals and full waking arousals. These data were used to map sleep state architectures during rooming in (with a cot by the bed) and bed-sharing in a sleep lab environment.

The infant physiological data and some behavioural data have previously been analysed to provide statistical measures of infant risk scenarios including overlaying, overheating, suffocation, entrapment etc (Ball 2002). However, this is the first time the infant physiological data have been used to explore shared sleep state and arousal synchrony, and the first time the parental physiology data have been explored.

The following research questions are addressed as primary outcomes in this thesis:

a. Are sleep state distributions of breastfeeding mothers and infants affected by whether the infant is slept in the bed or in a cot by the bed? *Potential indicator that proximity affects sleep-state-distribution*

b. Are sleep state distributions of breastfeeding mothers and infants affected by whether they are regular or occasional bed-sharers? *Potential indicator that regularity of normal sleep condition affects sleep-state-distribution*

c. Do breastfeeding mothers demonstrate sleep state synchrony with their infant during triadic bed-sharing as suggested for dyadic mother and infant pairs?

d. Do breastfeeding mothers demonstrate sleep state synchrony with their infant if the infant is slept in a cot by the bed? *Potential indicator that proximity affects sleep-state-synchrony*

e. Is there any difference in sleep state synchrony between regular bed-sharing mothers and infants, and occasional bed-sharing mothers and infants in either bed-sharing or cot by the bed conditions? *Potentially indicating that regularity affects sleep state synchrony*

f. Do breastfeeding mothers demonstrate arousal synchrony with their infant during bed-sharing? *Potential indicator of enhanced maternal care capacity*

g. Do breastfeeding mothers demonstrate arousal synchrony with their infant if the infant is slept in a cot by the bed? *Potential indicator that proximity affects maternal care capacity*

h. Is there any difference in sleep state synchrony between regular bed-sharing mothers and infants, and occasional bed-sharing mothers and infants in either bed-sharing or cot by the bed conditions? *Potentially indicating that regularity affects sleep state synchrony*

i. Are sleep state distributions of fathers affected by whether the infant is slept in the bed or in a cot by the bed? *Potential indicator that proximity affects sleep-state-distribution*

j. Are sleep state distributions of fathers affected by whether they are regular or occasional bed-sharers? *Potential indicator that regularity of normal sleep condition affects sleep-state-distribution*

k. Do fathers demonstrate sleep state synchrony with their infants during social sleep, and does proximity or regularity influence that synchrony?

l. Do fathers demonstrate arousal synchrony with their infants, and does proximity or regularity influence that synchrony?

Chapter 2

BACKROUND

This chapter highlights the data linking SIDS and night time infant death to sleep state, arousal patterns and reciprocal awakenings and reviews the current data regarding sensory exchange.

The discourse on how and where to sleep an infant has long roots; Blair & Ball (2004) note references found both in Roman medical texts (Norvenius 1993) and the Old Testament (Byard 1994). They further attest to the longstanding nature of the debate by relating Hiley's (1995) reference to historical documentation of the bed-sharing debate in the UK dating to the thirteenth century, "when, against a climate of concern at the prevailing high rates of infanticide, bishops instructed their clergy to urge mothers not to sleep with their babies, in an attempt to eliminate a potential means of covert infant suffocation" (Hiley 1995).

Contemporary focus on where to sleep an infant has shifted away from covert infanticide to Sudden Infant Death Syndrome (SIDS) and accidental night time infant death. Bed-sharing has been implicated in SIDS and accidental night time infant deaths, including where one or both parents are smokers (Blair et al, 1996; Blair, et al, 2000; Mitchell & Milerad. 1999; Carpenter et al. 2004)), or have been using prescription or illegal drugs (Nakamura et al. 1999), have consumed alcohol (Mitchell & Scragg 1993), or are excessively fatigued (Byard 1998). Further, coroners have commonly associated bed-sharing and the adult bed with SIDS and accidental infant death, especially overlaying, (Thogmartin. 2001; Kemp, et al. 2000; Drago and Dannenberg. 1999; Nakamura, et al. 1999). However, evidence also exists to suggest that some aspects of bed-sharing are beneficial to both mother and infant, including a positive relationship with breastfeeding (McKenna, Mosko, et al. 1997), which is believed to be protective against SIDS (Mitchell, Taylor, et al. 1992; Hoffman, Damus, et al. 1988); beneficial to infant health (Cunningham, Jeliffe, et al. 1991; Cunningham. 1995; AAPWGB. 1997); facilitate infant social and emotional development through enhanced bonding and attachment between mother and infant (Anders. 1994); and sensory exchange (McKenna, Mosko, et al. 1997), which will be discussed in detail later.

Combined with clear indications that bed-sharing for at least a part of the night on a regular or occasional basis is widespread in the UK (Ball. 2002) and US (McCoy, Hunt, et al. 2004) the situation creates confusion as to what advice should be given about bed-sharing and leaves parents with conflicting messages on night time care giving. On the one hand, health authorities have an obligation to the population in its broadest terms, focusing their recommendations on behaviours that stand to offer the largest number of families the least risk, and therefore generally recommend against bed-sharing (AAPTFSIDS 2005, Kattwinkel, Hauck, et al. 2006). This is a situation reminiscent of the 'Rose effect' where "examples of blood pressure and cholesterol [were used] to show that shifting the distribution curve of a single risk factor by a small amount in an entire population has a greater effect on death rates than does treating only people with high levels of that risk factor" (Manuel et al. 2006). The Rose effect was similarly used to justify a population based strategy rather than targeting 'at risk' individuals. In the case of bed-sharing, such blanket recommendations, whilst understandable at the population level, mean that many families who do not demonstrate any of the contraindicative behaviours associated with bed-sharing may be missing out on the benefits that bed-sharing may offer (Gessner & Porter 2006). Further, many point out that the basis for recommendations not to bed-share use unreliable data due to the inclusion of sofa-sharing and waterbed-sharing amongst the bed-sharing populations (Gessner & Porter 2006), do not satisfactorily identify the differences in risk between bed-sharers in specific high-risk groups (smoking, drinking or sedated parents) and those who do not (Pelayo, Owens et al. 2006), and are contradicted by observable trends in SIDS and infant mortality rates (Gessner & Porter 2006). To understand the dilemma faced by parents and health authorities a clearer understanding of the relationship between SIDS, sensory exchange and night time care is required.

The greatest risk of SIDS occurs during the first 6 months of life, peaking between 3 and 4 months amongst the infant population as a whole (Sparks, et al. 2002) and at 2 months for bed-sharing infants (Blair 2006). Ficca, Fagioli, et al. (1999) highlight the development of sleep state rhythm in infants noting progressively fewer awakenings out of REM occurring over the first 6 months of life, emphasising the disassociation of infant ultradian rhythms to the circadian rhythms of adults. The development of adult like sleep patterns occurs in stages over the first few months, moving from scarce circadian component to prominent circadian component at around 7 weeks and then to prominent 12 hour cyclic circadian component at around 12 weeks (Fukuda & Ishihara. 1997). This pattern, which demonstrates a shift toward more adult like sleep over the first 4 months, suggests major developmental change in the regulation of infant physiology. It is worth noting that this data did not distinguish infant feeding method which may influence infant growth pattern and physiological development (Lucas 1992, Crawford 1993), or sleeping arrangement which may influence infant physiology (McKenna & Mosko 1990; 1994; Mosko & Richards 1997).

It has been noted in numerous studies that sleep patterns of SIDS infants differ from those of non SIDS infants. Infants who were monitored and later died of SIDS showed abnormal patterning of sleep waking states with comparatively fewer waking epochs during the 3-7 am period of the morning (Schechtman, Harper, et al. 1992). This pattern is mirrored in the subsequent siblings of SIDS victims (Schechtman, Harper, et al. 1994) and in 'near miss

SIDS' infants (Coons & Guilleminault. 1985). This early morning period has been identified by Hoppenbrouwers, Jensen, et al. (1982) as the period when most SIDS deaths occur.

The time 'normal' infants spend in REM and Quiet sleep are known to shift from more Quiet (NREM stage 3 & 4) in the first period of the night to more REM sleep toward morning (Stradling. 1993). In comparison to control infants, SIDS infants spend more time in Quiet sleep during the morning (Schechtman, Harper, et al. 1992). Combined with the suggestion that an inhibitory mechanism to arousal exists during Quiet sleep (Coons & Guilleminault. 1985; Ward, Bautista, et al. 1992) the situation has led to suggestions that the fewer morning awakenings identified in SIDS infants may be caused by inhibited arousal resulting from greater proportion of Quiet sleep at this time in the mornings (Schechtman, Harper, et al. 1992). Greater time spent by infants in Quiet sleep during the morning hours may therefore be a contributing factor to SIDS.

During REM sleep apparently 'normal' infants in their first month who later died of SIDS demonstrated fewer sleep epochs obscured by artefact (which, are often the result of movement) than age matched controls (Schechtman, Harper, et al. 1992), leading Schechtman, Harper, et al. (1992) to conclude that SIDS infants demonstrate reduced movement during sleep. Again, these findings mirror those in 'near miss SIDS' infants (Coons & Guilleminault. 1985). Frequency of movement during sleep has been linked to development of the Central Nervous System (CNS), correlating to the maturation process and suggested as an indicator of normal and abnormal CNS development (Fukumoto, Nobuko, et al. 1981). Reduced movement during REM sleep, possibly linked to CNS maturity, may therefore be a factor in SIDS.

Respiratory pauses (apnoea) during sleep have been noted in SIDS infants (Schulte, Albani, et al. 1982) and obstructive apnoeas have been found in apparent life-threatening event (ALTE) and subsequent SIDS infants (Engleberts. 1995). If larger than 10-20 seconds, and accompanied by serious bradycardia, such obstructive apnoea can lead to hypoxia – suspected to occur in some SIDS (Guilleminault & Coons. 1983; Harper, et al. 1981). Although unproven, the implication of apnoea in SIDS death has received considerable attention and fuelled by the fact that the period of greatest frequency of obstructive apnoea coincides in 'normal' infants with the age range of highest SIDS risk (Hoppenbrouwers, Hodgman, et al. 1993) is often considered a highly probable component in SIDS. However, obstructive apnoea has been detected in preterm, term, and subsequent siblings of SIDS infants with no pathological consequence (Hoppenbrouwers, Hodgman, et al. 1993) and may be normal for infants (Peterson. 1983).

Rather than the apnoea itself, it may be that a depressed arousal response due to immature (Pettigrew, et al.1985), premature (Sterman & Hodgman. 1988) or abnormal (Kalnins. 1986) autonomic function in some infants interferes with the ability to reinstate normal breathing and therefore leads to death. Certainly the effects of maternal smoking, known to increase the risk of SIDS (Blair et al, 1996; Blair et al, 2000; Mitchell & Milerad. 1999; Carpenter et al. 2004), have been linked with suppression of the autonomic function and can lead to blunted responses to hypoxia, which is a characteristic of some SIDS victims (Guilleminault & Coons. 1983). The development of neural substrates for autonomic control is susceptible to some components of cigarette smoke (e.g. Nicotine) and prenatal maternal smoking has been shown to negatively affect active sleep arousals in pre-term infants (Sawani, Jackson, et al. 2004), whilst exposure to cigarette smoke post-natally has similarly been found to depresses the infant arousal response (Franco et al 2001).

Pre-natal exposure to cigarette smoke also alters baseline heart rate, cardiac tone and control (Schectman, Raetz, et al. 1992; Franco, Szliwowski, et al. 1998). Some victims of SIDS have demonstrated higher overall heart rates prior to death than age matched control across all sleep states at age 1 month or less but was not noted during waking regardless of age (Schetchtman, Harper, et al. 1988).

These data would seem to support a link between autonomic control, apnoea, and arousal and implies that disruption to the coordination and control of one or more of the interrelated cardiovascular and autonomic control functions may lead to inability to cope with episodic challenges to the breathing and/or arousal systems and may thus lead to higher risk of SIDS (Schechtman, Harper, et al. 1995; Kahn, Franco, et al. 1997).

Episodic challenges frequently occur during sleep and during transitions between sleep states and the link has led many to seek defective, dysfunctional or degenerating neuronal circuitry in the autonomic nervous system (ANS) (part of the central nervous system (CNS)) as a cause the sudden night time death (Schechtman, Harper, et al.1992; Kahn, Riazi, et al. 1983; Schectman, Raetz , et al. 1992; Kinney & Filiano. 1988; Sparks, Davis, et al. 1996). This is because it is the ANS that regulates many of the rescue responses to potentially life-threatening events including responses to respiratory, cardiac, thermal, and blood pressure. However, there is a possibility that the ANS is not the only regulatory system at work in infant physiological control or rescue response during sleep.

Almost all of the data regarding SIDS and the relationship between sleep and arousal patterns in infants presented so far has been obtained from solitary sleeping infants. Indeed, almost all understanding of infant sleep physiology has been obtained from solitary sleeping infants; polysomnography on "bottle fed, solitary sleeping infant[s] became the gold standard method used to produce data on 'normal' infants sleep physiology" (McKenna & McDade 2005; 136). However, the practice of sleeping infants alone is nearly exclusive to 'Western' societies and does not represent global, historical, evolutionary, or the entirety of modern, infant sleep strategies (Ball 2003, McKenna & McDade 2005). It is possible that our understanding of infant sleep physiology, and therefore of SIDS and night time infant death, has not accounted for an evolutionarily derived regulatory system for infant physiological control and rescue response during sleep that is external to the infant itself; the presence of a parent.

In evolutionary terms social sleep is the most likely sleep strategy for our ancestors and can be seen in all non-human primates (excluding some prosimians, who cache their infants) (Lozoff. 1979). As the human infant is the most neurologically immature of the primate order at birth, and therefore demonstrates considerable dependency on caregivers (predominantly on the mother) it would seem likely that natural selection would favour caregivers who were available and responsive, and infants who could respond to such (Trevathan. 1987; McKenna & Mosko. 1994). It would therefore seem unlikely that natural selection would favour the prolonged separation of mother and infant in solitary sleeping arrangements. Unlike the range of physical and social benefits conferred by an evolutionarily derived mother infant relationship (see chapter 2), there is less to suggest that infants benefit directly from their relationship to the father, either during wakefulness or sleep. Rather, the human evolutionary paternal role is often represented as one of indirect investment through resource provision and protection, channelling resources such as nutrition through the mother. Fathers and infants do not share the physical relationship of gestation, birth or breastfeeding. Fathers participate in the day to day care of infants in few mammal species (3% to 5% (Clutton-Brock 1989)) in particular fewer than half of all primate species exhibit direct paternal infant care (~40% (Klienman & Malcom 1981)). Amongst primates, humans are unique in that paternal investment occurs in a social context of large multimale – multifemale communities, and where most adult members of these communities reproduce (Alexander, 1990; Geary, 2000). This has particular relevance to the father infant relationship as paternal investment has been associated with both paternity certainty (Bales 1980; Buse 1984) and with enhanced mating effort (Smuts et al from Hewlett 1992), as well as being influenced by paternal wealth and status (Flinn; Hames; from Hewlett 1992). Unlike the maternal investment in human infants these influences predict that fathers' investment is dependent on whether their investment will increase opportunities for exclusive reproductive access to the mother, increased future reproduction through enhanced access to the mother, or the balance between investing in the survival of existing offspring or attempting to produce new ones (sometimes referred to as Dad and Cad strategies respectively (Dawkins 1976; Draper & Harpending 1982).

To complicate matters many social influences on paternal investment have been identified, indeed, much research about paternal infant care has taken place since the 1980s (Lamb 1981; 1987) generally identifying an increasing paternal participation in childcare amongst Euro-American populations. The emergence of the 'house-husband', fathers in post-industrialised societies who (usually on a temporary basis) are the caretakers of an infant or young child, is well documented in the US (Orloff & Monsoon 1992) and Europe (Bergman & Hobson 1992; Osnter 1992; Knijin & Shelten 1992) However, Hewlett (1992) warns about the misperception that the behaviour of Euro-American fathers as representative of a universal norm as there is a huge range of variation in father-infant interaction across human societies. Two extreme examples lie with the Sambia and the Aka. Among the Sambia, where complex beliefs about the biological determination of sex and gender mean that all children are considered as female until ritually enrolled into manhood and fathers are forbidden to have contact with their offspring to preclude gender/sex contamination (Herdt 1987). In contrast Hewlett describes the

Aka as "intimate fathers" closely involved in infant care, spending an average of 51.6% of a 24 hour period either holding, or within arms reach of their infant (Hewlett 1992), clearly expressing both paternal infant care and the social nature of Aka sleep.

Even in western societies, where solitary sleep for infants is considered a cultural norm, the practice of solitary sleep has only become widespread during the last 165 years (Hardyment. 1983). However, solitary infant sleep has obtained scientific validation, and is considered amongst the scientific and lay communities at large as the 'normal' place for infant sleep. McKenna and McDade (2005) argue that such a mind set is the result of a self-fulfilling prophecy of circular science; by virtue of the established infant physiological gold standard having been based on bottle fed, solitary sleeping infants (as discussed above) leading to a model of what constitutes desirable, healthy infant sleep, leading to all future measurements of healthy sleep as a comparison to the original flawed gold standard. The result is that bed-sharing, formula fed infants are considered to display abnormal, undesirable physiology because they fall outside of the erroneous ideal established from formula fed solitary sleeping infants.

This situation is summarised by Ball (2003) who refers to the practice of solitary sleep as "Evolutionarily bizarre and historically novel", and by McKenna who declares that in order to understand infant sleep, the context in which infant sleep, breathing and arousal patterns evolved for over 4 million years must be recognised (McKenna and Mosko. 1990; McKenna and Mosko. 1994). That context of infant sleep in human evolution is one of close proximity to, or contact with a mother; a context of social sleep. As such, it can be hypothesised that the behaviour of mother infant co-sleeping proffers benefits to evolutionary fitness (McKenna. 1989; Trevathan & McKenna 1994). Given the physiological immaturity of the human infant, the proximity of the established physiology of a mother could act as an external regulatory system for an infant, or developmental bridge (McKenna & Mosko. 1994), extending postnatally some aspects of physiological regulation provided *in-utero.* The sensory signals that an infant was exposed to during gestation, tidal rhythms of blood, movement, touch, temperature, nutrient and gas exchange, may well pre-sensitise an infant to maternal sensory cues and prepare a foetus for postnatal physiological regulation involving similar modalities after birth (McKenna & Mosko. 1994). Indeed, Anders and Zeanah maintain that a parent "literally regulates behavioural, neurochemical, autonomic, and hormonal functions of the infant by different aspects of the relationship: nutritional, warmth, sensory stimulation, and rhythmic responsiveness" (Anders & Zeanah 1984: 65 from McKenna, Mosko, et al. 1990). Such exchange of physiological cues between mother and infant may stimulate infant physiological control and/or engage a rescue response during sleep.

If exchange of physiological cues between mother and infant do occur postnatally during co-sleeping then one should expect to see differences in the patterns of sleep between infants when sleeping alone and with their mother. The following section addresses research to date of mother infant co-sleeping. It is presented to illustrate both the development of method and scope of research.

McKenna & Mosko (1990) used electroencephalograms (EEG), electroculogram (EOG) and electromyography (EMG) recordings to gather data on 5 mother infant dyads sleeping in the same single sized bed in a hospital. None of the mother infant pairs regularly slept together at home. Sleep stages were scored at 30s epochs using the Rechstaffen & Kales (1968) system for the mothers and Guilleminault & Souquet (1979) system for the infants (McKenna, Mosko, et al. 1990).

The study revealed that bed-sharing mothers and infants spent an average of 46% and 44% respectively of the night in the same sleep state at the same time, Simultaneous activity time (SAT), compared to 29% and 28% respectively for randomly matched infant and mother pairs (McKenna, Mosko, et al. 1990). It was argued that this demonstrated bed-sharing mother infant dyads shared more simultaneous activity time and that an inherent organisation of sleep patterns was not responsible for these phenomena (McKenna, Mosko, et al. 1990).

It was also noted that bed-sharing infants experienced more awakenings than randomly matched pairs and that the percentage of overlapping epochal awakenings (EW – when sleep is followed by an epoch reflecting at least 50% wakefulness (Mosko, Richard et al. 1997)) was greater amongst bed-sharing mother infant dyads than amongst randomly paired mothers and infants (55% versus 23% and 11% versus 9.2% respectively) (McKenna, Mosko, et al. 1990). The results were used to suggest that mothers are more likely to wake when their infants are awake in co-sleeping pairs and that this reflects a heightened response to infants by mothers during co-sleeping. A heightened response may allow swifter maternal interventions to less extreme infant cues and therefore be protective against SIDS and night time infant death, as well as facilitating feeding before an infant becomes too fractious (McKenna, McDade 2005).

It was noted that 48% of maternal arousals were associated with an arousal in their infant, and 71% of infant arousals were associated with an arousal in their mother (combining transient arousals (an abrupt, transient shift in EEG frequency (Mosko, Richard et al. 1997) and epochal awakenings) (McKenna, Mosko, et al. 1990). Mothers therefore demonstrated an arousal associated with almost ¾ of the infant arousals observed, data which were used to suggest a protective behaviour and demonstration of arousal synchrony in co-sleeping mother and infant pairs (McKenna, Mosko, et al. 1990).

What is clear from these data is that mother and infant sleep does demonstrate indications of synchrony in some aspects of social sleep beyond that expected by chance. These data does not, however, demonstrate whether such synchrony is unique to bed-sharing, as it does not reveal whether the same patterns would have occurred between the mother infant pairs during separate sleep conditions although this is addressed in a subsequent study, McKenna & Mosko (1994) (reviewed below). The use of randomly matched alternative partners from within the study data would be inadequate representation of either a separately sleeping infant of the same mother, or as a way of isolating behavioural or environmental influences of sleeping an infant in a cot by the bed or in a completely different room. Further, potential influences on parent and infant physiology and interaction such as maternal smoking, illegal or prescription drug use, breastfeeding, etc. were not recorded or accounted for during analysis.

To address some of these deficiencies a further 3 mother infant pairs were observed sleeping one night separately (in adjacent rooms) and one night side by side on the same bed using the method highlighted above (McKenna & Mosko. 1994). The two test nights followed an adjustment night to avoid "first night effect" (Agnew, et al. 1966) during which, mother and infant slept separately in adjacent rooms. Two of the mother infant pairs were regular solitary sleepers, and one was a regular co-sleeper. Again potential influences on parent and infant physiology and interaction such as maternal smoking, illegal or prescription drug use etc., were not recorded or accounted for during analysis.

Infants in two of three mother infant pairs demonstrated less quiet sleep on the bed-sharing night in comparison to the solitary sleep night, an average decrease of 47%. Mothers showed a slight increase in quiet sleep (McKenna, Mosko, et al. 1994). It was argued that bed-sharing infants therefore experience less quiet sleep than solitary sleeping infants and that if arousals are indeed suppressed during periods of quiet sleep (stage 3-4 sleep) (discussed above) then the reduction in the time an infant spends in quiet sleep during bed-sharing seen here, may potentially reduce exposure to SIDS risk.

A comparison of simultaneous activity time between mother and infant pairs on the bed-sharing and solitary sleeping nights revealed a pattern similar to that observed in the previous study. Mother infant pairs exhibited an average of 26% simultaneous activity time on the solitary sleeping night (23-38% range) and 45% simultaneous activity time on the co-sleeping night (26-64% range). (McKenna, Mosko, et al. 1994). McKenna & Mosko et al. (1994) assert that the simultaneous activity time figures are indicative of increased sleep state synchrony during co-sleeping, but it must be noted that the small sample number means application of any conclusion to the wider population is limited. Moreover, simultaneous activity times included periods of waking and so may simply be an artefact of more breastfeeding observed on bed-sharing nights (Ball 2006).

Arousal data showed considerable variation and statistical significance was not achieved for any comparisons. Comparatively high arousal rates (combined TAs and EWs) from one infant who routinely co-slept at home (65% increase on the co-sleeping night from the mean (14/hour) of the solitary night) was used to suggest that regularity of co-sleeping has some effect on arousal patterns (McKenna, Mosko, et al. 1994). Similarly, variation in maternal arousal rates for the three mothers over the two test nights were used to suggest that mothers experience a higher frequency of arousals during co-sleeping than solitary sleeping (a combined arousal increase of 113%, 62% and 5% respectively during co-sleeping). Due to the sample size such a conclusion regarding the affects of bed-sharing and solitary sleeping on arousal frequency may have been premature.

Despite the variability in arousal frequency there was considerable overlap in arousals (combined TAs and EWs) between dyad members on the co-sleeping nights for all pairs (McKenna, Mosko, et al. 1994). It suggests that the increase in shared arousals may be due to proximity and therefore partner induced. This would be a clear demonstration of interaction between mother and infant during co-sleeping.

Although the data from the McKenna & Mosko (1990) and McKenna & Mosko et al. (1994) studies go some way to supporting the notion that co-sleeping affects both mother and infant arousal and sleep patterns, elevating overall arousal frequency and leading to greater periods of overlapping sleep state, it is clear that the trends noted were not expressed equally in all infants or mothers. Further, questions as to the effect of regularity of co-sleeping are raised and the reliability of the data is questionable due to the small sample size.

A larger study by Mosko, Richard et al. (1997), of 35 breastfeeding mother infant pairs with infants 11–15 weeks old and composed of 20 regular bed-sharing and 15 regular solitary sleeping pairs has addressed some these issues. In recognition of the potential for 'normal' night time behaviour to influence mother and infant physiological behaviour, the term bed-sharing was defined as "An infant sharing a bed with its mother at least 4 hours per night, 5 nights per week" whilst solitary sleep was defined as "bed-sharing no more than 1 night per week for any part of the night" (Mosko, Richard et al. 1997).

Testing occurred across 3 nights (one bed-sharing (BN), one solitary sleeping (SN), and one adaptation night matching usual home condition). Bed-sharing occurred in the same twin size bed and solitary sleep occurred with the infant in an adjacent room with the doors open (Mosko, Richard et al. 1997).

Infant arousals averaged over both routine conditions and both test nights demonstrated fewer arousals occur in infants during stage 3-4 sleep independent of test condition or regularity of bed-sharing, supporting the theory that arousal potential may be suppressed in infants during quiet sleep (stage 3-4) (discussed above) (Mosko, Richard et al. 1997).

Comparison of infant epochal awakenings between test nights revealed a higher frequency on the solitary sleep night during stage 1-2 and REM sleep, but lower frequency during stage 3-4 sleep than on the bed night ($p=.014$) (Mosko, Richard et al. 1997). This suggests that proximity to a mother promotes infant epochal awakenings during deep (stage 3-4) and reduces/suppresses infant epochal awakenings during active (stage REM) sleep. The effect of proximity on epochal awakenings therefore appears to be sleep stage selective.

Transient Arousals were noted to only show significant difference between regular bed-sharing infants and regular solitary sleeping infants, regardless of test condition during stage 3-4 sleep versus stage 1-2 and REM where regular bed-sharers demonstrate a higher frequency of transient arousals ($p=.016$) (Mosko, Richard et al. 1997). This finding suggests that regular bed-sharing infants may be attuned to environmental stimulation during close proximity sleeping that regular solitary sleepers are not.

Support for this theory may be seen in the temporal overlap of mother and infant arousals. The number of arousals (EW and TA combined) that overlapped between mother and infant averaged 46.4% on the BN versus 23.9% on the SN ($p=.001$ for RBs and $p=.004$ for RSs). For the RBs the increased arousals on BN were noted for mother first, infant first, and simultaneous arousals with the greatest increase in those where the infant aroused first. A similar yet less magnified pattern was seen in the RS (Mosko, Richard et al. 1997). It would therefore suggest that proximity between mother and infant during sleep increases arousal synchrony, and that infants and mothers who frequently sleep in close proximity demonstrate a greater number of synchronous arousals when bed-sharing than regular solitary mother infant dyads do whilst bed-sharing. This may reflect an increased sensitivity, or habituation, to the sleeping partners arousal cues as a learned response, perhaps an attunement to the environmental stimulation provided by bed-sharing. Potentially this may equate to a dose effect, the more a mother and infant bed share the more attuned they become and the greater arousal synchrony they display.

A study from the Institute of Child Health, Bristol (UK), provides some published data by Fleming, Sawczenko, et al. (1998) and some by Young, Fleming et al. (2001) on 10 breastfeeding mothers with healthy infants comprised of 5 pairs of Routine Bed Sharers (RBS) and 5 pairs of Routine Room Sharers (RRS). Routine Bed Sharers were defined as mothers and infants who slept in the same bed (with or without the mother's partner) for at least 6 hours per night, 7 nights per week. Routine Room Sharers were defined as mothers and infants who slept in the same room, however did not bed share for more than 3 nights per week for any part of the night (Young. 1999). Whilst the category of routine bed-sharers seems fairly focussed (and interestingly is the first time that a mother's partner is introduced to the bed-sharing equation), the category of routine room sharers is quite broad. Indeed, using the 6 hour per night figure from routine bed-sharers definition, a routine room sharing family could spend 18 hours a week (~43% of overall weekly sleep time) in the same condition as a routine bed sharing family.

During test nights, bed-sharing took place with mother and infant in a double bed and room sharing took place with infant in a cradle by the mother's bed. The mother infant pairs were monitored using EEG and infrared video tape recording on 2 consecutive nights (one night in each test condition, randomly assigned) at 2, 3, 4 and 5 months after birth in sleep laboratory conditions.

The interquartile period of each test night was used during analysis (Young. 1999).

Mothers were found to spend more time awake on the bed-sharing nights (BN) than on the room sharing nights (RN) regardless of routine sleeping condition, whilst infants, again regardless of routine sleeping condition, were found to show the opposite trend. During the bed-sharing night, the sleep cycles of regular bed-sharing mothers' were observed to undergo a variation from around 90 minutes (apparent in adult females) to become closer to 60 minutes (apparent in infants less than 3 months) (Fleming, Sawczenko, et al. 1998). This pattern strongly suggests a variation in maternal sleep cycle toward greater concordance, or synchrony, with that of a bed-sharing infant, however, it is unclear as to how the sleep cycles were defined and identified; episodes of breastfeeding could be argued to effectively reset both mother and infant sleep cycles, thereby demonstrating truncated maternal sleep cycles, rather than attenuated maternal sleep cycles.

On the room sharing night both regular room sharing and regular bed-sharing infants spent a similar percentage of the night in REM (43% & 42% respectively), whilst on the bed sharing night regular room sharers showed and increase in REM to 51% and regular bed-sharers a decrease to 35% of the night. For quiet sleep the regular room sharing infants showed almost no variation between bed-sharing night (40%) and room-sharing night (39%), whilst the regular bed-sharing infants showed an increase in quiet sleep on the bed-sharing night (42%) from the room-sharing night (35%) (Young, Fleming et al. 2001). These trends in distribution of REM would appear to indicate that the effects of sleep condition on the REM sleep state of an infant are dependent on regularity of exposure to that condition; bed-sharing increasing the quantity of REM sleep in infants to whom bed-sharing is novel, and reducing it in infants to whom the condition is familiar. Why this should be is unclear. That regular bed-sharing infants demonstrate increased percentage of quiet sleep on bed-sharing nights seems at odds with previous data from the two Mckenna and Mosko studies and inconsistent with the theory that bed-sharing may reduce risk from arousal deficiency in quiet sleep by selectively reducing the time an infant spends in quiet sleep.

A possible reason for differences observed in distribution of sleep state in the McKenna and Mosko studies may be related to the small sample size. However, it may also lie in the way data have been pooled and analysed in the Young, Fleming et al. study. The data presented by Young, Fleming, et al. (1991) has been collected, as noted, from the same 10 mother infant pairs on five consecutive occasions, however, during analyses all data have been lumped together. The situation calls into question the results for three reasons. Firstly, any anomalies or outlying trends displayed by any of the parent infant dyads will be amplified by the repeated use of data from any observations of them. Secondly, it has been established that infant physiological patterns undergo considerable change during the first 6 months of life and so the pooling of such a wide age range in the analysis may mean the data does not appropriately describe the situation at any of the age ranges. Lastly, data from each consecutive occasion has been treated as an independent data point whereas they are clearly related data, having originated from the same subjects. This casts some doubts over the validity of the Young, Fleming, et al. (1991) study. The observations of REM distribution may for example be explained by over-representation of younger infants amongst the bed-sharing sample and over-representation of older infants amongst the solitary sleeping sample (younger infants display higher proportions of REM than older infants, as discussed earlier).

Further, although fathers are identified as forming part of the routine sleep environment for some of the families (an undisclosed number), no fathers were present during testing. Despite the study's attempts to explore naturalistic behaviour the absence of fathers where they would normally be present suggests an unnatural oversimplification of the bed-sharing environment.

A recent study by Baddock et al. (2006) explored bed-sharing behaviour of 40 families in New Zealand using infra-red video surveillance and physiological monitoring (ECG, plethysomography, and pulse oximeter, nasal airflow, shin and rectal temperature and external CO_2) in their own homes. As with previous bed-sharing studies, all infants were breastfed, however, fathers were present during test nights in 18 of the 40 families.

In their discussion Baddock et al. (2006) suggest that "some sleep positions promoted mother infant interactions, facilitating breastfeeding and frequent contact including uncovering the infants' head from bedding" (Baddock et al. in 2006). However, insufficient data is provided to support this conclusion.

Despite including the fathers in the test setting, physiological data were only collected for the fathers for periods of the night when the infant was located next to them in the bed (median 3.1h/night) (Baddock in 2006). Further, test protocols did not allow the comparison of father's presence or absence as there were not discrete test nights (one with the father present and one with the father absent). No physiological data were presented in the analyses or discussion. Despite these methodological issues, the study concluded that a fathers' presence "does not appear to alter the mother infant relationship" (Baddock in 2006). Clearly, insufficient data is provided to support such a conclusion.

Video tape data were again used by Ball (2006)to study 20 families bed-sharing at home (10 currently breastfeeding and 10 who had never breastfed). Key behaviours were transcribed from the video at 3 minute intervals throughout the night.

A propensity for greater face to face orientation between breastfeeding mothers and infants (47%) than bottle feeding mothers and infants (32%) was noted (p=.02), together with more time spent by the mother facing the infant amongst breastfeeding mothers (73%) than bottle feeding mothers (59%) (p=.05) (Ball 2006). Breastfeeding infants were more likely to be positioned at mothers breast height (100%) than bottle fed infants (29%) (p=.02), who were more likely to be placed at mothers head height (71% - p=.01). Both of these aspects of orientation and position are used to identify that breastfeeding mother infant pairs bed-share more safely than bottle feeding mother infant pairs; firstly because maternal orientation toward the infant suggests a greater potential for maternal awareness of the infant; and secondly because the infant and mother position observed amongst all breastfeeding dyads created a characteristically safer sleeping environment for the infant. In this characteristic position the mother is curled up around the infant providing a barrier with her upper legs that prevents downward movement of the infant (under the covers), and a barrier with her arms that prevents upward movement of the infant (into the pillows). The position also prevents the mother from rolling onto the infant and protects against other bed-sharers doing so (Ball 2006). Ball identifies that this characteristic position is also described by Mosko et al. (1997), Richard et al. (1996) and depicted by Young (1999) suggesting that it represents an evolutionarily derived behaviour, common to breastfeeding (the evolutionary norm) that increases infant night time safety (Ball 2006).

A greater number of maternal (4:2 p=.001), infant (3:2 p=.006) and mutual (3:1 p=.003) arousals amongst breastfeeding dyads compared to bottle feeding dyads were also noted (Ball 2006). Increased infant arousals may be protective against SIDS as previously discussed. More frequent maternal arousals may indicate a greater potential for maternal awareness of the infant and increased opportunities for interventions in potentially dangerous situations. More shared arousals may suggest mother infant sensory exchange as described by McKenna (discussed above).

Fathers were observed to generally sleep beyond 20cm and facing away from their infant. The presence of a father was not found to affect mother infant orientation or positioning (including the adoption of the characteristic mother infant sleep position amongst breastfeeding mother infant pairs), excepting significant difference in the location of the infant in the bed; on triadic nights the infant was positioned in the middle of the bed (between parents) for 65% of the night compared to 0% of dyadic nights (p=.028) where the mother always positioned herself in the centre of the bed and moved the infant from side-to-side, always on the outside of her (Ball 2006).

The presence of the father was found to significantly affect arousals, significantly reducing the number of arousals for mothers and infants across the board; infant (5:3 p=.037), maternal (6:4 p=.037) and mutual (5:3 p=.028) (Ball 2006). Fathers themselves displayed considerable variation in arousal synchrony with their infants, ranging from 0-100%.

Clearly the study of infant and parent social sleep and bed-sharing is in its infancy and not without limitations. Despite this, the data gathered thus far clearly highlights that the established perceptions of normal infant sleep that pervade the medical and research community, based on a cultural ideal of where an infant should sleep (solitary), conflict with emerging patterns of infant sleep derived from an evolutionary ideal of where an infant should sleep. Infant sleep is certainly not homogenous, and the emerging picture of social sleep is one of considerable complexity. Factors identified so far that affect social sleep include definition of types of social sleep, proximity (solitary, room-sharing and bed-sharing) regularity of bed-sharing, feeding type, and the presence of the father. Such complexities in social sleep have prompted a re-examination of the recording of sleep practice, especially in SIDS data.

A good example of the misunderstanding regarding diversity in social sleep can be found in the European Concerted Action on SIDS (ECAS) investigation (Carpenter et al. 2004), a case control study using data from 745 SIDS cases and 2411 live controls from across 20 European regions was criticised for its failure to sufficiently represent the complexities of bed-sharing. The main findings suggested that bed-sharing conveyed significant risks if the mother was a smoker, during the first weeks of life (OR at 2 weeks 27.0 [13.3-54.9]), and a significant yet less pronounced risk if the mother was a non-smoker (at 2 weeks 2.4 [1.2 – 2.6]) only significant within the first 8 weeks of life (Carpenter et al. 2004). These data were used to recommend against all bed-sharing, especially for the first 8 weeks of life (Carpenter et al. 2004). The study however, does not provide a satisfactory definition of bed-sharing, "[failing to] differentiate between babies who slept in bed with their parents and those who co-slept on sofas or other inappropriate sleep surfaces" (UNICEF 2004). This raises questions since sofa-sharing is known to be a significant risk factor for SIDS (OR 15.79 (4.43-56.24) Blair et al. 1999) and may account for the increase risk which has been found (UNICEF 2004).

Whilst Tappin et al. (2005) separated bed-sharers from sofa-sharers they also failed to account for the full complexity of social sleep. Their 2005 case control study used data from 123 infants who died of SIDS and 263 controls from Scotland, UK. They noted that bed-sharing when under 11 weeks conveyed a significant risk of SIDS (OR 10.20 (1.29-133)) (Tappin et al. 2005). However, SIDS cases were classified as bed-sharers based on the location in the bed for <2 hours, 2-5 hours, >5 hours prior to the time of death. A SIDS infant may therefore be classed as bed-sharer having spent only the first 30 minutes of the night in the parents' bed and the remainder of the night in a cot or other sleep condition where they were subsequently found dead. Contrastingly, control cases were required to have spent all night, or day, sharing the bed to be classed as bed-sharers. Ball (2002) has identified that only 3% of bed-sharing is habitual (all night every night), whilst 1/3 is more flexible and often reactive, combination bed-sharing where parents may move their infant between the bed and other sleep surfaces during the night (Ball 2002). As the inclusion criteria for identifying the SIDS cases as bed-sharers was that they had spent any time in the parental bed during the night, regardless of how long and at what point, it could be argued that the categories used by Tappin et al (2005) represent two discrete populations who express very different behaviours; Controls equate to Habitual bed-sharers, whilst SIDS cases equate to Combination bed-sharers.

Returning to the Carpenter (2004) study, infant feeding method at the time of death was not recorded. This may be an important misunderstanding of the complexities of social sleep for several reasons. Firstly, breast milk is specifically designed to meet all the nutritional needs of an infant, (Hernell et al in Freir 1980) and contains maternal antibodies which provide some passive immunity to the infant (Filteau 1994) including some protection from gastrointestinal, respiratory and ear infections (Howie & Forsyth 1990). In comparison, formula milk does not confer passive immunity and is less easily digested, leading to bouts of longer and deeper infant sleep as the body attempts to digest the formula and reduced resistance to some illnesses (Ball 2003; Howie & Forsyth 1990). Both of these effects may confer greater SIDS risk, as depressed arousal in quiet sleep (Horne 2004) and susceptibility to illness (Vennemann 2005) are both associated with SIDS risk (discussed above). Also, formula milk feeding infants have been noted to demonstrate slower development of the brain, central nervous system and sight (Lucas 1992, Crawford 1993). As previously discussed, poor maturation of the central nervous system may be a contributory factor in SIDS.

Secondly, breastfeeding has physiological benefits to both the mother and the baby which are inherent in the close contact necessary for breastfeeding. Breastfeeding facilitates mothers and infants bonding (Klaus & Kennel 1976), helps attenuate maternal response to infant cues (Barr 1988) and promotes more affectionate maternal response (Feldman & Eidelman 2002). Infants who are breastfed cry less (Christensson 1995, Barr 1988) possibly because breastfeeding promotes skin to skin contact which can act to calm a fractious infant, reduce maternal and infant stress and provide an analgesic effect for the infant (Gray, Watt et al 2000) and a relaxing / calming effect in the mother due to oxytocin release (UNICEF BFI 2003).

Although at first glance these physiological aspects may not appear to directly affect the outcomes observed in Carpenter (2004), they are strongly related to bed-sharing practices as bed sharing promotes successful breastfeeding (Hooker et al. 2001; Ball 2003). The relationship can be observed in the high numbers of breastfeeding mother infant pairs that bed-share during the first month of life (73%) (Ball 2003). As such, we might expect to see a considerable proportion of bed-sharers from the Carpenter (2004) study being breastfeeders. There is evidence that breastfeeding mothers adopt a 'protective' sleeping position not observed in bottle feeding mothers (Ball 2006; Mosko et al. 1997; Richard et al. 1996; Young 1999) (discussed above), which is now promoted as an aspect of safe bed-sharing (UNICEF 2005). By failing to account for the relationship between feeding method in social sleep Carpenter (2004) has lumped two groups (breastfeeders and bottle feeders) with distinctly different SIDS risk into one, obscuring the true SIDS risks for either group. Should this data be taken at face value, and bed-sharing be discouraged for babies under 8 weeks old, there is potential to negatively affect breastfeeding rates amongst a group for whom the risk is lower than Carpenter's (2004) data may indicate and therefore negatively affect mother and infant health outcomes.

It would appear then, that social sleep is complex, both in practitioner and practice. Parents and infants engage in a range of social sleep from habitual bed-sharing, through combination bed-sharing (a spectrum category in itself), through to habitual room-sharing (with infant sleep surface being by-the-bed or further away in the room) (Ball 2002), each with apparently discrete effects on behaviour and/or physiology (McKenna & Mosko 1990; McKenna & Mosko et al. 1994; Mosko, Richard et al. 1997; Fleming, Sawczenko, et al. 1998; Young. 1999; Young, Fleming et al. 2001; Baddock 2006; Ball 2006). Further, feeding method may not only influence the choice of infant sleep location, with breastfeeding infants being more likely to bed-share, especially during the first weeks of an infants' life (Ball 2002), but also night time behaviour and physiology through increased mother infant attunement (McKenna & Mosko 1990; McKenna & Mosko et al. 1994; Mosko, Richard et al. 1997; Fleming, Sawczenko, et al. 1998; Young 1999; Young, Fleming et al. 2001; Baddock 2006; Ball 2006). The presence of fathers may also influence the dynamics of social sleep (Ball 2006), but this is very poorly understood. It is also clear that the current lack of understanding of social sleep impacts on our understanding of SIDS and night time infant death (Carpenter 2004, Tappin 2005) which could have profound effects on the advice offered to parents about social sleep and on infant and maternal well-being in general.

This study therefore seeks to add to the body of knowledge regarding social sleep by further investigating parent infant sleep state and arousal in relation to proximity, and regularity of bed-sharing, for both mothers and fathers following predictions generated by the theory of sensory exchange.

Chapter 3

METHODS

Ethics approval for this study was obtained from North-Tees NHS LREC.

Recruitment and data collection

Recruitment and data collection are as published by Ball (Ball 2002); a brief reprise follows.

Families with breastfed infants under 3 months of age were recruited from N. Tees region through health visitors, baby clinics and local publicity. Only parents and infants who considered low-risk for SIDS based on recognised influencing factors (non-smoking mothers, breastfeeding, not living in social deprivation etc.) were accepted. Families also had to either regularly sleep their infant in a cot by the side of the parent's bed, or with the infant in the parent's bed. Seventy-three families responded and of these 37% were both eligible for the study and able to participate (n=27).

Circumstances under which co-sleeping is practised, and its frequency were assessed from a series of seven sleep diaries that participating parents were required to complete, together with an interview about their night-time infant care practices and normal sleeping arrangements.

Physiological and video tape monitoring took place at the University of Durham's sleep lab at Queen's Campus, Stockton on Tees (within the N. Tees Health area) on 3 consecutive nights. The first night provided an adjustment night when participants followed their normal sleep practices in order to acclimatise them to the environment and minimise effect on their behaviour

(Agnew et al. 1966). On the second and third nights (in random order) parents and infants were monitored sleeping with the infant in the bed and with the infant in a cot by the bed.

The sleep lab was decorated and dressed to resemble a normal domestic bedroom with en-suite bathroom facilities. Parents were provided with a range of bedding from which they choose the bedding most similar to that they normally used. Parents were also provided with facilities such as a baby bath, TV and video, radio and a kitchenette with refrigerator and microwave, allowing them to follow a 'normal' preparatory routine for sleep.

Prior to sleep physiological monitoring sensors were attached to the parents and infants. These consisted of paediatric respiratory plethysmography bands placed around the infant's chest, temperature probes attached to the infant's skin in the axillary region and inserted rectally, and a pulse oximeter probe (rubber type, not clip) attached to the infant's foot. Infants wore a thin stretch-suit to help keep the instruments in place. Parents wore respiratory plethysmography bands and a pulse oximeter. The sensor leads from each subject were gathered into 'umbilical cords' which relayed data to computer monitoring equipment (WinVisi Sleep System -- Stowood Scientific Instruments) in the adjacent control room. Leads could be easily detached from a header box placed at the head of the bed and cot to facilitate nappy changing and movement around the room.

Video recordings were made from a ceiling mounted low-light intensity camera positioned opposite the bed or bed and cot. Infra-red lights allowed video recordings to be made in the dark. The video signal was transmitted to the adjacent monitoring room where it was continuously recorded to an 8-hour VHS videotape and traces generated by the physiological monitoring equipment were superimposed on the video signal using a gen-log device.

This provided a continuous picture of subjects' physiology and further facilitated observational and physiological data synchrony.

A technician remained in the monitoring room for the duration of the night and when necessary, replaced sensors that became detached. They were also prepared to intervene in any situation where an infant appeared to be in immediate danger (criteria for interventions were agreed with N. Tees paediatricians and ethics committee), though no such interventions were necessary. Recordings were terminated when parents and infant arose in the morning.

Measuring Sleep States

Many sleep studies, such as those of McKenna and Mosko (described above), use polysomnography with a technician in attendance to map sleep architecture, however this process has certain limitations; (1) the electrodes required for sleep staging can disturb sleep; (2) some children will not tolerate electrodes applied to the head and face; (3) complex recordings require the presence of an experienced technician and extensive instrumentation (Morielli, Ladan, et al. 1996). The need for full polysomnography to determine sleep and wakefulness in infants has, however, been shown to be unnecessary. Harper, Schechtman, et al. (1987) have demonstrated that discrete Quiet Sleep (NREM), Waking, and REM sleep states can be identified in infants 1 week to 6 months of age using cardiac and respiratory measures only, obtaining 84.8% concordance with sleep state data derived from polygraph recordings which included EEG, eye movement, whole body movement, facial muscle electromyography, cardiac and respiratory recordings.

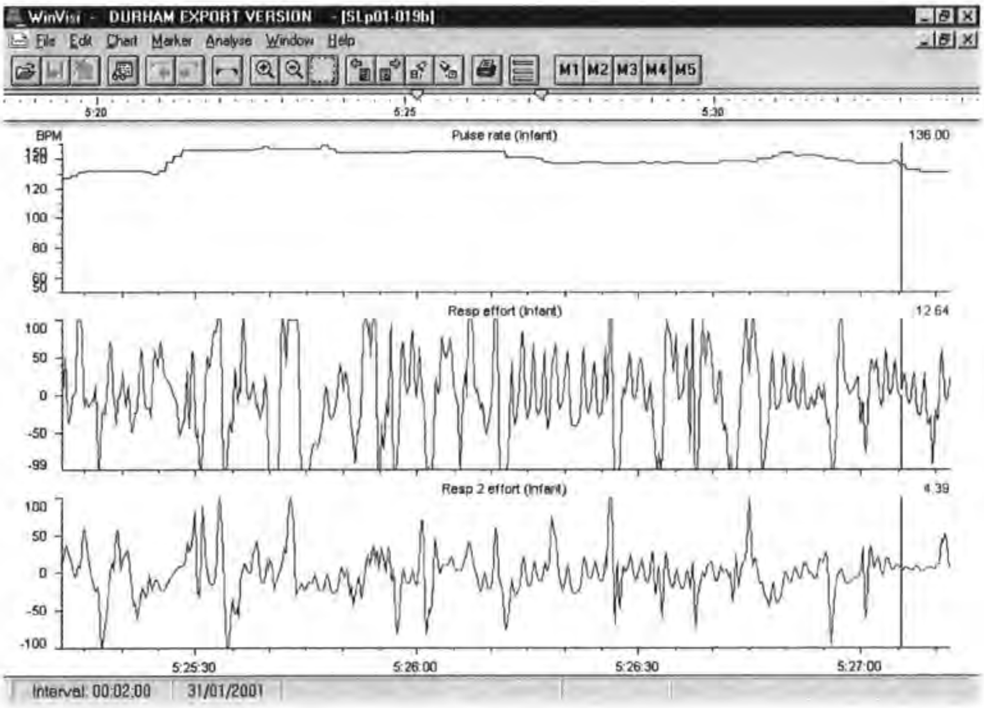
Infant sleep/wake states were therefore determined using a combination of a simplified version of the cardio-respiratory video method employed by

Morielli, Ladan, et al. (1996) for distinguishing sleep and wakefulness in children and cardio-respiratory measures used for distinguishing discrete sleep states in infants used by Harper, Schechtman, et al. (1987).

Sleep stages were subjectively assigned to 4 sleep state categories, awake (AWK), active asleep (REM), quiet sleep (QS) and indeterminate (IND), according the characteristics predominant in any 1 minute epoch. The following principle characteristics were used to determine sleep state categories (after Schechtman, Harper, et al. 1992; Young, Sawczenko & Fleming. 1997);

AWK – variable and generally high heart rate and great variability in respiratory rate, usually of high amplitude (Figure 1)

Figure 1: Cardio-respiratory markers of wakefulness



REM – intermediate heart rate and irregular respiratory rate with generally intermediate amplitude, often showing transient arousal and movement artefacts (Figure 2).

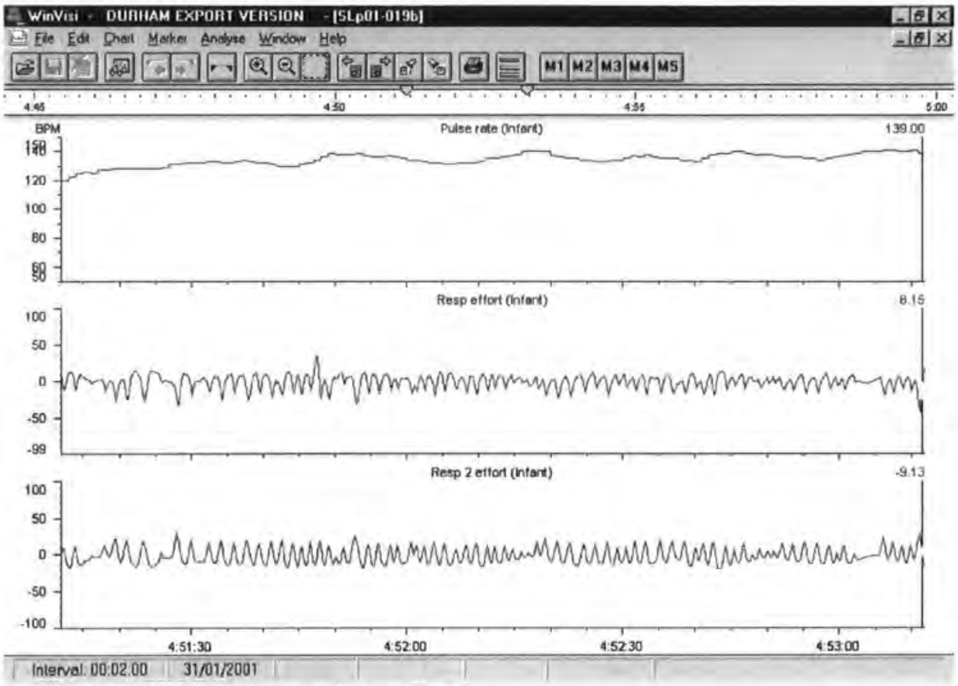


Figure 2: Cardio-respiratory markers of REM

QS – low heart rate with little variation, regular respiration with generally low amplitude and no, or very minor movement artefacts (Figure 3)

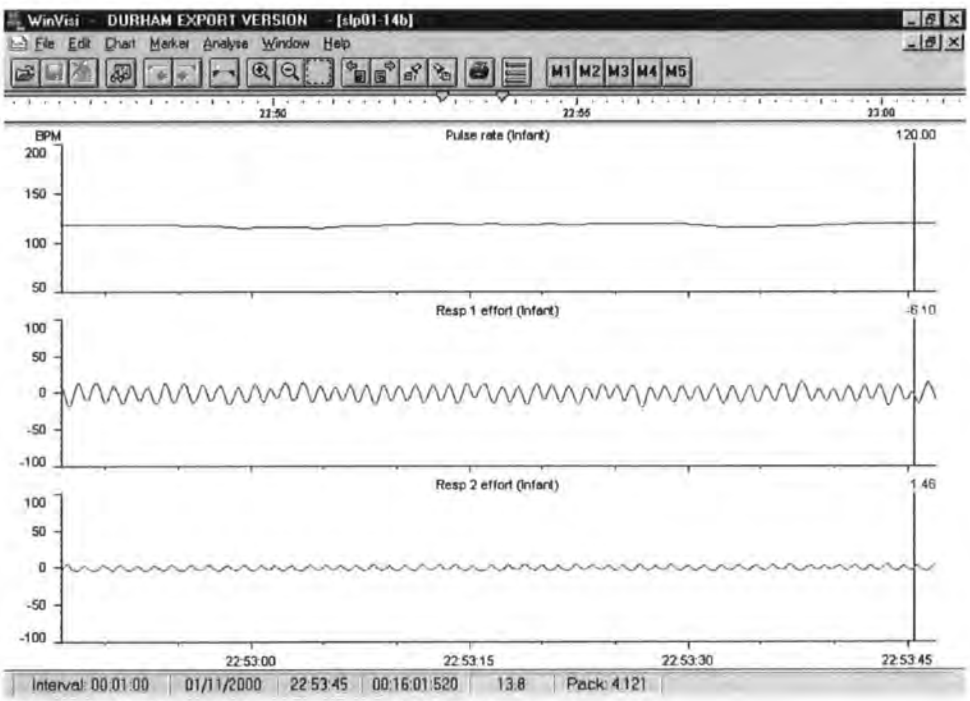


Figure 3: Cardio-respiratory markers of Quiet sleep

IND – Unable to assign to one of the above categories

During analysis epochs of indeterminate sleep state for any subject, have been excluded.

The following behavioural characteristics were used to assist determination of sleep state in infants, adapted from Anders, et al. (1971), Brazelton. (1973) and Precht, et al. (1968);

QS – eyes closed without movement, no body movement except startles and regular respiration

REM - eyes closed with rapid eye movements, frequent body, limb or face movements and an irregular respiratory pattern.

AWK – eyes open.

IND – unable to determine subject into one of the above categories

The same techniques and principles were applied to determining the sleep states of the mothers and fathers, however, whilst an infant displays discrete behavioural and physiological characteristics for each sleep stage including waking, adult sleep states can not always be so clearly identified. Adults are capable of consciously entering into relaxed states in which their cardio-respiratory patterns and behavioural characteristics mimic sleep. The use of respiratory plethysmography, pulse oximetry and videotape observation can not satisfactorily determine between an adult in REM sleep and one in a state of relaxed wakefulness. It has been suggested by Fleming (FSID conference 2004) that parents 'pretending' to be asleep could successfully present REM-like cardio-respiratory patterns as well as sleep-like behavioural characteristics leading to over-representation of REM sleep and under-representation of wakefulness. Predominantly this suggestion was related to fathers who may pretend to be asleep in order to avoid care-giving activities through the night. The suggestion that fathers may adopt a strategy of deception to avoid night time care activities is supported by UK poll conducted by Mother & Baby Magazine which identified that "more than one-half of British fathers react to their infant's night time crying by either continuing or pretending to sleep" (Sleep & Health 2004).

Measuring Arousals

"The change in sleep-wake behaviour can be partial, as witnessed in physiological variables, or lead to a complete behavioural awakening" (Franco et al. 2001). In this study partial/movement arousals were considered abrupt changes in cardio-respiratory pattern indicative of movement from Quiet sleep into REM, or from simultaneous heart rate and respiratory effort artefacts indicative of a movement arousal after Rechtschaffen & Kales' (1968). Full waking arousals were determined using a combination of cardio-respiratory cues identified by strong fluctuations in cardio-respiratory pattern indicative of waking (after Mosko, Richard, et al. 1997; Gerard, Harris, et al. 2002) accompanied by clear behavioural indicators (i.e. eyes open) obtained via video-taped behaviour (after Morielli, Ladan, et al. 1996).

Figure 4 illustrates a series of transient/movement artefacts identified by simultaneous spikes in heart rate and respiratory effort which out of character with the preceding and following cardio-respiratory pattern (section 1). The transient/movement artefacts of section 1 precede a full waking arousal seen in section 2, identified by strong fluctuations in cardio-respiratory pattern lasting more than 30 seconds. The identification of this full awakening would be confirmed by behavioural observations of the subject at the identical time-point.

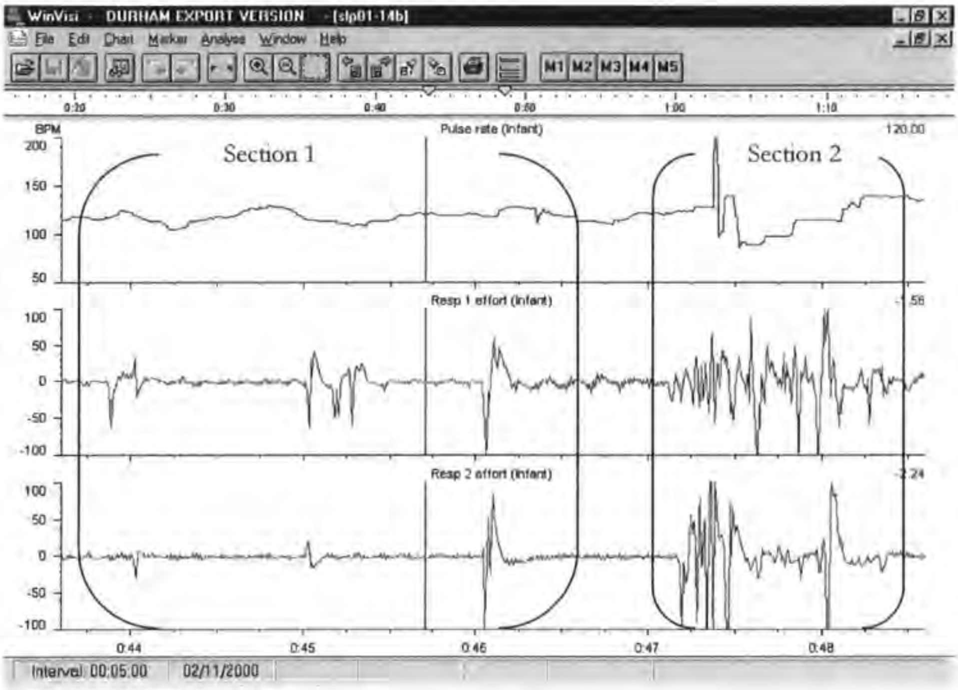


Figure 4: Cardio-respiratory markers of transient/movement artefact and full waking arousal

In diagnosis of obstructive sleep apnoea (OSA) in infants Morielli, Ladan, et al. (1996) used a cardio-respiratory-video (CRV) method and obtained concordance of 93.8% (+/-2.5%) with full polysomnography (including EEG) when identifying sleep/wakefulness in children 2-12.5 years suggesting that the addition of video tape recording to simultaneously observe behaviour enhances the sleep/wake determination (Morielli, Ladan, et al. (1996).

All physiological data were blind coded and then compared to the video taped behavioural observations. Periods of disagreement between physiological data and video taped behavioural data were reviewed to increase reliability.

Data Coding

A four hour period of the night was used from each observation during analysis. In all but one case (family 13) this period was formed from two hours taken each side of the median point of the observation. The period was long enough for all subjects to potentially experience at least two full sleep cycles (REM through Quiet sleep to REM again) but reduced the effect of erratic data at the beginning and end of the night caused by the process of going to bed and getting-up. For family 13 the analysis period on the cot night comprised of four hours following the mother's time of first sleep. This is because both mother and father were awake until around 2am, reducing the overall observation period. There were still 52 minutes between the end of the analysis period and the end of the observation period, providing an adequate buffer from the effects of the family waking up.

All data were coded by the author eliminating the potential for between-coder error.

Data analysis

Prior to analyses data were tested for normality. Anomalous data were identified and explored; individual cases with anomalous data are discussed in the results section. Analysis was conducted using Statistical Package for the Social Sciences (SPSS) ver.12.0.1. Non-parametric tests were used due to the non-normal data distribution observed within the data set. Mann Whitney U analysis was used for testing different conditions within between two independent samples; observations from both groups are combined and ranked, with the average rank assigned in the case of ties. Wilcoxon Signed Ranks Test analysis was used for testing different conditions within two related samples; information about both the sign of the differences and the magnitude of the differences between pairs is considered. Simple sign test analysis was used for testing the relative concordance of a single variable to the range of a related population; the sign test computes the differences between the two variables for all cases and classifies the differences as either positive, negative, or tied. Independent-Samples t Test analysis was used for testing demographic characteristics; the Independent-Samples t Test procedure compares means for two groups of cases.

Chapter 4

RESULTS

Study Population

The study aimed to recruit equal numbers of families whose infant normally slept in the parents' bed, or in a cot adjacent to the parents' bed. Seventy-three families responded to calls for volunteers, and of these 37% were both eligible for the study and agreed to participate. The main reasons for excluding families from the study were infant age (infants had to be under 12 weeks of age to participate), premature infant, outside local area without transportation, not currently breastfeeding, and father unable/unwilling to participate in overnight monitoring. Six potential participants dropped out prior to attending the test nights. The reasons for families dropping out prior to the study date were infant illness and childcare difficulties for siblings (although some families brought between 1 and 3 siblings under the age of 5 with them to the lab, and we provided fold-out beds for them to sleep on).

The final number of participating families was 21, composed of 10 regular bed-sharing and 11 occasional bed-sharing. Of the bed-sharing families, the 11^{th} was included in the original study for a comparison only, having previously lost an infant to SIDS. Table 1 below summarises the main socio-demographic characteristics of the participants.

Table 1	Whole sample	Bed-sharers	Cot sleepers
Mother's Age (mean)	30	30	29
Father's Age (mean)	32	31	33
Infant's Age on monitoring nights (mean)	9 wks 3 days	9 wks 6 days	8 wks 6 days
Infant's gestational age (mean)	40 wks 1 day	39 wks 5 days	40 wks 4 days
Infant's birthweight (mean)	8lb	7lb 12oz	8lb 6 oz
Maternal Parity (mean)	2.3	2.4	2.2
Household income (mean)	£24939	£24116	£25844
Home ownership (proportion)	66.6%	55%	80%
Proportion of fathers employed	80.5%	82%	90%
Proportion of mothers employed	66.6%	64%	60%
Proportion of fathers with higher education quals	57.1%	54.5%	60%
Proportion of mothers with higher education quals	47.6%	36.4%	70%
Proportion of parents married	76.1%	73%	80%
Proportion of infants with parent who smokes	23.9%	27.3*	20%

T tests reveal no significant differences between the bed-sharing and cot-sleeping sub-samples.

* The parents of 1 habitually bed-sharing infant were both heavy smokers. For the remaining infants fathers only smoked, and all described themselves as 'social' smokers.

Table 1: Summary of the main socio-demographic characteristics of the participants

A range of families participated in this study, however they could generally be characterised as reasonably well-off, or well educated, or both. There were no substantive differences in the subgroup that were regular bed-sharers and the subgroup that regularly slept their baby in a cot. All but 2 infants were categorised as low-risk for SIDS according to common criteria (Conroy and Smith, 1999). The two exceptions were one cot-death sibling (cot sleeper) and one infant whose parents were both heavy smokers (bed sharer). Neither infant were considered to be at particularly high-risk for SIDS due to the absence in both cases of other factors commonly associated with increased risk (e.g. low income, lone parent, rented housing etc).

Sleep log data

Comparison of the data on normal night time care giving at home with the same variables derived from videotapes and nightly logs found that sleep lab nights did not differ significantly from home nights for any of the variables examined (table 2).

Table 2	Home sleep logs	Sleep Lab	t-test
Infant age	63 days	66 days	p=0.56
Time infant fed	22:26	22:38	p=0.21
Time infant fell asleep	22:44	23:07	p=0.19
Time mother went to bed	23:16	23:24	p=0.24
Time father went to bed	23:27	23:42	p=0.27
No. times baby woke in night	1.7	1.9	p=0.59
Duration baby awake in night	1:00	0:44	p=0.10
Frequency of feeds in night	2	1.4	p=0.06

Table 2: Comparison normal night time care giving at home derived from videotapes and nightly logs

Sleep state distribution data validity

Prior to data analysis three families were removed from the data set. The infant in family 5 had received their first set of immunisations prior to the observation and the parents made use of paracetamol suspension to treat their infants' discomfort. Immunisations stress the infant's physiology and may produce abnormal cardio-respiratory data. Paracetamol in adults has a significant effect on oxygen consumption, carbon dioxide production and cardiac output and similar effects may occur in infants, depending on dose (Arana, Morton et al. 2001). It was decided that these aspects rendered the observations unsuitable for inclusion. Equipment failure meant that no data were available from family 9's test nights. Family 17 slept their infant prone during the testing rendering the data unsuitable for inclusion based on the increased risk of SIDS and the known differences in sleep characteristics between infants sleeping prone and supine (McKenna & McDade 2006). The remaining data were tested to establish whether they were distributed normally. Means, medians and standard deviation data were obtained and compared (Table 3).

Table 3		Sleep States (minutes)			
		Awake	REM	QS	Total
Infants	Mean	51.94	139.09	49.74	188.83
	Median	42.00	144.00	47.00	199.00
	Std. Deviation	31.85	33.28	21.03	31.97
	Minimum	3.00	69.00	2.00	126.00
	Maximum	115.00	213.00	81.00	238.00
Mothers	Mean	39.14	141.94	58.14	200.09
	Median	36.00	143.00	59.00	205.00
	Std. Deviation	28.03	23.94	30.53	28.02
	Minimum	1.00	82.00	0.00	97.00
	Maximum	144.00	194.00	119.00	240.00
Fathers	Mean	21.19	165.44	51.53	216.97
	Median	15.00	169.00	46.50	223.50
	Std. Deviation	22.23	36.08	33.65	24.31
	Minimum	0.00	92.00	0.00	144.00
	Maximum	80.00	222.00	149.00	241.00

Table 3: Distribution of sleep state data

It was noted that the data matrix contained considerable range and skewing of data within a number of fields. In consideration of this, nonparametric tests which do not assume normal data distribution were employed for all data analyses.

Parental Smoking

The effect of parental smoking by the father in families 1, 6, 10, 11, 16, and by the mother in family 6 was examined to determine if there was a significant difference in sleep state distribution between the smoking and non-smoking parents.

Tables 4 and 5 compare the means, medians and ranges of the one smoking mother and all non-smoking mothers on the by-the-bed (n=16) and bed-sharing nights respectively.

Table 4		Sleep States (minutes)			
By-the Bed night		Awake	REM	QS	Total
Non-Smokers	Mean	44.18	136.24	58.71	194.94
	Median	38.00	129.00	59.00	202.00
	Std. Deviation	32.35	27.82	35.32	32.16
	Minimum	4.00	82.00	3.00	97.00
	Maximum	144.00	192.00	119.00	237.00
		Awake	REM	QS	Total
Smoker	Mean	69.00	143.00	28.00	171.00
	Median	69.00	143.00	28.00	171.00
	Std. Deviation	69.00	143.00	28.00	171.00
	Minimum	69.00	143.00	28.00	171.00
	Maximum	144.00	192.00	119.00	237.00

Table 4: Comparison of means, medians and ranges of the one smoking mother and all non-smoking mothers on the by-the-bed night

Table 5		Sleep States (minutes)			
Bed Night		Awake	REM	QS	Total
Non-Smokers	Mean	28.25	147.88	63.06	210.94
	Median	30.00	145.00	62.00	209.50
	Std. Deviation	14.78	19.98	21.67	15.72
	Minimum	1.00	117.00	31.00	188.00
	Maximum	51.00	194.00	111.00	240.00
Smoker		98.00	143.00	0.00	143.00

Table 5: Comparison of means, medians and ranges of the one smoking mother and all non-smoking mothers on the bed-sharing night

On the cot night the mothers sleep state distribution clearly falls within the range of the non-smoking mothers and within the standard deviation. On the bed-sharing night however, the smoking mother falls outside of both the range and standard deviation of the non-smoking mothers for waking, quiet sleep and total sleep time. Because the mother infant relationship is fundamental to the analysis and the smoking mother represented a unique outlier her family (6) were removed from all further analyses.

Table 6 shows comparison of sleep state distribution between smoking and non-smoking fathers on the bed-night, revealing no significant differences.

Table 6	Sleep States			
	Awake	REM	QS	Total
Mann-Whitney U	23.00	22.00	19.50	24.50
Wilcoxon W	101.00	32.00	97.50	39.50
Z	-0.122	-0.243	-0.546	-0.580
Asymp. Sig. [2*(1-tailed Sig.]	0.953	0.862	0.599	0.574

Table 6: Comparison of sleep state distribution between smoking and non-smoking fathers on the bed-night

Table 7 shows comparison of smoking and non-smoking fathers on the cot-night, revealing no significant differences in sleep state distribution.

Table 7	Sleep States			
	Awake	REM	QS	Total
Mann-Whitney U	14.00	22.00	22.50	17.50
Wilcoxon W	92.00	32.00	32.50	32.50
Z	-1.213	-0.243	-0.182	-1.479
Asymp. Sig. [2*(1-tailed Sig.]	0.262	0.862	0.862	0.143

Table 7: Comparison of sleep state distribution between smoking and non-smoking fathers on the cot-night

Given that no significant differences were observed between the two test conditions for smoking and non-smoking fathers, these were combined when exploring whether regular bed-sharing, smoking fathers experienced differing sleep state distribution to occasional bed-sharing, smoking fathers (table 8).

Table 8	Sleep States			
	Awake	REM	QS	Total
Mann-Whitney U	120.00	102.00	117.00	133.00
Wilcoxon W	211.00	292.00	208.00	364.00
Z	-0.134	-0.825	-0.205	-0.472
Asymp. Sig. [2*(1-tailed Sig.]	0.910	0.426	0.821	0.654

Table 8: Comparison of regular bed-sharing, smoking fathers sleep state distribution to occasional bed-sharing, smoking fathers sleep state distribution

Clearly, within this sample there were no significant effects on fathers' sleep state distribution regardless of whether they smoked or not.

Distribution of sleep states were also examined for the other members of the families where the father smoked to determine if they experienced significantly different sleep state distribution than families in which the parent did not smoke. No significant differences were noted between sleep state distribution of the mother or infant of regular bed-sharing, smoking fathers and regular bed-sharing non-smoking fathers on the bed-sharing night (table 9), or the cot night (table 10).

Table 9	Sleep States							
	Infant				Mother			
	Awake	REM	QS	Total	Awake	REM	QS	Total
Mann-Whitney U	4.00	5.00	7.50	4.00	2.00	8.50	5.00	4.00
Wilcoxon W	32.00	11.00	35.50	10.00	30.00	14.50	11.00	10.00
Z	-1.481	-1.257	-0.686	-1.481	-1.949	-0.457	-1.126	-1.486
Asymp. Sig. [2*(1-tailed Sig.]	0.183	0.267	0.517	0.183	0.067	0.667	0.267	0.183

Table 9: Sleep state distribution of the mother and infant of regular bed-sharing, smoking fathers and regular bed-sharing non-smoking fathers on the bed-sharing nights

Table 10	Sleep States							
	Infant				Mother			
	Awake	REM	QS	Total	Awake	REM	QS	Total
Mann-Whitney U	8.00	5.00	7.00	8.00	10.00	8.00	6.00	10.00
Wilcoxon W	44.00	11.00	43.00	14.00	46.00	44.00	12.00	16.00
Z	-0.816	-1.429	-1.021	-0.816	-0.408	-0.816	-1.225	-0.408
Asymp. Sig. [2*(1-tailed Sig.]	0.497	0.194	0.367	0.497	0.776	0.497	0.279	0.776

Table 10: Sleep state distribution of the mother and infant of regular bed-sharing, smoking fathers and regular bed-sharing non-smoking fathers on the by-the-bed nights

Similarly, no significant differences were noted between sleep state distribution of the mother or infant of occasional bed-sharing, smoking fathers and regular bed-sharing non-smoking fathers on the bed-sharing night (table 11), or the cot night (table 12).

Table 11	Sleep States							
	Infant				Mother			
	Awake	REM	QS	Total	Awake	REM	QS	Total
Mann-Whitney U	0.00	4.00	4.00	0.00	0.00	4.00	5.00	2.00
Wilcoxon W	15.00	7.00	7.00	3.00	15.00	7.00	8.00	5.00
Z	-1.936	-0.387	-0.387	-1.936	-1.936	-0.387	0.000	-1.162
Asymp. Sig. [2*(1-tailed Sig.]	0.095	0.857	0.857	0.095	0.095	0.857	1.000	0.381

Table 12: Sleep state distribution of the mother or infant of occasional bed-sharing, smoking fathers and regular bed-sharing non-smoking fathers on the bed-sharing night

Table 12	Sleep States							
	Infant				Mother			
	Awake	REM	QS	Total	Awake	REM	QS	Total
Mann-Whitney U	5.00	2.50	3.50	5.00	4.00	4.000	5.00	4.00
Wilcoxon W	8.00	5.50	18.50	8.00	7.00	19.000	8.00	19.00
Z	0.000	-0.977	-0.586	0.000	-0.387	-0.387	0.000	-0.387
Asymp. Sig. [2*(1-tailed Sig.]	1.000	0.381	0.571	1.000	0.857	0.857	1.000	0.857

Table 12: Sleep state distribution of the mother or infant of occasional bed-sharing, smoking fathers and regular bed-sharing non-smoking fathers on the by-the-bed night

Therefore families in which the father smokes have been included in all subsequent data analysis.

Absent fathers

Absence of the father on the bed-sharing night in family 11 and on the by-the-bed night in families 16 and 18 was examined to determine if fathers' absence had an effect on the mothers' and infants' sleep state distribution.

The sleep state distribution for the infant and mother of family 11, occasional bed-sharers, fall consistently within the range and within the standard deviation for all sleep states and total sleep (table 13).

Table 13	Sleep States (minutes)							
All other Famillies	Infant				Mother			
	Awake	REM	QS	Total	Awake	REM	QS	Total
Mean	34.20	162.20	44.33	206.53	28.07	148.47	62.53	211.00
Median	30.00	159.00	47.00	210.00	29.00	147.00	62.00	209.00
Std. Deviation	20.56	26.36	22.05	20.80	15.28	20.53	22.33	16.27
Minimum	3.00	109.00	2.00	160.00	1.00	117.00	31.00	188.00
Maximum	81.00	213.00	76.00	238.00	51.00	194.00	111.00	240.00
Family 11	38.00	159.00	44.00	203.00	31.00	139.00	71.00	210.00

Table 13: Comparison of sleep state distribution for the infant and mother of family 11 during absence of father compared to all other families on the bed-sharing night

It would therefore appear that the absence of the father from family 11 on the bed-sharing night did not cause the sleep state distribution of the mother or infant to vary from the normal distribution of sleep states observed amongst the families where the father was present.

This was not, however, the pattern observed for the infant and mother of families 16 and 18, both regular bed-sharing families, when the father was absent on the cot nights (table 14).

Table 14	Sleep States (minutes)							
All other families	Infant				Mother			
	Awake	REM	QS	Total	Awake	REM	QS	Total
Mean	60.93	124.07	55.80	179.87	46.00	136.47	56.33	192.80
Median	62.00	119.00	59.00	179.00	38.00	129.00	50.00	202.00
Std. Deviation	30.87	22.22	20.10	30.97	33.76	28.50	36.90	33.41
Minimum	7.00	86.00	20.00	127.00	4.00	82.00	3.00	97.00
Maximum	114.00	158.00	80.00	234.00	144.00	192.00	119.00	237.00
Family 16	115.00	97.00	29.00	126.00	17.00	157.00	67.00	224.00
Family 18	110.00	92.00	38.00	130.00	44.00	112.00	86.00	198.00

Table 14: Comparison of sleep state distribution for the infant and mother of family 16 & 18 during absence of father compared to all other families on the by-the-bed night

These data indicate that the absence of the father may have had some influence on the infants sleep state distribution with both infant REM and quiet sleep falling below the standard deviation from the median of infants where the father was present. Because however, the sleep state distribution of families with absent fathers fell generally within the range expressed by those families with fathers present these data were further explored using a simple Sign test. Table 15 demonstrates the level of significance for the deviation of the mothers' and infants' sleep state distribution on the cot night amongst families where the father was absent (16 & 18) from the mothers' and infants' sleep state distribution of on the cot night for families where the father was present.

	Table 15	Infant		(minutes)		Mother		(minutes)	
Family		awk	REM	quiet	total slp	awk	REM	quiet	total sleep
	Median (Mins)	115	97	29	126	17	157	67	224
	Greater (n cases)	0	14	13	15	13	3	6	2
	Lesser (n cases)	15	1	2	0	2	12	9	13
	Equal (n cases)								
16	p<=	0.0001	0.001	0.0074	0.0001	0.0074	0.0352	0.607	0.0074
	Median (Mins)	110	92	38	130	44	112	86	198
	Greater (n cases)	2	14	12	13	6	13	4	8
	Lesser (n cases)	13	1	3	2	9	1	11	7
	Equal (n cases)						1		
18	p<=	0.0074	0.001	0.0352	0.0074	0.607	0.0018	0.118	1

Table 15: Level of significance for the deviation of the mothers' and infants' sleep state distribution on the cot night amongst families where the father was absent

The Sign test indicates that the absence of the father on the cot night significantly affected the sleep state distribution of the mother and infant for both family 16 & 18 leading to more infant waking time and less infant REM, quiet sleep and total sleep during the fathers' absence. The mother's sleep was also affected by the father's absence in both families, although the mother of family 18 experienced less REM only, whereas the mother of family 16 experienced significantly less waking time and more REM and total sleep time.

It must be noted that these data should be treated with considerable caution as the sample size was too small to satisfactorily investigate the effects of father presence/absence and the relationship to families normal sleep condition. Given the concern that these data raise however, both families 16 and 18 were removed from the data set for all subsequent analyses.

The cleaned data set therefore consisted of 15 families (8 regular bed-sharing and 7 occasional bed-sharing).

Mother and infant sleep state distribution

Comparison of the distribution of sleep states for mothers and infants between the two sleeping conditions were conducted (table DA1).

Table 16		Infant (minutes)				Mother (minutes)			
Condition	Cases	awk	REM	quiet	total	awk	REM	quiet	total
Bed Night	Total	29.50	160.50	45.00	210.00	27.00	150.50	60.50	210.00
Cot Night	Total	62.00	119.00	59.00	179.00	38.00	129.00	50.00	202.00
Asymp. Sig. (2-tailed)		0.016	0.002	0.026	0.078	0.016	0.009	0.615	0.047

Table 16: Comparison of sleep state distribution for mothers and infants between the two sleeping conditions

Results indicate that infants spend a significantly greater period awake on the by-the-bed night than on the bed-sharing night (p=.016). Infants also spend significantly less time in REM (p=.002) and significantly more time in quiet sleep (p=.020) on the by-the-bed night.

Mothers spend significantly more time awake (p=.016) and significantly less time in REM sleep (p=.009) on the by-the-bed night than on the bed-sharing night, and demonstrate significantly more time spent in sleep overall (p=.047) on the bed night.

Comparisons of shared sleep states between the infant and mother on the by-the-bed and bed-sharing nights were examined (table 17).

Table 17	(minutes)	REM	QS	Total Sleep
Condition	Cases	Mother & Infant	Mother & Infant	Mother & Infant
Bed Night	Total	113.5	18	125
Cot Night	Total	85	15	111
Asymp. Sig. (2-tailed)		0.004	0.572	0.013

Table 17: Comparison of shared sleep states between the infant and mother on the by-the-bed and bed-sharing nights

Results indicate that mother infant pairs spent significantly more time in shared REM (p=.004) and in total shared sleep (p=.013) on the bed-sharing nights. There was no significant difference in the amount of quiet sleep between the two conditions.

Mother infant pairs were then separated according to the regularity of their normal bed-sharing practice and both sleep state distribution and shared mother infant sleep state were separated and explored. Table 18 shows sleep state distribution for regular bed-sharing mothers and infants between the bed-sharing and by-the-bed nights.

Table 18		Infant (minutes)				Mother (minutes)			
Condition	Cases	awk	REM	quiet	total	awk	REM	quiet	total
Bed Night	Regular Bed-sharers	36	180	42	205	36	147	59	201
Cot Night	Regular Bed-sharers	74.5	106.5	42	165	42.5	126.5	54.5	192.5
Asymp. Sig. (2-tailed)		0.063	0.018	0.063	0.327	0.063	0.018	0.398	0.208

Table 18: Sleep state distribution for regular bed-sharing mothers and infants between the bed-sharing and by-the-bed nights

Results indicate that regular bed-sharing infants experience significantly more time in REM (p=.018) on the bed-sharing nights than on the by-the-bed nights, as do regular bed-sharing mothers (p=.018). No other significant differences in sleep state distribution sleep between the two conditions for regular bed-sharing mothers or infants.

Table 19 shows sleep state distribution for occasional bed-sharing mothers and infants between the bed and cot nights.

Table 19		Infant (minutes)				Mother (minutes)			
Condition	Cases	awk	REM	quiet	total	awk	REM	quiet	total
Bed Night	Occasional bed-sharers	29	157	59	212	21	154	62	220
Cot Night	Occasional Bed-sharers	37	131	77	204	29	145	37	206
Asymp. Sig. (2-tailed)		0.176	0.043	0.176	0.176	0.128	0.237	0.271	0.091

Table 19: Sleep state distribution for occasional bed-sharing mothers and infants between the bed and cot nights

Amongst occasional bed-sharing mother and infants, only infants' REM is significantly affected by sleep condition, with infants experiencing significantly more REM on the bed-sharing night (p=.043).

Table 20 explores the time regular bed-sharing infant and mother pairs spend in shared sleep on the bed-sharing night and by-the-bed night.

Table 20	(minutes)	REM	QS	Total Sleep (REM+QS)
Condition	Cases	Mother & Infant	Mother & Infant	Mother & Infant
Bed Night	Regular Bed-sharers	118	16	130
Cot Night	Regular Bed-sharers	78.5	17	104
Asymp. Sig. (2-tailed)		0.018	0.449	0.028

Table 20: Time spent in shared sleep on the bed-sharing night and by-the-bed night by regular bed-sharing infants and mothers

This indicates that regular bed-sharing infant and mother pairs spend significantly more time in shared REM sleep (p=.018) and overall sleep (p=.028) on the bed-sharing night than the by-the-bed night.

Contrastingly, table 21 shows that the amount of shared sleep occasional bed-sharing infant and mother pairs experience, does not differ between the bed-sharing night and the by-the-bed night.

Table 21	(minutes)	REM	QS	Total Sleep (REM+QS)
Condition	Cases	Mother & Infant	Mother & Infant	Mother & Infant
Bed Night	Occasional bed-sharers	109	20	125
Cot Night	Occasional Bed-sharers	85	12	115
Asymp. Sig. (2-tailed)		0.091	0.735	0.176

Table 21: Comparison of shared sleep for occasional bed-sharing infants and mothers on the bed-sharing night and the by-the-bed night

To determine whether the differences observed in sleep state distribution between the test nights for each of the normal family sleep practices are indeed significant, the two groups were compared. Table 22 shows regular bed-sharing mothers and infants compared to occasional bed-sharing mothers and infants on the bed-sharing night.

Table 22		Infant (minutes)				Mother (minutes)			
Condition	Cases	awk	REM	quiet	total	awk	REM	quiet	total
Bed Night	Regular	36	180	42	205	36	147	59	201
Bed Night	Occasional Bed-sharers	29	157	59	212	21	154	62	220
Asymp. Sig. (2-tailed)		0.318	0.209	0.053	0.318	0.128	0.902	0.62	0.128

Table 22: Comparison of regular bed-sharing mothers and infants and occasional bed-sharing mothers and infants sleep state distribution on the bed-sharing night

These data show that the regularity of the test families' normal bed-sharing behaviour does not affect the mother's and infants' sleep state distribution on the bed-sharing night.

Table 23		Infant (minutes)				Mother (minutes)			
Condition	Cases	awk	REM	quiet	total	awk	REM	quiet	total
Cot Night	Regular	74.5	106.5	42	165	42.5	126.5	54.5	192.5
Cot Night	Ocassional	37	131	77	204	29	145	37	206
Asymp. Sig. (2-tailed)		0.004	0.094	0.021	0.004	0.189	0.397	0.694	0.281

Table 23: Comparison of regular bed-sharing mothers and infants and occasional bed-sharing mothers and infants sleep state distribution on the by-the-bed night

Table 23, however demonstrates that regularity of the test families' normal bed-sharing behaviour does effect the infants' sleep state distribution on the by-the-bed night, with regular bed-sharing infants experiencing significantly greater time awake (p=.004) and significantly less time in quiet sleep (p=.021) and overall sleep (p=.004) than occasional bed-sharing infants. Mothers sleep state distribution was not significantly effected.

Father and infant sleep state distribution

The relationship between father and infant pairs were explored in a similar fashion. Comparison of the distribution of sleep states for fathers between the two sleeping conditions were conducted (table 24).

Table 24		Father (minutes)			
Condition	Cases	awk	REM	quiet	total
Bed Night	Total	15	177	43	222
Cot Night	Total	18	161	49	221
Asymp. Sig. (2-tailed)		0.6	0.345	0.311	0.649

Table 24: Comparison of the distribution of sleep states for fathers between the bed-sharing and by-the-bed conditions

Results indicate that test condition (bed-sharing night / by-the-bed night) does not significantly effect fathers' sleep state distribution.

Comparisons of shared sleep states between the infant and father in the by-the-bed and bed-sharing nights were examined (table 25).

Table 25	(minutes)	REM	QS	Total Sleep (REM+QS)
Condition	Cases	Father & Infant	Father & Infant	Father & Infant
Bed Night	Total	120	10	125
Cot Night	Total	90	6	100
Asymp. Sig. (2-tailed)		0.001	1.000	0.003

Table 25: Comparisons of shared sleep states between the infant and father in the by-the-bed and bed-sharing nights

This analysis shows that father and infant share significantly more REM sleep (p=.001) and more sleep overall (p=.003) on the bed-sharing night than on the by-the-bed night.

Father infant pairs were then separated according to the regularity of their normal bed-sharing practice and sleep state distribution between the two test conditions (bed-sharing and by-the-bed) were further explored. Table 26 shows the comparison of the sleep state distribution of regular bed-sharing fathers on the bed night and the cot night.

Table 26		Father (minutes)			
Condition	Cases	awk	REM	quiet	total
Bed Night	Regular Bed-sharers	15	171	43	222
Cot Night	Regular Bed-sharers	19.5	164	35.5	218.5
Asymp. Sig. (2-tailed)		0.735	0.735	0.612	0.779

Table 26: Comparison of the sleep state distribution of regular bed-sharing fathers on the bed night and the cot night

Results indicate that regular bed-sharing fathers experience no significant effect to their sleep state distribution between the bed-sharing and by-the-bed test conditions.

Table 27		Father (minutes)			
Condition	Cases	awk	REM	quiet	total
Bed Night	Occasional bed-sharers	15.5	181	38	222
Cot Night	Occasional Bed-sharers	13	151	54	227
Asymp. Sig. (2-tailed)		0.463	0.345	0.345	1.000

Table 27: Comparison of the sleep state distribution of occasional bed-sharing fathers on the bed night and the cot night

Similarly, occasional bed-sharing fathers experience no significant effect to their sleep state distribution between the bed-sharing and by-the-bed test conditions (table 27).

In addition, comparisons of shared sleep states between the infant and father on the bed-sharing nights were also explored in relation to the infants' relative proximity to the father in the bed (table 29). Infant sleep position in the bed was coded to identify whether he/she spent the majority of the observation period on the outside of the mother (relative to the father) or between the mother and father. Table 28 provides an overview of the pattern of infant sleep location by regularity of normal sleep location, revealing no differences between infant location regardless of normal bed-sharing behaviour.

Table 28		(minutes)		% of observation	
Condition	Cases	Outside Mum	Next to Dad	Outside Mum	Next to Dad
Bed	Regular bed-sharers (n7)	79	162	32.78	67.22
	Occasional bed-sharers (n6)	17.5	223.5	7.26	92.74
Asymp. Sig. (2-tailed)		0.628	0.628		

Table 28: Infant sleep location by regularity of normal sleep location

Periods where an infant slept on the mother were considered as 'outside of the mother' to reflect that the mother is the most likely to address infant care issues in those positions.

Table 29 Condition	(minutes) Cases	REM Father & Infant	QS Father & Infant	Total Sleep Father & Infant
Outside	All	123	14	132
Between	All	120	2	126
Asymp. Sig. (2-tailed)		0.71	0.33	0.414

Table 29: Comparison of shared sleep states between the infant and father on the bed-sharing nights by infants' relative proximity to the father in the bed

These data suggest that father and infant shared sleep is not affected by whether the infant is positioned between the mother and father, or outside of the mother during bed-sharing.

Arousal synchrony data validity

Arousal data were tested to establish distribution characteristics. Means, medians and standard deviation data were obtained and compared (Table 30).

		Infant Transient Arousals Frequency	Infant Waking Arousal Frequency	Infant Total Arousal Frequency	Mother Transient Arousals Frequency	Mother Waking Arousal Frequency	Mother Total Arousal Frequency	Father Transient Arousal Frequency	Father Waking Arousals Frequency	Father Total Arousal Frequency
N	Valid	29	29	29	29	29	29	28	28	28
	Missing	0	0	0	0	0	0	1	1	1
Mean		9.2286	1.5779	10.8083	4.4128	.9276	5.3397	4.7739	1.1107	5.8871
Median		9.4600	1.4900	10.9500	4.4800	1.0000	5.2300	4.6050	1.2400	5.9800
Std. Deviation		3.10731	.57729	3.14873	1.99921	.44877	1.93364	1.82696	.76970	2.21682
Minimum		2.24	.50	4.48	.50	.25	1.49	1.74	.00	2.24
Maximum		16.93	2.99	18.17	8.46	1.99	9.21	9.46	2.74	10.46

Table 30: Comparison of means, medians and ranges infant, mother and father transient and waking arousals

It was noted that the data matrix contained considerable range and skewing of data within a number of fields including waking arousals for mothers, infants all arousal data for fathers. In consideration of this, nonparametric tests which do not assume normal data distribution were employed on all arousal data analyses.

Arousal synchrony in mother infant pairs

Comparisons of the frequency of transient/movement, full waking and total combined number of arousals between the all mothers and infants were performed (table 31)

Table 31		Infant	(medians)		Mother	(medians)	
Condition	Cases	Transient	Waking	Total	Transient	Waking	Total
		per/hour	per/hour	per/hour	per/hour	per/hour	per/hour
bed	all	10.08	1.37	10.95	3.98	0.75	4.98
cot	all	8.96	1.49	10.21	4.48	1	5.73
Asymp. Sig. (2-tailed)		0.485	0.248	0.300	0.381	0.257	0.624

Table 31: Comparisons of the frequency of transient/movement, full waking and total combined number of arousals between the all mothers and infants

The data revealed that test condition (bed-sharing night or by-the-bed night) had no significant effect on the number of transient/movement, waking or combined total arousals for mothers or infants when regularity of normal family sleeping practice is aggregated.

The data was further analysed by testing regular bed-sharing families and occasional bed-sharing families separately for each of the test condition nights (bed-sharing night and by-the-bed night). Table 32 explores arousal patterns for regular bed-sharing mothers and infants on the bed-sharing night and by-the-bed night. This reveals that regular bed-sharing mothers experience significantly more transient/movement arousals per hour ($p=.027$) and consequently more overall arousals per hour ($p=.046$) on the bed-sharing night than on the by-the-bed night.

Table 32		Infant			Mother		
Condition	Cases	Transient	Waking	Total	Transient	Waking	Total
		per/hour	per/hour	per/hour	per/hour	per/hour	per/hour
bed	regular bed-sharers	7.47	1.24	8.96	4.98	0.75	6.72
cot	regular bed-sharers	8.34	1.37	9.71	3.36	1	4.73
Asymp. Sig. (2-tailed)		0.600	0.610	0.499	0.027	0.400	0.046

Table 32: Comparison of the frequency of transient/movement, full waking and total combined number of arousals for regular bed-sharing mothers and infants on the bed night and cot night

Table 33 explores arousal patterns for occasional bed-sharing mothers and infants on the bed-sharing night and by-the-bed night. This reveals that occasional bed-sharing mothers experience no significant variation to the number of transient/movement, or waking arousals between the bed-sharing night and the by-the-bed night.

Table 33		Infant			Mother		
Condition	Cases	Transient	Waking	Total	Transient	Waking	Total
		per/hour	per/hour	per/hour	per/hour	per/hour	per/hour
bed	occasional bed-sharers	10.46	1.49	12.2	3.49	0.5	4.48
cot	occasional bed-sharers	11.2	1.74	13.2	4.73	1	5.98
Asymp. Sig. (2-tailed)		0.735	0.206	0.612	0.31	0.414	0.235

Table 33: Comparisons of the frequency of transient/movement, full waking and total combined number of arousals for occasional bed-sharing mothers and infants on the bed night and cot night

Father arousals

Comparisons of the frequency of transient/movement, full waking and total combined number of arousals between all fathers were performed (table 34).

Table 34		Father		
Condition	Cases	Transient per/hour	Waking per/hour	Total per/hour
bed	all	4.23	0.75	5.98
cot	all	4.73	1.24	5.98
Asymp. Sig. (2-tailed)		0.146	0.167	0.177

Table 34: Comparisons of the frequency of transient/movement, full waking and total combined number of arousals for all fathers across test conditions

The data revealed that test condition (bed-sharing night or by-the-bed night) had no significant effect on the number of transient/movement, waking or combined total arousals for fathers when regularity of normal family sleeping practice is aggregated.

The data were further analysed by testing fathers of regular bed-sharing families and fathers of occasional bed-sharing families separately for each of the test condition nights (bed-sharing night or by-the-bed night). Table 35 explores arousal patterns for regular bed-sharing fathers on the bed-sharing night and by-the-bed night. This reveals that regular bed-sharing fathers experience no significant differences in transient/movement arousals or overall arousals per hour on the bed-sharing night than on the by-the-bed night.

Table 35		Father		
Condition	Cases	Transient per/hour	Waking per/hour	Total per/hour
bed	regular bed-sharers	2.99	0.5	3.49
cot	regular bed-sharers	4.48	1	5.85
Asymp. Sig. (2-tailed)		.674	.078	.612

Table 35: Comparison of arousal patterns for regular bed-sharing fathers on the bed-sharing night and by-the-bed night

Table 36 explores arousal patterns for occasional bed-sharing fathers on the bed-sharing night and by-the-bed night. This reveals that occasional bed-sharing fathers experience no significant variation to the number of transient/movement, or waking arousals between the bed-sharing night and the by-the-bed night.

Table 36		Father		
Condition	Cases	Transient per/hour	Waking per/hour	Total per/hour
bed	occasional bed-sharers	4.36	1.74	6.22
cot	occasional bed-sharers	4.73	1.24	7.47
Asymp. Sig. (2-tailed)		.074	.753	.237

Table 36: Comparison of arousal patterns for occasional bed-sharing fathers on the bed-sharing night and by-the-bed night

Table 37 explores arousal patterns for occasional bed-sharing and regular bed-sharing fathers on the bed-sharing night. This reveals that regularity of normal bed-sharing behaviour makes no significant difference to the number of transient/movement, or waking arousals on the bed-sharing night.

Table 37		Father		
Condition	Cases	Transient per/hour	Waking per/hour	Total per/hour
bed	regular	2.99	0.5	3.49
bed	occasional bed-sharers	4.36	1.74	6.22
Asymp. Sig. (2-tailed)		0.128	0.535	0.383

Table 37: Comparison of arousal patterns for occasional bed-sharing and regular bed-sharing fathers on the bed-sharing night

Table 38 explores arousal patterns for occasional bed-sharing and regular bed-sharing fathers on the by-the-bed night. This reveals that regularity of normal bed-sharing behaviour makes no significant difference to the number of transient/movement, or waking arousals on the by-the-bed night

Table 38		Father		
Condition	Cases	Transient	Waking	Total
		per/hour	per/hour	per/hour
cot	regular	4.48	1	5.85
cot	occasional bed-sharers	4.73	1.24	7.47
Asymp. Sig. (2-tailed)		0.209	0.165	0.128

Table 38: Comparison of arousal patterns for occasional bed-sharing and regular bed-sharing fathers on the by-the-bed night

Shared Arousals

Occasions where a parent experienced a full waking arousal in the same minute, or the minute following a transient/movement or full waking arousal in their infant were explored.

Table 39 explores the distribution of shared arousal data as a ratio of all infant arousals. It was noted that the data matrix contained considerable range and skewing of data. In consideration of this, nonparametric tests which do not assume normal data distribution were employed on all data analyses.

Table 39		Bed Night Mother Infant Shared Arousal as a Ratio of Total Infant Arousals	Cot Night Mother Infant Shared Arousal as a Ratio of Total Infant Arousals	Bed Night Father Infant Shared Arousal as a Ratio of Total Infant Arousals	Cot Night Father Infant Shared Arousal as a Ratio of Total Infant Arousals
N	Valid	14	15	13	15
	Missing	1	0	2	0
Mean		5.9286	2.8733	4.2692	3.0533
Median		5.15	1.9	4	2.3

Std. Deviation	4.31142	2.5982	3.15526	3.08611
Minimum	0	0	0	0
Maximum	14.3	7.9	9.3	12.3

Table 39: Distribution of mother infant and father infant shared arousals as a ratio of all infant arousals

Table 40 shows the number of infant arousals that occur to every shared arousal between mother and infant, and father and infant for all cases on the bed-sharing and by-the-bed nights.

Table 40			
Condition	Cases	Mother Infant	Father Infant
bed	all	5	4
cot	all	2	2
Asymp. Sig. (2-tailed)		.052	.638

Table 40: Comparison of the number of infant arousals that occur to every shared arousal between mother and infant, and father and infant for all cases on the bed-sharing and by-the-bed nights

No significant differences between the conditions were observed, however the number of infant arousals that occur to every shared arousal between mother and infant came close to being significantly greater on the bed-sharing night (p=.052).

Table 41 shows the number of infant arousals that occur to every shared arousal between regular bed-sharing mother and infant, and regular bed-sharing father and infant on the bed-sharing and by-the-bed nights. No significant relationships were observed.

Table 41			
Condition	Cases	Mother Infant	Father Infant
bed	regular bed-sharers	6	3
cot	regular bed-sharers	3	3
Asymp. Sig. (2-tailed)		.091	.345

Table 41: Number of infant arousals that occur to every shared arousal between regular bed-sharing mother and infant, and regular bed-sharing father and infant on the bed-sharing and by-the-bed nights

Table 42 shows the number of infant arousals that occur to every shared arousal between occasional bed-sharing mother and infant and occasional bed-sharing father and infant on the bed-sharing and by-the-bed nights. No significant relationships were observed.

Table 42			
Condition	Cases	Mother Infant	Father Infant
bed	occasional bed-sharers	5	7
cot	occasional bed-sharers	2	2
Asymp. Sig. (2-tailed)		.398	.249

Table 42: Number of infant arousals that occur to every shared arousal between occasional bed-sharing mother and infant, and occasional bed-sharing father and infant on the bed-sharing and by-the-bed nights

Chapter 5

DISCUSSION

Previous studies have identified that proximity of mother and infant, regularity of bed-sharing and presence of the father during bed-sharing affect the sleep patterns and behaviour of breastfeeding mothers and infants. These studies represent the beginning of an understanding of the complexities of social sleep and bed-sharing in particular. Their value has been to highlight a potentially more appropriate way of understanding social sleep, and pointing out the negative effects that oversimplifying social sleep and bed-sharing could have to mother and infant health and wellbeing. This study contributes to the growing understanding of social sleep environments and their relationship to parent and infant behaviour and physiology. The data obtained on 15 regularly and occasionally bed-sharing families were used to investigate the claims of shared sleep and arousals found in breastfeeding mother infant dyads in pioneer studies and to more closely examine the effects of proximity on mother infant physiology in bed-sharing compared to rooming-in, using both regular and occasional bed-sharing families. Further, the physiology of fathers was introduced to the equation for the first time, exploring the relationship between fathers and infants during bed-sharing and room-sharing, thereby creating a more naturalistic understanding of social sleep.

The mother infant sleep data presented should be considered with the understanding that it has been obtained in the presence of the fathers on test nights. As yet, there are no clear data regarding the effect of paternal presence on mother infant sleep physiology and behaviour in social sleep; Baddock (2006) maintains that paternal presence makes no difference to the mother infant dyad, whilst Ball (2006) maintains that infants are located differently in the bed during triadic bed-sharing and that infant, mother and mutual infant-mother arousals are increased during triadic bed-sharing.

Mother infant shared sleep state during bed-sharing

McKenna and Mosko (1990) noted that bed-sharing, breastfeeding mothers shared 46% of their infants sleep state (awake, REM, stage 1-2 sleep and stage 3-4 sleep) through the night and infants shared 44% of their mothers' sleep states. Calculations of simultaneous activity time included being awake. As breastfeeding infants feed frequently day or night, it is possible that the amount of simultaneous activity time recorded by McKenna and Mosko (1990) is an artefact of wakefulness during feeding. Breastfeeding infants feed at least every three hours during the first months of life for periods of 45 minutes per feed. Inclusion of waking during analysis of simultaneous activity time may therefore include at least 2 feeds of 45 minutes within any 8 hour period (18.75% of an 8 hour observation), which would leave only around a quarter (27.25% and 25.25%) of mother infant time in simultaneous sleep. It is unclear if statistical significance would have been reached for simultaneous activity time if waking had not been included.

Simultaneous activity time provided the foundation stone in McKenna's theory of sensory exchange (discussed earlier) and so it is important to test whether the patterns he observed are present if waking is discounted. Therefore, time spent in shared sleep state for bed-sharing mother infant pairs was explored in this study, excluding shared awake time, which was a median of 36% of the analysis period. Results indicated that bed-sharing mother and infant dyads spent a total median simultaneous sleep state time of 51.87% (125.0 minutes). This was composed of a median of 47.1% (113.5 minutes) of the analysis period in simultaneous REM sleep and a median of 7.47% (18.0 minutes) of the analysis period in simultaneous Quiet sleep). These data appear to be roughly concordant with McKenna and Mosko (1990) and suggest that whilst including waking in measurements of simultaneous activity time may present a methodological oversimplification of the social sleep environment, the underlying patterns that McKenna observed in his early studies remain when waking is discounted from analyses of simultaneous sleep activity.

The affect of proximity on mother infant shared sleep state

During their 1994 study McKenna and Mosko went on to compare the differences between simultaneous activity time amongst breastfeeding mothers and infants on bed-sharing and solitary sleep nights. They noted that on the solitary night, mother infant pairs shared 26% simultaneous activity time whilst on the bed-sharing night they shared 45% simultaneous activity time. Again, they included waking periods in their analysis. This study, however, once again measured only shared sleep time to avoid the effects that breastfeeding may have in over-exaggerating shared waking time. Regardless, mother and infant pairs demonstrated significantly more (12%; p=.013) simultaneous overall sleep time in the bed-sharing (BS) condition than in the by-the-bed (BTB) condition (BS 51.87% (125.00 minutes), BTB 46.06% (111.00 minutes). However, while overall shared sleep was significantly greater on the bed-sharing night this was not the case for both REM and Quiet sleep when viewed separately; with shared REM sleep being of significantly longer duration on the bed-sharing night than on the by-the-bed night. and shared Quiet sleep not differing significantly.

These data therefore support the pattern of simultaneous activity time between breastfeeding bed-sharing mothers and infants noted by McKenna and Mosko (1990 & 1994), and also reveal a further layer of complexity. It appears that bed-sharing only affects shared REM sleep and not shared Quiet sleep; having more sleep without an increase in Quiet sleep may confer the benefit of greater mother and infant rest, without an increase in infant exposure to Quiet sleep. The depressed arousal threshold, with which Quiet sleep is associated, has been linked to SIDS (see background).

Mother and infant sleep state distribution during bed-sharing and by-the-bed sleep

Comparison of sleep state distribution of mother and infant sleep revealed that both mothers and infants experienced significantly less time awake on the bed-sharing night and infants spent significantly less time in Quiet sleep on the bed-sharing night (Table 16). There was a corresponding rise in mother and infant REM sleep on the bed-night. This pattern demonstrates that sleep contact affects mother and infant shared sleep and mirrors the findings of McKenna & Mosko (1994). These data support predictions based on sensory exchange, which would expect to see the reduction of Quiet sleep during bed-sharing as a reflection of evolutionarily adaptive behaviour protective of the higher arousal thresholds of Quiet sleep.

The effect of regularity of bed-sharing on mother infant sleep state distribution during bed-sharing

Mothers and infants exhibited significantly different amounts of REM between sleep conditions (bed-sharing and by-the-bed) when mother infant dyads were separated by normal sleep practice (regular bed-sharers and occasional bed-sharers). Regular bed-sharing mothers and infants both experienced significantly less REM on the by-the-bed nights, as did occasional bed-sharing infants. Therefore, infants spent more time in REM on bed-sharing nights than by-the-bed nights regardless of the regularity of bed-sharing in their normal sleep behaviour. No significant differences in waking time or quiet sleep were noted for either regular or occasional bed-sharers between the two sleeping conditions

When comparisons were made of sleep distribution between regular bed-sharers and occasional bed-sharers within each sleep condition, it was revealed that although regularity made no difference on bed-nights, there were significant differences observed on cot-nights; Regular bed-sharing infants were awake significantly more and in Quiet sleep significantly less on by-the-bed nights than were occasional bed-sharers. Interestingly, the regular bed-sharing infants showed no variation in their Quiet sleep from the bed-sharing night (median 42 minutes) to the by-the-bed night (median 42 minutes) but more than doubled (51.68%) their time awake (BS median 36 minutes, BTB median 74.5 minutes). Contrastingly, the occasional bed-sharing infants displayed a 23.38% increase in their Quiet sleep between the bed-sharing night (median 59 minutes) and the by-the-bed night (median 77 minutes), and a 21.6% rise in time spent awake (BS = median 29 minutes, BTB = median 37 minutes). These data indicate quite different affects of sleep condition between regular and occasional bed-sharers that do not emerge with less rigorous analysis. It would appear that regular bed-sharing infants experience considerable disruption to their sleep when separated from physical contact with their mothers. It is possible that infants find it more difficult to adapt to increased separation than to increased contact, though no data are available to support this theory.

The decrease in Quiet sleep amongst occasional bed-sharing infants displayed during the bed-sharing night follows the pattern highlighted amongst bed-sharing breast-feeding infants as a whole. As such it supports the theory that bed-sharing allows positive infant stimulation resulting from evolutionarily adaptive sensory exchange between parent and infant during bed-sharing (as proposed by McKenna (1994). However, regular bed-sharers did not display an increase in Quiet sleep on the by-the-bed nights as such a theory might predict. It is possible that the amount of Quiet sleep experienced by regular bed-sharing infants on the by-the-bed night did not increase as a result of the overall increase in wakefulness that they experienced. It may also be possible that the data represents stability in the sleep physiology of regular bed-sharing infants not seen amongst occasional bed-sharers, possibly due to enhanced maturation of the CNS and/or circadian sleep cycle. Further research should consider exploring this dimension.

The affect of regularity of bed-sharing on mother infant shared sleep state during bed-sharing

Regularity of normal sleep condition (regular and occasional bed-sharing) only affected the shared sleep of regular bed-sharing mothers and infants on the bed-sharing night. This group experienced 150.32% ($p=.018$) more REM and 125% ($p=.028$) more overall sleep on the bed-sharing night than on the by-the-bed night. This pattern has not been noted in sleep state distribution previously, though an increase in synchronous mother infant arousals for regular bed-sharing mothers and infants on the bed-sharing night have been noted by both McKenna and Mosko (1990), McKenna et al. (1994) and Mosko and Richard (1997) and used to suggest an attunement between the mother and infant. Such attunement refers to increased observable inter-relationship between mother and infant physiology and behaviour. As the level of attunement of mothers and infants during bed-sharing is not seen to such a degree in by-the-bed sleep regardless of the regularity of that sleep behaviour then the findings of this study may support the theoretical presence of attunement and sensory exchange.

Arousals

Mother infant arousals during bed-sharing and by-the-bed sleep

Previous studies have gathered arousal data from mothers and infants during social sleep. Mckenna and Mosko (1994) identified that regular bed-sharing, breastfeeding mothers and infants experience more transient and waking arousals when bed-sharing than when sleeping separately. This study, with 8 regular-bed-sharing, breastfeeding mother infant dyads, also found that regular bed-sharing mothers experience more transient/movement and overall arousals per hour on the bed-sharing night than on the by-the-bed night, but this pattern was not observed amongst infants. No other significant differences in mother or infant arousals were identified, either when aggregating all mothers and infants regardless of regularity of bed-sharing or when occasional bed-sharing infants and mothers were considered separately.

It is possible that the use of a single regular-bed-sharing, breastfeeding mother infant dyad in the McKenna and Mosko (1994) study artificially emphasised the relationship between bed-sharing and arousal frequency and that the use of a larger data set has more accurately identified the true relationship. Alternatively, as McKenna and Mosko (1994) used EEG to obtain arousal data, it may be that the pattern of arousal frequency in the present study is inaccurate; EEG provides a far more sensitive monitoring of transient arousals than were afforded to this study using plethysomography and pulse oximetry. However, whilst accuracy of EEG arousal identification may account for the differences observed in transient arousal data, waking arousals should not be subject to such variation. There are clear behavioural phenomenon associated with waking (Anders, et al. 1971; Brazelton 1973; Precht, et al. 1968), and identification of waking arousals in this study were supported by simultaneous video tape recordings of the participants, allowing behavioural and physiological cross-referencing, which has produced a concordance of 93.8% (+/-2.5%) with full polysomnography (including EEG) when identifying sleep/wakefulness in children 2-12.5 years (Morielli, Ladan, et al. (1996). Thirdly, it may be due to the different degree of separation between mother and infant in the two studies; whereas the current study explores bed-sharing and by-the-bed social sleep, McKenna and Mosko (1994) explored bed-sharing and infants sleeping apart in an adjacent room with the doors open. It could be hypothesised that if mother and infant arousals are linked to proximity (possibly by sensory exchange, as McKenna (1990) suggests), then an infant sleeping in another room to their mother is likely to experience considerably fewer arousals than a bed-sharing infant (as observed in McKenna and Mosko (1994)), whilst an infant sleeping in the comparatively close proximity of a cot by-the-bed, would display less significant variation from the bed-sharing night (as observed in the current study).

Later Mosko and Richard (1997) gathered arousal data from 20 routine bed-sharing mother infant dyads and 15 routinely solitary sleeping dyads, across bed-sharing and solitary nights (using EEG). They also identified an increase in both transient and waking infant arousals on the bed-sharing night, which persisted for transient arousals on the solitary sleeping night amongst regular bed-sharing infants, but only during Quiet sleep (Mosko and Richard 1997). They used these data to suggest that bed-sharing might minimise long periods of Quiet sleep and therefore be protective against exposure to periods of sleep when arousal threshold is high.

Although Mosko and Richard (1997) claim that the solitary sleep condition (infant apart in an adjacent room with the doors open) places the infant and mother within hearing range, it also places the infant at considerably greater distance from the mother than the separate sleeping condition of the current study. Therefore, the present study could not provide comparable data and did not examine arousal data by sleep-state, believing that the pattern of reduced infant Quiet sleep during bed-sharing identified from arousal data by Mosko and Richard (1997) had already been established by this study in the distribution of infant sleep state (above).

Shared mother and infant arousals

Shared arousals have been identified by McKenna and Mosko (1990) who noted that bed-sharing, breastfeeding mothers demonstrated arousals during 71% of their infants' arousals and remained asleep through only 11% of their infants' epochal awakenings. Later, Mosko and Richard et al. (1997) noted that mother and infant arousals overlapped more during bed-sharing (46%) than solitary sleeping (23.9%). Both McKenna and Mosko (1990), and Mosko and Richard (1997) used these data to suggest that breastfeeding mothers display sensitivity to infant awakenings during bed-sharing and demonstrate a high level of maternal attentiveness. In turn, the relationship between shared arousals and maternal attentiveness has been used to assert that bed-sharing may be beneficial, as higher levels of mother infant arousal overlap offer the potential for maternal intervention at an earlier stage during episodes of infant distress (McKenna 1990).

However, exploring arousal overlap per se, does not address the aspect of whether an arousal, shared or otherwise, carries the potential of a maternal intervention. Whilst the theory of sensory exchange suggests unconscious cues between social sleeping mother and infant, allowing subtle, even unconscious maternal intervention, it is beyond the scope of this study to explore these. Rather, this study presents a consideration of arousal data in the context of their theoretical link to maternal intervention by exploring shared mother and infant arousals in which the mother achieves a state where she is able to make a conscious intervention. Therefore, shared mother and infant arousals are explored as a ratio of total infant arousals to shared mother infant arousal, where the mother awakens. This measure has been used to reflect maternal ability to undertake conscious intervention during an episode of infant distress i.e. for a mother to consciously intervene as a result of a shared arousal, she must achieve waking. This measure of arousal behaviour reflects only the consciously functional aspects of shared mother infant arousal that McKenna (1990) theorises and is referred to hereafter as 'shared arousal achieving parental consciousness' (SAAPC).

Shared arousals achieving parental consciousness were analysed by comparing the number of overall infant arousals (transient or waking) that occur during the whole observation period, to those occasions where a maternal full waking arousal occurred in the same or subsequent epoch as an infant arousal (transient or waking). This measurement does not imply causation; it provides a ratio of times when an infant arouses, to the number of times a mother could consciously respond to an infant arousal during/immediately following maternal sleep.

The data were indicative of a link between bed-sharing and increased maternal potential for conscious intervention in infant risk situations; mothers and infants experienced more shared arousals achieving parental consciousness on the bed-night than the by-the-bed night. However, this association did not achieve significance (p=.052). No significant differences in the ratio of infant arousals to shared arousals were observed by sleep condition or regularity of bed-sharing. A larger study or increased accuracy in identifying transient arousals may elicit a different pattern. As they stand, these data indicate that even though bed-sharing breastfeeding mother infant dyads share more arousals than by-the-bed or room-sharing breastfeeding mother infant dyads (Mosko and Richard (1994), it may not imply that they express greater functional maternal sensitivity to their infants; at least, not in terms of allowing conscious intervention by the mother in a potentially harmful scenario, such as head-covering or compression. Unfortunately this measure does not allow assessment of the unconscious maternal interventions implicit in McKenna's theory of sensory exchange.

Young's 1999 study does not explore arousals.

Fathers sleep state

Given the variation in fathering roles and father infant relationships discussed above, it is somewhat unsurprising then that fathers have not been considered primary players in the social sleep scenario. However, in those contexts where fathers feature in the sleep environments of infants they should be considered part of the whole complex of social sleep.

Only two studies have so far accounted for paternal presence during social sleep, Baddock (2006), who concluded that the father's presence made no difference to the mother infant dyad, whilst Ball (2006) maintained that infants are located differently in the bed during triadic bed-sharing and that infant, mother and mutual infant-mother arousals are increased during triadic bed-sharing. No previous studies exploring social sleep have including the physiological relationship between the father and the infant. This is despite the regular presence of fathers in home sleeping arrangements (Ball et al. 1999). Just as the use of sleep physiology data from solitary sleeping infants being used to develop the scientific 'gold standard' of normal infant sleep has been criticised, so too should the absence of the father when attempting to understand parent infant social sleep.

Fathers sleep state distribution

The distribution of fathers' sleep states does not alter across sleep condition. When all fathers are aggregated, irrespective of regularity of normal bed-sharing practice, they are awake a median of 3 minutes more, in Quiet sleep 6 minutes more and in REM sleep a median of 16 minutes less on the by-the-bed night. None of these differences were significant. Similarly, no significant differences were noted when fathers were separated by regularity of normal bed-sharing practice. The data clearly suggest that sleep condition and regularity of normal bed-sharing practice make no discernable difference to paternal sleep state distribution.

It is interesting to note that although it did not reach statistical significance, the pattern of paternal waking and Quiet sleep observed for the bed-sharing and by-the-bed nights reversed between the regular and occasional bed-sharers. Regular bed-sharers spent more time awake and less time in Quiet sleep on the by-the-bed night, whilst occasional bed-sharers spent less time awake and more time asleep on the by-the-bed night. This may reflect paternal habituation to sleeping practice, or a negative effect of novel sleeping practice; where fathers experiencing their normal social sleep condition are awake less and in deeper Quiet sleep more, than when experiencing a novel social sleep condition.

Fathers and infants shared sleep state

The effects of proximity on father and infant shared sleep state

When father infant pairs are considered regardless of regularity of normal bed-sharing practice it observed that they share significantly more REM sleep and more sleep overall on the bed nights than the by-the-bed nights. It seems likely that this is simply a consequence of the increased time infants spend in REM on bed-sharing nights (a rise from 49.38% to 66.6% of the observation period), as fathers spend a consistently large proportion of their nights in REM sleep regardless of the sleep conditions (BN 73.44% BTB 66.8% of the observation period ($p=.345$)).

However, as Ball (2006) has identified, whilst mother and infant remain side by side, regardless of the fathers' presence during bed-sharing, the infant and father are not always side by side during bed-sharing. This introduces two further characteristic states of father infant proximity during bed-sharing; infant located on the outside of the mother from the father, and infant located between the mother and father. Shared father infant sleep was therefore explored considering these two measures of father infant proximity and revealed that location of the infant in the bed relative to the father made no significant difference to the amount of REM or Quiet sleep that bed-sharing fathers and infants shared.

Given the clear absence of proximity affect on father and infant shared sleep when aggregating across normal sleep condition, an investigation of the effects of regularity of normal sleep condition on father and infant shared sleep state were not undertaken. This may be an area for future study.

Arousals

Father arousals during bed-sharing and by-the-bed sleep

Analysis of fathers' transient and full awakening arousals revealed that no significant differences occurred between test nights when regularity of normal bed-sharing were aggregated or considered independently or between regular or occasional bed-sharing fathers when test nights were aggregated or considered independently. These data strongly suggest that the fathers arousal behaviour is entirely unaffected by the location of the infant or the infants' regular sleep location, whether that be in or by the bed.

Shared Father infant arousals during bed-sharing and by-the-bed sleep

A similar picture is presented when exploring shared father infant arousals. Analysis was conducted using the measure of shared arousals achieving parental consciousness discussed earlier. No differences were observed between test conditions or by regularity of normal be-sharing behaviour. It would appear that paternal sleep organisation is not affected by the location of the infant during sleep, or by the regularity of bed-sharing.

Absent Fathers

Although not a primary outcome of the study it was interesting to note that whilst the absence of the father from family 11 on the bed-night did not appear to have any effect, the absence of the father from families 16 & 18 on the cot night made a significant difference to both infant and mother sleep. Infants from both families experienced more waking and less REM, Quiet and overall sleep in the fathers' absence. For family 18 the mother experienced less REM and for family 16 the mother experienced less waking time and more REM and overall sleep. Whilst these data should be treated with caution due to the small sample size and because they employ a median value of an unrelated sample as comparison (the test protocol lacking a within subject comparison night i.e. father present and father absent), this data does support Ball's (2006) assertion that fathers influence the bed-sharing environment and refute Baddock's (2006) assertion that the fathers presence makes no difference to the mother or infant during triadic sleep. Certainly this finding would suggest that there is good reason for future studies to consider paternal influence on social sleep; whilst the current study shows that fathers experience no affects of infant location or regularity of bed-sharing practice on their sleep organisation, it may be that their presence has an affect on both mother and infant sleep.

Limitations of the data

When the original recruitment for this study was undertaken one smoking mother and 5 smoking fathers were included in the sample. During analysis the family in which the mother smoked (and father also) were removed. This was because the mothers' sleep state distribution fell outside of the range and standard deviation of the non-smoking mothers for waking, Quiet sleep and total sleep time. The remaining 4 families in which the father smoked were included, as the fathers sleep state distribution was in each case within the range and standard deviation of the non-smoking fathers. However, in light of the results presented in the current study, it would appear that using this method to determine effect of parental smoking for inclusion may not be appropriate. The data show that fathers are not influenced by the aspects of social sleep that this study tests, however, the study reveals some secondary evidence that may suggest fathers' presence in social sleep affects the mother and infant. So, whilst smoking fathers may not display dissimilar sleep state distribution from non-smoking fathers, their presence in social sleep may have differential affect on the mother and infant in the family. This aspect of fathers' impact on social sleep has not been controlled for in this study and should be investigated in future studies.

Despite the original data set containing 21 families, the final data set contained only 15 families (8 reg & 7 occ). One family was excluded due to a suffering a previous SIDS infant; one due to inoculations and use of paracetamol; one due to use of prone infant sleep position; one due to maternal smoking (also had absent father on cot night); one to equipment failure; 2 due to paternal absence on the cot night. Not only does this attest to the variation of night time sleep experience and highlight the complexity of the social sleep environment, but it should also act as caution to future studies that should endeavour to recruit beyond their study population target number by somewhere in the region of a third.

It must be noted that direct comparison between the results of the current study and other studies cited herein were made under the following provisions. All previous studies used ECG monitoring to establish arousal data, allowing very accurate identification of transient arousals lasting ≥2 seconds. In the current study cardio-respiratory measures were used to identify transient arousals, in which were included movement arousals, whilst a combination of cardio-respiratory measures and video taped behavioural data were used to determine full waking arousals (see methodology). Although this led to reduced accuracy in identifying transient arousals (see above) it was designed to reduce the negative effect that ECG equipment can have on the behaviour of the test subject (see methods) and promote more naturalistic behaviour in accord with the anthropological paradigm of the study. The success of this endeavour is not measurable from this study, and the loss of accurate identification of transient arousals should be given consideration in future study design. Similarly, the inability to determine between an adult sleeping and an adult pretending to sleep would be ameliorated by the use of EEG.

Chapter 6

CONCLUSIONS

This study contributes to the growing understanding of social sleep environments and their relationship to parent and infant behaviour and physiology through the exploration of sleep physiology of 15 regularly and occasionally bed-sharing families. Claims of shared sleep and arousals found in breastfeeding mother infant dyads were tested and a new examination of the effects of proximity on mother infant physiology in bed-sharing compared to rooming-in was conducted using both regular and occasional bed-sharing families. This study also introduces the relationship between fathers and infants during bed-sharing and room-sharing using paternal physiology for the first time, thereby creating a more naturalistic understanding of social sleep. Data were acquired by physiological monitoring and infra-red video capture over three nights (one adjustment night and two test nights) in the Durham University Sleep Lab.

This research addressed the following 12 questions and came to the following conclusions:

a. Are sleep state distributions of breastfeeding mothers and infants affected by whether the infant is slept in the bed or in a cot by the bed? *Potential indicator that proximity affects sleep-state-distribution:*

Both mothers and infants experienced less time awake on the bed-sharing night and infants spent less time in Quiet sleep on the bed-sharing night. This pattern is consistent with findings of McKenna & Mosko (1994) that sleep contact affects mother and infant shared sleep.

b. Are sleep state distributions of breastfeeding mothers and infants affected by whether they are regular or occasional bed-sharers? *Potential indicator that regularity of normal sleep condition affects sleep-state-distribution*

Regular and occasional bed-sharers experience quite different effects of sleep condition that do not emerge with less rigorous analysis. Regular bed-sharing infants experience considerable disruption to their sleep when separated from physical contact with their mothers, but greater stability in their sleep physiology between by-the-bed sleeping and bed-sharing than occasional bed-sharing infants. It may be possible that this reflects enhanced maturation of the CNS and/or circadian sleep cycle amongst regular bed-sharers. Further research should consider exploring this dimension.

c. Do breastfeeding mothers demonstrate sleep state synchrony with their infant during triadic bed-sharing as suggested for dyadic mother and infant pairs?

Breastfeeding bed-sharing mothers and infants do demonstrate a degree of sleep state synchrony.

d. Do breastfeeding mothers demonstrate sleep state synchrony with their infant if the infant is slept in a cot by the bed? *Potential indicator that proximity affects sleep-state-synchrony*

Mothers and infants spent a greater proportion of the night in simultaneous sleep during bed-sharing than rooming-in. Data also revealed a further layer of complexity in that the increase in shared sleep is attributed to an increase in shared REM only.

e. Is there any difference in sleep state synchrony between regular bed-sharing mothers and infants, and occasional bed-sharing mothers and infants in either bed-sharing or cot by the bed conditions? *Potentially indicating that regularity affects sleep state synchrony*

Regularity of normal sleep condition only affected the shared sleep of regular bed-sharing mothers and infants on the bed-sharing night. This pattern has not been noted in sleep state distribution previously, but may represent an attunement between the mother and infant.

f. Do breastfeeding mothers demonstrate arousal synchrony with their infant during bed-sharing? *Potential indicator of enhanced maternal care capacity*

Bed-sharing breastfeeding mothers did experience arousal synchrony with their infants.

g. Do breastfeeding mothers demonstrate arousal synchrony with their infant if the infant is slept in a cot by the bed? *Potential indicator that proximity affects maternal care capacity*

Bed-sharing breastfeeding mothers and infants share more arousals than by-the-bed or room-sharing breastfeeding mothers and infants. However, they also reveal that shared arousals may not imply greater functional maternal sensitivity to their infants; at least, not in terms of allowing conscious intervention by the mother in a potentially harmful scenario.

h. Is there any difference in sleep state synchrony between regular bed-sharing mothers and infants, and occasional bed-sharing mothers and infants in either bed-sharing or cot by the bed conditions? *Potentially indicating that regularity affects sleep state synchrony*

No significant differences in arousal synchrony were observed between regular bed-sharing mothers and infants, and occasional bed-sharing mothers and infants by sleep condition or regularity of bed-sharing.

i. Are sleep state distributions of fathers affected by whether the infant is slept in the bed or in a cot by the bed? *Potential indicator that proximity affects sleep-state-distribution*

Sleep condition made no discernable difference to paternal sleep state distribution.

j. Are sleep state distributions of fathers affected by whether they are regular or occasional bed-sharers? *Potential indicator that regularity of normal sleep condition affects sleep-state-distribution*

Regularity of normal bed-sharing practice made no discernable difference to paternal sleep state distribution.

k. Do fathers demonstrate sleep state synchrony with their infants during social sleep, and does proximity or regularity influence that synchrony?

Fathers did not demonstrate sleep state synchrony with their infants during social sleep and whether the infant was slept by-the-bed, beside the father or to the outside of the mother (relative to the father during bed-sharing) made no difference to sleep state synchrony.

l. Do fathers demonstrate arousal synchrony with their infants, and does proximity or regularity influence that synchrony?

Paternal arousal behaviour was entirely unaffected by the location of the infant or their regular sleep location.

Although not a primary outcome of the study it was interesting to note that the absence of the father on the cot night made a difference to both infant and mother sleep. Infants experienced more waking and less REM, Quiet and overall sleep in the fathers' absence and one mother experienced less REM and the other mother experienced less waking time and more REM and overall sleep. Whilst these data should be treated with caution they would suggest that there is good reason for future studies to consider paternal influence on social sleep as it may be that paternal presence has an effect on both mother and infant sleep. There was also some suggestion of paternal habituation to sleeping practice, or a negative effect of novel sleeping practice; fathers experiencing their normal social sleep condition are awake less and in deeper Quiet sleep more than when experiencing a novel social sleep condition. This trend did not reach significance however.

Previous studies have identified that proximity of mother and infant, regularity of bed-sharing and presence of the father during bed-sharing affect the sleep patterns and behaviour of breastfeeding mothers and infants. These studies represent the beginning of an understanding of the complexities of social sleep and bed-sharing in particular. Their value has been to highlight a more sophisticated way of understanding social sleep, and pointing out the deficiencies of a less nuanced approach.

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