An Anthropological Investigation into the Complex Nexus of Maternal Sleep and Postpartum Depression

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“An Anthropological Investigation into the Complex Nexus of Maternal Sleep and Postpartum Depression”

by

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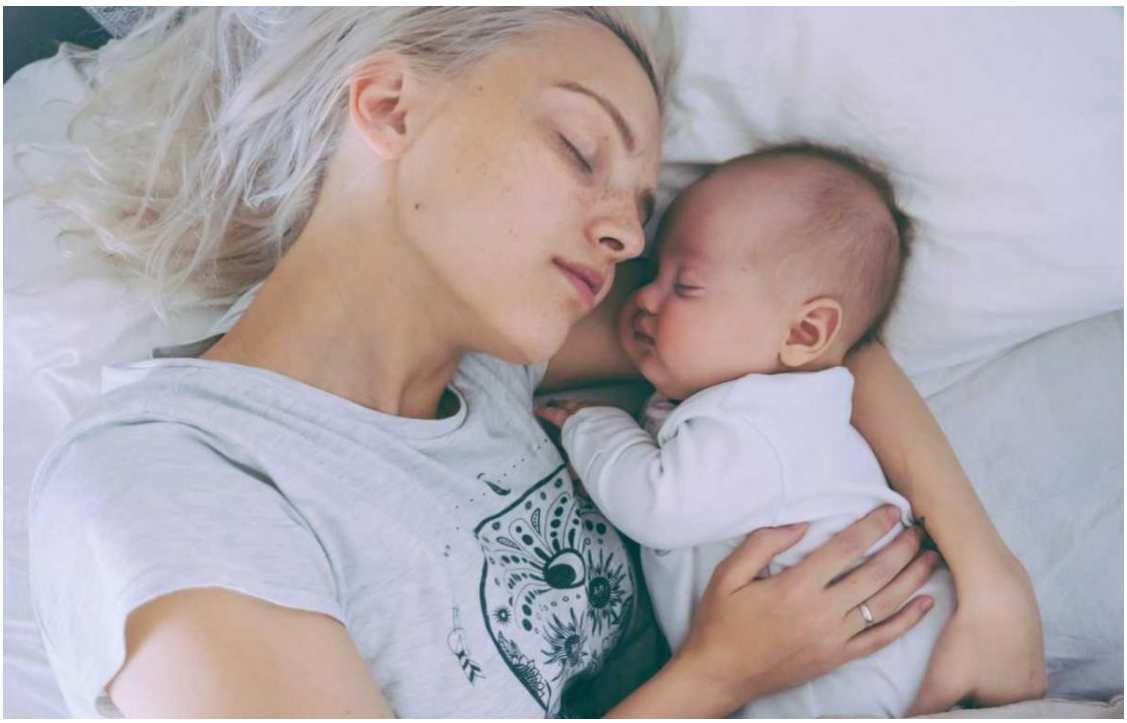

Figure 1: Co-Sleeping Mother and Baby (Hornung, 2019)

i. Abstract

It is widespread knowledge that new mothers experience sleep disruption in the postpartum period, and that they are also more vulnerable to mood disorders, like postpartum depression, during this time. However, what is less commonly acknowledged is the relationship between the two. The objective of this research was to determine how objective and subjective sleep varied between mothers and non-mothers, and how their relationship with the expression of mood disorders differed between age-matched individuals in a postpartum and non-postpartum sample. It also aimed to identify the effects of postpartum depression on the maternal-infant relationship. Data was collected using actigraphs, sleep diaries, and the Edinburgh Postnatal Depression Scale every month from 2-6 months of age, and through videosomnography which was carried out in the Parent-Infant Sleep Lab at 2, 4 and 6 months of age. Findings suggested that maternal sleep fragmentation was the most significantly affected parameter, but that though mothers' sleep was detrimentally influenced during the postpartum period, it was less frequently linked with depression than poor sleep in the non-postpartum sample. It was deduced that the relationship between the two may have been mediated by breastfeeding in the postpartum sample. Though not statistically significant, a relationship was identified between depression and negative maternal-infant interactions. This can have negative consequences for infant development, both socially, cognitively, and emotionally (Hatton et al, 2004; Murray and Cooper, 1997). As 160,000 new mothers experience PPD each year in the UK (Ball, 2020), it is imperative that the primary causal factor is determined to enable preventative measures to be put in place for the improvement of both maternal and infant health.

ii. Acknowledgements

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Introduction:

Women undergo major physical changes following parturition and the onset of lactation, and it is commonly known that during this time the demands of infant sleep and new parenthood affect women's sleep. Maternal sleep is driven by the feeding demands of an infant, and therefore differs according to feeding type, as does the risk of depression, which is known to be greater during the postpartum period (Goyal et al, 2009; Be Bei et al, 2010). Sleep and mood disorders are controlled by the same neurotransmitters in the brain (Posmontier, 2008a), and therefore it is of little surprise that depression and insomnia are often co-morbid (Durkheim et al, 2009). Similarly, depression and sleep are linked by the circulating hormone, prolactin, which additionally mediates milk synthesis (Torner and Neumann, 2002). Depression has been linked to feeding-type (Blyton et al, 2002); Torner 2016; Groer et al, 2006), as have variations in sleep distribution and deprivation (Blyton et al, 2002; Montgomery-Downs et al, 2010). Maternal sleep, feeding, and depression are therefore inextricably linked.

This thesis aims to identify the differences in depression, objective sleep and perceptions of sleep between mothers and non-mothers. It attempts to ascertain the relationship between depression and sleep, and how this differs between postpartum and non-postpartum samples. It also aims to illustrate the effects of depression on maternal-infant interactions during the postpartum period.

In order to provide a research-based understanding of the complex nexus of depression, sleep, and infant feeding, Chapter 2 comprises a literature review. This covers the normal sleep architecture of adult, maternal, and infant sleep, and how the latter two are interrelated. It examines the relationship between infant-feeding type and sleep, and infant-feeding type and depression, which necessitates a detailed overview of the role of the circulating hormone, prolactin, in feeding, sleep, and depression. Sleep and feeding are culturally contextualised, and mood disorders in non-postpartum and postpartum relationships are summarised.

Chapter 3 details the methods used in the development of this study, including sections on ethics, participant recruitment, gratuities, data collection, and analytical methods. Chapter 4 details the results and findings gained through these methods, and visualises the data using graphs and tables.

After this, there are several discussion chapters, where the data outlined in Chapter 4 is interpreted and presented in the context of the existing literature detailed in Chapter 2.

Chapter 5 discusses the differences in sleep parameters, both objective and subjective, between mothers and non-mothers. It looks at total sleep time; sleep fragmentation; how the sleep period is modified to account for

sleep fragmentation; and the causes of night-time awakenings and how these fluctuate across different time-points in the postpartum period.

Chapter 6 analyses the complex relationship between depression, sleep, and to some extent feeding. It places the findings in the context of prolactin and the role it plays in the above factors.

Chapter 7 examines the relationship between depression and maternal interactions, interrogating whether depression scores are associated with time spent: watching, interacting, and snuggling with the infant.

The final chapter, Chapter 8, provides an overview of the conclusions drawn from the findings of this study. It interrogates the methodological and research limitations placed upon it, and the consequences of these for the results produced. It examines the extent to which the research objectives of the study were met, and provides some suggestions and directions for future research.

Literature Review

1. Introduction:

Women undergo major physical changes following parturition and the onset of lactation, and it is commonly known that during this time the demands of infant sleep and new parenthood affect women's sleep, the patterns of which are dictated by infant-feeding demands (Gay et al, 2004). Women are also known to be at greater risk of suffering from depression during this period (Goyal et al, 2009; Be Bei et al, 2010). This literature review will provide a broad foundation of knowledge for the study at hand to investigate the triadic relationship between these factors. It will first outline the relationship between sleep and mood disorders, in both postpartum and non-postpartum populations. It will summarise the symptomatology of postpartum depression (PPD), and will examine the bi-directional relationship it has with sleep, also highlighting its risk factors, and the consequences it carries for mother and infant. The role of cultural beliefs about sleep that subsequently affect the expression of PPD will be discussed, and PPD contextualised within a Western cultural setting. It will then describe the average sleep architecture of non-mothers, mothers, and infants. The influence of infant-feeding type on sleep will be discussed, including the role of maternal-infant trade-offs, levels of maternal prolactin, and the biological demands of the infant, which are intertwined with the relationship between feeding-type and sleep. This will be concluded with an examination of the findings surrounding the relationship between infant-feeding type and depression.

2. Sleep and Mood Disorders:

2.1 Sleep and Mood Disorders in Non-Postpartum Populations

Sleep and mood are controlled by the same neurotransmitters in the brain (Posmontier, 2008a). It is therefore unsurprising that sleep disturbances are a hallmark of mood disorders (Perlman et al, 2006), especially of major depressive disorder, for which it is a key symptom (Huhne et al, 2018). There is much evidence to suggest a bi-directional relationship between sleep disruptions and mood disturbances (Bei Bei et al, 2010), which are also involved with bipolar disorder and seasonal affective disorder (Huhne et al, 2018). For example: shorter sleep duration predicts an increase in depressive symptoms (Perlman et al, 2006); insomnia and depression are often comorbid (Durkheim et al, 2009); and impaired sleep has been linked with negative emotions, anxiety, and depression (González-Mesa et al, 2019; Okun, 2016).

Disrupted circadian rhythms may contribute to mood disorders by affecting sleep. Circadian rhythms have developed in response to daily changes resulting from the earth's rotations. The 24hour clocks have developed and act in response to environmental cues, or "zeitgebers", such as light and darkness, activity patterns, and

meal times. When disrupted, these rhythms result in: internal and external desynchronization with one's body-clock and the environment respectively; low circadian rhythm amplitude; and changes to sleep architecture, such as longer sleep onset latency (SOL) as seen in depressed patients (Huhne et al, 2018). This relationship carries through into the postpartum period, where sleep deprivation plays a significant role in mood disorders (John et al, 2008).

2.2 What is Postpartum Depression?

Mood disorders are highly prevalent in the postpartum period, with 160,000 women being treated for postpartum mental health issues in the UK alone, costing the NHS £1.2 billion annually (Ball, 2020). These issues can manifest as disorders of varying severity that all fall under the bracket of postpartum depression, including the postpartum blues, PPD, and postpartum psychosis. The blues is a period of transient PPD that presents itself as a weepy state in the first few days postpartum, characterised by a labile mood, irritability, restlessness, confusion, and forgetfulness, which generally resolves itself within the first week-10 days postpartum. Postpartum psychosis is the most severe and rare postpartum mood disorder, and in the most extreme cases can lead to infanticide (Kendall-Tackett and Kauffman-Kantor, 1993; Lawson et al, 2015), infant abuse, and neglect (Lawson et al, 2015; O'Hara, 2009; O'Hara and Segre, 2009). PPD, the mood disorder that is of interest to this study, is less extreme than postpartum psychosis, but both more severe and long-lasting than the postpartum blues. It can occur at any time within the first year postpartum, and can last anywhere from two weeks (Kendall-Tackett and Kauffman-Kantor, 1993) to two years (Posmontier, 2008b). It is experienced by 13-20% of new mothers (Goyal et al, 2009), but unfortunately, is often overlooked as a result of the similarities between its symptoms and the "normal" concomitants of childbirth. PPD is characterised by: tearfulness, despondency, insomnia, numbness, suicidal thoughts, anxiety and despair, and irrational fears about the baby's or mother's health (O' Hara, 2009; Kendall-Tackett and Kauffman-Kantor, 1993).

Women are already more likely to develop serious mood disorders than men during their lifetime, but this is especially the case during the childbearing years (Goyal et al, 2009). Childbirth is a critical event that leaves women vulnerable to mood disturbances, resulting in 30-75% of new mums experiencing at least mild and transient mood disturbances in the first few days postpartum (Bei Bei et al, 2010). While in previous times there has been some dispute as to whether PPD is any different to non-puerperal depression, in biological terms it is partly a result of the removal of the placenta and the rapid decline in oestrogen and progesterone levels after parturition, and therefore it is directly linked with childbirth. This is supported by evidence showing psychiatric symptoms to peak at around 10 days PP, which coincides with the maximal drop in these hormones (Kendall-Tackett and Kauffman-Kantor, 1993).

While it has biological causes, PPD can also be induced by psychosocial factors. Its strongest predictors are: a history of psychopathology and psychological disturbance during pregnancy; poor marital relationships; low social support; stressful life events; low social status (O'Hara and Swain, 2009; Ross et al, 2004); antenatal depression; and low self-esteem (Goyal et al, 2009). As with most major depressive disorders, it is also strongly affected by sleep (Hiscock and Wake, 2001).

2.3 Sleep and Postpartum Depression

Sleep insufficiency is a major manifestation of PPD (Bei Bei et al, 2010), which may underlie the progression from postpartum blues to PPD (Swain et al, 1997), as it causes exhaustion, impatience, and poor concentration and quality of life, all of which increase PPD risk (Lewis et al, 2018). A strong correlation exists between infant sleep patterns and maternal fatigue, and the onset of depressive symptoms (Dennis and Ross, 2005; Tikotzky, 2014), with adequate sleep having been proven to reduce PPD (Armstrong et al, 1998). Predictors of PPD include reduced rapid-eye movement (REM) latency, decreased total sleep time (TST), and, most importantly, infant crying (Dennis and Ross, 2005). Mothers with a high Edinburgh Postnatal Depression Scale (EPDS) score are more likely to report their infant crying often, waking more than three times between 22:00-06:00, and obtaining fewer than 6 hours sleep in a 24-hour period (Dennis and Ross, 2005). EPDS scores have also been linked with sleep fragmentation, sleep efficiency, and wake after sleep onset (WASO) (Park et al, 2013). Furthermore, sleep onset latency (SOL), WASO, and sleep efficiency have been shown to predict PPD symptom severity (Posmontier, 2008a). Depressed mothers tend to have poorer sleep quality and sleep efficiency, report more sleep disturbances, and experience increased negative effects on their daytime functioning (Huang et al, 2004). Okun (2016) found 90% of depressed mothers reported sleep deprivation, and showed shorter sleep duration across the 6 months preceding a depressive episode, whose length often predicted the severity of the episode. As sleep may contribute to the development and extent of PPD symptoms, sleep in the postpartum period may be a modifiable risk factor for the development of PPD (Park et al, 2013).

As poor sleep quality is a risk factor for depression, and depression is a risk factor for poor sleep quality, the directionality of the relationship is unknown. It seems the two exacerbate each other, with depressive symptoms acting as a predictor of sleep quality at 6 months, which then itself predicts depressive symptoms at 6 and 12 months (Saxbe et al, 2016). The two form a vicious cycle, not only in terms of maternal sleep and depression, but also with regards to the infant; as infants usually entrain to maternal circadian rhythms, when mothers experience sleep disturbances the infant may then entrain to these. This perpetuates sleep disturbances in the mother, and increases maternal depression (Posmontier, 2008a), as infant sleep "problems" are linked with increased depressive symptoms in mothers (Piteo et al, 2013).

In Australia, it was found that of 738 mothers, 46% found their infants' sleep to be problematic, whether that was due to infants having to be nursed to sleep, taking longer to fall asleep, waking more often, or sleeping in the parental bed, amongst other factors. These beliefs had a positive correlation with depression scores, while mothers who reported good sleep quality, (irrespective of its objective measures), were less likely to suffer from depression (Hiscock and Wake, 2001). Similarly, Lawson et al (2014) found 17 of 22 participants exhibited a relationship between PPD and their subjective perceptions of sleep deprivation, and their depressive symptoms were highly reduced upon the receipt of insomnia treatment. These findings suggest that perceptions of poor sleep and an awareness of its negative effects on daytime functioning might have a stronger effect than the actual quality and quantity of sleep itself (Bei Bei et al, 2010), demonstrating the importance of maternal subjective perceptions of sleep quality on the expression, (or lack thereof), of PPD.

2.4 Consequences of Postpartum Depression

Postpartum depression is highly detrimental to both mother and infant on several levels. It can result in lower personal, household, and social functioning (Posmontier, 2008b); poor maternal-infant bonding; long-term emotional and behavioural issues for the infant (Lewis et al, 201; Okun, 2015); a higher risk of future depressive episodes for both parents (Lewis et al, 2018); and increased social withdrawal and family dysfunction (Piteo et al, 2013).

Women with depression are less likely to breastfeed (Durkheim et al, 2009), which is highly problematic as breastfeeding bestows a multitude of benefits on both mother and infant. These include: passive immunity (Parish, 1951; Hanson and Korotkova, 2002; Sellen, 2007); collaborative immunity (Miller, 2017); the facilitation of the formation of the maternal-infant bond (Bowlby, 1969; Ball, 2006; Mobbs, Mobbs and Mobbs, 2016); and the limiting of iron available for pathogens and thus the decreasing of infections (WHO, 1989; Bullen, Ward and Rogers, 1991; Stuart-Macadam, 1995; Quinn, 2014). Breastfeeding also has long-term benefits. It reduces oestrogen levels in mothers, which are a risk factor for cancer (Micozzi, 1995). It aids the suckling infant by reducing over-nutrition; breastfeeding infants are more likely to recognise when they are satiated (Colen and Ramey, 2014), which consequently reduces obesity, (another risk factor for cancer), in later years (Micozzi, 1995). Furthermore, formula-feeding infants are at an increased risk of developing other cancers, especially lymphoma, before the age of 15 compared with breastfeeding infants (Micozzi, 1995). Considering all these benefits, PPD is particularly problematic due to its impact on breastfeeding capabilities and duration, as mother-infant dyads are less likely to reap the short and long-term benefits it confers (Durkheim et al, 2009).

3. Sleep Biology:

3.1 Sleep Architecture

Sleep is comprised of three states: active sleep, otherwise known as rapid eye movement (REM) sleep, slow-wave (SWS) or non-rapid eye movement (NREM) sleep, and indeterminate sleep, within which the criteria of neither REM nor NREM sleep can be identified (Sheldon, 2006). These states possess distinctive characteristics and are themselves sub-divided into stages. Together, the REM and NREM sleep states form a cycle that occurs 4-6 times per major sleep episode, and lasts approximately 90 minutes (Hunter et al, 2009; Rama, Cho, and Kushida, 2006). Within this cycle, the ratios of the two states vary across the night; earlier cycles primarily exhibit SWS, and the first REM states may only last a couple of minutes. These then lengthen until they dominate the cycle in the final third of the night (Rama, Cho, and Kushida, 2006).

NREM sleep comprises approximately 75% of TST in adults, and is characterised by minimal movements, and decreased muscle tone (Sheldon, 2006). This state contains four stages, (the percentages of which are approximate). Stage 1 is the most frequent transitional stage from wakefulness to other sleep stages and regularly follows arousals, covering just under 10% of TST. 10-12 minutes after stage 1, stage 2 follows, lasting for 45% of TST. Stages 3 and 4 are biologically relatively similar, and are known as delta sleep - the deepest part of sleep, from which it is hard to awaken. Combined, these make up 20% of TST (Hunter et al, 2009; Rama, Cho and Kushida, 2006).

REM sleep fills the remaining 25% of TST, with the first episode occurring 60-90 minutes after the onset of NREM sleep. REM sleep is characterised by muscle movements, twitches, stretching, vocalisations, bursts of "phasic muscle activity", respiratory irregularity, and phasic eye movements (Sheldon, 2006). Its two stages, tonic and phasic sleep, each have their own defining features. In the tonic stage, there is skeletal-muscle atonia, and mono and polysynaptic reflexes are suppressed, while the phasic stage is characterised by rapid eye movements, transient swings in respiration, heart rate and blood pressure, and tongue movements and muscle twitches (Rama, Cho, and Kushida, 2006).

3.2 Infants' Sleep

Infants generally obtain their sleep in 2-3 sleeping bouts, and do not have a circadian rhythm for the first few months of life (Ball, 2013). Their sleep architecture is therefore widely different to that of adults and is constantly undergoing change as sleep develops and consolidates (Henderson et al, 2010; Sheldon, 2006). For example, infants' first REM period initially occurs in the first 15 minutes of sleep onset, as new-born sleep onset generally ensues through REM sleep. However, by 3 weeks this is only true in two-thirds of cases, and their sleep architecture undergoes progressive change during the first 12 weeks until sleep-onset occurs in NREM sleep, leaving only 18% of sleep-onsets to occur in REM sleep by 6 months. This is partially affected by the significant reduction in REM sleep that occurs across the first 6 months of life. As TST only decreases

very slightly over the first year of life, this reduction demonstrates the redistribution of sleep stages that occurs during this period (Sheldon, 2006).

Infants exhibit frequent night-wakings during the first 2 months, but their ability to sustain sleep develops rapidly over the first few months of life (Henderson et al, 2010). Sleep consolidation generally transpires across the first 6 months, over which time the duration and timings of sleep periods undergo significant alterations. A critical period for this occurs at 10-12 weeks, during which both sleep behaviour and physiology exhibit maturation, and sleep-wake patterns subsequently undergo reorganisation (Sheldon, 2006). Circadian rhythms are not present in infants from birth but begin to develop at this point (Ball, 2020; Galland et al, 2020); sleep subsequently becomes evenly distributed across day and night (Galland et al, 2012), and there are regular alterations between REM and NREM sleep (Sheldon, 2006).

The duration of the longest sleep period LSP also fluctuates, undergoing its greatest changes in the first 3 months, until it reaches a stasis between 3 and 12 months (Henderson et al, 2010). The existing literature states that infants' LSP at 3 weeks are 3.5 hours, increasing to 6 hours at around 6 months. Sleep periods begin to lengthen between 3-6 weeks, and by the latter the LSP is no longer randomly distributed, but begins to occur at night. By 3 months, day-time sleep consolidates into discrete naps, followed by the regulation of the LSP and longest wake period occurring during the night and day respectively by 12-16 weeks (Sheldon, 2006).

True slow-wave sleep occurs at around 8-12 weeks, with quiet sleep developing into more distinctive NREM states by 16-24 weeks. By 3 months, sleep is comprised of two times the amount of NREM sleep than REM sleep, with active sleep dropping to 30% TST by 8 months. Adult percentages are reached at around 3-5 months (Sheldon, 2006).

While adults sleep for only 25-30% of 24 hours, new-borns sleep for an average of 70%; at birth, their TST is approximately 16-17 hours in a 24-hour period, which gradually decreases to 14-15 hours and 13-14 hours by 16 weeks and 6-8 months respectively (Sheldon, 2006), though these parameters are hugely variable (Galland et al, 2012). Despite their TST being so much greater than that of adults, their sleep architecture is intrinsically different and is driven by the need to feed; due to the low solute concentration of breastmilk, and infants' small stomachs, they need to feed little and often, even throughout the night. This need, and the resulting mismatch between maternal and infant sleep architecture, leads to fragmented maternal sleep (Tully and Ball, 2012).

3.3 Maternal Sleep

Normally, adults obtain an average of 7-9 hours of sleep a day. However, in previous studies of the postpartum period, mothers average 7.53 hours of sleep, with only 6.15 and 6.75 hours of this occurring nocturnally at 1

month and 3-4 months postpartum respectively (Hunter et al, 2009). New mothers exhibit increased stage 0 sleep, reduced stage 4, and reduced REM sleep (Karacan et al, 1969), and their overall TST and SE are decreased (Matsumoto et al, 2003; Lee and Zaffke, 2000; Kang et al, 2002).

Maternal sleep disturbances can last for up to a year postpartum (Lee and Zaffke, 2000), and are at their greatest during the first week after birth (Swain et al, 1997). During the postpartum period, mothers experience more WASO (Karacan et al, 1969; Matsumoto et al, 2003; Kang et al, 2002) and an increased number of night-time awakenings. In order to compensate for this, they tend to sleep later into the morning and nap during the day (Swain et al, 1997; Gay et al, 2004). Such sleep disturbances vary according to a variety of factors. For example, they are more prominent in primiparas compared with multiparas (Hunter et al, 2009; Lee and Zaffke, 2000; Durkheim et al, 2009) during the first 3 months, after which time the differences appear to dissipate (Lee and Zaffke, 2000).

Other influential factors include: the sex of an infant; maternal age; hormonal changes (Thomas and Foreman, 2005); PPD; and feeding type, frequency, and efficiency (Durkheim et al, 2009; John et al, 2008). In a study comparing postpartum fatigue (PPF) at 10 days, 1 month, and 3 months in 4,578 women, the most fatigue was experienced at 10 days postpartum, decreasing as time progressed, (38.8%, 27.1%, and 11.4% respectively). The experience of PPF was affected by maternal age, (e.g. those aged 20-24 were less susceptible than those aged 30-34 at all time points); maternal education; parity; and level of sleep deprivation (Henderson et al, 2019). Women were more likely to experience PPF if they were breastfeeding, or if they reported anxiety, depression, or sleep problems. These mothers were more likely to use negative language when describing their infants and, crucially, were more likely to perceive their infants as difficult (Henderson et al, 2019).

3.4 Cultural Influences

To gain a holistic understanding of PPD and sleep expectations and perceptions, cultural factors must be considered alongside social, psychosocial, and biomedical perspectives. Reviews of literature concerning the impact of cultural rituals and traditions on PPD have shown women's perceptions of them to be influential; if cultural traditions and beliefs are not perceived as helpful they can have negative consequences for the postpartum mood (Bina, 2008). Considering the importance of a cultural stance, the above findings are particularly significant when considering maternal sleep and PPD in a Western setting due to the pervasive cultural beliefs and expectations surrounding infant sleep and the "good baby", which influence maternal subjective perceptions of how their infant should be sleeping. In Western, educated, industrialised, rich, and democratic (WEIRD) societies, an independent and self-reliant personhood is idealised. In infants, this is forged spatially and temporally through solitary and continuous night-time sleep respectively (Gottlieb, 2004; Tomori, 2015). As the Global North idealises a baby who sleeps "through the night", parents are faced with a mismatch between this cultural expectation and the reality of infant sleep (Ball, 2013). Subsequently, infants

are often subjected to sleep training to get them to achieve this social ideal of continuous night-time sleep (Tomori, 2015) and are given their own room, teaching them to self-soothe independently of breastfeeding or parental comfort (Morelli et al, 1992).

In WEIRD settings, the temporal expectations placed on infants are also the result of the labour demands of the capitalist workplace and the time constraints they impose; to facilitate optimal productivity in factory labour, it was necessary for parents to achieve a solid, uninterrupted period of sleep at night as opposed to chunks throughout the day and night. Since the development of capitalism, infants' biological clocks have therefore had to be retrained to reflect this (Millard, 1990). Night-time awakenings, although biologically natural and necessary to facilitate night-time feeding, are consequently perceived as problematic (Tomori, 2015). Due to this disparity between the biological and capitalist rhythms, parental expectations of infant sleep and a "good baby" or a "good sleeper" are rarely met (Tomori, 2015). It is crucial that the Global North stops pathologizing night-time awakenings in infants (Ball, 2013). Essentially, as maternal perceptions of night-time sleep have been shown to be particularly important in the development of PPD, these underlying cultural expectations combined with a widespread inability to meet them could conceivably be significantly detrimental to maternal mood in the postpartum period.

The influences of WEIRD cultural practices surrounding infant sleep are thrown into sharp relief when infant sleep practices are compared cross-culturally. Nishihara and Horiuchi (1998) found that their sample of Japanese mothers did not perceive their sleep to be disturbed, despite experiencing similar levels of sleep disruption to US women in the postpartum period. This finding is the result of culturally-developed attitudes towards, expectations of, and practices surrounding infant sleep. In Japan, co-sleeping, or *soine,* is the cultural norm, and as a result mothers find night-time awakenings to be much less problematic as their infant is in their immediate vicinity, which facilitates night-time breastfeeding (Tahann, 2014) and gives infants the proximity they biologically require (Tomori, 2017). Similarly, this is also the case in the Beng people of Western Africa, who believe leaving infants alone to be cruel and subsequently have them in very close proximity at all times. For these co-sleeping cultures, night-time awakenings are not perceived as problematic, as night-time feeds are facilitated at little cost to maternal sleep (Gottlieb, 2004).

4. Infant-Feeding Type and Sleep:

4.1 The Influence of Feeding Type

Nocturnal sleep organisation is directly affected by feeding type, which dictates the regularity of night-time feeds, and the distribution of NREM and REM sleep. Parental sleep is driven by the sleep-wake patterns and feeding-demands of the infant, and thus is also affected by infant-feeding type. Although both new mothers and fathers obtain less sleep in the postpartum period, maternal sleep suffers more disruption, and is more

affected by whether the infant is formula-feeding or breastfeeding (Gay et al, 2004). As even a sleep loss of more than 30 minutes per night can negatively affect daytime functioning and social interactions (Doan et al, 2007), feeding type is an important factor to consider when looking at maternal sleep.

It is a pervasive and misguided belief that breastfeeding mothers obtain worse sleep than their formula-feeding counterparts (Montgomery-Downs et al, 2010). Sleep is often a motivating factor behind the switch from breastfeeding to formula (Rudzik and Ball, 2016); as formula is widely believed to improve infant sleep, it is often implemented as a solution in response to sleep disruptions (Brown, 2016). Considering the abundance of benefits conferred to both mother and infant by breastfeeding, this belief is highly problematic. Not only has it been found that formula-feeding does not improve sleep (Montgomery-downs et al, 2010), but also that formula-feeding infants' parents achieve 40-45 minutes less TST during the night, even when fathers help with feeding (Doan et al, 2007). This is corroborated by further findings that while breastfeeding mothers experience more WASO than those who formula-feeding, they average approximately 30 minutes more sleep per night (Doan et al, 2014). However, both groups obtain a comparable TST across a 24hour period (Gay et al, 2004; Quillin and Glenn, 2004). Further evidence to support this shows that while breastfeeding infants demonstrate greater sleep fragmentation, their TST is no different to that of formula-feeding infants (Rudzik et al, 2018). This is due to mothers compensating for nocturnal sleep disruptions by sleeping in later in the morning and napping during the day (Swain et al, 1997; Gay et al, 2004).

The above differences can be attributed to variations in feeding demands across feeding types; breastfeeding infants feed more frequently than those who are formula-feeding (Butte, 1992). Breastmilk has a low substrate concentration; it is high in sugar and low in fat and protein. As a result of this, and the fact that infants have such small stomachs, they need to feed little and often, even during the night (Tully and Ball, 2012). Breastfeeding infants are more adept than formula-feeding infants at knowing when they are satiated; as they are in control of the supply they will simply stop feeding once they are full. Subsequently, they feed in small amounts relatively frequently (Butte, 1992). However, formula-feeding infants struggle to recognise when their hunger is satisfied; as they are not in control of their food supply, they will continue feeding for longer after they are full than breastfeeding infants will. They therefore feed with slightly less regularity than breastfeeding infants, taking in more milk in a smaller number of doses (Brown, 2016). As maternal and infant sleep patterns are driven by feeding patterns, the differences in feeding frequency between formula-feeding and breastfeeding infants are reflected in maternal and infant waking frequencies throughout the night (Butte, 1992).

4.2 Maternal-Infant Trade-Offs

As the need to feed throughout the night is at odds with the maternal need to sleep, a trade-off must occur in response to these two demands, which mothers often choose to redress through co-sleeping (Tomori,

Palmquist, and Dowling, 2016), or "breastsleeping" (McKenna and Gettler, 2015). This allows the mother to provide on-demand care and feeds for the infant, while inflicting minimal disruption upon her sleep patterns (Tomori, Palmquist, and Dowling, 2016). Mothers that co-sleep are often unaware of how often they feed their infants during the night, due to the ease conferred by the proximity of co-sleeping (Rudzik and Ball, 2016); while they may feed their infants more frequently throughout the night and therefore have more fragmented sleep, co-sleeping enables them to sleep through feeds, and subsequently night-time feeds do not detract as significantly from their TST. Formula-feeding mothers do not have the option to redress the balance in this way; though they can co-sleep, it does not facilitate night-time feeds as mothers still need to rise and make up a bottle for their infant (Tomori, 2017).

4.3 The Influence of Endocrinology: Prolactin:

Maternal sleep also differs across feeding types due to the biological composition of breastmilk. Breastmilk has a soporific effect and contains specific bioactive proteins that influence sleep behaviour; four of the key nucleotides within it have a strong circadian rhythm (Montgomery-Downs et al, 2010), meaning mothers often experience feelings of drowsiness after a feed (Blyton et al, 2002). Furthermore, it leads to an increase in circulating prolactin (PRL) (Montgomery-Downs et al, 2010); changes in circulating hormones have been shown to have an effect on sleep in other circumstances, so it is likely that they play a role in the sleep changes experienced by women in the postpartum period (Blyton et al, 2002).

PRL increases during gestation, but its activity is blocked by oestrogen and progesterone. However, after parturition and the onset of lactation, there is a withdrawal of both oestrogen and progesterone, which results in increased levels of circulating PRL (Blyton et al, 2002; Kendall-Tackett and Kaufman-Kantor, 1993; Tay et al, 1996; Powe et al, 2010). PRL is synthesised in the lactotrophic cells of the anterior pituitary (Hill et al, 1999; Torner and Neumann, 2002), and is released episodically following a circadian rhythm in both males and females, with a much greater concentration being released during the night compared to the day (Hill et al, 1999). As well as having a role in reproduction, growth, behaviour, and immunomodulation (Roky et al, 1995), it stimulates the growth and development of mammary glands (mammogenesis), promotes milk synthesis (lactogenesis), and maintains milk secretion (galactopoiesis) (Torner and Neumann, 2002).

There are two distinct phases of lactation, both of which are under hormonal control. Milk secretion is dependent on PRL from the anterior pituitary, while milk removal is dependent on oxytocin from the posterior pituitary (Cowie, 1984). PRL enhances the production of specific enzymes that are involved in lactose and milk protein synthesis, and is released in response to suckling (Tay et al, 1996; Powe et al, 2010). Nipple stimulation causes sensory impulses to be sent from the nipple to the brain (WHO, 2009), resulting in PRL being rapidly released from the anterior pituitary, which then binds to receptors in the alveolar cells, resulting in increased milk production (Seaton, 2007). This reflex is at its greatest during the first two months of

lactation (Cowie, 1984), and PRL levels are at their highest approximately 30 minutes after the start of a feed, suggesting the most important effect of suckling is inducing the production of milk for the next feed (WHO, 2009).

Frequent suckling is therefore associated with higher concentrations of PRL, which fall to baseline levels between feeds (Tay et al, 1996; Powe et al, 2010). Basal levels of PRL are significantly higher in nursing women. Levels increase further during nursing and sleep, and decrease with reduced feeding frequency; in the absence of suckling, PRL levels fall, and milk production slows (Seaton, 2007; Powe et al, 2010; Liu et al, 1990). Even with supplementation, the number of feeds and therefore the rate of suckling becomes reduced, and subsequently PRL levels are detrimentally affected (Tay et al, 1996; Powe et al, 2010). In the complete absence of breastfeeding, normal levels of PRL are generally reached 2-3 weeks postpartum (WHO, 2009). Evidence for the influence of PRL on lactation can be seen in mothers with milk insufficiency caused by a relative or complete PRL deficiency. In these cases, the administration of exogenous PRL has been found to increase milk volume (Powe et al, 2010).

As PRL is the main hormone for milk synthesis, its levels are higher in breastfeeding women. However, in addition to its role in milk production, it promotes deep sleep (SWS/NREM) and helps regulate the sleep-wake cycle. It is primarily produced at night, with its concentration rising after sleep onset and reaching a maximum level during the early hours of the morning (Roky et al, 1995; Spiegal and Reuchlin, 1994). A nocturnal rise in PRL has been noted during lactation, which is believed to be a mechanism developed to ensure milk supply is maintained during extended periods without suckling (Stern and Reuchlin, 1990). Although TST remains similar across feeding types, breastfeeding women experience a prominent increase in SWS/NREM sleep, and a compensatory reduction in REM sleep in comparison, which can be explained by the increased PRL in breastfeeding women. In fact, it has been found that regardless of the time of a feed, breastfeeding mothers always return to SWS/NREM upon falling asleep. Formula-feeding mothers, meanwhile, do not experience such an increase, and as the synthesis and release of PRL can itself be detrimentally affected by the physical and emotional stress of supplementary feeding, their sleep may be negatively impacted (Blyton et al, 2002).

4.4 Infant-Feeding Type and Postpartum Depression

Infant-feeding type not only affects sleep, but also has an impact on the development of PPD through its effect on PRL levels. An association has been found between high PRL levels and low anxiety scores, suggesting the high levels of PRL experienced in lactating women may reduce anxiety (Asher et al, 1995). This is illustrated by women who breastfeed having lower EPDS scores, and higher levels of PRL, while those with PPD exhibit greater levels of progesterone and lower levels of PRL. Furthermore, progesterone is positively associated with depression in formula-feeding mothers, while in breastfeeding mothers it is negatively

associated (Abou-Saleh et al, 1998). PRL also plays a crucial role in priming, triggering, and ensuring normal maternal behaviour, by way of which it may be protective against PPD (Abou-Saleh et al, 1998).

Further evidence from this interrelationship comes from a systematic review of 48 studies, which showed that PPD was predictive of early breastfeeding cessation, while also being predicted by early breastfeeding cessation itself (Días and Figueiredo, 2014). Additionally, the reduction in PPD in breastfeeding mothers has been attributed to the influence of increased oxytocin that comes with lactation from birth to 3-months, which reduces stress and therefore in turn likely reduces PPD (Figueiredo et al, 2014).

It has also been found that WF and WASO are more prominently linked to PPD than TST, and that the number of night-time awakenings is more detrimental than the length of time spent awake after sleep onset (Park et al, 2013). Such sleep disruptions and therefore PPF are more prevalent in breastfeeding mothers, which has been strongly correlated with PPD, although the directionality of the relationship is unclear (Henderson et al, 2019).

5. Conclusion:

From the existing literature, it is apparent that there are consequential links between depression, feeding behaviours, and sleep. One can also see that the directionality of the relationship between any of the above three factors is anything but clear. Despite this, what is clear is that PRL plays an integral role in linking the three. PPD is prevalent in postpartum populations in the UK, as are low breastfeeding rates, and postpartum fatigue, all of which have negative consequences for both maternal and infant health. This triad confers a myriad of health implications to mother-infant dyads in the UK, and therefore it is imperative that the relationship is interrogated further in order to inform preventative health measures, which can be put in place to guard against its detrimental effects to maternal-infant health, and the mother-infant relationship.

Methodology

6. Ethical Considerations:

Before setting out on this project, full ethical approval was gained from the Anthropology Department's Ethics and Data Protection Subcommittee by my supervisor, Helen Ball. The research proposal was reviewed and confirmed to be ethically appropriate under the University Policy on Ethical Approval. I familiarised myself with this, along with the ethical guidelines of the Human Biology Association (HBA, 2016), the American Anthropological Association (AAA, 2012), and the Association of Social Anthropologists (ASA, 2011). The outline for Visual Ethics (Wiles et al, 2008) proposed by the Economic and Social Research Council (ESRC) was also utilised as most other ethical outlines do not pay specific attention to the ethical issues encountered in visual data collection (Wiles et al, 2008). For the purposes of adhering to these guidelines, participants were given a detailed information sheet prior to participating which outlined the study's research methods and objectives, what participation would entail, and what participants would receive in return for their assistance (Appendix I). The document detailed how participants' privacy and anonymity would be maintained throughout the project with the implementation of pseudonyms/anonymous ID codes, data encryption, and the password protection of online files. Additionally, participants' right to withdraw themselves and their data from the project at any time from registration to completion, without reason and without consequence to themselves or others, was highlighted.

In order to participate, participants were required to sign a written consent form (Appendix VII) to clarify that they had read and understood the information sheet, had been given the opportunity to ask questions pertaining to the study, and were willing to participate in the project and allow any data collected to be investigated under the research aims outlined in the information sheet. The ethics forms themselves were stored according to GDPR guidelines, (i.e. in a locked space or password protected where necessary). It also included a section to be signed upon completion of the three overnight stays, to confirm participants had been given the option to view their videos, and were happy for them to be used anonymously in academic presentations, and kept for use in relevant studies over the next 6 years.

7. Participant Recruitment:

7.1 Target Population

Participants were required to be non-smokers, over 18, and to live in and around County Durham to enable easy data collection. As one of the original aims of the project was to identify the impact of feeding-type on sleep and PPD, combination feeders were not permitted as their inclusion would have made it impossible to

identify the impact of feeding-type upon sleep and PPD. Initially, the target population for recruitment covered three groups of women: first-time mothers with infants under two months who were exclusively breastfed; first-time mothers with infants under two months who were exclusively formula-feeding; and non-mothers of reproductive age. However, 3 months into recruitment, uptake was slow and consequently the age parameter of 2 months was extended to 3 months and second-time mothers were included. Every effort was made to age-match mothers and non-mothers to minimise the influence of age-differences on the results.

Participants were rewarded for participation with a gratuity of £100 worth of High Street vouchers; £20 per overnight stay, and £40 for completing the actigraphy and sleep diaries during the months. There is some dispute over the use of gratuities in research, as they may be interpreted as coercive, and because they can have the undesirable effect of simply transforming research into a marketable good (Head, 2009). However, while the threshold between a coercive and encouraging amount is a fine line (Head, 2009), the quantity suggested in exchange for the time an effort provided was not believed to be considerable enough to be coercive. Furthermore, the use of monetary incentives has become so widespread that there is now a "culture of expectation" (McKeganey, 2001, p. 1237 in Head, 2009) with regards to payment, to the extent that not presenting participants with a gratuity can in some cases be deemed unethical (Head, 2009).

Additionally, the use of gratuities does garner some benefits. For example, it has been found to reduce the inherent power imbalance between researcher and participant (Thompson, 1996), and to encourage participation, as shown in a meta-analysis which discovered that the average response rate increased by a total of 19% when gratuities were immediately enclosed, and by 7% when a gratuity was promised upon study completion (Hopkins and Gullickson, 2010). Given the duration and multiple elements of this study that required completion, it would not have been prudent to present participants with the complete gratuity amount at the beginning of the study. The sum for the monthly actigraphy and sleep diaries was therefore not given until all months were completed, but participants were paid upfront each time for the overnight stay upon arriving at the sleep lab, which hopefully will have been of some benefit.

7.2 Recruitment Methods

A leaflet (Appendix II) and a poster (Appendix III) were created containing key study information: research aims, what participation would involve, and what participants would gain in return for their assistance. The survey and poster were posted on the Baby Sleep Information Source (BASIS) Facebook page and were sent to the Durham Infancy and Sleep Centre (DISC) mailing list. This contained useful contacts, such as leaders of La Leche League groups in and around County Durham, who then disseminated the call for participants to their respective groups. While the NHS would have been an excellent place to start recruiting mothers, the ethics process required to do so was simply too long for the time constraints of the study.

Facebook pages for local nurseries, children's play areas, La Leche League meetings, and parent and baby massage groups were contacted with information about the study, which they then shared to their respective social media pages and in some cases to their mailing lists. Leaflets and posters were distributed and put up in the local area, including in Durham, Middlesbrough, Houghton-Le-Spring, and Birtley. They were primarily distributed to community centres, leisure centres, nurseries, churches and their adjacent halls, and parent and baby groups.

When sharing the poster on social media, a link was included to a survey, which was created using the free online platform "JISC", which enables users to create surveys with certain filters, and is more professional and efficient than some other platforms like *Survey Monkey.* The platform was created for use by academic institutions and, most importantly, is GDPR compliant, which some other commercial platforms are not. Through this survey, women could register their interest and leave contact details to be sent more information. Separate surveys were created for mothers and non-mothers. Upon filling out the online form, participants were contacted with further information about the study, including an information sheet (Appendix I) and a video providing an overview of an overnight stay in the sleep centre, (available at: https://www.youtube.com/watch?v=uasjsQsgdcc&feature=youtu.be). Additionally, they were sent a second online survey, which was designed to assess their eligibility for the study and therefore contained route-out options for mothers/women who were, for example, smokers or combination-feeders. While the response for the initial form was relatively successful, garnering 191 responses in total, (primarily from breastfeeding mothers), there was a lot of drop-off between this and the form in the follow-up email.

To try and reach non-mothers, an advertisement was placed on Durham University's Dialogue Signposts page, an online news and announcements page for the University. This was done in conjunction with another Master's student's project, and while the first posting did not result in many sign-ups, the second proved more fruitful and resulted in the desired quota of 10 non-mothers being filled. While this was a highly efficient method of recruiting non-mothers, the resulting sample will have led to relatively ungeneralisable results, as nearly all participants were primarily drawn from a pool of white, middle-class, highly educated women.

Despite many shares and much interest from the above routes, uptake of participants was still slow. New recruitment material was therefore created that was more concise and visually accessible, showing all the information on one photo which could then be easily distributed on social media and other platforms (Appendix IV). This was then shared to the BASIS Facebook page and to the DISC mailing list.

A press release was issued to local newspapers and press (e.g. the Northern Echo), calling for participants from all groups (Appendix V). Help was obtained from the University communications and publicity team,

who provided a list of relevant contacts and assistance with the press release. This was not as successful as anticipated, resulting in only two sign-ups.

While snowball sampling does affect the generalisability of a sample as it is not a random method of recruitment, it has been found to be an effective method of obtaining participants (Saldaña and Omasta 2018). Current participants were therefore asked to share information regarding the project with their friends and colleagues, both mothers or non-mothers, who they thought might be interested in taking part. This did result in some additional sign-ups with regards to the breastfeeding and non-mother groups.

Despite all these recruitment routes, formula-feeding mothers continued to be difficult to find; after 5 months of recruitment drives, only 3 were participating, and one did not wish to complete the overnight stays and subsequently dropped out of the study. Research suggests that formula-feeding mothers are more likely to have a lower education-level, and to be of lower socio-economic status than those who breastfeed (Brown, 2016). In terms of recruitment for this study, it is unlikely to be a coincidence that these are the social groups who are also less likely to volunteer for research (Brown, 2016).

Volunteering rates may also have resulted from the social prejudice against formula-feeding; in general, and especially since the "Breast is Best" campaign, formula-feeding mothers have been widely stigmatised for their infant-feeding choices, despite many of them turning to formula-feeding due to factors outside their control (Brown, 2016). It was noted upon discussion with some participants and their partners, that the research was being interpreted as a direct comparison of breastfeeding and formula-feeding mothers and their sleep patterns. It is plausible that this perception of the study as pitting one group against another was widespread and may have contributed to the exceedingly slow uptake of formula-feeding mothers, who may have been wary of participating if they believed they would be measured up against breastfeeding mothers. In an attempt to negate this, a separate call for formula-feeding participants was put out by way of a press release (Appendix VI), which aimed to dilute the emphasis on the comparative element of the study. Unfortunately, this was completely unsuccessful and no further sign-ups occurred.

8. Questionnaires, Sleep Diaries, and Actiwatches:

8.1 Actigraphy

Upon confirming their willingness to participate, participants, (and their babies where applicable), were delivered Actiwatches, which were worn for 5 nights per month for 5 months, 2-6 months postpartum. Prolonged periods of over 3 days of recording are recommended for the assessment of circadian sleep/wake patterns (So et al, 2005), and 5 days is considered the minimum necessary to obtain aggregated measures that reliably characterise the individual (Sadeh and Acebo, 2002). Participants used them on consecutive nights

and were not required to do anything to start or stop the watches recording, aside from putting them on before going to bed. Mothers wore them on their wrists, while infants' were placed on the ankle. While they occasionally did fall off the babies, this was easily rectified by covering the watch with a sock.

Actigraphy has a long history of use in medicine and sleep research, and the objective measurements of sleep and waking it provided gave an objective point of comparison for the subjective sleep diaries which were kept by participants over the course of the 5 nights. It is superior at estimating periods of sleep rather than of wakefulness, as due to being based on motion it can occasionally mistake stillness for sleep, meaning increased wakefulness during the night can therefore lead to a decrease in its accuracy (Sadeh and Acebo, 2002). Polysomnography would have been an alternative method of data collection that would have mitigated this, but it is far more invasive than actigraphy. Furthermore, while some findings suggest that in general it provides more precise data (Nishihara and Horiuchi, 1998), other evidence has shown that when the two methods are compared, actigraphy is a valid method for monitoring sleep in infants under 6 months of age, with no difference in accuracy across the 6 months (So et al, 2005).

Actigraphy could be considered a precarious method for data collection, as it leaves it primarily in the hands of participants; they may forget to wear the watches, or be unable to diagnose or resolve any technical issues that could otherwise be quickly identified and rectified by a researcher in a laboratory setting (Sadeh and Acebo, 2002). However, for the purposes of this study, its merits outweighed the issues; it is less intrusive than other methods, (e.g. polysomnography, or electroencephalography), less expensive, and less cumbersome. Most importantly, it enables sleep to be measured outside the laboratory, in a home environment, which is highly beneficial as it is likely to result in more valid and reliable data (Sadeh and Acebo, 2002).

Actigraphy data was analysed using the software Action W 2.7. This enabled different algorithms to be used to analyse maternal and infant sleep to allow for more accurate analysis; the standard *Sadeh* algorithm was used for the former, and *Sadeh Infant* for the latter. Zero crossing mode (ZCM) was enabled in the software programme, which measures the frequency of movement, light, and temperature in 1-minute epochs, and is therefore necessary when using the aforementioned algorithms, as they classify periods of sleep/wakefulness based on movement. When marking the data, the beginning and end of sleep periods were set to "snap to" at 200 ZCM. Any activity above this threshold was classified as significant, meaning participants were then classified as awake. Where activity was generally low and therefore could not be used as an indicator of wakefulness, the sleep periods suggested by the algorithm were used. The algorithm produces data for a large number of sleep parameters and factors, most of which were not necessary for this study. The parameters chosen were total sleep time (TST), wake frequency (WF), wake after sleep onset (WASO), and major sleep period (MSP). The data for these was extracted and compiled into a database in Excel.

8.2 Sleep Diaries

While sleep diaries alone have been found to lack accuracy due to their subjective nature, it is advised that they be used in conjunction with actigraphy as a means to identify bed times, rise times and periods when an Actiwatch is off the wrist or ankle (Insana and Montgomery-Downs, 2010; Sadeh and Acebo, 2002). Subsequently, participants were given a sleep diary for each night of home actigraphy. The diaries (Appendix IX) contained two columns, one for the mother and one for the baby, (to be used where applicable). Participants were asked to fill out when they themselves were asleep or awake, and when their baby was feeding, crying, and sleeping, either on the mum, near the mum, or away from the mum, in 15-minute periods from 18:00-08:00. The evening portion could be completed prior to going to bed, while the overnight portion was to be completed the next morning in retrospect. A space for additional comments about any unusual activity throughout the night was provided, as is recommended (Sadeh and Acebo, 2002).

From the data gained from the sleep diaries, certain sleep parameters were determined. First the MSP was calculated, from sleep-onset to sleep offset. WASO was then calculated as the sum of minutes spent awake within the MSP, which was then subtracted from this to give the TST. The wake frequency throughout the night was then determined.

8.3 The Edinburgh Postnatal Depression Scale (EPDS)

In addition to the sleep diaries, participants were given a questionnaire aiming to determine their level of postnatal depression over the last 7 days. The Edinburgh Postnatal Depression Scale (EPDS) (Appendix VIII) was developed to help health professionals diagnose PPD in new mothers, and is used extensively in sleep studies, including in those investigating depression in partners of new mothers (Edmondson et al, 2010; Paul and Pearson, 2020), and in antenatal groups (Milgrom et al, 2008; Paul and Pearson, 2020; Wickberg et al, 2005). It was therefore deemed appropriate, and necessary, to use the EPDS as a tool to assess depression in both mothers and non-mothers in this study. This was both to maintain consistency in the categorisation of depression across the groups within the study, but also to ensure it was comparable with other studies on sleep and depression.

The EPDS is comprised of 10 short statements that each have four possible answers. The mother underlines the answer that most closely describes how she has felt during the past week. Questions 1-2 and 4 are scored from 0-3 corresponding to increasing severity, while questions 3 and 5-10 are reverse scored. The total score is the sum total of the scores for each of the items. The severity ranges are as follows: none or minimal depression (0-6), mild depression (7-13), moderate depression (14-19), and severe depression (19-30) (McCabe-Beane et al, 2015). The EPDS has been shown to successfully identify major depression, but it may be less successful in its diagnosis of minor depression (Murray and Cox, 1990), and therefore it may not have

accurately identified this in participants. The scale has been validated for use in women with older children (Cox et al, 1996), so was useful given that second-time mothers were also included in the study.

For this study a score of above 10 was used to categorise participants as suffering from moderate-severe depression, which has been used by previous studies and found to have a sensitivity of 100%, a specificity of 80-87% (Jadresic et al, 1993, Eberhard et al, 2001), and a confidence interval of 72-100% (Eberhard et al, 2001). A score above the threshold of 12/13 is likely to indicate a serious depressive illness (Cox et al, 1987), thus those who scored above 13 were advised to contact their GP, had they not done so already.

9. The Sleep Centre: Overnight Studies:

Participants were required to come into the sleep centre when their babies were 2 or 3, 4, and 6 months old. The sleep lab is located in a small cottage with a bedroom which, aside from the three built-in infra-red cameras used for monitoring, is designed to replicate a normal, Western, sleeping arrangement (Fig. 2); it contains a bed, bedside tables, TV, lamps, wardrobe, and a cot for use when necessary.

In addition to this, there is a monitoring room where the individual carrying out the overnight monitoring spends the night, keeping an eye on the equipment, ensuring the cameras are on the mother and baby, and that the baby is safe. For participants with infants, the individual doing the monitoring was required to stay awake throughout the night in order to ensure the safety of the baby and intervene in the event that the baby was in danger, (e.g. incidences of head-covering, which is a common risk factor Sudden Infant Death Syndrome).

Figure 2: The Bedroom in the Parent-Infant Sleep Lab (photo taken from the introductory video).

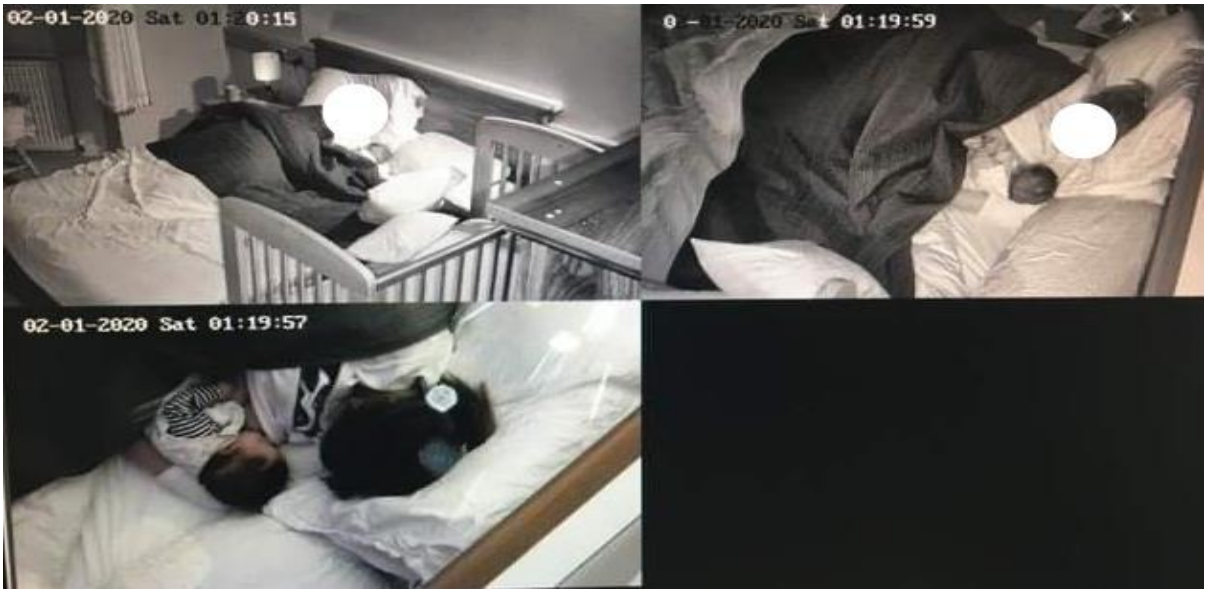

Figure 3: Mother and Infant Co-Sleeping in the Parent-Infant Sleep Lab.

Participants were advised to arrive a little before they would usually settle down for the evening, and upon arrival were given a brief tour, and the study was explained. Participants were given the opportunity to ask questions, and to look at the software that would be used to monitor them throughout the night, (n.b. Noldus videosomnography), which was used in addition to actigraphy. Participants were invited to carry out their night-time routines as normal, both with regards to their infants and themselves, and practices like co-sleeping were welcomed, and was practiced for varying lengths of time by several participants (e.g. Fig. 3).

It has been found that sleep organisation is affected by laboratory conditions, especially in young infants, who exhibit increased fussy-crying and decreased alertness during the first 4 hours in the laboratory, even when only video monitoring is used. This indicates the need for a stage of adaptation to the new environment (Sostek and Anders, 1975), which would normally be solved by way of a habituation night. However, the time constraints placed on this study meant these were not feasible, so it is possible that the data collected during these nights do not accurately reflect infants' usual sleep. This is also true of adults' sleep; they experience a delay in Stages IV and I-REM sleep, as well as more awake periods. "First-night effects" often settle by the second night (Agnew et al, 1966), and are not always present in either mothers or infants (Richard and Mosko, 2004). Technically, the first overnight stay could have counted as a habituation night for the following two, but in most instances only one overnight was able to take place, (see limitations section).

The data collected was analysed using the software *Noldus-The Observer*. This software enables the duration, frequency, and sequence of events during a video to be identified and recorded through the use of a coding procedure. This is created by the researcher according to what is being investigated. For example, for this project the coding taxonomy included infant location, infant and maternal awake and sleep states, infant behaviour, and maternal interactions with the infant (please see Appendix X for details on coding procedure

and specifications). I had assistance from a Laidlaw Scholar in coding the data. As the data was being coded by two individual researchers, it was important to conduct a reliability analysis to ensure that it was being coded sufficiently similarly that the inter-observer differences were not significant enough to affect the data. We therefore tested for this by each coding the same video, one at the start and one at the end of the study. We tested for similarities in frequency-sequence and duration-sequence. The former compares all event types, comparing their timing and overlapping across the two coded videos. The latter compares the duration of events across the two videos and whether they overlap. Prior to coding all the videos, we both coded the first hour of a randomly selected video. The duration-sequence analysis was not an issue, as the Kappa was almost immediately above 0.90. However, the frequency-sequence analysis proved slightly more difficult, and it was necessary to re-code the video several times, making adjustments and clarifications to our coding procedure before we were able to achieve a satisfactory frequency-sequence Kappa of 0.85, and a Kappa of 0.98 for the duration-sequence analysis. After coding all the videos, we repeated the reliability analysis to confirm that our coding had been consistent throughout, and chose a second randomly selected video. Unfortunately, while the Kappa for the duration-sequence was pleasingly high, at 0.97, it was less satisfactory for the frequency-sequence, at 0.75, meaning 25% of the video was coded in an inconsistent manner between the two researchers indicating coder drift. While in an ideal scenario, the videos would have been re-coded as a result of this, this was not possible due to the limitations placed on the study by the COVID-19 restrictions. Consequently, one must bear in mind that the frequency-based outcomes are less robust than the duration-based ones.

10. Data Analysis:

The data from the sleep diaries, actigraphy, EPDS, and videosomnography were all compiled into a single spreadsheet. This ultimately contained each participant's EPDS scores; TST, WF, WASO, and MSP from both actigraphy data and sleep diaries from monthly data collections; TST, WF, WASO, and MSP from actigraphy taken on overnight stays; and behavioural data regarding maternal interactions with infants from the videosomnography carried out on the overnights. The latter included time spent engaging in interacting with, snuggling with, and watching the baby. Due to an overwhelming quantity of missing data sets for both infant actigraphy and sleep diaries, only data from the maternal sleep measures were analysed.

In order to identify patterns within the data to ascertain what variables might be influencing each other, it was visualised using pivot tables and pivot charts. The data was plotted in graphs for the following: means of sleep parameters, (TST, WF, WASO, MSP), obtained through sleep diaries and actigraphy; percentage of depressed participants in each group over time; mean depression scores over time; the relationship between depression and each sleep parameter for each collection method over time.

Initially, data was going to be analysed using repeated measures statistical analyses in SPSS to ascertain both significant differences between the maternal and non-maternal groups with regards to sleep and PPD scores, and the relationship between PPD and sleep parameters in both groups. However, as a result of the pandemic, issues with recruitment, and technological problems, there was too much missing data from individual participants and it was not possible to run such tests. Consequently, the data that was collected was analysed through descriptive techniques and the relevant statistical tests were carried out at individual time points where there was sufficient data to ascertain whether there was a significant difference/relationship between two variables. These tests were non-parametric, as after running Kolmogorov-Smirnov tests on the data, it was found not to be normally distributed in all instances. Therefore, Spearman's Correlations were used to test relationships between sleep parameters and depression, while Mann Whitney-U tests were used to ascertain the difference between sleep parameters and depression in each group for each method of data collection.

Results

The flow-chart below illustrates the flow of potential participants through the recruitment and enrolment process and their participation in the study.

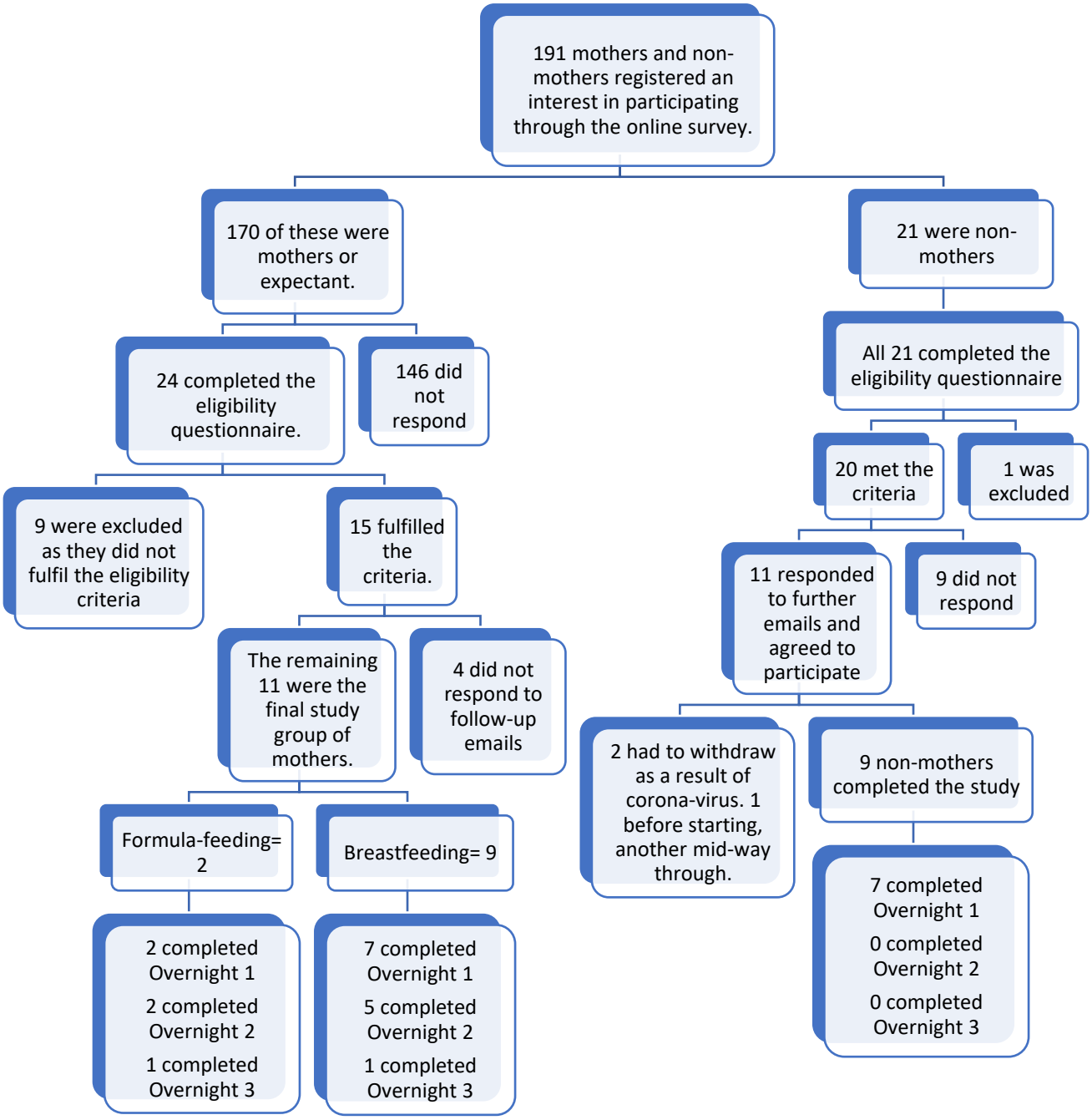

Figure 4: Participant Recruitment

The study had aimed to recruit equal numbers of formula-feeders, breast-feeders, and non-mothers to enable a comparison of feeding types in analysis. As is illustrated in Figure 2, while the final study pool contained 9 non-mothers and 9 breast-feeders, only 2 formula-feeding mothers had agreed to participate. Consequently, comparisons of sleep and depression according to feeding-type were not possible, and so the formula-feeding

and breast-feeding categories were amalgamated and data was simply analysed according to whether participants were mothers or non-mothers. The following tables detail the sample size of participants for each sleep parameter over time for actigraphy and sleep diaries in both subject groups.

Table 1:
Mothers' Sleep Diaries: Sample Size:

Months	TST (n=)	MSP (n=)	WASO (n=)	WF (n=)
2	7	7	7	7
3	9	9	9	9
4	10	10	10	9
5	11	11	11	11
6	10	10	10	10

Table 2:
Non-Mothers' Sleep Diaries: Sample Size:

Months	TST (n=)	MSP (n=)	WASO (n=)	WF (n=)
2	8	8	8	8
3	3	3	3	3
4	4	4	4	4
5	6	6	6	6
6	5	5	5	5

Table 3:
Mothers' Actigraphy: Sample Size:

Months	TST (n=)	MSP (n=)	WASO (n=)	WF (n=)
2	6	6	6	6
3	6	6	6	6
4	4	4	4	4
5	3	5	5	5
6	7	8	8	8

Table 4:
Non-Mothers' Actigraphy: Sample Size:

Months	TST (n=)	MSP (n=)	WASO (n=)	WF (n=)
2	8	8	8	8
3	3	3	3	3
4	4	5	5	5
5	5	6	6	6
6	4	5	5	5

11. Sleep Parameters:

11.1 Total Sleep Time:

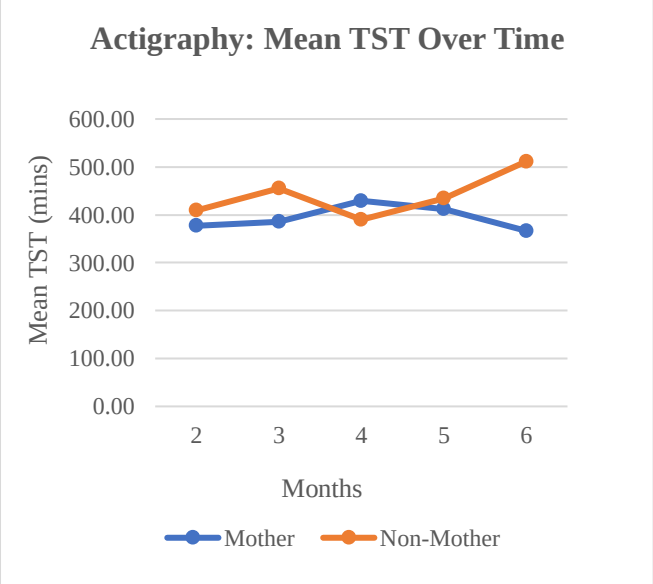

Figure 5: Objective TST Over Time in Mothers and Non-Mothers

Table 5: Mann Whitney-U Tests: Mothers' and Non-Mothers' Actigraphic TST

Month	U	Z	p
2	16.0	-1.0344	.301
3	6.0	-.775	.439
4	5.0	-.866	.386
5	9.0	-.245	.806
6	8.0	-1.134	.257

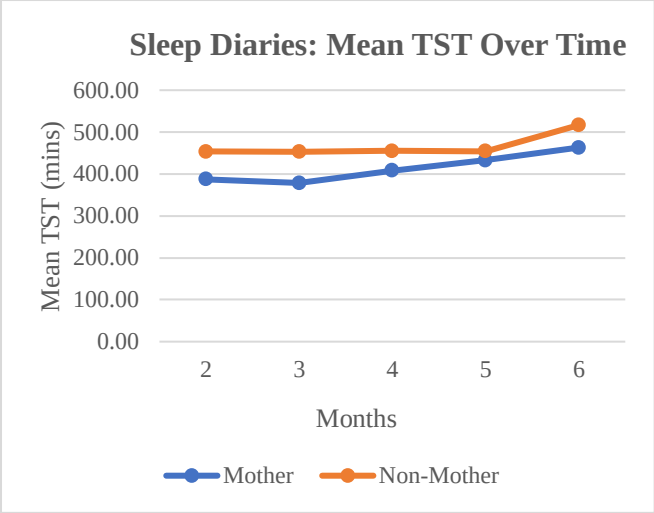

Figure 6: Perceptions of TST Over Time in Mothers and Non-Mothers

Table 6: Mann Whitney-U Tests: Mothers' and Non-Mothers' Sleep Diary TST

Month	U	Z	p
2	7.5	-2.379	.017
3	6.0	-1.387	.166
4	13.0	-.990	.322
5	28.0	-.503	.615
6	18.0	-.857	.391

The actigraphic data in Fig. 5 shows non-mothers' TST to be consistently higher than mothers', aside from in month 4, at which point mothers' TST peaks, while non-mothers' dips. Mann Whitney-U tests revealed no significant differences in the objective TST of mothers and non-mothers at any time.

Fig. 6 shows perceptions of TST over time to not be vastly different, either in trend or mean, between the two groups. Mann Whitney-U tests were run on the data at each time point for actigraphy (Table 6), and sleep diaries (Table 7) and from the results it can be seen that mean TST was only significantly different in month 2, (*U=7.5, Z=-2.379, P=.017).*

11.2 Major Sleep Period:

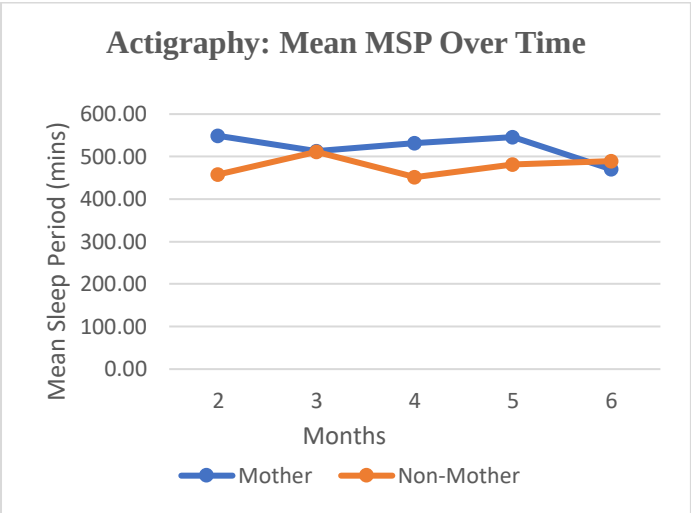

Figure 7: Objective MSP Over Time in Mothers and Non-Mothers

Table 7: Mann Whitney-U Tests: Mothers' and Non-Mothers' Actigraphic MSP

Month	U	Z	p
2	13.0	-1.420	.156
3	9.0	.000	1.0
4	4.0	-1.470	.142
5	8.0	-1.601	.109
6	19.0	-.146	.884

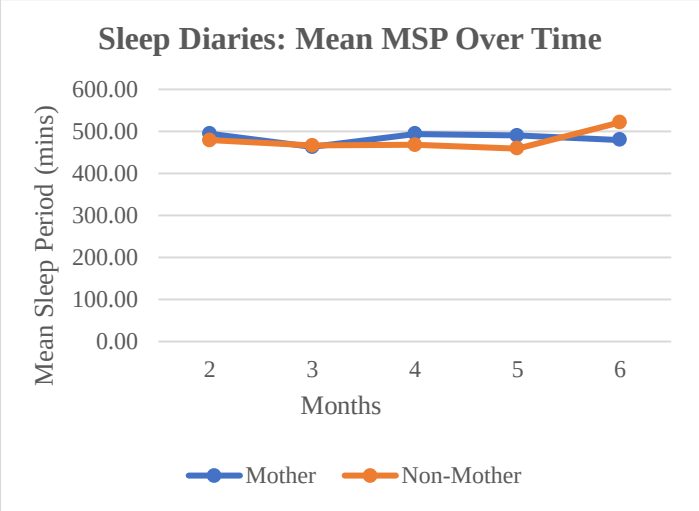

Figure 8: Perceptions of MSP Over Time in Mothers and Non-Mothers

Table 8: Mann Whitney-U Tests: Mothers' and Non-Mothers' Sleep Diary MSP

Month	U	Z	p
2	25.0	-.347	.728
3	11.5	-.370	.711
4	19.5	-.071	.944
5	22.5	-1.056	.291
6	21.0	-.490	.624

Mothers' and non-mothers' actigraphically-measured MSP trends seemed to mirror each other (Fig. 7). Mothers generally had a longer sleep period than non-mothers, aside from in months 2 and 6, during which they had almost identical lengths. The largest difference is seen in month 2, and sleep period lengths are then similarly different in months 4 and 5. MSP was not significantly different between the two groups in any of the months (Table 7).

Sleep diary MSP (Fig. 8) was more similar in month 2 and 3, but the following 3 months showed a greater difference in mean length. The length of non-mothers' sleep periods decreased slightly from months 2 to 5, and then exhibited a very large incline in the final month. Meanwhile, the MSP of mothers dropped sharply in months 3, to then rise and slightly decline over the following 3 months. MSP was not significantly different between the two groups in any of the months (Table 8).

As with the other sleep parameters, the sleep diaries underestimated the MSP in both groups, apart from in the non-mothers in month 6. The mothers' measures were more similar than those of the non-mothers, with the general trend of the actigraphy largely reflected in the sleep diaries; a decrease in month 3, followed by an increase, and a further decline in months 5-6. Non-mothers' subjective reports of MSP, meanwhile, showed little similarity with the objective data, with the trends almost mirroring each other.

11.3 Wake Frequency

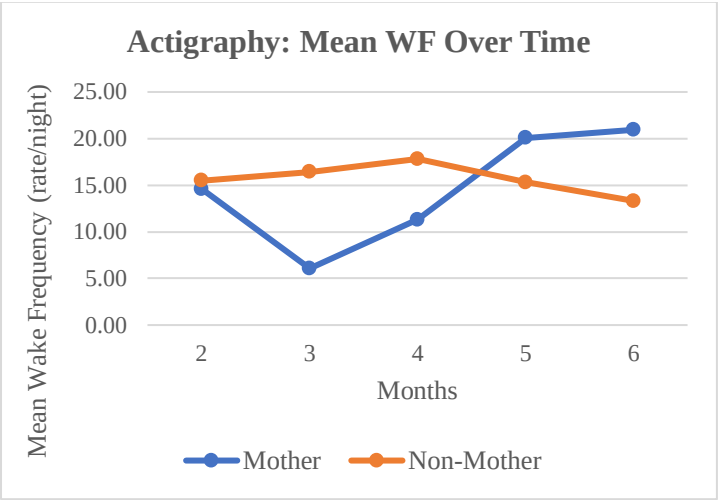

Figure 9: Objective WF Over Time in Mothers and Non-Mothers

Table 9: Mann Whitney-U Tests: Mothers' and Non-Mothers' Actigraphic WF

Month	U	Z	p
2	18.5	-.711	.477
3	6.0	-.775	.439
4	5.0	-1.225	.221
5	14.5	-.561	.575
6	9.0	-1.612	.107

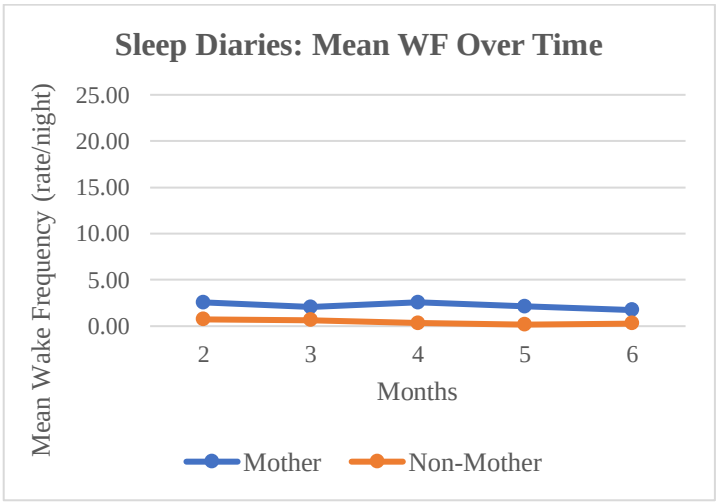

Figure 10: Perceptions of WF Over Time in Mothers and Non-Mothers

Table 10: Mann Whitney-U Tests: Mothers' and Non-Mothers' Sleep Diary WF

Month	U	Z	p
2	3.0	-2.896	.004
3	2.5	-2.056	.040
4	1.0	-2.627	.009
5	1.0	-3.240	.001
6	2.5	-2.768	.006

The actigraphy showed non-mothers' WF to be comparatively stable across the 5 months, while mothers' WF was more changeable (Fig. 9), although there was no significant difference in wake frequency between mothers and non-mothers at any time point (Table 10).

Sleep diary data showed perceptions of WF were quite different in both mean and trend (Fig. 10) with the reported frequency of waking among mothers being significantly higher than that of non-mothers at all time points (month 2: *U= 3.0, Z=-2.896, p=.004;* month 3*: U=2.5, Z=-2.056, p=.040;* month 4*: U=1.0, Z=-2.056, p=.009;* month 5*: U=1.0, Z=-3.240, p=.001;* month 6*: U=2.5, Z=-2.768, p=.00*6). Perceptions of WF were far lower than the objective measurements, but may reflect the sensitivity settings of the actiwatches. There was a noticeable drop in frequency of night wakings reported by mothers and observed via actigraphy when babies were 3 months of age.

11.4 Wake After Sleep Onset

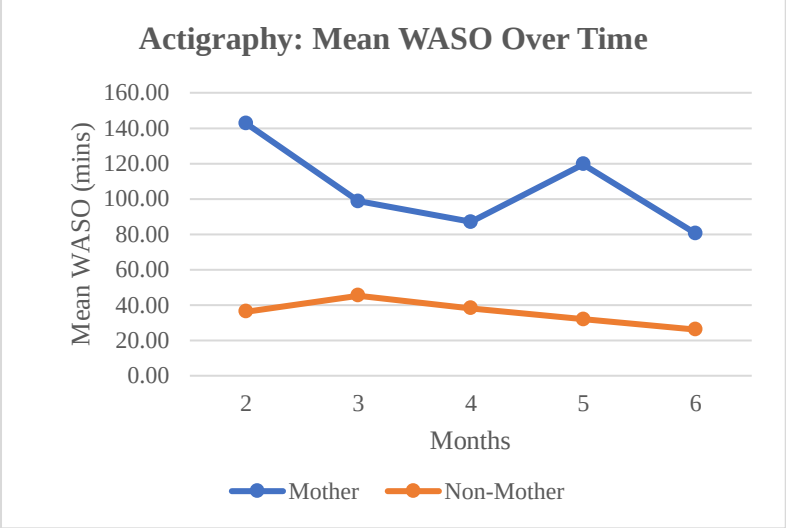

Figure 11: Objective WASO Over Time in Mothers and Non-Mothers

Table 11: Mann Whitney-U Tests: Mothers' and Non-Mothers' Actigraphic WASO

Month	U	Z	p
2	2.0	-2.840	.005
3	3.0	-1.549	.121
4	5.0	-1.225	.221
5	2.0	-2.562	.010
6	5.0	-2.199	.028

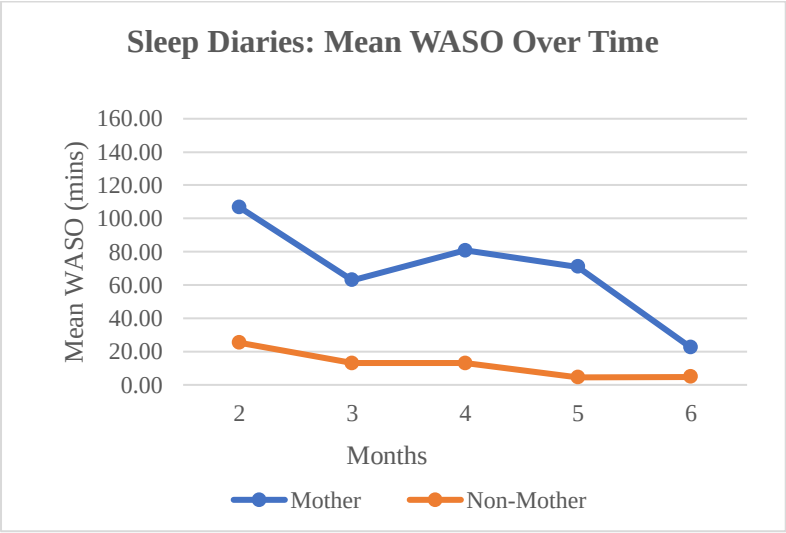

Figure 12: Perceptions of WASO Over Time in Mothers and Non-Mothers

Table 12: Mann Whitney-U Tests: Mothers' and Non-Mothers' Sleep Diary WASO

Month	U	Z	p
2	2.0	-3.014	.003
3	1.0	-2.315	.021
4	4.0	-2.268	.023
5	1.0	-3.236	.001
6	22.0	-.379	.704

There is great variation between mothers and non-mothers in regards to actigraphically-measured WASO (Fig. 11). Non-mothers appeared to have a relatively low and consistent duration of WASO at all time points. Meanwhile, mothers' WASO was highly erratic over the 5 months, dropping sharply to then increase and decrease again. Objectively measured WASO means were significantly different between the two groups in month 2, *(U=2.0, Z=-2.840, p=.005)*, month 5, (*U=2.0, Z=-2.562, p=.01*), and month 6, (*U=5.0, Z=-2.199, p=.028)*, as can be seen in Table 11.

Subjectively reported WASO was also considerably different between mothers and non-mothers (Fig. 12). While non-mothers declined somewhat over the 5 months, it did so in a relatively stable manner. Mothers' WASO on the other hand exhibited greater variability. Similar to the actigraphy, and somewhat unsurprisingly, the means differed vastly between the two, and the difference was significant in all but month

6, *(*month 2: *U=2.0, Z=-3.014, p=.003;* month 3: *U=1.0, Z=2.315, p=.021*; month 4: *U=4.0, Z= -2.268, p=.023*; month 5: *U=1.0, Z=3.236, p=.001),* as shown in Table 12.

Both mothers and non-mothers sleep diary scores largely underestimated their WF compared with the actigraphy. However, non-mothers more accurately reflected the trend, gradually decreasing, and staying relatively stable compared with the mothers in both measurements. Mothers exhibited a decrease in WASO in both measures in months 2-3, and months 5-6, but the months in between were presented rather differently in the two measures.

11.4 Causes of Night-Waking

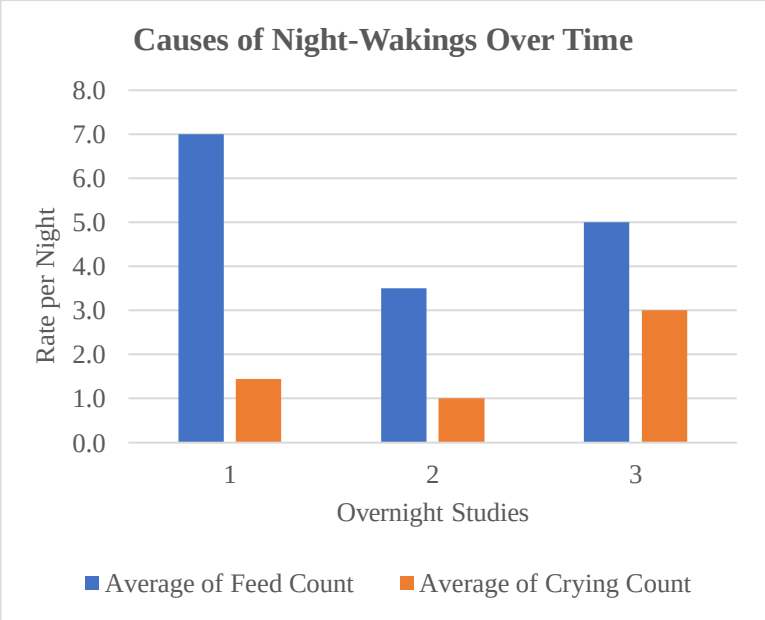

Figure 13: Causes of Night-Wakings Over Time

Table 13: Sample Size of Mothers on Overnight Studies:

Overnights	Total (n=)
1	9
2	6
3	2

The trends obtained from the videosomnography (Fig. 13) showed that causes of night-wakings could largely be attributed to feeding at all times, and was far more "disruptive" to maternal sleep during the night than crying. The frequency of night-time feeds was at its highest at age 2-3 months (observation 1), and its lowest at age 4 months (observation 2). Though crying was also at a low at age 4 months, its frequency peaked at age 6 months (observation 3).

12. Depression:

12.1 Depression Over Time

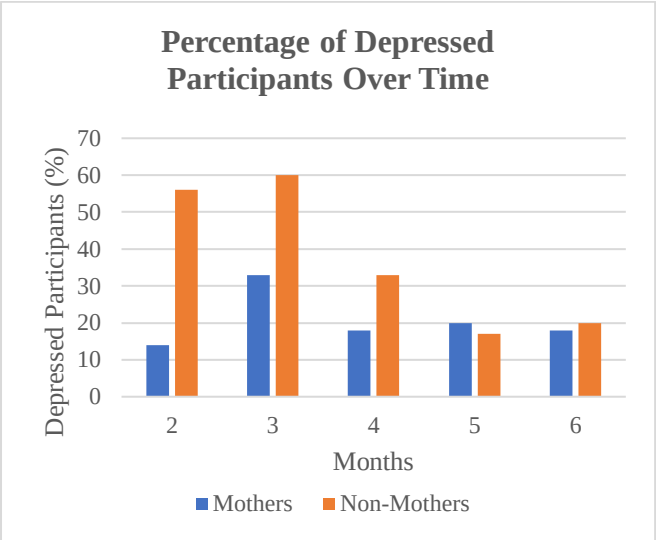

Figure 14: Percentage of Depressed Participants Over Time

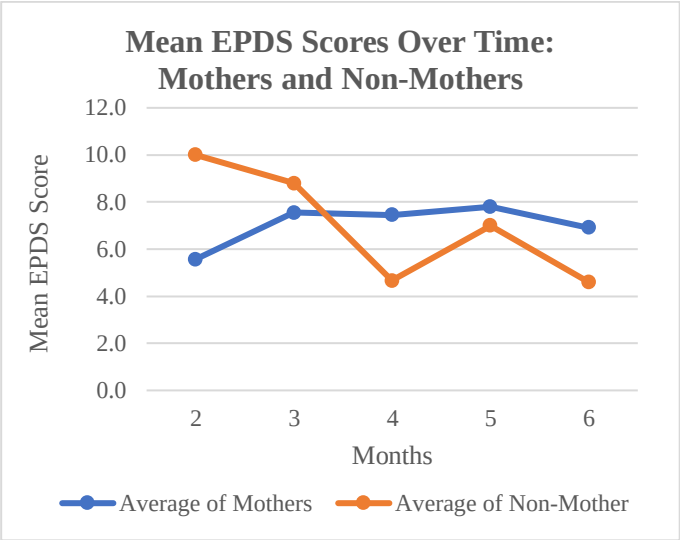

Figure 15: Mean Depression Scores Over Time

Table 14: Sample Size of EPDS Scores Over Time:

Months (n=)	Mothers (n=)	Non-Mothers (n=)
2	7	9
3	9	5
4	11	3
5	10	6
6	11	5

Fig. 14 shows the percentage of each group that scored above the 'moderate depression' threshold over time. At the outset, there was a much higher percentage of non-mothers exhibiting depression than mothers. This then peaked at the 3rd data collection point, and the number then decreased substantially but still only fell below the percentage of mothers with moderate-or-above depression scores in month 5. However, this can partially be attributed to the drop-out of non-mothers with high EPDS scores over time. Contrastingly, the maternal group started off with a relatively low proportion of depressed participants, which also peaked at 3 months. This can be partially attributed to some mothers starting the study at 3 instead of 2 months, (see Table 14 for sample sizes at each time point).

Fig. 15 visualises the mean depression scores for each group over time, as detailed in Table 15. While the mothers' mean increased slightly in month 3, it then remained relatively stable over the following 4 months. Non-mothers', however, was significantly more erratic. It initially began much higher than mothers, but dropped rapidly from months 3-4, then rose again, only to fall once more in month 6. The significant reduction in month 4 is in part a result of 2 international non-mothers having to withdraw from the study as a result of the pandemic.

Despite the apparent differences in mean EPDS scores over the months (Fig. 15, Table 15), a Mann Whitney-U test was run at each time point (Table 16) and showed that there were no significant differences in EPDS scores between the two groups at any given data collection point.

Table 15: Mean EPDS Scores Over Time		
Month	**Mothers**	**Non-Mothers**
2	14.0	13.8
3	11.7	12.3
4	16.0	11.0
5	18.5	19.0
6	15.5	11.0

Table 16: Mann Whitney-U Tests: Depression Differences in Mothers and Non-Mothers			
Month	**U**	**Z**	**p**
2	15.5	-1.711	.087
3	11.5	-1.007	.314
4	11	-.865	.387
5	27.5	-.276	.783
6	19.0	-.979	.328

12.2 Relationship between Sleep Diary and Actigraphic Sleep Parameters and Depression Over Time

The relationship between sleep parameters as recorded by sleep diaries, and EPDS scores, were explored by running Spearman's correlations which found that there was no significant relationship between depression and sleep parameters as recorded by mothers' sleep diaries (Table 17). However, analysis of non-mothers' sleep diaries and depression scores showed some significant relationships (Table 19). There was a negative correlation between MSP and depression at data-collection point 3, *(r(2)=-1.000, p=.001).* At point 4 there was a significant negative relationship between TST and depression *(r(2)=-1.0, p=.001),* a positive relationship between WF and depression *(r(2)=1.0, p=.001),* and between WASO and depression *(r(2)=1.0, p=.001),* and a significant negative relationship between MSP and depression, *(r(2)=-1.0, p=.001),* although this did only include a very low number of cases.

Spearman's correlations of maternal actigraphic sleep parameters and depression scores (Table 18) showed a significant, positive relationship between depression and TST in month 2, which was responsible for 83% of the variance, (*r(6)=.833, p=.039).* There was a significant positive relationship between WF and depression in month 3, responsible for 90% of the variance, (*r(5)=.900, p=.037).* And finally, there was a significant, negative correlation between WASO and depression in month 5, which was responsible for 84% of the variance, *(r(6)=-.841, p=.036).*

Non-mothers' data (Table 20) showed a negative correlation between MSP and depression, *(r(8)=-.738, p=.037),* which was responsible for 74% of the variances, suggesting that those non-mothers who were more depressed were spending a shorter amount of time in bed. There was a negative correlation between WF and depression and between WASO and depression in month 4, *(r(2)=-1.0, p=.001),* suggesting fewer wake episodes and shorter waking duration in those who were depressed. There was also a positive correlation between MSP and depression *(r(2)=1.0, p=.001)* in month 4. In month 6, there was a negative correlation between TST and depression *(r(4)=-1.0, p=.001).* However, this is highly changeable due to depressed participants dropping out, and it is therefore unlikely that it represents any valid findings.

Table 17: Mothers' Sleep Diary Data and EPDS Scores: Spearman's Correlations:												
	TST			**WF**			**WASO**			**MSP**		
Month	**R**	**p**	**N**	**R**	**p**	**N**	**R**	**p**	**N**	**R**	**p**	**N**
2	.194	.713	6	.206	.658	7	.463	.296	7	.393	.383	7
3	.252	.548	8	-.608	.109	8	-.551	.157	8	-.252	.548	8
4	-.136	.708	10	-.274	.476	9	-.115	.753	10	-.401	.250	10
5	-.153	.673	10	-.439	.205	10	-.385	.271	10	-.239	.507	10
6	.157	.665	10	-.136	.709	10	.524	.120	10	.544	.104	10

Table 18: Mothers' Actigraphy Data and EPDS Scores: Spearman's Correlations:												
	TST			**WF**			**WASO**			**MSP**		
Month	**R**	**p**	**N**	**R**	**p**	**N**	**R**	**p**	**N**	**R**	**p**	**N**
2	**.833***	.039	6	.154	.770	6	-.031	.954	6	.679	.138	6
3	.100	.873	5	.900*	.037	5	.00	1.00	5	.500	.391	5
4	.211	.789	4	-.738	.262	4	-.738	.262	4	.105	.895	4
5	-.400	.600	4	-.609	.200	6	-.841*	.036	6	-.754	.084	6
6	-.327	.474	7	-.145	.731	8	.458	.254	8	.289	.487	8

Table 19: Non-Mothers' Sleep Diary Data and EPDS Scores: Spearman's Correlations:												
	TST			**WF**			**WASO**			**MSP**		
Month	**R**	**p**	**N**	**R**	**p**	**N**	**R**	**p**	**N**	**R**	**p**	**N**
2	-.192	.649	8	-.407	.317	8	-.383	.349	8	.119	.779	8
3	-.500	.667	3	-.500	.667	3	-.500	.667	3	-1.000**	.001	3
4	-1.0	.001	2	1.0	.001	2	1.0	.001	2	-1.0	.001	2
5	.224	.718	5	.395	.510	5	.395	.510	5	.447	.450	5
6	-.400	.505	5	-.580	.306	5	-.410	.493	5	-.400	.505	5

Table 20: Non-Mothers' Actigraphy Data and EPDS Scores: Spearman's Correlations:												
	TST			**WF**			**WASO**			**MSP**		
Month	**R**	**p**	**N**	**R**	**p**	**N**	**R**	**p**	**N**	**R**	**p**	**N**
2	-.623	.099	8	.333	.420	8	.119	.779	8	-.738*	.037	8
3	.500	.667	3	-.500	.667	3	.500	.667	3	.500	.667	3
4	M	M	M	-1.0	0.001	2	-1.00	0.001	2	1.0	0.001	2
5	-.258	.742	4	-.783	.118	5	-.447	.450	5	-.355	.581	5
6	-1.0*	0.001	4	.600	.285	5	.821	.089	5	-.900*	.037	5

13. Depression and Maternal-Infant Interactions:

Video data was used to analyse maternal behaviour on each overnight study. The behaviours were calculated as a percentage of the MSP, and then the means of this were calculated for each overnight. Due to the pandemic, not all overnights were completed. Thus, overnight 1 consisted of data from 9 mothers, 3 of whom were categorised as depressed during the month of their stay in the lab. Only 6 mother-infant dyads completed overnight 2, and 2 completed overnight 3. Of these, only 1 mother was depressed in each group.

Non-depressed mothers spent rather more time interacting with their infants in both overnight 1 and overnight 2, a difference which was especially distinctive in the latter. However, on overnight 3, the percentage of the night spent interacting was higher in the depressed mother. This pattern was also true of other behaviours; non-depressed mothers spent more time snuggling with their infant than non-depressed mothers in the first 2 overnight studies, and then in the final one was exceeded by their depressed counterparts. On the first overnight, non-depressed mothers spent more time watching their infants, but this was not sustained in the following two overnights. Depressed mothers remained far more stable, watching their infants for a more consistent amount of time, which exceeded that of the non-depressed mothers in the final two overnights. However, this can almost definitely be significantly attributed to the low number of mothers who completed their third overnight, when only one depressed and one non-depressed mother completed their observations.

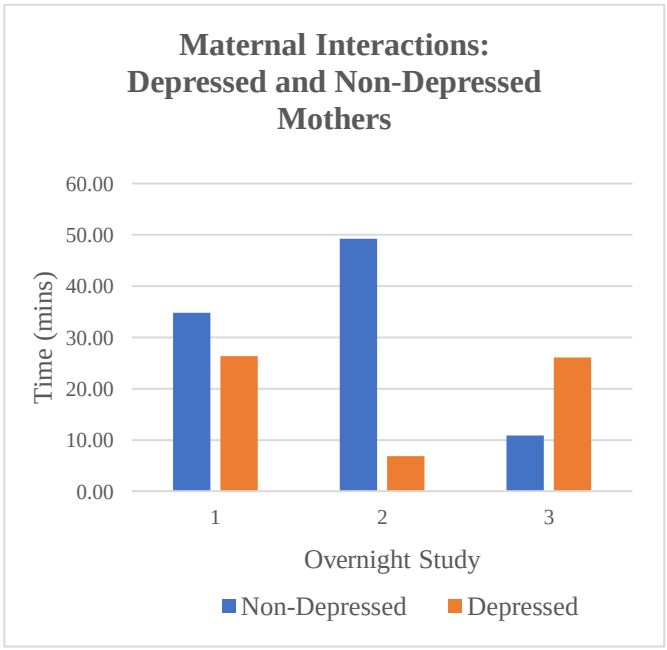

Figure 16: Depression and Time Spent Interacting with Infant

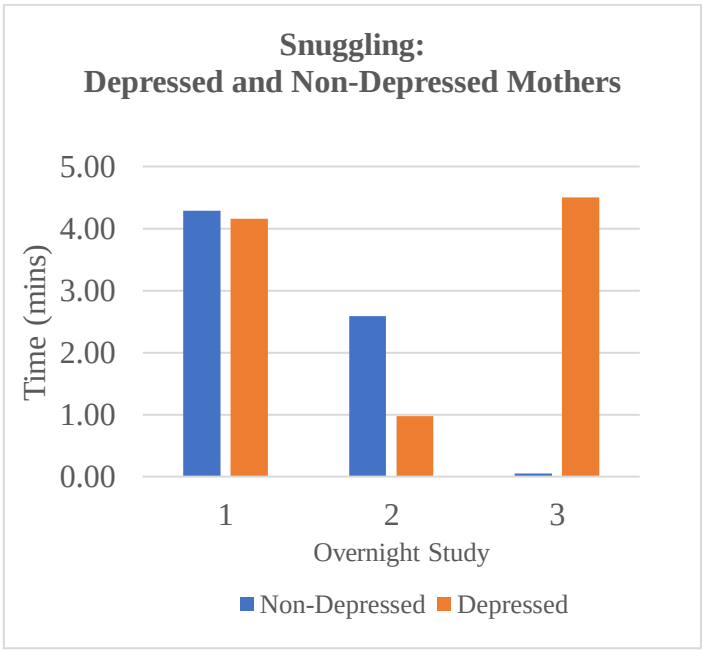

Figure 17: Depression and Time Spent Snuggling with Infant

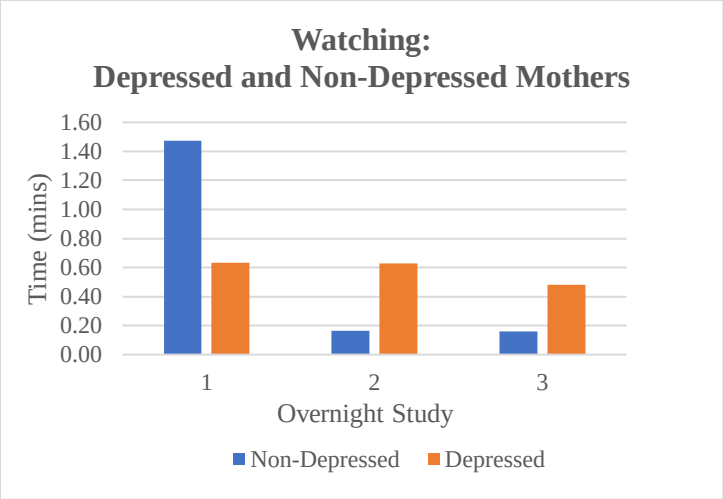

Figure 18: Depression and Time Spent Snuggling with Infant

Table 21: Sample Size of Depressed and Non-Depressed Mothers on Overnight Studies:

Overnights	Depressed (n=)	Non-Depressed (n=)
1	3	6
2	2	4
3	1	1

Mann Whitney-U tests were run on depression and maternal-infant interactions to ascertain whether there was a significant difference in time spent interacting with, watching, or snuggling with an infant according to whether mothers were depressed or not. All p-values fell above the significant figure if 0.05, and thus it can be said that there was no significant difference between the mean ranks of depressed and non-depressed participants on the overnight stays. However, this may be a result of the very low number of participants in the groups in total, and the even smaller number that were classified as depressed during their stay, (EPDS >10).

Table 22: Overnight 1: Mann Whitney-U Tests: Behavioural Differences According to Depression

Behaviour	U-Value	Z-Value	p-Value
Interacting	8.000	-.258	.796
Snuggling	9.000	.000	1.000
Watching	9.000	.000	1.000

Table 23: Overnight 2: Mann Whitney-U Tests: Behavioural Differences According to Depression

Behaviour	U-Value	Z-Value	p-Value
Interacting	2.000	-.293	.770
Snuggling	2.000	-.293	.770
Watching	1.5000	-.632	.527

Table 24: Overnight 3: Mann Whitney-U Tests: Behavioural Differences According to Depression

Behaviour	U-Value	Z-Value	p-Value
Interacting	0.000	-1.000	.317
Snuggling	0.000	-1.000	.317
Watching	0.000	-1.000	.317

Discussion

14. Sleep in New Mothers and Non-Mothers:

It is well documented that maternal sleep is often detrimentally affected in the postpartum period (Gay et al, 2004; Kang et al, 2002; Karacan et al, 1969; Lee and Zaffke, 2002; Matsumoto et al, 2003; Swain et al, 1997). Based on the findings of this study, the following section will discuss which specific parameters of sleep were most affected in the mothers in this study at 2-6 months postpartum compared to a non-postpartum sample, and what was causing maternal night-waking incidents at different time-points.

14.1 Sleep Fragmentation

Sleep fragmentation was analysed by looking at objective and perceived WF and WASO across the study period, which showed that the mothers in this study reported elevated sleep disruption in comparison to their non-maternal counterparts. According to sleep diaries, mothers experienced longer WASO than non-mothers, and higher WF. Mothers objectively experienced longer WASO than non-mothers in all months, which was significantly different in months 2, 5, and 6, while their subjective WASO was significantly different in all months aside from month 6. Mothers' objective WF was only higher in the final two months and not significantly so at any point, but according to their sleep diaries, mothers believed they experienced a higher WF, which was significantly different at all time-points. This reflects the findings of earlier studies, which have shown that WF and WASO are the sleep parameters most significantly affected in the postpartum period (Montgomery-Downs et al, 2010); in essence, maternal sleep "problems" are a result of sleep disruption, as opposed to sleep deprivation (Montgomery-Downs et al, 2010b).

Mothers have been found to experience increased WASO (longer periods of night waking) (Karacan et al, 1969; Matsumoto et al, 2003; Kang et al, 2002). Sleep "disturbances" can last for up to a year postpartum (Lee and Zaffke, 2000), and sleep fragmentation is exacerbated as maternal sleep patterns are driven by the nocturnal needs of the infant in the early postpartum (Butte, 1992), leading to frequent night-time awakenings in response to a signalling or crying infant, and to carry out night-time feeds (Durkheim et al, 2009; John et al, 2008). In WEIRD societies where solitary infant sleep is a pervasive cultural norm, this is very disruptive to maternal sleep. It can be assumed, therefore, that mothers' changeable sleep disturbances were due to infants' own sleep and nocturnal needs constantly undergoing changes and development, especially as over the first 6 months of life, (the period covered by this study), sleep behaviour and physiology mature and sleep-wake patterns undergo reorganisation (Henderson et al, 2010; Sheldon, 2006). The critical period for infant sleep to mature and undergo reorganisation is around 10-12 weeks, when sleep begins to consolidate in some babies (Sheldon, 2006), which explains the findings that both WF and WASO decreased in both sleep diary

data and actigraphy in month 3, (approx. 12 weeks postpartum). This correlates with the findings of Matsumoto et al (2003), whose results showed that in the early postpartum period, TST decreased and WASO increased, but the latter reduced in length at around 3 months postpartum. At this time, true slow-wave sleep develops, comprising double the amount of REM sleep (Sheldon, 2006). The reduction in WF and WASO around this time may have reflected this alteration, as REM sleep is characterised by stretching, muscle movements, twitches, and vocalisations (Sheldon, 2006), which may cause some disruption to maternal sleep despite not being active signalling on the part of the infant.

WF and WASO can be seen to increase once more in months 4 and 5. This can be attributed to another developmental stage in infants' night-time sleep being reflected in maternal sleep fragmentation. Changes at 4-5 months which cause babies to resume night-waking, despite their sleep appearing to consolidate at 3 months. There is an ideal in the West that sleep development has a linear progression, consistently improving from birth, but this is biologically inaccurate. Thus, though parents refer to this period of night-waking after 3 months as "sleep regression", it is perfectly normal (H. Ball, personal communication, 24th November 2020). Mothers sleep fragmentation at months 4 and 5 therefore likely reflects this developmental period in their infants' sleep.

14.2 Causes of Night-Waking

Maternal sleep disturbances are partially dictated by infant-feeding frequency and efficiency, factors which alter according to infant feeding-type (Durkheim et al, 2009; John et al, 2008). While an initial aim of this study was to compare maternal sleep according to feeding type, this was not possible due to issues with recruitment which meant formula-feeders were highly underrepresented in the study population *(n=2)* in comparison to breast-feeders *(n=9).* Despite the negative implications of this for achieving the original study objectives, this unbalanced distribution of feeding-types can be put to use in explaining the WF in the mothers who did take part, and its causes, (see Fig. 11).

The causes of night-waking, as ascertained through videosomnography carried out in the overnight studies, showed them to differ across the postpartum period. Feeding frequency caused the most disruptions to maternal sleep, with its apex being an average of 7 times per night at 2 months of age, with lower frequencies in the following overnight studies. This can likely be explained by the higher number of breastfeeding dyads to formula-feeding dyads. At such a young age, infants must feed little and often, taking in small quantities of milk as a result of their small stomachs (Tully and Ball, 2012). This is especially true of breastfed infants; formula-fed infants feed less frequently throughout the night, taking in more milk in a smaller number of doses as they are less able to identify when they are satiated than breastfed infants (Brown, 2016). As infants' stomachs begin to grow in capacity across the course of the study, one can see the frequency of feeding

decreasing in relation to the initial data collection point at month 2 (Fig. 11), as their habit of feeding little and often was replaced by longer, more sparse feeding bouts.

The other cause of night-waking that was analysed was crying, which was very low in the first two overnight studies, (ages 2 months and 4 months), with an average of 1.4 and 1 times per night respectively. However, this then increased to 3 times per night in the third overnight, (age 6 months). It has been suggested by previous research that as time progresses, mothers' wake-threshold increases; as sleep pressure builds up across the months, mothers are less likely to be awoken by small signals from their infant (Montgomery-Downs et al, 2010b). It is possible that the large increase in crying frequency that can be seen in month 6 is a result of this; if smaller movements and noises were not sufficient to arouse their mothers, infants may have been obligated to signal more forcefully for maternal attention throughout the night as time progressed. This may also have an association with infants' sleep locations. As mothers often use co-sleeping as a mechanism to mediate the trade-off between maternal sleep and infant feeding (Rudzik and Ball, 2016), it therefore stands to reason that they are more likely to have co-slept when feeding frequency was at its highest - in the initial months. The resulting lack of physical proximity in later months would therefore have necessitated more forceful signalling on the part of the infant.

14.3 Other Factors Influencing Night-Waking

The sex of the infant is influential with regards to WF. Unfortunately, it was not possible to account for this factor; the study population was relatively homogenous, with only 2 girls in a sample of 11 infants. A previous study analysing sleep in new mothers using sleep diaries found that male infants tended to feed more frequently, have shorter sleep periods, more sleep episodes, and less sleep than female infants, which subsequently resulted in more fragmented sleep for mothers (Thomas and Foreman, 2005). It is therefore possible that the average subjective WF and WASO as recorded by mothers in their sleep diaries may have been influenced by the dominant presence of male babies in the study.

Parity can influence night-time sleep fragmentation; primiparas tend to have more disrupted sleep than multiparas (Hunter et al, 2009; Lee and Zaffke, 2000; Durkheim et al, 2009; Waters and Lee, 1996). This is believed to be because maternal role "acquisition" induces more fatigue and sleep disruption than maternal role "expansion" (Waters and Lee, 1996). Though this study population was intended to only include primiparas, recruitment had to be extended to multiparas as a result of slow-uptake. Despite their inclusion, it was not deemed necessary to analyse the results on the basis of parity, as its influences on WF have been found to dissipate by 3 months, leaving the two groups with a similar frequency of sleep disturbances (Lee and Zaffke, 2000). Subsequently, parity is likely to only have affected sleep fragmentation in the initial month, when infants were at 2 months postpartum.

Night-time awakenings are also influenced by maternal age, with an older maternal age predicting a shorter TST (Thomas and Foreman, 2005). However, age was relatively diverse across the mothers, (with a range of 24-40), and therefore is unlikely to have held much influence. Moreover, every attempt was made to age-match mothers and non-mothers, and subsequently this should not have affected the results to any great degree.

14.4 Total Sleep Time

The quantities of TST obtained by the participants were very similar to those measured in other studies. At 2-3 months, mothers were obtaining 6.30-6.43 or 6.50-6.31 hours of sleep per night according to actigraphy and sleep diaries respectively, which by 4 months had increased to 7.15 and 6.80 hours per night respectively. This aligned with previous findings that mothers of healthy infants achieve approximately 7.18 hours per night at 2-3 months postpartum (Thomas and Foreman, 2005), and 6.75 hours of TST per night at 3-4 months (Cottrell and Karraker, 2002). Non-mothers TST also fell within the existing parameters, which have suggested an average non-mothers' TST to be 7-9 hours per night (Hunter et al, 2009), with one study more specifically citing 8.53 hours as the average (Quillin, 2004).

As with previous research (Blyton et al, 2002; Durkheim et al, 2009; Montgomery-Downs et al, 2010b), this study's findings suggest that despite increased sleep fragmentation, TST is not significantly affected by the postpartum period; none of the months as recorded by either sleep diaries (Table 6) or actigraphy (Table 5) showed a significant difference in TST. This is because mothers account for sleep disruption by elongating their sleep period, enabling them to obtain semi-normal durations of sleep (Gay et al, 2004; Montgomery-Downs et al 2010b; Swain et al, 1997). This pattern is identifiable in the mothers of this study; excluding in months 3 and 6, mothers exhibited a longer MSP in both actigraphy and sleep diary data than non-mothers. At these time-points, the length of WASO was at its lowest, both objectively and subjectively. Sleep diaries also showed WF to be at its lowest in months 3 and 6, and objectively the lowest WF coincided with month 3. Despite these alterations to WF, WASO, and MSP, maternal TST remained largely unaltered. In months when WF and WASO were reduced, the need to do this was removed and thus their MSP became truncated, at no consequence to their TST.

When MSP was not elongated in compensation, there were adverse effects on TST. For example, in terms of actigraphy, WF was at its highest in month 6, and both TST and MSP were at their very lowest. Despite WF increasing, it seems that in this month mothers did not increase their MSP in response to sleep disruption and consequently their TST was reduced. Additionally, when mothers' MSP was at its lowest and was most similar to non-mothers', their TST dropped significantly below non-mothers. This is evident in the actigraphic data in months 3 and 6, and the sleep diary data for month 3, which demonstrate that while MSP is almost identical between the two groups, mothers achieve substantially shorter TST. This is also supported by the converse

relationship shown in the sleep diary data in months 4, 5, and 6; while both groups exhibit very similar lengths of TST, MSP in mothers leaps above that of their non-maternal counterparts.

Essentially, these findings suggest that although sleep fragmentation is elevated in mothers, mothers counteract the lack of sleep by extending their sleep period, enabling them to obtain TST of a comparable length to non-mothers. This lends further support to the idea that the parameters of sleep affected by the postpartum period are not those that reflect sleep deprivation, but those that represent sleep disruption.

15. Depression and Sleep:

15.1 Depression

The percentage of mothers categorised as depressed was substantially lower than the percentage of non-mothers, which was true of all study months, aside from month 5. This suggests that non-mothers are more inclined towards depression than postpartum women. Previous findings have shown that women are generally more inclined towards mood disorders than men, but they also show women to be at their most susceptible to these during the postpartum period (Goyal et al, 2009), with 30-75% of women suffering from mood disturbances in the first few days after birth (Bei Bei et al, 2010), and 13-20% experience PPD later in the postpartum period (Goyal et al, 2009). This is somewhat supported by mothers' average depression scores, which were higher than non-mothers' in 3 out of the 5 months. However, they were a lot less erratic than non-mothers, and consequently the mean range of their EPDS scores was much smaller; mothers' ranged from 5.57-7.56, while non-mothers' ranged from 4.67-10.00. The fact that the percentage of mothers with PPD was lower, and that their EPDS scores, though often higher than non-mothers, were comparatively stable, suggests that there may be some mechanism at play which is not only reducing the prevalence of PPD but also mediating its presentation during the postpartum period.

While it is not possible to concretely identify the mechanism by which PPD was mediated in this group, based on previous findings one can speculate that it is likely to have been achieved through breastfeeding. Breastfeeding has been shown to have a protective effect against anxiety and depression (Torner, 2016; Groer et al, 2006) due to its influence on rates of circulating prolactin (PRL). Hormonally, PRL plays a role in the expression of depression; findings show that depressed patients demonstrate very low rates of PRL (Torner, 2016; Groer et al, 2006). Additionally, PRL enhances certain behaviours that have been identified as protective against depression. These include enhanced maternal-infant bonding, and maternal behaviour and interactions with the infant (Abou-Saleh et al, 1998). The role of PRL in these maternal behaviours is supported by findings

from animal studies showing that those who lack a functioning prolactin receptor show a significant deficit in maternal care (Lucas et al, 1998, in Larsen et al, 2012).

Given this, the distribution of feeding-types within this study is of great significance; 9 out of the 11 mothers in the final sample were *exclusively* breastfeeding. PRL is higher in breastfeeding mothers than in formula-feeding mothers and non-mothers; PRL surges are doubled in lactating women, and where the normal levels of PRL in non-lactating women stand at 20 ng mL^{-1}, lactating women can present with anything from 30-90 ng mL^{-1} (Blyton et al, 2002). Increased levels of PRL can last for up to 13 months when suckling and feeding is frequent (Bunner et al, 1978); feeding bouts lead to an increase in PRL as it is released in response to suckling (Montgomery-Downs et al, 2010), and it promotes lactogenesis and galactopoiesis (Torner and Neumann, 2002). Frequent suckling is therefore associated with greater PRL concentrations, which drop to baseline levels even between feeds (Tay et al, 1996; Powe et al, 2010). Without lactation, PRL levels in formula-feeding women reduce to those of non-mothers at about 2-3 weeks postpartum (WHO, 2009). It is therefore unsurprising that in a sample dominated by exclusive breastfeeders, fewer mothers were classified as depressed than non-mothers, as it has been found that breastfeeders exhibit fewer negative moods and depression compared with both formula-feeders and non-mothers (Torner, 2016; Groer et al, 2006). This was certainly true of this study, in which one formula-feeder had the highest depression scores in the study in the majority of the months, and the other was also above the depression threshold on several occasions (EPDS >10).

The influence of the feeding type of this group on depression is further evident in the relationship between feeding frequency and depression scores. While Mann Whitney-U tests showed no significant difference between the actual EPDS scores of the two groups at any time-point, the mean EPDS score for non-mothers was initially higher than that of the mothers during months 2 and 3, after which point mothers' EPDS scores superseded non-mothers. EPDS scores were the most distinctive between the two groups in month 2, *($U= 15.5, Z= -1.711, p=.087$),* when both the percentage of mothers who were depressed and mean maternal EPDS scores were at their lowest. This time-point corresponds to a peak in feeding frequency (Fig. 13). Bearing in mind the relationship between PRL and breastfeeding, one can assume that average PRL levels also peaked in month 2, induced by frequent suckling. Considering the links previously discussed between breastfeeding and low anxiety and depression scores (Asher et al, 1995; Abou-Saleh et al, 1998; Groer et al 2006), it seems likely that the low depression scores and percentage of mothers who were depressed in month 2 can be attributed to the interaction between feeding type and depression; as so many participants were breastfeeding, their high levels of PRL induced by lactation may have had a protective effect against depression.

While the high rates in the UK may throw into question the findings that more non-mothers were classified as depressed than mothers, I believe the PPD rates of the UK also need to be considered in terms of infant-

feeding practices. In Britain, exclusive breastfeeding is a rare occurrence, and despite widespread knowledge of the benefits of breastfeeding, formula-feeding has become the social norm (Tomori, 2017). As a consequence, we have the worst breastfeeding rates in the world at 6 months (Infant-Feeding Survey, 2010). While breastfeeding is "supported" by healthcare workers and promoted with campaigns such as "Breast is Best", and though the WHO recommendation for optimal breastfeeding for both maternal and infant health is 6 months-2 years (WHO, 2009), only 1% of mothers in the UK manage to achieve this (Infant-Feeding Survey, 2010). In light of this, it is to be expected that levels of PPD would be significant in the general population, where the protective effects of breastfeeding against anxiety and depression are not being experienced.

15.2 Sleep and Depression

Non-mothers' sleep parameters were more frequently correlated with depression scores than mothers' in both the subjective (Table 19) and objective (Table 20) measures. Mothers' objective sleep parameters were more frequently significantly correlated with depression than their subjective ones; there were no significant correlations between the latter and depression. Meanwhile, both non-mothers' objective and subjective sleep parameters were significantly correlated on more occasions than mothers', with their objective sleep outcomes showing a slightly stronger relationship to depression.

As with depression, the results regarding sleep can be interpreted in the context of infant-feeding. As discussed above, PRL concentrations are elevated in lactating women, playing a vital role in milk supply and production. But PRL also has an effect on sleep, promoting deep sleep and regulating the sleep-wake cycle (Roky et al, 1995; Spiegal and Reuchlin, 1994). It is released episodically following a circadian rhythm, and higher quantities are released during the night than during the day in lactating women (Bunner et al, 1978: Hill et al, 1999). This is believed to be a mechanism through which to sustain milk-supply during long periods without suckling (Stern and Reuchlin, 1990). Essentially this means that maternal sleep differs across feeding types due to the biological composition of breastmilk; it has a soporific effect as it contains specific bioactive proteins that influence sleep behaviour. Four of the key nucleotides within it have a strong circadian rhythm (Montgomery-Downs et al, 2010), meaning mothers often experience feelings of drowsiness after a feed. While lactating women do experience more WASO, it has been found that after an arousal they return directly to deep sleep, irrespective of the time of night at which they have awoken. In addition to this, they spend more time in SWS/NREM (deep) sleep and less time in REM sleep than their formula-feeding or non-maternal counterparts (Blyton et al, 2002). This is crucial, as a key symptom of depression is a decrease in SWS/NREM (deep) sleep (Berk, 2009). I would propose that the relationship between sleep and depression was muted in the maternal sample due to the high prevalence of breastfeeding women, whose lactation may have enabled them to spend more time in deep sleep, as well as preventing PPD.

It has been found that breastfeeding mothers are less likely to perceive their infants' night-time awakenings as problematic than formula-feeding mothers; breastfeeding mothers see them as something natural, something to be accommodated, while formula-feeding mothers view them as a problem to be fixed (Rudzik and Ball, 2016). It is clear that with regards to the relationship between sleep and depression, perceptions of sleep are of great importance and influence the expression and development of depression (Bei Bei et al, 2010; Hiscock and Wake, 2001), and have been found to be more important than the objective quantity and quality of sleep itself (Armitage et al, 1997). It is therefore possible that the lack of correlation between depression and sleep parameters in the mothers of this study can be explained by their feeding type and subsequent perceptions of night-time awakenings; as most were breastfeeding, they were unlikely to view night-time awakenings as problematic, and so though they were experiencing heightened sleep fragmentation, this was not negatively perceived and therefore did not translate into depression.

16. The Influence of Depression on Maternal-Infant Interactions:

There is a noted relationship between maternal-infant relationships and PPD; findings have shown not only that depression may lead to detrimental effects to maternal-infant bonding, but also that enhanced maternal-infant bonding and interactions may be protective against PPD.

It has been found that PPD negatively affects maternal-infant interactions, especially during the first year postpartum (Beck, 1995). It seemed that in this study mothers who were depressed did exhibit fewer interactions with their infant. While there was no significant difference found between the amount of time mothers spent interacting with, snuggling with, or watching their infants on the overnight studies, it was clear that those who were depressed largely spent less time interacting with their infants. This was true on the first two overnights, as was the case with the amount of time they spent snuggling with them. While non-depressed mothers spent more time watching their babies on the first overnight, on the final two the depressed mothers exceeded the mothers in the time spent on this behaviour. There is much evidence to suggest PPD expressly affects physical touching and overt signs of affection (Murray and Cooper, 2015), which is certainly true of the findings of this study, during which depressed mothers were less likely to snuggle and interact with their infants. Depressed mothers are less likely to be affectionate, sensitive, and responsive; they are less likely to pick-up on infant-cues, and thus are less likely to meet infants' needs or respond with positive feedback (Letorneau et al, 2011).

It is of great importance that PPD be identified and prevented as much as possible due to the negative effects it confers on the infant, which can be both cognitive and behavioural (Hatton et al, 2004). For example, infants of depressed mothers are more likely to have lower levels of interactive behaviour, concentration, and affective

sharing, and to report more behavioural difficulties surrounding sleeping, eating, temper tantrums, and separation difficulties, as well as emotional disturbances in later infancy (Murray and Cooper, 1997).

As such a large proportion of participants were breastfeeding and this is known to prime and trigger the maternal-infant bond and interactions (Abou-Saleh et al, 1998), it may have affected the expression of the influence of depression on maternal-infant interactions.

17. Limitations:

Over the course of this project, many obstacles were encountered. Initially, recruitment was a significant problem. While sufficient breastfeeding mothers and non-mothers were recruited, the number of formula-feeding mothers in the study was only 2; it was exceedingly difficult to find formula-feeding mothers who were interested in participating. The consequences of this for the project were quite substantial, as the initial research question was primarily based on a direct comparison of sleep and maternal interactions across feeding types. As a result of the low uptake of formula-feeders, this element unfortunately had to be removed from the study. Furthermore, the comparison between depressed and non-depressed participants was then relatively difficult, as it became apparent that those who were depressed were less likely to return complete EPDS forms and sleep diaries.

Using actigraphy as a data collection method was particularly challenging. On many occasions, both mothers and non-mothers either forgot/chose not to carry out the actigraphy on the dates requested, leaving the batteries to run out and subsequently preventing data from being collected. However, while human error played some part in obstructing data collection, the watches themselves were the most significant impediment. Despite being programmed properly, they repeatedly did not record data, even when instructions were followed by participants. When trying to download files, they would simply present with an error message reading, "Run-Time Error 6", and the data would be unreadable. Despite repeatedly contacting the providers of both the software, (Action W 2.7), and the distributors of the watches, (Watchware), no diagnosis or solution was offered by either. This technological failing resulted in more than a third of data being unreadable, and therefore was an obstruction to the accurate analysis of the data in this project. As a consequence, repeated measures analysis could not be carried out and there were very large gaps in the data, affecting analyses of sleep changes over time.

The most destructive obstacle was, of course, the pandemic. This caused two participants to drop-out of the study, and it was no longer possible to continue recruiting. Unfortunately, lockdown arose midway through data collection, with most participants having completed only one or two overnight studies as opposed to the

three intended. As a result of the pandemic and the national lockdown, these could not continue and therefore no more overnights were carried out. This meant that the latter two "control" measures for the study at 4 and 6 months of infant age were heavily lacking in data, and there was little videosomnography data to compare with that from actigraphy and sleep diaries. Furthermore, while it was eventually decided that we could distribute actigraphs, sleep diaries, and questionnaires via the post, there was a month at the beginning of lockdown in which little or no data was collected, despite me distributing any materials I could during the week prior to lockdown. Though posting materials was a sufficient substitute given the circumstances, it was logistically rather difficult to ensure all participants had their watches at the correct time due to: the limited number of watches; participants being difficult to contact; delivery taking longer than planned; and having to work around available collection/delivery dates. The cumulative effect of all these factors meant that not all participants' data months correspond exactly to their infants' ages, which may mean the results are not as clear-cut or valid as they perhaps would have been under normal circumstances.

The resulting study sample was relatively homogenous in terms of race, socio-economic status, and education. Participants were primarily white, middle-class, and had obtained some form of higher education, with several holding postgraduate degrees. The results provided therefore lack generalisability to, for example, ethnic minorities, groups of lower socio-economic status, and those with a lower level of education. Furthermore, the infants in the sample were equally homogenous, and as well as reflecting the socio-economic status and race of their mothers, all were male aside from two.

The COVID-19 pandemic had a notable effect on participants' depression scores; those who had previously had significantly lower scores showed a sizeable increase, and the number of participants classified as having moderate-severe depression, (>10), also rose. Consequently, the number of participants marked as such in this study is unlikely to be representative of a normal population of either mothers or non-mothers in normal circumstances.

It must be noted that the month in which there were the most correlations between sleep parameters and depression was the month with the fewest number of participants represented in the data. Due to drop-outs, issues with collection of/dropping off materials, technological malfunctions on the side of actigraphs, and general human error in filling out sleep diaries, some months had very few usable data sets. For example, the actigraphy in months 3 and 4 only contained results from 3 and 2 participants in the mothers' and non-mothers' groups respectively. The findings are therefore likely to be skewed and not representative of the study group, let alone a wider population.

With regards to the videosomnography, it was difficult to code the data remotely without access to the Sleep Lab; though the software could be downloaded remotely, it was difficult to do so with any efficiency as the

video files were so large that downloading them was an arduous, time-consuming process. The remote coding was found to be inaccurate and thus had to be re-done upon re-entering the lab. Fortunately, access was eventually gained at the beginning of July, which made matters infinitely easier.

18. Conclusions:

This study has provided an analysis of the relationship between postpartum depression and maternal sleep parameters, (TST, WASO, WF, and MSP). It has also examined the differences between maternal and non-maternal sleep and interrogated why these might occur. The findings show that mothers experience more sleep fragmentation, and have more erratic sleep than their non-maternal counterparts. TST was not found to be significantly affected by the postpartum period, and results suggest mothers extend their TST in response to sleep disruption at night by extending their MSP. Maternal sleep fragmentation was therefore found to be more significantly affected by the postpartum period than sleep duration.

The causes of night-time awakenings have been identified at 2, 4, and 6 months of age. Waking was caused by feeding more frequently than crying at each time-point, with month 2 showing a peak in feeding frequency, which is believed to represent changes to infant-feeding needs over time.

Findings suggest that women are already at a high risk of developing a major depressive disorder, irrespective of the postpartum period. Fewer mothers were depressed than non-mothers, and their EPDS scores were decidedly less erratic. Both objective and subjective sleep and depression were more significantly correlated in non-mothers, suggesting that in the postpartum period there is a mechanism at play mediating the relationship between the two and the expression of depression. Upon analysis, it has been proposed that this mechanism is breastfeeding and the associated circulating hormone, PRL.

Finally, although not statistically significant in any cases, it seems that there is some relationship between maternal-infant interactions and depression; depressed mothers were less likely to engage in physical displays of affection with their infants, such as snuggling and interacting. This may have significant negative impacts on infants in later infancy, as infants of depressed mothers have been found to display cognitive and behavioural issues (Murray and Cooper, 1997). However, despite this apparent connection between the two, it would be rash to draw concrete conclusions regarding this relationship due to the unavoidably small number of observations carried out in this area of the study.

19. Directions for Future Research:

This study has attempted to interrogate the relationship between postpartum depression and sleep. It is clear from its findings that a more in-depth analysis of the sleeping-feeding-depression nexus is required. It is a complex interaction, the directionality of which has regrettably not been ascertained by this study. Given the excessive health implications of PPD, not breastfeeding, and poor sleep on both mothers and infants, it is important that this be given more detailed attention,

Given the suggestion that breastfeeding may mediate the effects of depression on maternal-infant interactions it would be prudent for future research efforts to examine the influence of infant feeding-type on maternal-infant interactions, and whether depression affects these differently according to feeding-type.

It would also be useful for future studies to include a questionnaire or interview to extricate how mothers perceive their infants' WF/WASO. It has previously been found that maternal perceptions of these differ according to infant feeding type (Rudzik and Ball, 2016), but it would be useful to pursue this further and ascertain whether the relationship between maternal perceptions of infants' sleep fragmentation and depression also differs according to feeding type.

It is possible that sleep location may have had an influence on the amount of crying exhibited by infants, which is important as crying has been strongly correlated with depression scores (Dennis and Ross, 2005). It would therefore be wise to investigate the relationship between sleep location and depression, and whether co-sleeping decreases the need for infants to signal to mothers so forcibly. If so, co-sleeping could be implemented as a preventative measure against the development of depression, by way of its positive effects on the frequency of infant crying.

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Appendices

Appendix I: Information Sheet

INFORMATION FOR VOLUNTEERS:

New-Mum-Sleep: An Exploration of How Sleep is Experienced by Mothers of Infants Aged 1-6 Months in Comparison to Non-Mothers

Researchers at Durham University's Infancy & Sleep Centre invite women with babies under 2 months old, and women without babies, to take part in a study exploring women's sleep changes during the first 6 months of motherhood.

What is the study about? Various aspects of new motherhood can affect sleep, including how mothers feed their babies, where babies sleep, and whether postnatal depression is experienced. This study will compare the sleep of new, first-time mothers who choose to either breastfeed or formula feed, with the sleep of women of the same age who are not mothers during the same period. We aim to find out how sleep patterns vary for all 3 groups of women, and how they relate to mood and daytime functioning.

Who do we need? Women of reproductive age who have not had a baby, and women who have recently had their first baby – babies must be under 2 months of age at the time of signing up. All participants must be non-smokers and over 18.

What will it involve? We would like to monitor your sleep (and your baby's sleep if applicable), for 5 nights every month using actigraphy and sleep diaries. Actigraphs are small wrist-worn devices (similar to a fit-bit) that monitor sleep patterns. We will ask you to wear one for 5 days, and ask that babies wear one around their ankle for the same period. Though the watch may be of some concern to parents, there are no potential risks as the watch can be worn over a baby grow and is made from hypoallergenic steel so is unlikely to cause an allergic reaction. The watch is programmed and will begin collecting data at 6pm and will be stopped by the researcher when it is collected from you. We will also ask you to record your sleep and your baby's sleep on a paper form known as a sleep diary. This allows us to compare your sleep perceptions with the data from the actigraph. We will arrange to drop off and pick up the actigraphs and sleep diaries to your home, workplace, or wherever is convenient to you. We will also ask you to complete a questionnaire each month that will allow us to assess mood (e.g. post-partum depression/PPD) and day-time functioning. If your answers suggest you may be experiencing PPD we will recommend you contact your GP or Health Visitor and sign-post you to sources of support. We would also like you to spend a night in our Sleep Lab when your baby is 2, 4 and 6 months old, (3 nights in total). Non-mothers will be age-matched to participating mothers and their data will be collected at the same time points.

The Overnight Study: This will take place in the Sleep Lab, located at Hilton Cottage in Durham, which is like a domestic bedroom with video cameras for us to record sleep patterns and movements, and mother-baby interaction during night-time. When you come to the lab you will follow your normal routine, sleep for the night, and leave in the morning (we provide breakfast). A researcher will be present in another room while you are there to make sure everything records properly. We will ask you to wear an actigraph during your sleep study nights so we can assess the accuracy of the actigraph against the video recordings. This will help us to validate the results.

If you are willing to take part in this research, you will be asked to complete a consent form and an enrolment form about you and your baby. Please see our video about taking part in a sleep study at Hilton Cottage here: https://www.youtube.com/watch?v=uasjsQsgdcc&feature=youtu.be

Confidentiality: All information we collect will be securely stored and remain confidential according to GDPR. All information will be identified using anonymous codes, and your name will not appear in any publications or reports.

Paper copies of information will be stored in a locked location, and online files will be encrypted and password protected. Approval from the Durham University Ethics Committee has been obtained and the project is covered by Durham University indemnity insurance.

A Thank You: As a gratuity we can offer you a £20 high street gift voucher for each of the 3 overnight studies in our sleep lab, and £40 in vouchers for completing the 5-day sleep monitoring for 5 months, (from when your infant is 2-6 months where applicable), to compensate for your time and any expenses you incur in helping us with this research (up to £100 total per participant).

If you choose to help us with this study, you can change your mind at any point and if you decide that you do not wish to continue, you may withdraw at any time and do not have to give us a reason; any information you have provided will be destroyed on request. If you have any further questions or concerns about this study, please speak to the researcher or their supervisor. If you remain unhappy or wish to make a formal complaint, please submit a complaint via the University's Complaints Process.

For more information please contact Ms Fran Tugwell, Durham Infancy & Sleep Centre Project Researcher at francesca.tugwell@durham.ac.uk // 07870 325 692 or Dr Charlotte Russell, Durham Infancy & Sleep Centre Manager, at infancy.sleep.centre@dur.ac.uk // 0191 334 0260. This project is supervised by Durham Infancy & Sleep Centre Director, Professor Helen Ball, Durham Infancy & Sleep Centre, Department of Anthropology, Durham University.

Durham University is responsible for providing information about how personal data is used.

For its general policy, see https://www.dur.ac.uk/research.innovation/governance/privacynotice/generic/

Appendix II: Recruitment Leaflet

The Parent-Infant Sleep Lab:

The Parent-Infant Sleep Lab is located at Hilton Cottage, Old Elvet, in Durham City Centre. Since 1995, researchers at the Parent-Infant Sleep Lab have been studying parent-infant sleep and infant feeding, looking at more than 5,000 parents and their infants, transforming the way parents sleep with and care for their infants as a result of their findings. Previous such studies have included research into the positives and negatives of co-sleeping, safe twin sleep, the relationship between physical proximity on postnatal wards and breastfeeding, and the use of side-car cribs in said wards. As a result of the latter, the use of side-car cribs in postnatal wards has spread internationally to the USA and Australia, demonstrating the importance and practical implications of the research carried out. In recognition of this, the team were awarded the Queen's Anniversary Prize for Higher and Further Education in 2017.

The lab also has an online Baby Sleep Information Source, set up in 2012 in conjunction with UNICEF UK, La Leche League, and the National Childbirth Trust with funding from the Economic and Social Research Council (ESRC), which continues with support from Durham University and provides a useful information source for parents based on evidence-based research.

What do we want to find out?

Through this study we want to uncover variations in the sleep of our three study groups, including:

- how standard parameters vary between the three groups
- how sleep position, night-time movement, and responsiveness vary between the three groups
- how perceptions of sleep duration and fragmentation vary between the three groups
- how daytime functioning varies between the three groups

As a thank you...

For helping us with project, we would like to offer you a £20 high-street voucher per overnight stay, and £40 in vouchers for completing the sleep diaries and actigraphy to compensate for your time.

LOVE2SHOP

NEW-MUM-SLEEP: HOW SLEEP IS EXPERIENCED BY MOTHERS OF INFANTS AGED 1-6 MONTHS IN COMPARISON TO NON-MOTHERS

Durham University

Who do we need?

We are looking for three groups of participants:

- Mothers who are exclusively breastfeeding
- Mothers who are exclusively formula-feeding
- Women of reproductive age without children

All women must be over 18 and all infants must be under the age of 3 months at enrolment. For the purposes of this study, infants born prematurely (under 37 weeks gestation at birth), and those born with a low birth-weight (under 2500g), are not eligible to take part.

As a thank you...

For helping us with project, we would like to offer you a £20 high-street voucher per overnight stay, and £40 in vouchers for completing the sleep diaries and actigraphy to compensate for your time.

LOVE2SHOP

What do we want to find out?

Through this study we want to uncover variations in the sleep of our three study groups, including:

- how standard parameters vary between the three groups
- how sleep position, night-time movement, and responsiveness vary between the three groups
- how perceptions of sleep duration and fragmentation vary between the three groups
- how daytime functioning varies between the three groups

Interested in taking part?

If you have any further questions or would like to know more and register your interest in taking part in this study, please contact:

Ms Fran Tugwell,
Durham Infancy & Sleep Centre Project Researcher
francesca.tugwell@durham.ac.uk
07870 325 692

Alternatively, use our short survey to assess your eligibility and register your interest at:

https://durham.onlinesurveys.ac.uk/enrolment-expression-of-interest

or watch our short introductory video at:

https://www.youtube.com/watch?v=uasjsQsgdcc&feature=youtu.be

Thank you for considering taking part in this study, we look forward to hearing from you soon!

Appendix III: Recruitment Poster

NEW-MUM-SLEEP:

HOW SLEEP IS EXPERIENCED BY MOTHERS OF INFANTS AGED 1-6 MONTHS COMPARED TO NON-MOTHERS.

Durham University

WHO DO WE NEED?

Mums with babies under 3 months who are exclusively breastfeeding or formula feeding, and non-mothers of reproductive age.
All participants must be over 18 and non-smokers.

WHAT IS THE STUDY ABOUT?

Many parts of new motherhood can affect sleep, including how mothers feed their babies, where babies sleep, and postnatal depression. This study will compare the sleep of new mothers who choose to breastfeed or formula feed with women of the same age who are not mothers. Through this we aim to find out how sleep patterns vary across these groups and how they are related to mood and daytime functioning.

WHAT DO WE NEED FROM YOU?

You (and your baby, where applicable) will spend three nights in our sleep lab, located at Hilton Cottage (see inset), over the course of six months, when your baby is 2-3, 4, and 6 months old. At home, you will need to write a sleep diary for 5 nights a month and wear an Actiwatch, to track your sleep (see inset).

Font

AND IN RETURN?

As a thank you and to compensate for your time and any expenses, we would like to give you a £20 high street voucher for each of the 3 overnight studies and £40 in vouchers for completing the 5-day sleep monitoring at 2, 3, 4, 5, and 6 months.

INTERESTED IN TAKING PART?

For more information, please contact:
Ms Fran Tugwell, Durham Infancy & Sleep Centre Project Researcher at
francesca.tugwell@durham.ac.uk
or call 07870 325 692

Appendix IV: Social Media Recruitment Material

PARTICIPANTS NEEDED

CAN YOU TAKE PART?

Do you live in or around County Durham? Do you have a baby under 3 months old? Are you a non-mother of reproductive age? Are you a non-smoker and over 18? Then you're eligible to take part in the latest study at the parent-infant sleep centre!

WHAT DO YOU HAVE TO DO?

We'll give you and your baby (where applicable) an Actiwatch (like a Fitbit) to wear for 5 nights a month, and you will need to keep a sleep diary for those 5 nights. You will also spend 3 nights in our sleep centre at 2-3, 4, and 6 months!

WHAT ARE WE LOOKING AT?

How sleep patterns vary between non-mothers, breastfeeding mothers, and formula-feeding mothers, and how this is related to mood and daytime functioning!

WHAT WILL YOU GET IN RETURN?

Apart from taking part in some very valuable research, you will also get **£100 worth of high-street vouchers!**

Durham University

TO TAKE PART:

Contact Francesca Tugwell at: francesca.tugwell@durham.ac.uk, or fill out this short form: https://durham.onlinesurveys.ac.uk/enrolment-expression-of-interest

Appendix V: Original Press Release

New Mothers and Non-Mothers Needed for Study into New-Mum Sleep.

What's it about?
Durham University's Parent-Infant Sleep Lab is looking for mothers with infants under 3 months old and non-mothers of reproductive age to take part in a study about new-mum sleep.

Many elements of being a new mum can affect sleep, including how mothers feed their babies, where their babies sleep, and whether mothers experience postnatal depression. This study will compare the sleep of new, first-time mothers who choose to either breastfeed or formula feed, with the sleep of women of the same age who are not mothers during the same period. We aim to find out how sleep patterns vary for all 3 groups of women, and how they relate to mood and daytime functioning.

They are looking for mothers with infants under 3 months at the time of registration to take part, as well as non-mothers of reproductive age. All women must be over 18 and non-smokers and live in the North-East of England.

What will you need to do?
Participants (and their babies where applicable), will wear an Actiwatch for 5 nights a month for 6 months. This is like a Fitbit and will be provided. They will also need to keep a sleep diary for the same 5 nights, and spend 3 nights in the sleep centre in Durham city centre corresponding to when their baby is 2-3, 4, and 6 months. Non-mothers will be age-matched to mothers and will also come into the sleep centre.

National award

The Lab's work with more than 5,000 parents and babies during the last 20 years has substantially increased parents' understanding of babies' sleep, how best to care for babies during the night, and how best to keep them safe when asleep.

As a result, the Lab was recently awarded the Queen's Anniversary Prize for Higher Education - the highest accolade for any academic institution and part of the national honours system in the United Kingdom for its research into babies' sleep.

The team conducts studies in people's homes, in hospitals and in Durham University's own sleep lab where parents and babies can be observed during the night with cameras and via breathing, heart rate and temperature monitors.

Parents interested in taking part can contact Francesca Tugwell at francesca.tugwell@durham.ac.uk, register their interest by filling out a brief form at: https://durham.onlinesurveys.ac.uk/enrolment-expression-of-interest, or find out more from https://www.dur.ac.uk/disc/current/nms/

Appendix VI: Press Release for Formula-Feeders

Formula-feeding mothers needed for sleep study by Durham University

For immediate release – 23 January 2020

- **Image available**

Durham University's Durham Infancy & Sleep Centre (DISC) is looking for mothers with babies under three months old who are formula-feeding. Participants will receive £100 worth of high-street vouchers as a thank you for participating.

Many elements of being a new mum can affect sleep, including how mums feed their babies, where their babies sleep, and whether they experience postnatal depression. This study will look at the sleep of new, first-time mothers who choose to either breastfeed or formula feed, in comparison to the sleep of women of the same age who are not mothers during the same period.

The aim is to find out how sleep patterns vary for all three groups of women, and how they relate to mood and daytime functioning.

The DISC team are looking for mums with infants under three months at the time of registration. All women must be over 18 and non-smokers and live in the North-East of England.

Participants and their babies will wear an Actiwatch for five nights a month for six months. This is like a Fitbit and will be provided. Participants will also need to keep a sleep diary for the same five nights, and spend one night in the Sleep Centre in Durham City corresponding to when their baby is two to three, four, and six months, (three in total).

The DISC team have worked with more than 5,000 parents and babies over the last 20 years and have substantially increased parents' understanding of babies' sleep, how best to care for babies during the night, and how best to keep them safe when asleep.

In 2017, the Sleep Centre was awarded the Queen's Anniversary Prize for Higher Education - the highest accolade for any academic institution and part of the national honours system in the United Kingdom - for its research into babies' sleep.

The team conducts studies in the Sleep Centre which is based in Hilton Cottage, Old Elvet, Durham. The centre is designed to replicate a domestic bedroom, but is equipped with video cameras to record sleep patterns and movements, and mother-baby interaction during the night. Participants will follow their usual night-time routine and breakfast will be provided in the morning.

If you are interested in taking part please contact Francesca Tugwell at francesca.tugwell@durham.ac.uk and register your interest by filling out a brief form at: https://durham.onlinesurveys.ac.uk/enrolment-expression-of-interest, or find out more from https://www.dur.ac.uk/disc/current/nms/

ENDS

MEDIA INFORMATION

If you would like further information please contact Francesca Tugwell at francesca.tugwell@durham.ac.uk

Photograph available

A photo of a mum and baby is available on request from Francesca Tugwell at francesca.tugwell@durham.ac.uk

Useful web links

Durham Infancy and Sleep Centre (DISC)

About Durham University

Durham University is a globally outstanding centre of teaching and research based in historic Durham City in the UK.

We are a collegiate university committed to inspiring our people to do outstanding things at Durham and in the world.

We conduct boundary-breaking research that improves lives globally and we are ranked as a world top 100 university with an international reputation in research and education (QS World University Rankings 2020).

Our commitment to providing a wider student experience that fosters participation and leadership at Durham and beyond means our graduates are among some of the most sought after in the world and we are ranked in the top 50 globally for the employability of our students by major companies (QS 2020).

We are a member of the Russell Group of leading research-intensive UK universities and we are consistently ranked as a top 10 university in national league tables (Times and Sunday Times Good University Guide, Guardian University Guide and The Complete University Guide).
For more information about Durham University visit: www.durham.ac.uk/about/

End of Media Release

Appendix VII: Consent Form

Participant Name_____

CONSENT FORM

New-Mum-Sleep Study: how sleep is experienced by mothers of infants aged 1-6 months in comparison to non-mothers

Yes / No	I confirm that I have read the information sheet for participants in this study and have agreed that I am willing to take part. Where applicable I confirm I am willing for my baby to take part.
Yes / No	I understand participation in the study will involve collecting sleep data on myself (and my baby*) for 5 nights per month for 6 months according to an agreed schedule, and wearing an actigraph device for these same 5 nights (wrist-worn for adults, ankle-worn for babies).
Yes / No	I understand participation in the study will involve spending 3 nights (with my baby*) in the Durham University sleep lab at Hilton Cottage according to an agreed schedule, wearing an actigraph device for this night, and being videoed while I am sleeping.
Yes / No	I understand that any information collected for this project will be identified by an anonymous participant ID and stored securely according to GDPR requirements.
Yes / No	I have spoken to …….. who has fully explained the project to me and she has answered my questions to my satisfaction.
Yes / No	I understand that I/we may withdraw from the study at any time, without giving a reason.
Yes / No	I understand I will be given the opportunity to watch the overnight videos made in the sleep lab, and give my final consent for them to be used in this study at that time.

Participant signature (pre-videosomnography) _____

Date _____

To be completed AFTER videosomnography

Yes / No	I have been offered the opportunity to view all of my videos and I consent to them being used in this study.
Yes / No	I give my consent for my data to be used anonymously in academic presentations. I understand my identity will not be used in any publications or reports.
Yes / No	I give my consent for my videos to be saved for up to 6 years following the completion of this study for use in further relevant research.
Yes / No	I confirm that the above statements are correct.

Participant signature (post-videosomnography)_____

Date _____

Durham Infancy & Sleep Centre (DISC), Department of Anthropology, Durham University, UK. infancy.sleep.centre@dur.ac.uk // 0191 334 0260 // www.dur.ac.uk/disc
Please contact us as above should you have further questions.

Appendix VIII:

Edinburgh Postnatal Depression Scale

Please CIRCLE the number next to the answer which comes closest to how you have felt IN THE PAST 7 DAYS, not just how you feel today.

Here is an example, already completed.

I have felt happy:

0 Yes, all the time.
1 Yes, most of the time.
2 No, not very often.
3 No, not at all.

In the past 7 days:

1. I have been able to laugh and see the funny side of things.
   0 As much as I always could.
   1 Not quite so much now.
   2 Definitely not so much now.
   3 Not at all.

2. I have looked forward with enjoyment to things.
   0 As much as I ever did.
   1 Rather less than I used to.
   2 Definitely less than I used to.
   3 Hardly at all.

3. I have blamed myself unnecessarily when things went wrong.
   3 Yes, most of the time.
   2 Yes, some of the time.
   1 Not very often.
   0 No, never.

4. I have been anxious or worried for no good reason.
   0 No not at all.
   1 Hardly ever.
   2 Yes, sometimes.
   3 Yes, very often.

5. I have felt scared or panicky for no very good reason.
   3 Yes, quite a lot.
   2 Yes, sometimes.
   1 No, Not much.
   0 No, not at all.

PLEASE TURN OVER…

In the past 7 days:

6. Things have been getting on top of me.
   - 3 Yes, most of the time I haven't been able to cope at all.
   - 2 Yes, sometimes I haven't been coping as well as usual.
   - 1 No, most of the time I have coped quite well.
   - 0 No, I have been coping as well as ever.

7. I have been so unhappy that I have had difficulty sleeping.
   - 3 Yes, most of the time.
   - 2 Yes, sometimes.
   - 1 Not very often.
   - 0 No, not at all.

8. I have felt sad or miserable.
   - 3 Yes, most of the time.
   - 2 Yes, quite often.
   - 1 Not very often.
   - 0 No, not at all.

9. I have been so unhappy that I have been crying.
   - 3 Yes, most of the time.
   - 2 Yes, quite often.
   - 1 Only occasionally.
   - 0 No, never.

10. The thought of harming myself has occurred to me.
    - 3 Yes, quite often.
    - 2 Sometimes.
    - 1 Hardly ever.
    - 0 Never.

Appendix IX: Mum and Baby Sleep Diary

Please tick the box (or boxes) to show what you and your baby were doing during each 15-minute period shown in the chart, starting at 6:00pm this evening. Leave the boxes blank for the periods when your baby wasn't sleeping, eating or crying/you weren't sleeping. When baby was sleeping please indicate whether each 15 minutes was mostly spent sleeping on you, near to you (i.e. within arm's reach), or away from you (further than arm's reach). It is OK to complete the evening portion before you go to bed, and the overnight in the morning.

Time	Baby					Mum
	Feeding	Crying	Sleeping			Sleeping
			On mum	Near to mum	Away from mum	
6:00pm						
6:15						
6:30						
6:45						
7:00						
7:15						
7:30						
7:45						
8:00						
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10:30						
10:45						
11:00						
11:15						
11:30						
11:45						
MIDNIGHT						
12:15						
12:30						
12:45						
01:00						
1:15						
1:30						
1:45						
2:00						
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5:30						
5:45						
6:00						
6:15						
6:30						
6:45						
7:00						
7:15						
7:30						
7:45						
8:00 am						

Was last night's sleep different from usual for you or for your baby?

If so, please tell us how it was different and what you think is the reason for the difference.

Thank you!

Appendix X: Video Coding Taxonomy

Baby Location:

- In arms
- In cot
- On/in bed
- Off camera
- Other

Baby Activity:

- **Crying:** coded when infant is red-faced, their chest is heaving, and mouth open.
- **Grizzling:** coded when infant is showing signs of slight distress but is not at the stage of crying.
- **Rooting/pre-feed behaviour:** coded when infant is nuzzling, turning head to search for breast, and exhibiting pre-suckling mouth-movements.
- **Snuggling:** coded when infant is awake and being cuddled, (not when breastfeeding).
- **Calm content:** coded when infant is peaceful, lying without much movement, and when asleep and breastfeeding.
- **Active content:** coded when infant can be seen playing with feet/legs/toys/their mother, or when kicking and waving limbs.
- **Can't see:** coded when infant is off-camera.

Maternal Activity:

- **Breastfeeding:** coded from onset to offset of a feeding bout, as represented by attachment/detachment from the breast. Coded as a single bout if the gap between feeds is less than 10 minutes.
- **Bottle-feeding:** coded from onset to offset of a feeding bout.
- **Interacting:** coded when the mother is playing with or talking to her infant, sleeping with an arm on the infant in the cot, or when snuggling.
- **Watching:** coded when the mother is sitting watching the infant, (i.e. not just giving them a cursory glance).
- **Not attending to infant:** when the mother is not watching or interacting, (e.g. when they are holding their infant but are simultaneously on their phone or watching TV).
- **Can't see:** mother and infant are out of sight of the camera.

Mum/Baby State:

- **Awake:** mother and infant are coded as awake if an arousal last for longer than 2 mins
- **Appears asleep:** coded if mother or infant is lying still and not moving. For infants, this is coded after 1 minute of being calm content to avoid unnecessary and incorrect switches between "awake" and "appears asleep"
- **Asleep:** Infants are coded as such when their eyes are closed and they have been settled for 2 minutes. This is based on whether their eyes are open as opposed to their movement to avoid incorrect coding, as infants tend to move and wriggle around in their sleep. Women are coded as asleep after 10 minutes of lying still with their eyes closed.
- **Out of sight:** coded as such when mother or infant is off-camera.