The Relationship between Sleep, Anxiety, and Emotion Recognition in the Perinatal Period.

By

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Thesis Overview

This thesis consists of two papers: a meta-analysis and an empirical study. The thesis also contains two press releases providing a summary of both papers. The research papers aimed to explore the state of the current literature regarding the relationship between sleep deprivation and anxiety in the perinatal period and explore how this relationship may influence a new parent's ability to accurately recognise emotions in infants.

The meta-analysis found an association between sleep problems and anxiety across the perinatal period irrespective of location, time of data collection and anxiety presentation. This was the first meta-analysis of its kind and further questioning into factors which may influence this relationship, including individual participant characteristics and differences between anxiety-related presentations is recommended. The findings of the meta-analysis also highlight an important possible difference between the measurement of sleep quality and sleep quantity as sleep constructs.

The empirical study used a within and between participants design to measure sleep, anxiety, and emotion recognition across the perinatal period. This pilot study found that new parents experience greater sleep disruption and higher anxiety than in pregnancy. Contrary to wider literature, sleep difficulties were not significantly associated with changes in anxiety. For the emotion recognition task, there was a trend for performance decreasing for both parents and controls for Happy stimuli, with performance remaining consistent for Neutral and Sad stimuli. Interestingly, parents' confidence increased at postpartum for all emotional states which differed to changes in confidence identified for control participants.

Dedications

To Johnny. You are my everything. You are the most supportive and understanding partner in life and without you, I would not be here, writing my thesis dedication to you. I did it! We did it! I love you. To Betty, you may be the neediest dog in the world and I'm so glad that it's me you need, as I need you. To Walter, the best boi, I loved you for seven years, and I'll miss you always.

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Chapter One

Meta-analysis: Sleep Deprivation and Anxiety in the Perinatal Period

Abstract

Purpose

A significant amount of research has been conducted exploring the relationship between sleep and anxiety across the perinatal period however, no meta-analysis has been conducted to synthesise the literature in this area.

Method

A search of five databases was completed using search criteria specifically for anxiety, sleep changes and the perinatal period. Papers were reviewed using predetermined inclusion and exclusion criteria, leading to a final number of 32 papers for meta-analysis. Data were extracted and analysed and each paper was reviewed for methodological quality. Subgroup analysis was also completed to explore factors which may be more influential in the relationship between sleep deprivation and anxiety.

Results

This review highlights a moderate, positive, association between sleep problems and anxiety across the perinatal period irrespective of location, time of data collection and anxiety presentation. A high level of heterogeneity was observed across study effects. Subgroup analysis identified differences at the level of sleep measurement, highlighting possible differences between the measurement of sleep quality and sleep quantity as sleep constructs.

Discussion

This is the first meta-analysis of its kind and promotes further questioning into factors which may influence this relationship, such as individual participant characteristics and

differences between anxiety-related presentations. The exploration of individual differences influencing sleep and anxiety in the perinatal period is recommended. Additional recommendations include the incorporation of both qualitative and subjective measures in future research to better understand the differences between physiological markers of sleep and self-rated sleep perception and future research into perinatal-specific anxiety.

Introduction

The human need for sleep is a "widespread biological phenomenon" (Hobson, 2005). Sleep is influenced by various factors including age and developmental stage, individual differences, social norms, cultural practices, and environmental contexts (Barry, 2020). Sleep serves various functions, affecting memory consolidation (Diekelmann et al., 2009), learning (Stickgold et al., 2000), restorative functions, macromolecular synthesis, and neural detoxification (Dijk & Landolt, 2019). Sleep is therefore understood as an actively regulated process, supporting the reorganization of neuronal activity as opposed to a cessation of activity (De Beritto., 2020; Hobson, 2002).

The perinatal period refers to pregnancy through to one year post-delivery. During this time, hormonal fluctuations of pregnancy, birth, and lactation initiate a variety of rapid physiological changes which accompany the dynamic restructuring of the emotional, physical, and social environment (Orchard et al., 2023). Together with these changes, the maternal brain undergoes significant structural and functional neuroplasticity with additional cognitive adaptations in preparation for caring for an infant (Hoekzema et al., 2017).

Emerging evidence has indicated that sleep disturbances during pregnancy are associated with women's poor health outcomes (Chang et al., 2010; O'Keeffe & St-Onge, 2013) and adverse pregnancy outcomes, including gestational hypertension, gestational diabetes, growth restriction and pre-term birth (Nodine & Matthews, 2013). Evidence has indicated that sleep disturbances continue into the postnatal period, with newborn sleep patterns and regular feeding throughout the night contributing to restless sleep and periods of waking for parents (Parsons et al., 2023). Perinatal sleep difficulties have been shown to negatively affect a broad range of cognitive processes (Anderson & Rutherford, 2012; Orchard et al., 2023) and are positively associated with anxiety (Clout & Brown, 2015; Hall et al., 2009; Lin et al., 2021; MoghaddamHosseini et al., 2021; Qui et al., 2016; Swanson et

al., 2011; Teoh et al., 2021; Wang et al., 2021; Wang et al., 2022; Yildirim & Demir, 2019). There is a growing body of evidence that explores the prevalence of sleep difficulties and anxiety across the perinatal period, however, there is currently no meta-analysis of the relationship between changes in sleep and associations with anxiety in the perinatal period.

Possible Causes of Sleep Problems in the Perinatal Period

Changes in sleep and sleep disorders are among the most widespread problems across pregnancy (Hunter et al., 2009; Palagini et al., 2014; Pien & Schwab, 2004) and the postnatal period (Parsons et al., 2023; Zhang et al., 2021). Both the quantity and quality of sleep have been shown to alter during pregnancy (Mindell & Jacobson, 2000; Smyka et al., 2020) and studies have documented trimester-specific changes in sleep throughout this period (Christian et al., 2017; Parsons et al., 2023; Zhang et al., 2021). Common causes of poor sleep during pregnancy are often physical, with nausea/vomiting, urinary frequency, and backache often experienced, which changes throughout trimester two and three where increased foetal movements, heartburn, cramps, tingling in the legs, and shortness of breath have been identified as negatively impacting sleep (Hutchinson et al., 2012; Mindell & Jacobsen, 2000; Mindell et al., 2015; Schweiger, 1972).

There are a variety of contributing factors to why many new parents experience problems with their sleep. In the postpartum period, mothers experience many changes which return the body to the non-pregnant state (Chauhan & Tadi, 2020). Physiological changes that are only experienced by a biological mother of a new baby, include changes linked to diuresis, menstruation and haemoglobin which can last up to 12 months following childbirth (Chauhan & Tadi, 2020), prompting further disruption to sleep. In addition to physiological factors, environmental changes occur through the natural process of having a new baby, affecting all those in a caring role in the home. It has been identified that an infant's sleep

quality and quantity directly influence a parent's own sleep, with parents having to be responsive and attend to the needs of an infant throughout the day and night, (Meltzer & Mindell, 2007). There are several further factors specific to the parenting role, including responding to feeding throughout the night, which is linked to poorer sleep (Kendall-Tackett et al., 2011) and it is important to consider the potential consequences of poor sleep for a pregnant person across the perinatal period.

Anxiety in the Perinatal Period

Complex neurobiological, social, and environmental changes in the perinatal period contribute to increased risk for mental illness (Dennis et al., 2017; Tomfohr-Madsen et al., 2021). Perinatal anxiety rates are high when compared with the general public (Viswasam et al., 2019) due to a variety of contributing factors. A meta-analysis reviewing 26 studies across pregnancy and the post-partum period identified that prevalence varied broadly across samples, with individual disorder prevalence estimates ranging from 1.1% for posttraumatic stress disorder to 4.8% for specific phobia, with the prevalence of having at least one or more anxiety disorder estimated to be 20.7% (Fawcett et al., 2019). Moreover, anxiety rates have been shown to be higher during times of stress, with two meta-analyses of 47 studies exploring depression and anxiety in pregnancy during the COVID-19 pandemic, revealing a prevalence of clinically significant generalised-anxiety across studies of 30.5% (Tomfohr-Madsen et al., 2021) and 34% (Sun et al., 2020).

The onset of anxiety difficulties across the perinatal period is variable. Longitudinal studies have reported that 21.2% of participants experienced an anxiety disorder in the first trimester, with specific phobia being most experienced, which reduced across the second and third trimester (Martini et al., 2013). The onset of Panic disorder, phobia otherwise not specified (Martini et al., 2013) and Obsessive-Compulsive Disorder (Kaya et al., 2015) have

been highlighted in the second trimester, and following birth. Postpartum rates of anxiety indicated that Agoraphobia, Specific Phobia, and Generalised Anxiety Disorder increased in the first 4 months following the birth of a baby (Martini et al., 2013).

Anxiety in the perinatal period has been associated with lower oxytocin levels, higher relationship difficulties and an anxious attachment style, whilst influencing upbringing attitudes (Eapen et al., 2014). Perceived difficulties in forming attachments with their infants, and low feelings of 'bonding' were also highlighted for mothers who experienced anxiety disorders compared to non-anxious mothers (Tietz et al., 2014). For mothers experiencing social anxiety, it was found that increased avoidance associated with anxiety led to mothers being less likely to interact with people they didn't know and less likely to encourage their infant to interact with others, with the infants showed reduced social interaction and social responsiveness (Murray et al., 2007).

Possible Causes of Anxiety in the Perinatal Period

Risk factors in the development of anxiety across pregnancy include medical factors, smoking, disease, or injury, (Soto-Balbuena et al., 2018) alongside hypertension and higher-risk pregnancies (Fairbrother et al., 2016; Kang et al., 2016). Antenatal anxiety has also been related to factors including lower levels of academic achievement, relationship difficulties, overall life satisfaction (Kang et al., 2016), changes in the behaviour or a relative and changes in the frequency of seeing family or friends (Soto-Balbuena et al., 2018).

In new parental roles, changes may occur at all levels of family life and anxiety can increase towards the end of maternity and paternity leave, influencing the stress in relation to returning to work (Grice et al., 2011). Alcoholism and drug addiction in a partner and changes in the frequency of seeing friends and family and the quality of these relationships, has also been identified as influential in developing anxiety in the postnatal period (Soto-

Balbuena et al., 2018). These factors contribute to increased difficulties in areas of marital life, personal wellbeing, stress, and mental health (Miller & Sollie, 1980).

Link Between Sleep Problems and Anxiety

In the general population, the need for sleep and overall sleep architecture changes throughout the lifespan, with an association between sleep deprivation and a triad of neurobehavioral comorbidities; increased irritability, attention-deficit, and increased anxiety (Alhola & Polo-Kantola, 2007; Dement, 1960). Anxiety is frequently reported to be associated with sleep problems (Pires, 2010), with lengthy periods of sleep deprivation shown to significantly increase state anxiety over shorter periods of sleep disruption (Pires et al., 2016). The relationship between sleep and anxiety is bi-directional, and studies exploring how sleep loss may perturb mood in a healthy population (Short & Louca, 2015) have found that poor sleep is associated with increased anxiety and overall reductions in emotional and physical wellbeing (Haack & Mullington, 2005).

The relationship between sleep deprivation and anxiety is complex. A meta-analysis reviewed 120 papers exploring sleep in anxiety-related disorders which highlighted an association between increased subjective sleep disturbance, decreased total sleep time, increased sleep disruptions and decreased sleep depth in participants with anxiety-related disorders compared to healthy controls (Cox & Olatunki, 2020). Sleep loss and insomnia are conceptualised as a common symptom, comorbidity or consequence experienced in disorders such as generalised anxiety disorder, panic disorder, obsessive-compulsive disorder, and post-traumatic stress disorder (Pires et al., 2016).

The Relationship Between Sleep and Anxiety in the Perinatal Period

In pregnancy, sleep difficulties in the first and second trimesters have been shown in to predict sleep difficulties and higher levels of anxiety experienced in the third trimester (De

Chiara et al., 2021; Ko et al., 2010; Kuo et al., 2014; Sedov & Tomfohr-Madsen, 2021; Smyka et al., 2021; Yang et al., 2018; Yu et al., 2017). Variability regarding changes in sleep across the first year postpartum, has also been observed, with a decline in sleep quantity, quality, and efficiency being associated with increased anxiety levels at 15 days post childbirth (Kuo et al., 2014) and at 42 days postpartum (Wang et al., 2018). Studies have found that shorter sleep duration and poorer sleep quality during pregnancy significantly predicted high and moderate anxiety levels at 3-months postpartum (Cohen et al., 2022; Gueron-Sela et al., 2021; Osnes et al., 2020) and 6-months post-partum (Cohen et al., 2022; Tomfohr et al., 2015).

Within the literature, subjective measures (e.g., questionnaires, validated psychometric assessments, sleep diaries) have largely been used to explore sleep difficulties, largely focusing on the construct of sleep quality, in terms of efficiency of overall sleep or perception of sleep, as opposed to duration of time asleep. In comparison, objective measures (e.g., actigraphy device) invariably record the construct of sleep quantity using various physiological markers. Variety is also observed in the subjective measurement of anxiety in the literature, as numerous questionnaires and validated psychometric assessments have been used in relation to differing presentations of anxiety (e.g., generalised anxiety, panic disorder, specific phobia). A low agreement has been identified between subjective and objective measures, and levels of anxiety have been observed to influence the perception of sleep difficulties, (Volkovich et al., 2016). There are varying estimates as to the relationship between sleep and anxiety in the perinatal period, therefore synthesising the literature is of importance.

Rationale

Sleep is an essential part of human everyday life, serving a multitude of functions.

The perinatal period is a time of great biopsychosocial change with associated risks in terms of impacting sleep and mental wellbeing. Many studies have explored the role between anxiety and sleep, during pregnancy or postpartum, with varying results, and fewer studies have focussed across the perinatal period. There is currently no published meta-analysis exploring the relationship between anxiety and sleep deprivation across the perinatal period. Given the variety in methodology to collect sleep and anxiety data across the literature and that published estimates have varied, a meta-analysis is important to summarise the current state of the literature. Additionally, quantitative summary in the form of a meta-analysis will provide an opportunity to explore how factors such as method of data collection and sleep construct may influence an observed association through a series of sub-analyses. Exploring these methodological factors may highlight opportunities for future research to evolve and may also influence clinical practice, through highlighting differences in what measures may be recording and how this may influence the relationship in question. The present meta-analysis will also look at factors in the literature that may impact the strength of the relationship between sleep and anxiety, such as the time point at which sleep is recorded, location of the study and which will also be separated by type of anxiety-related disorder.

Method

Identifying Primary Studies

Search of electronic databases

The present review was registered on the PROSPERO register of systematic reviews (28th January 2022, CRD42022287601). A systematic search for relevant papers was conducted on 1st August 2022 using five electronic databases: OVID Medline ® (1946), Embase (1974), APA PsycINFO (1967), PubMed and Web of Science (1997). No restrictions

were placed on the search databases. The aim of the search was to obtain a comprehensive overview of the literature into the relationship between sleep deprivation and anxiety in the perinatal period (pregnancy and the first year postpartum). The focus of the meta-analysis was on papers that analysed the linear correlation between levels of anxiety and sleep quality/quantity during the perinatal period. Papers that took an alternative analytical approach e.g., those that looked at sleep quality across anxiety disorder categories, were not included. Where papers reported collected data suitable to calculate a correlation, but did not do so, the authors were contacted. PRISMA guidelines were followed for meta-analytic method and reporting.

All databases were searched from their earliest record. Duplicates identified across the OVID databases (PsycINFO, Embase and Medline) were removed using the deduplicate function available at the point of searching. Any further identified duplicates were manually removed using Zotero referencing software. The key search terms (Table 1) were used to explore titles, abstracts, keywords and anywhere in the text that a term appeared.

The present meta-analysis aimed to review the current state of literature regarding sleep changes and anxiety in the perinatal period. 'Anxiety' was conceptualised to include generalised anxiety, perinatal anxiety, stress, obsessive-compulsive disorder, post-traumatic stress disorder, panic and phobias, defined as 'Anxiety Disorders' in the Diagnostic and Statistical Manual of Mental Disorders, 4th ed, text revised, (DSM-IV-TR, 2000), as these disorders are similar in symptom content (i.e., fear, distress, avoidance), and sleep disturbance has been linked to each of these disorders. PTSD and OCD have been removed from 'Anxiety Disorders' in the Diagnostic and Statistical Manual of Mental Disorders, 5th ed, (DSM-5; American Psychiatric Association, 2013), however, they were included in this meta-analysis to include potentially influential studies, and the small number of papers linked to each presentation would likely not fulfil the criteria for disorder specific meta-analysis at

this time. This decision aligns the present review with a recent meta-analysis exploring the relationship between sleep and anxiety-related disorders in the general population (Cox & Oltunji, 2020). Including PTSD and OCD in the search terms as per the DSM-IV criteria may also be useful clinically, where anxiety-related disorders have similar assessment and intervention pathways irrespective of diagnostic criterion. Free text search terms were combined across the constructs of Sleep, Perinatal and Anxiety with the Boolean operator "AND". Of note, the free-text search terms regarding sleep were purposefully broad to not include sleep disorders which may lead to significant selection bias and an overestimation of the prevalence of poor sleep quality in the population.

Table 1

Meta-analysis Search Terms

Construct	Free Text Search Terms
Sleep	Insomnia OR Sleeplessness OR Sleep-deprivation OR Sleep
Perinatal Period	Perinatal OR Postnatal OR Prenatal OR Postpartum OR Maternal OR Pregnan*
Anxiety	Anxi* OR Obsessive compulsive OR Panic OR Agoraphobia OR Post-traumatic stress OR Stress disorders OR Social phobia OR Phobia

Inclusion criteria

Studies were considered eligible for inclusion if they met the criteria outlined in Table 2.

Table 2

Inclusion and Exclusion Criteria

Inclusion criteria	Exclusion criteria
Participants are adults, within the perinatal period: pregnant or have a child up to the age of 1	Does not examine the association between sleep deprivation and anxiety within a perinatal population
Examines the link between sleep and perinatal anxiety	Studies including perinatal and/or postpartum women with severe sleep problems, such as restless legs syndrome (RLS) or obstructive sleep apnoea (OSA) as their inclusion may lead to significant selection bias and an overestimation of the prevalence of poor sleep quality
Examined the relationship between sleep quality and anxiety using correlation coefficients	Papers written in any language other than English
	Reviews, Editorials, Conference Abstracts
	Qualitative methodology
Published peer review journal article	Intervention studies
	Non-human subjects

Reference lists of papers included in the meta-analysis were screened by CG for any additional articles. To consider the risk of participant overlap, CG screened the method section including any demographic variables of papers published by the same research team, where details were available.

Validity and Reliability check

To provide validity and reliability regarding the search strategy, a random sample of 20% of the papers identified in the initial search, following removal of duplicates (n = 1184), were reviewed by a second rater ('RM', n = 237), using the same inclusion/exclusion criteria. A virtual meeting was held between the first (CG) and second (RM) rater to discuss included/excluded papers based on the criteria given. This was led by the second rater as to minimise the risk of collusion in identifying papers to include in the meta-analysis. Following clarification that post-traumatic stress disorder fell under the umbrella of 'anxiety' for this review, there were no disagreements on papers to be included in the meta-analysis.

Data Extraction

All data were extracted by the first author (CG). Full texts of the papers included for analysis were obtained and were quality-rated, with data extracted from each paper. Data extraction included demographic information, sample size, recruitment process, identification and recruitment of a perinatal population, measurement of sleep and measurement of anxiety. For papers where data extraction was not possible, the authors of the studies were contacted and asked to clarify or provide relevant information for the meta-analysis.

Where papers presented data for multiple anxiety measures ($k = 4$), those with the highest reliability statistics, as presented by the authors, were used to ensure data quality.

Quality Assessment Framework and Risk of Bias Assessment

A quality assessment framework (QAF; Table 3) was developed following the structure of Mingins et al., (2020). The QAF was designed to measure the methodological limitations of each study in relation to the goals of the meta-analysis, and factors associated with reliability and validity in the literature, such as problems with sample or measurements of sleep or anxiety. Each paper was rated (0–3) on four factors, with overall score being the total of these ratings. For the risk of bias assessment, the four areas of the Quality Assessment Framework were recoded as “low risk” (i.e., by combining the good and excellent categories) or “high risk” (i.e., by combining the poor and fair categories).

Table 3

Quality Assessment Framework

Item	Poor (0)	Fair (1)	Good (2)	Excellent (3)
Sample identification of a perinatal sample	Unspecified	Single restricted or non-random sample, for example, a specialist clinic providing maternal healthcare or previous research study or Single regional sample, for example, a regional parent support group/clinic, a NICU	Multiple restricted or non-random samples, for example, multi-region specialist clinics, National non-random sampling, for example, national parent support groups/clinic	Random Sample
Measurement of sleep Reliability/validity of measurement of sleep	Self-report through an unvalidated measure using Likert scale responses (e.g., 1 = no sleep disturbance, 2 = mild sleep disturbance etc.) or closed options (e.g., 'Good sleep', 'poor sleep') OR a self-report sleep diary without clear details	Self-report using a well validated measure (e.g., Pittsburgh Sleep Quality index [PSQI]; Basic Nordic Sleep Questionnaire [BNSQ]). This may be used alongside a self-report sleep diary OR solely use a sleep diary (including clear details e.g., Time to sleep, periods of waking)	Use of objective sleep measurement device (e.g., Actigraphy wrist device) which may be used alongside a validated sleep measures (e.g., PSQI) or self-report sleep diary	Use of objective measurement device (e.g., actigraphy device), following guidelines/protocol, for a minimum period of 5 nights, which will be used alongside a validated sleep measure (e.g., PSQI) or self-report sleep diary
Measurement of anxiety Reliability/validating of anxiety measure (to include generalised anxiety, OCD and PTSD)	Unspecified	Self-report through an unvalidated measure using Likert scale responses (e.g., 1 = low anxiety, 2 = mild anxiety, 3 = moderate anxiety etc.) or closed options (e.g., 'Yes/No' in response to experiencing anxiety)	Self-report using a well validated measure, but not validated for the present sample (not validated for perinatal groups). (e.g., GAD-7, STAI, HADS, DASS, PROMIS, OCI, IES-R)	Self-report using a well validated measure which is validated in the present perinatal population (e.g., PSI-SF, PSS, PRAQ-R2, PASS)
Appropriate use of statistical tests	Unspecified or inappropriate analysis	NA	NA	Appropriate analysis using statistical tests

The first factor referred to ensuring that the process for recruiting the sample was appropriate for the study, with a random sample being excellent; multiple/national restricted or non-random samples being rated as good and single restricted or non-random sample, for example, a specialist clinic providing maternal healthcare or single regional sample being rated as fair.

The second and third factor referred to the validity and reliability of measures used in the studies. These were the measurement of sleep and anxiety, respectively. In terms of sleep, studies were rated as excellent if they used an objective measurement device (e.g., actigraphy device), following clear guidelines/protocol. A rating of good was given for the use of an objective sleep measurement device (e.g., Actigraphy wrist device) which was used without reporting/using a clear guide/protocol, which may be used alongside a validated sleep measure (e.g., PSQI). Where self-report was used through a well validated measure, used alongside a self-report sleep diary, OR solely use a sleep diary (including clear details e.g., Time to sleep, periods of waking), this was rated as fair. A rating of poor was given to the measurement of sleep through unvalidated measure using Likert scale responses (e.g., 1 = no sleep disturbance, 2 = mild sleep disturbance etc.) or closed options (e.g., 'Good sleep', 'Poor sleep') OR a self-report sleep diary without clear details.

Regarding Anxiety, a rating of excellent was given to self-report measures that were validated for a perinatal population and a rating of good was given to measures which were validated for anxiety however, not validated for specific use in perinatal populations. Self-report methods, through an unvalidated measure using Likert scale responses (e.g., 1 = low anxiety, 2 = mild anxiety, 3 = moderate anxiety etc.) or closed options were given a fair rating, and where measures were unspecified, this was given a poor rating.

The final factor measured analysis and was scored only as poor or excellent with no intermediate values, in contrast to the other factors presented. A score of excellent was given

if statistical analysis was appropriate, and a score of poor was given if analysis was not specified. The final version of the criteria were used by the author (CG) to score all papers.

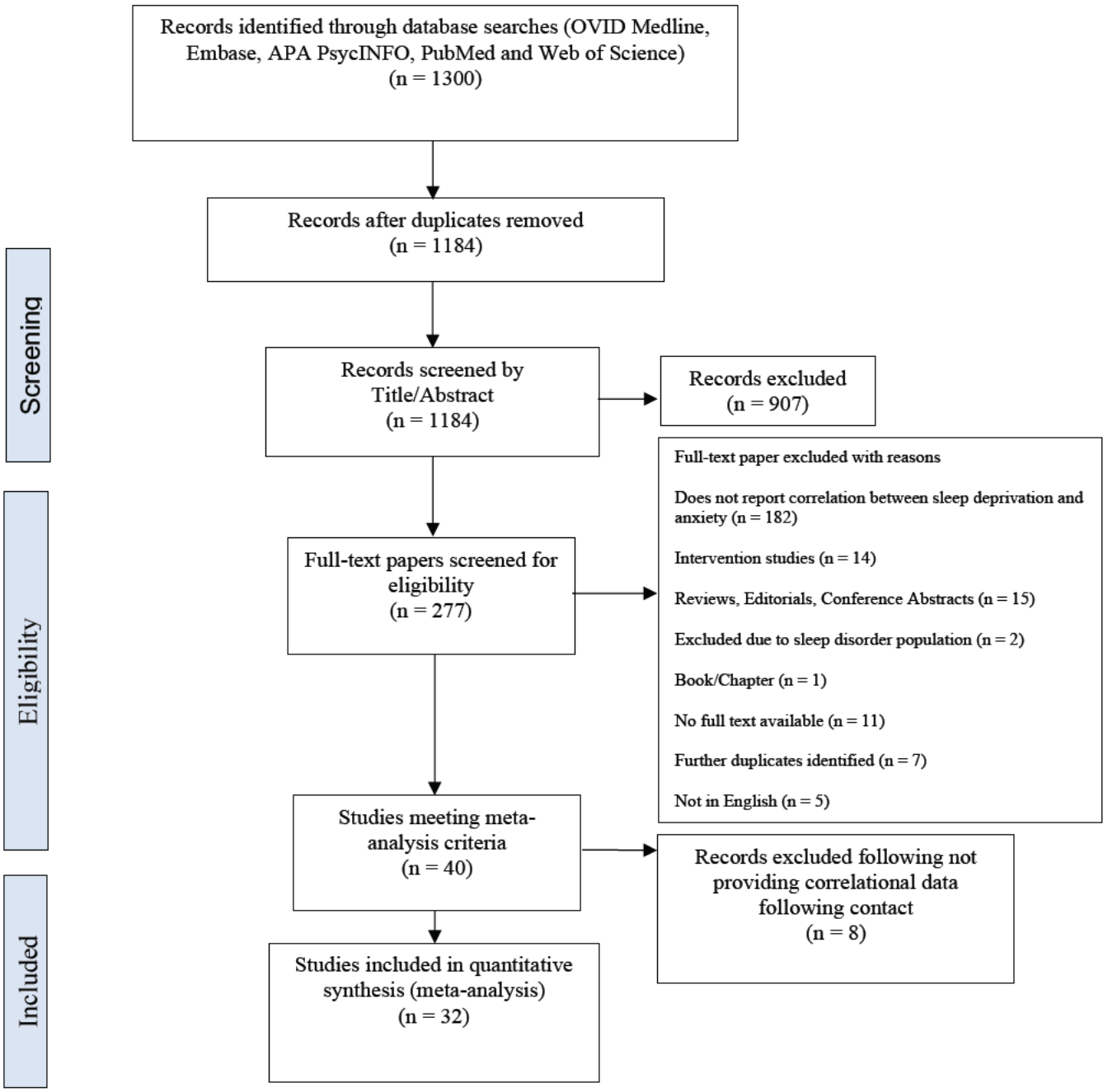
Results

Study Selection

The results of the systematic search are presented in Figure 1. The initial search yielded 1300 papers. Following the removal of duplicates, 1184 papers remained. The remaining papers were screened by title and abstract using the exclusion criteria in Table 2. Of the 1184 papers, 907 were screened out, with 277 papers remaining. Following a full-text search of the remaining 277 papers against the inclusion/exclusion criteria, 237 papers were excluded; with reasons illustrated in Figure 1. Forty papers satisfied criteria for the meta-analysis. Of these forty papers, ten (Bei et al., 2010; Carrega et al., 2019; Gao et al., 2019; Hall et al., 2009; Kugbey et al., 2021; Kuo et al., 2014; Polo-Kantolaet al., 2017; Teoh, 2021; Tham et al., 2016; Zhang et al., 2021) reported regression analysis without correlations and authors were contacted to provide correlational data. Two authors (Hall et al., 2009; Teoh, 2021) provided correlational data and could be included in the analysis, thus thirty-two papers were included in the meta-analysis.

Figure 1

PRISMA Diagram Illustrating the Results of the Systematic Search and the Application of the Exclusion Criteria



The relationship between anxiety and sleep measured in the perinatal period

The relationship between anxiety and sleep measured in the perinatal period, was reported by 32 studies recording 85 effects in 9127 participants. Due to the number of effects reported across some studies, the harmonic mean was calculated to estimate this sample size. The reported effect size was the Fisher's z transformed correlation coefficient for the relationship between anxiety and sleep measured in the perinatal period. This transformation was undertaken as the raw correlation coefficient is not linear in its distribution, becoming highly skewed at its boundaries. Fisher's z transformation returned an effect size where the distribution is approximately normal, and the variance is stable over different values of r. However, if not otherwise indicated then this effect size was back transformed into a Pearson's r correlation coefficient for presentations in tables and figures.

The relationship between anxiety and sleep measured in the perinatal period reported in the primary studies are reported in figure 3. The studies included used multiple methods to recruit participants; through antenatal clinics associated with local hospitals (26), random sampling through online/social media adverts and baby shows (4) and specialist clinics (2) with a nationwide reach, differences which are outlined in the risk of bias assessment. A greater number of studies were of cross-sectional (20) than longitudinal design (12), with many studies exploring sleep and anxiety in pregnancy (18), in the postpartum period (10) and a smaller number across the perinatal period (4). Many studies used subjective measures (30) to measure sleep, with a smaller number of studies using both objective and subjective measures (2). Regarding anxiety in the present studies, a variety of subjective measures were used to explore non-specific Anxiety (27), Obsessive-Compulsive Disorder (1), Postnatal-anxiety (1), Pregnancy-anxiety (1) and Post-Traumatic Stress Disorder (2). A small number of studies explored anxiety within the COVID-19 pandemic (2). Studies were conducted in

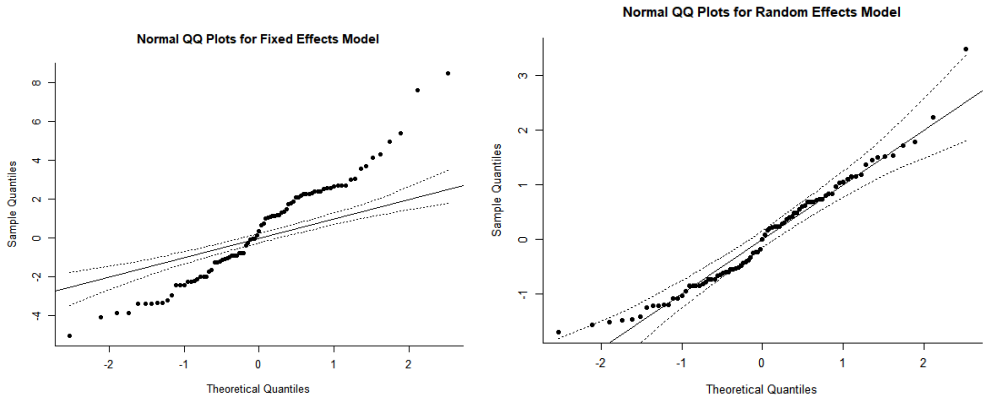
various locations around the world including Australia, Canada and the United States of America, Japan and China, Malaysia, Israel, Hungary, Italy, Türkiye, and Finland.

Selection of the meta-analytic model

The distribution of primary study effects is shown in Figure 2. The between studies variance (tau^2) in the random effects model was calculated using the TAU Method.

Figure 2

QQ plot of the distribution of Z correlations within the primary studies.



As can be seen from figure 2, there was clear evidence of non-linearity in the distribution of correlations in the fixed effect model, which is largely absent when the random effects model was used. Accordingly, the random effects model using the restricted maximum likelihood estimator appeared to be an appropriate analytical model for these data.

As multiple effects were reported for many studies the three factor random effects model (which controls for between and within study variation) was compared to the two factor random effects model (which only controls for between study variation).

Table 4

Comparison of the REM with and without within studies variation.

	Df	AIC	BIC	AICc	logLik	LRT	pval	QE

Three factor model	3	-89.62	-82.33	-89.32	47.81			598.05
Two factor model	2	-80.78	-75.91	-80.63	42.39	10.84	0.001	598.05

As can be seen from table 4, controlling for within studies variation (i.e., variation attributable to the use of different measures) resulted in a statistically reliable improvement in accuracy of the random effects model. The decomposition of variance attributable to sampling variation, between studies variation and within studies variation is presented in the table below (table 5). As approximately 10.5% of the total variation between studies could be attributed to within study variation, the three-level model was selected as the appropriate random effects model for analysis of these data.

Table 5

Sources of variation in the three-level model

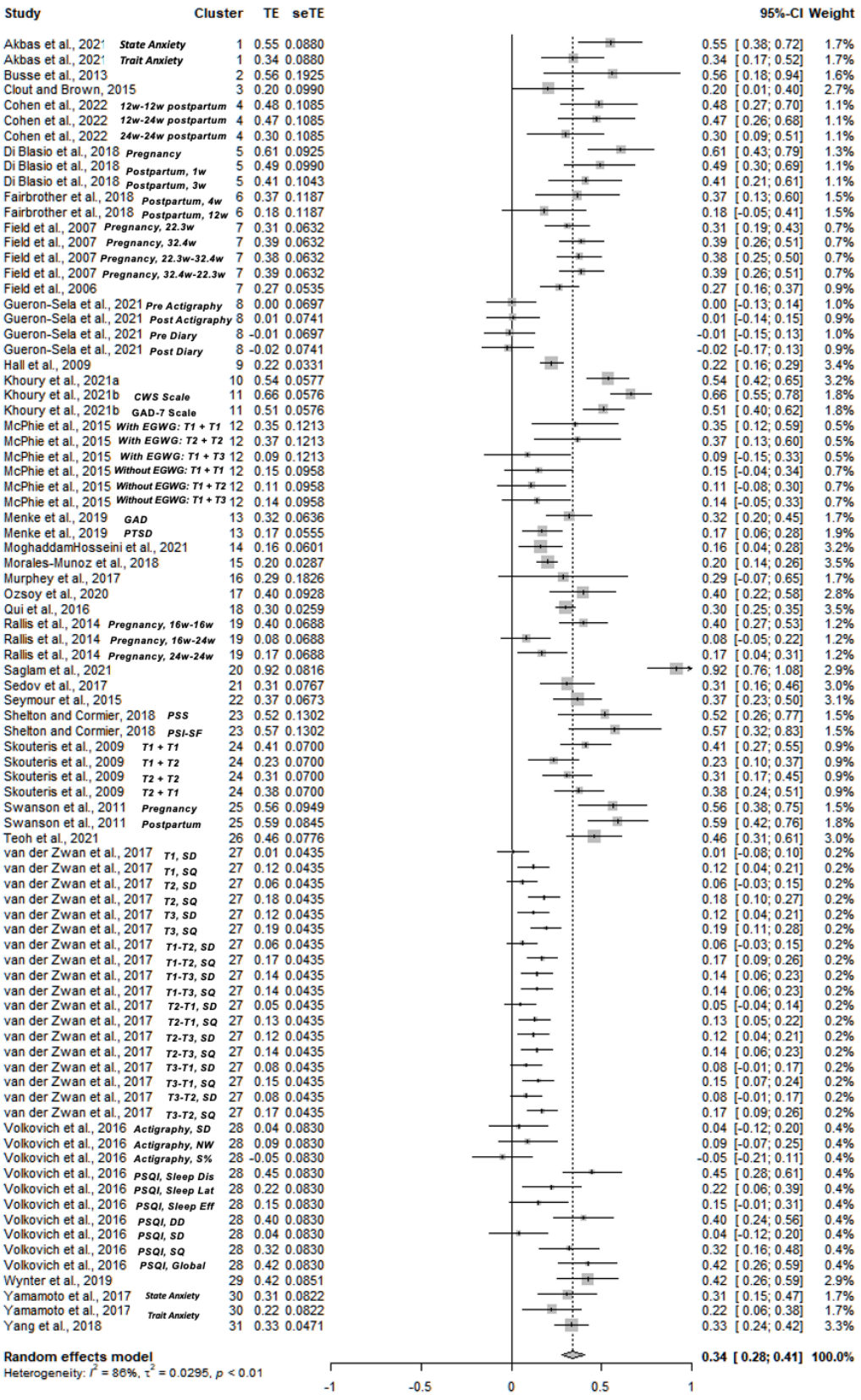
Source of variation	Percent of total variation
Sampling variation	10.74
Within-study variation	10.50
Between-study variation	78.75

Omnibus test

A three level random effects model was calculated using the generic inverse variance method. The random effects model suggested a weighted average correlation of r=0.34 and a 95% confidence interval of between 0.28 to 0.41, concluding that sleep deprivation across the perinatal period is associated with increased anxiety levels. The forest plot for the omnibus test can be seen in figure 3 and the table of effects can be seen in Appendix 4.

Figure 3

Forest Plot of Study Effects



Note: DD: Daytime Dysfunction, EGWG: Excessive Gestational Weight Gain, NW: Night Waking, Post: Postpartum, Pre: Pregnancy, PTSD: Post-Traumatic Stress Disorder, S%: Sleep Percentage, SD: Sleep Duration, Sleep Eff: Sleep efficiency, SQ: Sleep Quality, Sleep Dis: Sleep Disturbance, Sleep Lat: Sleep Latency, T1: Time 1, T2: Time 2, T3: Time 3, w: weeks.

Names of the subjective sleep and anxiety measures noted in Figure 3 can be seen below in Table 6.

Table 6

Glossary of abbreviations of subjective measures seen in Figure 3

Abbreviation	Full-form	Data measured
CWS Scale	Cambridge Worry Scale	Anxiety
GAD/GAD-7	Generalised Anxiety Disorder/Generalised Anxiety Disorder Scale, 7 items	Anxiety
PSS	Perceived Stress Scale	Anxiety
PSI-SF	Parenting Stress Index-Short Form	Anxiety
PSQI	Pittsburgh Sleep Quality Index	Sleep
PSQI Global	Total/Global score of Pittsburgh Sleep Quality Index	Sleep

A high level of heterogeneity in the primary studies was observed (Higgins' $I^2 = 86\%$, $Q = 598.06$, $p < 0.01$). This suggests that the level of variation in the included studies may be biased by the presence of uncontrolled or confounding factors. Therefore, subsequent analyses focused on identifying the sources of heterogeneity between the estimates of the relationship between anxiety and sleep in the included studies.

The effect of risk of bias

Risk of bias ratings for the 32 studies included in the meta-analysis are illustrated in table 7.

Table 7

Quality framework used to assess risk of bias

	Selection Bias	Measurement of Sleep Bias	Measurement of Anxiety Bias	Statistical Bias
Akbas et al., (2021)	High	High	Low	Low
Busse et al., (2013)	High	High	Low	Low
Clout & Brown (2015)	Low	High	Low	Low
Cohen et al., (2022)	Low	High	Low	Low
Di Blasio et al., (2018)	Low	High	High	Low
Fairbrother et al., (2018)	Low	High	Low	Low
Field et al., (2007)	High	High	Low	Low
Field et al., (2006)	Low	High	Low	Low
Gueron-Sela et al., (2021)	Low	Low	Low	Low
Hall et al., (2009)	Low	High	Low	Low
Khoury et al., (2021a)	Low	High	Low	Low
Khoury et al., (2021b)	Low	High	Low	Low
McPhie et al., (2015)	Low	High	Low	Low
Menke et al., (2019)	High	High	Low	Low
MoghaddamHosseini et al., (2021)	High	High	Low	Low
Morales-Munoz et al., (2018)	Low	High	Low	Low
Murphey et al., (2017)	Low	High	Low	Low
Ozsoy et al., (2020)	High	High	Low	Low
Qui et al., (2016)	High	High	Low	Low
Rallis et al., (2014)	Low	High	Low	Low
Saglam et al., (2021)	High	High	Low	Low
Sedov et al., (2017)	Low	High	Low	Low
Seymour et al., (2015)	Low	High	Low	Low
Shelton and Cormier, (2018)	Low	High	Low	Low
Skouteris et al., (2009)	High	High	Low	Low
Swanson et al., (2011)	High	High	Low	Low

Teoh et al., (2021)	Low	High	Low	Low
van der Zwan et al., (2017)	Low	High	Low	Low
Volkovich et al., (2016)	Low	Low	Low	Low
Wynter et al., (2019)	High	High	Low	Low
Yamamoto et al., (2017)	Low	High	High	Low
Yang et al., (2018)	Low	High	Low	Low

Selection Bias

There was variability in the ratings for selection bias. Twenty-one studies were rated as low risk with eleven studies being rated as having a high potential risk of selection bias. Studies rated as low risk of bias employed random sampling or selected participants from multiple restricted or non-random samples, for example, multi-region specialist clinics, national parent support groups/clinics. Those rated as high risk reported no details on the recruitment method (Skouteris et al., 2009) or recruited participants from a single source (Akbas et al., 2021; Busse et al., 2013; Field et al., 2021; Menke et al., 2019; MoghaddamHosseini et al., 2021; Ozsoy et al., 2020; Qui et al., 2020; Saglam et al., 2021; Swason et al., 2011; Wynter et al., 2019). Although the recruitment source was included for most of the reviewed papers, two studies did not describe details on how attempts were made to randomise recruitment (Field et al., 2006; Hall et al., 2009).

Measurement of Sleep Bias

Ratings for measurement of sleep bias were relatively consistent, with two studies being rated as low, and 30 studies rated as high risk. To receive a rating of 'low risk', studies had to use an objective measure of sleep, which may be used alongside a self-report validated subjective measure. The bias ratings illustrate that most studies in this review used a subjective measure to explore sleep, with several studies using unvalidated measures including self-rating Likert scales (Clout & Brown, 2015; Field et al., 2006, 2007) and self-

reporting of average sleep time (Yamamoto et al., 2017). Most studies used validated, subjective measures to record sleep, with the PSQI being most commonly used (Akbas et al., 2021; Cohen et al., 2022; Di Blasio et al., 2018; Fairbrother et al., 2018; McPhie et al., 2015; Menke et al., 2019; Murphey et al., 2017; Qui et al., 2016; Rallis et al., 2014; Saglam et al., 2021; Seymour et al., 2015; Skouteris et al., 2019; Teoh et al., 2021; Wynter et al., 2019; Yang et al., 2018). Other validated measures used by studies in the present review include the PROMIS (Busse et al., 2013; MoghaddamHosseini et al., 2021), MSQ (Hall et al., 2009), ISI (Khoury et al., 2021a, 2021b; Sedov et al., 2017; Swanson et al., 2011), BNSQ (Morales-Munoz et al., 2018; van der Zwan et al., 2017), PSQS (Ozsoy et al., 2020) and GSDS (Shelton & Cormier, 2018).

Of the two studies which were rated low risk of bias regarding the measurement of sleep, one used an actigraphy device alongside a subjective sleep diary (Gueron-Sela et al., 2021) and one used an actigraphy device alongside a subjective sleep diary and the PSQI (Volkovich et al., 2016).

Measurement of Anxiety Bias

Ratings for the measurement of anxiety bias were relatively consistent, with thirty studies being rated as low and two studies being rated as high. This suggests consistency in the use of validated methods to measure anxiety across the literature, with only two studies using methods to measure anxiety which were unspecified or were unvalidated, self-report scales (Di Blasio et al., 2018; Yamamoto et al., 2017). Of note, there was considerable variety observed in the validated subjective measures used across the literature. To explore non-specific anxiety, the most commonly used validated measures include the STAI (Akbas et al., 2021; Cohen et al., 2021; Field et al., 2006, 2007; Hall et al., 2009; Morales-Munoz et

al., 2018; Skouteris et al., 2009; Teoh et al., 2021), the PROMIS (Busse et al., 2013), the DASS-21 (Clout & Brown, 2015; McPhie et al., 2015; Qui et al., 2016; Rallis et al., 2014; Seymour et al., 2015; Wynter et al., 2019), the BAI (Gueron-Sela et al., 2021; MoghaddamHosseini et al., 2021; Ozsoy et al., 2020; Saglam et al., 2021; Volkovich et al., 2016), the CWS (Khoury et al., 2021a), GAD-7 (Khoury et al., 2021b; Menke et al., 2019), the HAM-A (Murphey et al., 2017); Swanson et al., 2011) and the PSS (Shelton & Cormier, 2018; Yang et al., 2018). To collect data regarding PTSD presentations, the IES-R was used (Menke et al., 2015) as was the LASC (Di Blasio et al., 2018). Only one studied used an OCD measure (OSQ-44; Fairbrother et al., 2018). Two studies explored perinatal-specific anxiety, using the PRAQ (van der Zwan et al., 2017) and PSI-SF (Shelton & Cormier, 2018).

Statistical Bias

Studies performed well when reviewed for statistical bias, with all studies being rated low risk of potential bias due to the appropriate use of statistical tests. The statistical procedure was well defined and was deemed appropriate for the data collected across the reviewed papers.

Subgroup Analysis

A series of subgroup analyses were conducted to assess the impact of study-level risk of bias on the overall effect. The four areas of risk of bias report in table 8 were recoded based on the Quality Assessment Framework as low risk (i.e., by combining the good and excellent categories) or “high risk” (i.e., by combining the poor and fair categories). The probability of the difference between the low and high-risk categories was determined by calculating the log ratio test for the model containing the moderating effect and the model with the moderating effect removed.

Table 8

Risk of bias Analysis

	Low Risk			High Risk				
	EFFECT	**95% CI**	**k**	**EFFECT**	**95% CI**	**k**	**LRT**	**P**
Recruitment	0.30	0.23; 0.37	65	0.4171	0.30; 0.54	20	2.54	0.12
Sleep Measurement	0.16	-0.02; 0.34	15	0.3636	0.30; 0.43	70	3.32	0.07
Anxiety measurement	0.34	0.27; 0.41	80	0.3890	0.15; 0.63	5	<0.0001	>0.999
Statistical	0.34	0.28; 0.41	85					

Note: LRT = Log Ratio Test, k = number of studies

As can be seen from table 8, no LRT is reported for 'statistical bias' as there is only one group (low risk). None of the areas of risk of bias achieved statistical significance. However, sleep measurement bias evidenced a trend to significance (LRT = 3.3163, p = 0.0686), with low-risk studies (actigraphy/objective measures) reporting smaller effect sizes – with the overall estimate not significant.

A subgroup analysis is a way of breaking down the study sample into subsets of participants based on a shared characteristic. For this analysis, five subgroup analyses were completed.

Differences in longitudinal and cross-sectional study effects

Across the studies there were differences in study design. For the purpose of analysis, a study effect was determined as 'cross-sectional' if the data were relating to the same

timepoints (e.g., sleep in trimester 3 and anxiety in trimester 3), even if the study effect was found within a longitudinal study design. A study effect was deemed 'longitudinal' if data were regarding different time points (e.g., sleep/anxiety in trimester 3 and sleep/anxiety at 3 months postpartum). A subgroup analysis was conducted to assess the differences between effect sizes reported from said longitudinal and cross-sectional study effects.

Table 9

Longitudinal and cross-sectional study effects, sub-analysis

	Level	EFFECT	95% CI	k	LRT	p	I^2	Q
Study design	Longitudinal	0.27	0.16; 0.37	25	<0.0001	>0.999	75.2%	96.75
	Cross-sectional	0.34	0.28; 0.41	60			86.9%	451.88

As can be seen from table 9, A high level of heterogeneity was observed across longitudinal (Higgins' I^2 = 75.2%, Q = 96.75) and cross-sectional study effects (Higgins' I^2 = 86.9%, Q = 451.88). No statistical significance was found between longitudinal and cross-sectional study effects, indicating that the association between sleep and anxiety is relatively stable over time.

Differences in studies country of origin

For this subgroup analysis, study effects were grouped by location. As can be seen in Table 10 there was not an even distribution of study effects across areas. China, Hungary, and Malaysia each had one study and these study effects were removed prior to analysis (n = 3); Yang et al., 2018 (China); Teoh et al., 2021 (Malaysia) and MoghaddamHosseini et al., 2021 (Hungary). A high level of heterogeneity was observed across study effects in Canada (Higgins' I^2 = 90.4%, Q = 62.37) and Türkiye (Higgins' I^2 = 89.3%, Q = 28.11), with a moderate level of heterogeneity observed across study effects in Australia (Higgins' I^2 = 57.6%, Q = 35.35), Finland (Higgins' I^2 = 65.7%, Q = 81.75), and the USA (Higgins' I^2 =

59.5%, Q = 39.46). No heterogeneity was observed for study effects in Israel (Higgins' I^2 = 0.0%, Q = 0.08) and Japan (Higgins' I^2 = 0.0%, Q = 0.53). There was no significant subgroup effect at the levels of country of origin. Of note, no studies have been conducted in the United Kingdom.

Table 10

Sub analyses based on country of origin

	Level	EFFECT	95% CI	k	LRT	p	I^2	Q
Country of origin	Australia	0.27	0.20; 0.35	16			57.6%	35.35
	Canada	0.40	0.24 0.54	7			90.4%	62.37
	Finland	0.17	0.097; 0.24	29			65.7%	81.75
	Israel	-0.0052	-0.076; 0.065	4	2.46	0.17	0.0%	0.08
	Italy	0.51	0.40; 0.63	3			3.7%	2.08
	Japan	0.27	0.15; 0.38	2			0.0%	0.53
	Türkiye	0.58	0.27 0.90	4			89.3%	28.11
	USA	0.39	0.30; 0.49	17			59.5%	39.46

Differences in the measurement of sleep

There was a difference in the way sleep was measured across the studies, with some employing objective sleep measures (e.g., Research-grade watch device) and others using subjective sleep measures (e.g., Sleep diaries; validated psychometric questionnaire). Study effects were split into the two categories. Regarding sleep constructs, study effects were grouped by whether measures reflected sleep quality (incorporating, perceived sleep quality and sleep efficiency) and sleep quantity (incorporating total time asleep).

Table 11

Sub analyses based on the objective or subjective measurement of sleep and differing sleep constructs

	Level	EFFECT	95% CI	K	LRT	P	I^2	Q
Type of measure	Objective	0.016	-0.052; 0.085	5	8.15	0.0043	0.0%	1.57
	Subjective	0.35	0.28; 0.41	80			85.9%	559.13
Sleep Construct	Quality	0.36	0.30; 0.42	77	9.69	0.0019	86.0%	543.51
	Quantity	0.097	-0.067; 0.26	8			57.8%	16.58

As seen in table 11, A high level of heterogeneity was observed across study effects using subjective sleep measures (Higgins' $I^2 = 85.9\%$, $Q = 559.13$) compared to objective sleep measures (Higgins' $I^2 = 0.0\%$, $Q = 1.57$). A high level of heterogeneity was observed for sleep quality (Higgins' $I^2 = 86.0\%$, $Q = 543.51$) and a moderate level of heterogeneity was observed for sleep quantity (Higgins' $I^2 = 57.8\%$, $Q = 16.58$). It is important to note both the marked differences in the number of effects used in this subgroup analysis and the overlap, as actigraphy devices are most likely to measure sleep quantity whereas, subjective measures are invariably measuring sleep quality.

The differences between type of measure and sleep construct were significant with a moderate effect size identified for subjective measures and a smaller effect size for objective measures. It should be noted that these results will be influenced by marked differences in the number of effects that have been used to calculate effect sizes for objective and subjective measures and type of sleep construct, with only two studies providing 5 objective study effects. The relatively low number of effect sizes used to calculate objective sleep measures and quantity of sleep may mean that these average values will change upon the publication of future studies.

A moderate effect was observed for sleep quality, and for sleep quantity, a very small effect size, with confidence intervals overlapping zero was observed, however these effects

were not significant. The differences between sleep constructs as defined by sleep quality and sleep quantity were significant (see table 11).

Differences in Anxiety

In the present literature, anxiety is measured using subjective measures. For this subgroup analysis study effects were grouped by type of anxiety measured; non-specific Anxiety, Obsessive-Compulsive Disorder (OCD), Postnatal-related anxiety (anxiety specific to the experience of postpartum), Pregnancy-related (anxiety specific to pregnancy *and* childbirth) and Post-Traumatic Stress Disorder (PTSD). See table 12.

Table 12

Sub analyses based on type of anxiety measured in a study

	Level	EFFECT	95% CI	k	LRT	p	I^2	Q
Type of Anxiety	Non-specific Anxiety	0.35	0.28; 0.41	60			83.8%	363.30
	OCD	0.27	0.093; 0.45	2			16.3%	1.19
	Postnatal-related	0.58	0.32; 0.83	1	0.31	0.58	-	-
	Pregnancy-related	0.12	0.095; 0.14	18			27.1%	23.33
	PTSD	0.34	0.0095; 0.67	4			85.3%	20.42

As can be seen in table 12, for all subgroups there is a significant correlation between anxiety and sleep deprivation, however, no significant differences were identified between subgroups, indicating no differences in the type of anxiety measured, whether pregnancy/postnatal related or other anxiety disorders. High levels of heterogeneity were observed across study effects exploring non-specific anxiety (Higgins' $I^2 = 83.8\%$, $Q = 363.30$) and PTSD (Higgins' $I^2 = 85.3\%$, $Q = 20.42$), with a low level of heterogeneity observed across study effects exploring OCD (Higgins' $I^2 = 16.3\%$, $Q = 1.19$) and Pregnancy-related anxiety (Higgins' $I^2 = 27.1\%$, $Q = 23.33$).

Differences in the time of measurement

As the perinatal period covers pregnancy and the first 12 months postpartum, a sub-analysis was run to explore differences between studies recording data in pregnancy and at postpartum. Two analyses were run to explore differences between anxiety and sleep measured at the two levels of 'pre' (pregnancy) and 'post' (postnatal). One study reporting two study effects was removed from both analyses due to not specifying when data was collected for participants who were 'pregnant or had a child under 12 months and the data were grouped for their analysis (Menke et al., 2019).

Table 13

Sub analyses of sleep and anxiety measured in pregnancy and at postpartum

	Level	EFFECT	95% CI	k	LRT	p	I^2	Q
Anxiety and Sleep	Pre	0.34	0.26; 0.43	64	<0.0000	>0.999	87.5%	505.42
	Post	0.36	0.25; 0.46	19			74.7%	71.12

As can be seen in table 13, none of the levels of pre/post measurement of anxiety and sleep achieved statistical significance, indicating stability across the perinatal period. High levels of heterogeneity were observed across study effects measuring anxiety in pregnancy (Higgins' $I^2 = 87.5\%$, $Q = 505.42$) and postpartum (Higgins' $I^2 = 74.7\%$, $Q = 71.12$).

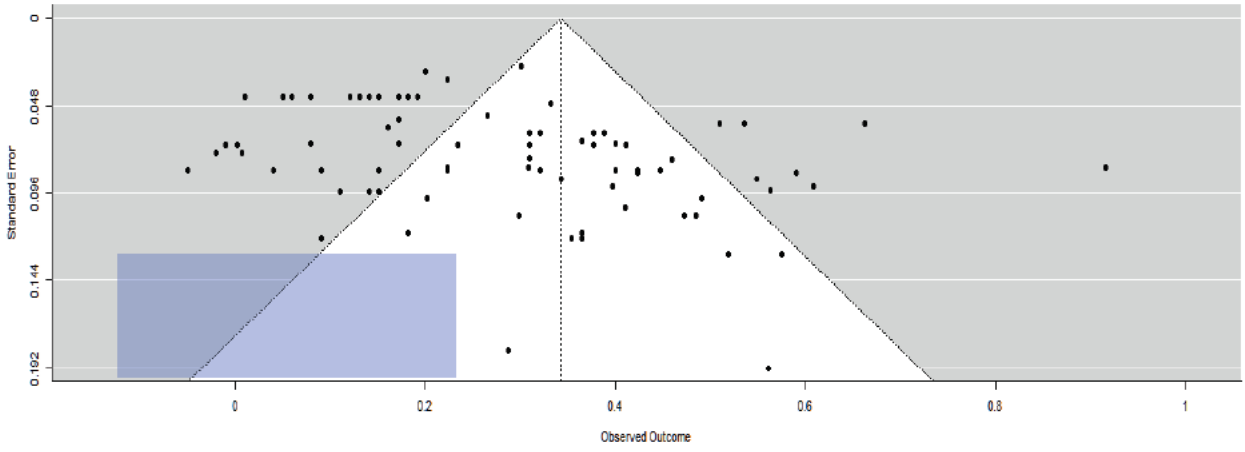
The Impact of Publication and Small Study Biases

Publication bias occurs when statistically significant results are published whilst there is reticence to publish papers with non-significant results. Small study bias is the tendency for studies with smaller sample sizes to show greater variability in their measurement variables, such as the relationship between anxiety and sleep. These biases can be identified in a funnel plot, which plots the size of the study's correlation (i.e., the importance of the study in the present synthesis) against the studies deviation from the meta-analytic average (i.e., the

discrepancy of the study within the rest of the literature). If there is an absence of publication bias, the effects from the studies with small sample sizes, showing greater variability, will scatter more widely at the bottom of the plot compared to studies with larger samples at the top of the plot which will lie closer to the overall meta-analytic effect. This creates a symmetrical funnel shape. If there is an absence of studies in the area of the plot associated with small sample sizes and non-significant results, then it is likely there is some publication bias which can lead to an overestimation of the true effect. The funnel plot of study level correlations is presented in figure 4.

Figure 4

Funnel plot of the relationship between anxiety and sleep. The 95% confidence interval of the expected distribution of the effect is shown as an inverted "funnel". The area marked in blue is the area of the funnel plot that is associated with publication bias.



As can be seen from figure 4, the previously noted heterogeneity is clearly present, in that there are a number of studies which are outside the 95% confidence interval for the meta-analytic effect however, there is evidence of effects in the area associated with the null hypothesis therefore there is no marked evidence of asymmetry and publication bias in the distribution of the study level correlations.

Discussion

Summary of findings

This meta-analysis was the first to review the relationship between sleep deprivation and anxiety across the perinatal period. The findings of the meta-analysis suggest that there is a positive association between sleep problems and anxiety across the perinatal period, with a moderate effect size.

To explore factors which may be influential in the relationship between anxiety and sleep problems, five subgroup analyses were conducted to break down the study sample into subsets of characteristics based on shared characteristics. Across the studies there was a difference in the way sleep constructs were measured, with sleep quantity largely overlapping objective sleep measures (e.g., Actigraphy device) and sleep quality largely overlapping with subjective sleep measures (e.g., Sleep diaries; validated psychometric questionnaire). The sub-analysis identified a significant difference in the size of effect based on how sleep was measured, with moderate effect sizes identified for subjective measures/sleep quality and no clear effect for studies that used identified for objective measures/sleep quantity. This difference between subjective and objective measures is in line with findings in the current literature (Volkovich et al., 2016). It can be hypothesised that subjective sleep measures capture not only the quality of sleep but an individual's perception, beliefs and expectations, and that these can be influenced by external variables including (but not limited to) societal views, cultural norms and social support.

There were marked differences in the number of effects used to calculate effect sizes for objective and subjective measures and sleep constructs, with only two objective studies providing five objective study effects. A high level of heterogeneity was observed for subjective measures/sleep quality which may be influenced by the variety of subjective measures used to record data for sleep quality. In comparison, a moderate level of

heterogeneity was observed for quantitative measures/sleep quantity and differences between sleep measurement aligns with previous findings of a low agreement between subjective and objective measures, which is likely related to the measurement of different elements of sleep alongside differing perceptions influenced by anxiety levels (Volkovich et al., 2016). The relatively low number of effect sizes used to calculate objective sleep measures and quantity of sleep may mean that these average values will change upon the publication of future studies.

Differences in the time of measurement across the perinatal period and longitudinal and cross-sectional study design were not significant, illustrating no significant differences between pregnancy and postnatal measurement. Differences in effect size based on the country of origin of included studies, were not significant, illustrating no significant variability across international locations and cultures. Of note, no studies have been conducted in the United Kingdom. Differences in effect size based on type of Anxiety were not significant, illustrating a generalisable relationship between sleep and anxiety, with no significant differences based on specific anxiety presentation. It could be considered that the shared features of anxiety presentations contribute to the reciprocal relationship with sleep deprivation, which is consistent with research which has identified a higher prevalence of anxiety disorders in the perinatal period in comparison to the general population, and the prevalence of having one or more anxiety disorder estimated to be around 20.7% (Fawcett et al., 2019) and 21.2% (Martini et al., 2013).

In the present review, the number of study effects for each anxiety presentation varied, ranging from one to sixty study effects dependant on presentation. The variability across the literature included in this review limits both the understanding of the mechanisms which may contribute to sleep difficulties in the perinatal period and has the potential for findings to be overgeneralised. Additionally, between study variance was high, so it is not

clear whether differences in effect size relate to the anxiety presentation, sleep construct or other methodological differences. Exploring the differences between the shared, common characteristics of anxiety presentations in relation to sleep changes in the perinatal period could be of interest for future studies, to further understand the contributing factors to this reciprocal relationship. Future research in this area may also benefit from reviewing and developing perinatal-specific sleep measures and exploring how perinatal-specific anxiety is experienced in comparison with generalised/non-specific anxiety.

Limitations of the evidence

Most studies reviewed agreed that sleep deprivation across the perinatal period is associated with higher levels of anxiety, however, heterogeneity was high. There are many possible explanations for this observed variance, including variability in the way that sleep was recorded and reported and variability in the anxiety-related presentations. Across the studies reviewed, subjective measures were mostly used to record data regarding sleep changes in pregnancy and the postpartum, evidencing moderate effect sizes. There was considerable variation in the subjective measures used, including unvalidated self-report measures (e.g., sleep diaries, Likert scales, self-report sleep time average) to a variety of validated sleep measures (e.g., PSQI; PROMIS; MSQ; ISI; BNSQ; PSQS; GSDS). Although all measures are exploring changes in sleep, the construct validity and reliability will likely vary across these measures, with the risk of certain measures being more influential than others. Of note, only one study used a perinatal specific sleep measure (Oszoy, 2020; The Postpartum Sleep Quality Scale) and so no analysis could be conducted to explore comparative differences in sleep between generalisable and perinatal sleep measures. This could be considered a limitation of the evidence as generalised sleep measures may not capture the unique experience of sleep in the perinatal period.

Few studies used objective measures for gathering sleep data in the perinatal period, with smaller effect sizes presented in comparison with subjective measures. Within the literature, a low agreement has been highlighted between subjective and objective measures of sleep which is likely related to the measurement of different elements of sleep alongside differing perceptions influenced by anxiety levels (Volkovich et al., 2016). Results should be interpreted with a degree of caution as studies using subjective and objective measures, were unequally weighted, which may contribute to bias in findings.

Studies included in the review recorded data from several countries, with multiple studies in Australia, USA, Canada, Finland, Israel, Italy, Japan, and Türkiye. Single studies were conducted in China, Hungary and Malaysia and were removed prior to analysis due to having a small number of study effects which may have contributed to variance in analysis. Of note, the studies included in the present review were from high income countries (HIC) as opposed to low- or middle-income countries (LMICs), which limits our understanding of the nuance of the relationship between anxiety and sleep in the perinatal period. It may be of interest for future research to be conducted in LMICs to consider the potential influence of cultural, environmental, and political differences, including (but not limited to), parenting style, working conditions, entitlements, feeding practices, family systems and caregiver support. No significant subgroup effect at the levels of country of origin were identified, illustrating a generalisable experience of sleep changes and associated anxiety in the perinatal period across varying locations and cultures in said high income countries. Of note, no studies have been conducted in the United Kingdom.

Whilst the literature has reported trimester-specific changes in sleep in pregnancy (Christian et al., 2017; Parsons et al., 2023; Zhang et al., 2021) and anxiety in pregnancy (Kaya et al., 2015; Martini et al., 2013), in the present review, no difference between

estimates was identified at the levels of cross-sectional and longitudinal design and time of measurement (pregnancy and postnatal).

Limitations of this review

Though the main risk of bias assessment was developed from the four areas of the Quality Assessment Framework, for analysis of heterogeneity, these were recoded as "low risk" (i.e., by combining the good and excellent categories) and "high risk" (i.e., by combining the poor and fair categories). The risk of bias assessment was formatted this way to align with risk of bias assessments used in research which typically offer ratings of 'low risk', 'high risk' and 'unclear risk'. Combining categories (e.g. good/excellent, poor/fair) may have limited the nuanced understanding of risk across studies and study effects. A limitation of the risk of bias assessment for recruitment bias, is that the criteria did not specify rating studies based on the level of key demographic variables reported (e.g., age, parity, relationship status, educational level. This lack of consideration limited the opportunity to explore causality through further sub-analysis into participant characteristics which may have provided further understanding of heterogeneity observed across sleep and anxiety data in the perinatal period.

Following the screening process, the authors of ten studies were contacted to provide additional data. Two authors provided correlations which were included in the meta-analysis however, eight authors did not provide additional data to be included in the analysis. Though the overall number of effects was high, not being able to access these data may have had a particular impact on subgroup analysis where groups were often made up of a smaller number of effects.

Implications for practice

The findings of the meta-analysis highlighted that sleep difficulties in the perinatal period were associated with anxiety irrespective of the presentation which may be of use to health and social care professionals working with pregnant people and new parents. In the United Kingdom, the National Health Service (NHS), offers free antenatal and postnatal appointments to pregnant people and new parents, however, it is unclear how changes in sleep are identified as a concern, and it is unclear whether further monitoring and sleep interventions are widely available. As changes in sleep are somewhat expected in the third trimester and in the postpartum period, where an infant requires feeding, soothing and changing in the night, societal views and expectations may be a barrier to accessing support for sleep and mental health concerns. Specifically, health and social care professionals could use both subjective and objective measures when assessing sleep changes in the postpartum period, considering how current sleep differs from pre-pregnancy sleep e.g., are there historic sleep difficulties? What does this change of sleep mean to the individual?

Of note, with the current review noting a larger association between subjective sleep measures and anxiety when compared to objective measures, it could be of use for professionals to explore a person's perspective on sleep, their beliefs, and expectations, as these elements could be incorporated into an intervention. If an individual routinely wears/uses a high-street sleep exercise and lifestyle device (e.g., Fitbit, Garmin watch, Apple watch, Ōura ring), this data could be incorporated into psychoeducation regarding the differences in sleep quality and quantity and could provide useful information regarding patterns of sleep disruption. It would also be beneficial for health and social care professionals to be offered training and supervision regarding screening for sleep and mental health difficulties, as levels of understanding may differ based on training backgrounds.

Additionally, both antenatal classes and postnatal groups, routinely share information regarding common experiences in the perinatal period to inform, normalise and validate

experiences. Findings regarding the relationship between sleep and anxiety across the perinatal period could be incorporated into the curriculum for such providers and could be beneficial in supporting signposting to locally available support around understanding and managing sleep difficulties and periods of associated anxiety.

Implications for future research

This review is the first of its kind to meta-analyse data regarding sleep deprivation and anxiety across the perinatal period. Although there are many factors that influence sleep loss, anxiety has been identified as an important factor to consider and this review highlights that the relationship between sleep deprivation and anxiety is experienced across the perinatal period and stable over time.

Future research could benefit from using objective measures to record sleep data alongside subjective measures as a low agreement was highlighted in the literature between the two methods (Volkovich et al., 2016). Using both objective and subjective measures to record sleep data would allow the exploration of the differences between the perceived quality of sleep and quantity of sleep in the perinatal period and support further analyses regarding how anxiety may influence this.

Within this meta-analysis, one study used a perinatal specific subjective sleep measure, with other studies opting to use measures validated for use in the general public. During the perinatal period, there are a host of factors unique to pregnancy and postpartum which are not captured by non-specific measures, and it could be recommended that future research considers the development of sleep measures for pregnancy and the postpartum period.

The anxiety-related presentations included in this meta-analysis were not equally weighted in terms of study numbers, study effects or participants and results of the review

may lead to overgeneralising of this relationship, which could benefit from future research. Additionally, future research may benefit from exploring anxiety presentations between participants with and without an anxiety-related diagnosis in the perinatal period and to also explore how anxiety presentations may change from pre-conception, into pregnancy.

Conclusion

This review highlights an association between sleep problems and anxiety across the perinatal period irrespective of location, time of data collection and anxiety presentation. This is the first meta-analysis of its kind and promotes further questioning into factors which may influence this relationship, such as individual participant characteristics and differences between anxiety-related presentations. The findings of the review highlight an important possible difference between the measurement of sleep quality and sleep quantity as sleep constructs. Although not the focus of this study, the exploration of individual differences influencing sleep and anxiety in the perinatal period is recommended. Additional recommendations include the incorporation of both qualitative and subjective measures in future research to better understand the differences between physiological markers of sleep and self-rated sleep perception and future research into perinatal-specific anxiety.

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Chapter Two

Empirical Paper: The Relationship between Perinatal Sleep Deprivation, Perinatal Anxiety, and Emotion Recognition

Abstract

Purpose

The perinatal period is a time of biopsychosocial change influencing sleep and mental wellbeing which in turn, impacts the development of mother-infant attachments. Studies have explored the role between anxiety and sleep in this period with varying results, influenced by the method of sleep data collection. This study investigates the relationship between sleep deprivation, perinatal anxiety, and emotion recognition in infants across the perinatal period.

Method

This study used within participants methodology recruiting expectant parents for two testing periods, in the third trimester of pregnancy and at three months postpartum. Participants completed recorded their sleep for seven nights through sleep diaries and an actigraphy device, before completing the Perinatal Anxiety Screening Scale (PASS; Somerville et al., 2014; 2015) and an emotion recognition task, in which they identified the emotion expressed in the faces of 48 pictures of babies under three months of age.

Results

New parents experienced greater sleep disruption and increased anxiety when compared to pregnancy, however no significant association was identified between sleep and anxiety. Performance decreased in the emotion recognition task for Happy stimuli, with

performance remaining consistent for Neutral and Sad stimuli. Interestingly, self-rated confidence increased across time points for all three emotions.

Discussion

Overall, the findings from the present study seem to suggest that despite periods of sleep deprivation and experiences of anxiety, new mothers retain the ability to accurately identify an infant's emotions and experience an increase in confidence levels increase when compared to pregnancy by the third month postpartum.

Introduction

The perinatal period refers to pregnancy through to when an infant is 12 months old. During this time, the birthing body and brain undergo a variety of hormonal fluctuations and rapid physiological changes, which accompany the dynamic restructuring of the emotional, physical, and social environment of parenthood (Hoekzema et al., 2017; Orchard et al., 2023). Fluctuations in sleep are particularly common in this period (Hunter et al., 2009; Mindell & Jacobson, 2000; Palagini et al., 2014; Parsons et al., 2023), as are difficulties with anxiety (Fawcett et al., 2019; Seymour et al., 2015; Wang et al., 2018). These changes are important in isolation, but particularly so when we consider how they interact. Allied to the risk to parents of these difficulties is the risk to child outcomes due to their impact on a parent's social and emotional abilities. There is a growing body of evidence that explores the prevalence of sleep difficulties, anxiety, and social understanding across the perinatal period, but less knowledge of the relationship between these factors.

Sleep in the Perinatal Period

Sleep difficulties are among the most widespread problems across pregnancy (Hunter et al., 2009; Palagini et al., 2014; Pien & Schwab, 2004) and the postnatal period (Parsons et al., 2023; Zhang et al., 2021). Changes in sleep quality and quantity of sleep have been highlighted across pregnancy, (Mindell & Jacobson, 2000; Smyka et al., 2020) and continue through to the first few months following childbirth (Parsons et al., 2023; Zhang et al., 2021). Studies exploring the trajectory of sleep difficulties across pregnancy have observed no significant differences by trimester of pregnancy (Khoury et al., 2021; Van der Zwan et al., 2017) and have identified that sleep difficulties in the first and second trimesters predict sleep difficulties in the third trimester (De Chiara et al., 2021; Field et al., 2006; 2007; Ko et al., 2010; Smyka et al., 2021; Yang et al., 2018).

During pregnancy, common causes of poor sleep are often physical, with nausea/vomiting, increased urinary frequency, and backache often experienced, alongside increased foetal movements, heartburn, cramps, and shortness of breath (Hutchinson et al., 2012; Mindell & Jacobsen, 2000; Mindell et al., 2015; Schweiger, 1972). In the postpartum period, there are multiple factors that contribute to sleep changes. New mothers experience a host of physiological and anatomical changes, which return the body to the non-pregnant state, including changes linked to diuresis, menstruation and haemoglobin that continue in the days following childbirth, lasting to around 12 months postpartum (Chauhan & Tadi, 2020). The quantity and quality of an infant's sleep is likely to directly influence parental sleep quality and quantity (Meltzer & Mindell, 2007), with parents required to fulfil the needs of the infant during daytime and night-time waking (Kendall-Tackett et al., 2011). It is important to consider the potential consequences of poor sleep for a pregnant person across the perinatal period and into postpartum.

Relationship Between Sleep Deprivation and Anxiety in the Perinatal Period

The relationship between sleep deprivation and anxiety is complex. The prevalence of anxiety presentations in the perinatal period varies broadly across samples. A meta-analysis reviewing 26 studies across pregnancy and the postpartum period identified that individual disorder prevalence estimates ranged from 1.1% for posttraumatic stress disorder to 4.8% for specific phobia, with the prevalence of having at least one or more anxiety disorder estimated to be 20.7% (Fawcett et al., 2019). Pregnant women have also been identified as being more likely to experience anxiety disorders than post-childbirth (Fawcett et al., 2019).

A meta-analysis reviewing 32 papers found that there was a positive association between anxiety and sleep deprivation across the perinatal period, identifying a significant

difference in results according to how sleep was measured (objective vs subjective) and dependant on the sleep construct (sleep quantity vs sleep quality) being explored (Chapter 1).

Sleep duration and sleep quality during pregnancy significantly predict anxiety levels at 3-months postpartum (Cohen et al., 2022; Gueron-Sela et al., 2021; Osnes et al., 2020) and 6-months post-partum (Cohen et al., 2022; Tomfohr et al., 2015). A decline in sleep quantity, quality, and efficiency has been associated with increased anxiety levels at 15 days postpartum (Kuo et al., 2014) and 42 days postpartum (Wang et al., 2018), with studies identifying recovery in sleep patterns ranging from 10 to 12 weeks postpartum (Kuo et al., 2014), 6 months postpartum (Okun et al., 2018) and 9 months postpartum (Wang et al., 2018).

There is an association between anxiety experienced during pregnancy and an over reporting of sleep difficulties as measured by subjective measures, which were not highlighted using objective tools (Gueron-Sela et al., 2021; Volkovich et al., 2016). When objective sleep quality is relatively low, women with higher levels of anxiety perceived their sleep as more disturbed than women with lower anxiety (Volkovich et al., 2016), however, this low agreement between subjective and objective measures is likely related to the measurement of different elements of sleep alongside differing perceptions influenced by anxiety levels (Volkovich et al., 2016).

The Measurement of Sleep in the Perinatal Period

A meta-analysis exploring the relationship between sleep and anxiety in the perinatal period found that there were key, significant, methodological differences in how studies recorded sleep data, with subjective measures being most used over objective measures (Chapter 1). A key paper identified a low agreement between measures which is likely related to the measurement of different elements of sleep (e.g., sleep quantity vs sleep quality), with

subjective data regarding quality of sleep likely being influenced by a multitude of factors, including (but not limited to) anxiety levels, personal expectations, social support, feeding preferences, physical illness, and mental health (Volkovich et al., 2016).

Regarding the objective measurement of sleep, Polysomnography (PSG) has been considered the "gold standard" for the measurement of sleep due to the ability to measure wake and sleep time and various sleep constructs (McCall& McCall, 2011). PSG use in research exploring sleep in the perinatal period is limited, with a preference for actigraphy devices to be used in a participant's home environment, as they provide a non-invasive, low-cost, and accessible alternative to lab-based sleep monitoring (Chapter 1; Parsons et al., 2020). Actigraphy devices work as a proxy measure of sleep based on movement, measuring movement through an internal accelerometer, alongside physiological parameters including heart rate, body temperature and respiration using infrared light photoplethysmography (PPG) (de Zambotti et al., 2019).

Sleep, Anxiety and Emotion Recognition

Perinatal Anxiety and poor sleep also have the potential to impact parent-child interactions and relationships. The parent-baby relationship starts in pregnancy and the continuing development of this relationship is a key psychological process for parents (Brockington, Aucamp & Fraser, 2006). Following childbirth, changes occur at all levels of family life such as new parental roles at home and returning to work (Grice et al., 2011) with potential impacts on marital life, personal wellbeing, stress, and mental health (Miller & Sollie, 1980; Yamamoto et al., 2017).

Accurate emotion recognition and ability to attune to a baby's needs may be of particular importance to new parents. A mother's ability to accurately identify her baby's emotional cues and to respond sensitively is key in the survival of the baby and is the basis

for establishing secure mother-infant attachment (Bowlby, 1969; Gunnar & Donzella, 2002; Gunnar & Quevedo, 2007; Hoffman et al., 2006) which is considered fundamental to the healthy cognitive, physical, emotional and social development of a baby (Perry, 2002; Schore, 2001a, 2001b; Siegel, 2001). Secure mother-infant attachment has been associated with a child's development regarding their beliefs around emotions and ability to identify them (Castro et al., 2015) which have been shown to continue into adult life (Colle & Del Giudice, 2011), with increased abilities to develop skills to regulate their own emotions (Brumariu, 2015).

Anxiety in mothers has been associated with difficulties in recognising opportunities to engage in warm and affectionate behaviours with their infant, and reduced sensitivity to their infant's cues (Barnett 1986; Feldman et al., 2009; Murray et al. 2007). High levels of anxiety following childbirth have also been associated with self-reports of difficulties in the mother-infant relationship, with preoccupations that the infant rejects them or is not meeting their expectations (Seymour et al., 2015). These beliefs were shown to be associated with decreased parental self-efficacy and decreased satisfaction of the parenting role, which in turn was found to promote further anxiety (Seymour et al., 2015). For mothers with Borderline Personality Disorder (BPD) increased difficulties in labelling and responding to infant emotional communication, difficulties with responding sensitively to their child's needs, and limited reflective capacity have been identified (Elliot et al., 2014).

Rationale

Sleep is an essential part of human everyday life, serving a multitude of functions. The perinatal period is a time of great biopsychosocial change with associated risks in terms of impacting sleep and mental wellbeing which in turn, influences the development of mother-infant attachments.

Many studies have explored the role between anxiety and sleep, at either pregnancy or postpartum with varying results, influenced by the method of sleep data collection, with limited data from objective measures. There are currently no studies exploring the relationship between sleep deprivation, perinatal anxiety, and emotion recognition across the perinatal period. We hypothesise that new mothers' ability to recognise emotions in infants will be reduced postpartum in comparison to pre-partum abilities, and that this decrease will be associated with changes in sleep. We also hypothesise that sleep changes in pregnancy and postpartum will be associated with increased levels of anxiety.

Method

This study used a within subjects' design recruiting parents in the third trimester of pregnancy. Sleep was measured at Time 1 (T1; Third Trimester) and at Time 2 (T2; at 3-months post-partum) using a sleep diary as a subjective measure and using Ōura rings (Oura, Oulu, Finland) or the Actiwatch Pro (Phillips Respironics, USA) as an objective measure. Perinatal anxiety was measured at T1 and at T2 using the Perinatal Anxiety Screening Scale (PASS; Somerfield et al., 2014). Recognition of infant emotions was measured during the period of sleep recording at both T1 and T2. The emotion recognition task was developed by Parsons (2020), using a series of 48 pictures of children under the age of 3 months. The study was pre-registered with the Open Science Framework (OSF) on February 11th 2022 (https://osf.io/xabt4).

Power analysis

An a-priori power analysis was completed for matched pairs t-tests using g*power (Faul et al., 2007) and medium-large effect size, ($dz = 0.5$), suggesting the need of $N>45$, to give power $(1- \beta) = 95\%$. Given the constraints of a ClinPsyD thesis and the impact of the

covid pandemic and postal strikes, it was not possible to achieve these participants numbers. Post-hoc power analysis, identified that the number of participants in the present study (N = 27), assuming a medium-large effect size, (dz = 0.5) gave the power (1- β) = 82%.

An a-priori power analysis was completed for an ANOVA (repeated measures with within and between interactions) using g*power (Faul et al., 2007) and medium-large effect size, (ηp^2 = 0.10), suggested the need of N>32 (16 participants per group; parent and control condition), to give power (1- β) = 95%. For this analysis, power was achieved; N = 27 (parent group) N = 25 (control group).

Participants

Participants were recruited through adverts (See Appendix 12) posted on social media, and through snowballing on social media. The adverts was also shared by the National Childbirth Trust (NCT) via their national and local social media pages. Recruitment took place between February 2022 and February 2023. The study was open to anyone residing in England, Wales, Scotland, and the Isle of Mann at the time of the study. Participants could participate in the study if they were expecting their first baby/babies and were to be in the third trimester of pregnancy for the first time point of testing (T1) and if they were over 16 years of age.

Twenty-seven participants completed data collection and assessment at T1 (pregnancy) and T2 (postpartum). Demographic characteristics of the participants at timepoint one are shown in table 1. All participants identified their gender as female, and participants had a mean age of 33.15 years (*SD* = 3.36). The average weeks gestation of participants at T1 was 34.96 (*SD* = 3.04). Of the 27 participants in the study, 20 identified themselves as ‘White – English, Welsh, Scottish, Northern Irish or British’ (74.1%), four identified themselves as ‘White – Any other background’ (14.8%), one participant identified

themselves as ‘Asian or Asian British – Chinese’ (3.7%) and one participant identified themselves as ‘Any other mixed or multiple ethnic background’ (3.7%). English was the first language spoken for most participants (85.2%), and Italian (n = 1), Polish (n = 1) and Russian (n = 1) were the first languages spoken of three participants (3.7% respectively). Most participants did not wear contact lenses or glasses (59.3%) and most of the participants were right-handed (92.6%). Adoptive and prospective adoptive parents were also eligible for the study, but none were recruited. At T2, the average age of the infant was 12.26 weeks, (*SD* = 4.09).

Table 1

Demographic characteristics of participants at baseline (T1) and age of infant at T2

Item	Category	Number	Mean	Std. deviation	Percentage (%)
Gender	Female	27			100
Age	Age, Years	26	33.15	3.36	
	Missing	1			
Gestation	Gestation (Weeks)	27	34.96	3.04	
Handedness	Right-handed	25			92.6
	Left-handed	1			3.7
	Missing	1			3.7
Ethnicity	White – English, Welsh, Scottish, Northern Irish or British	20			74.1
		1			3.7
	Asian or Asian British – Chinese	4			14.8
	White – Any other Background	1			3.7
	Any other mixed or multiple ethnic background	1			3.7
	Missing				
First Language Spoken	English	23			85.2
	Italian	1			3.7
	Russian	1			3.7
	Polish	1			3.7
	Missing	1			3.7

Contact Lens/Glasses Wearer	Yes	10			37.0
	No	16			59.3
	Missing	1			3.7
Item	Category	Number	Mean	SD	Range
T2 – Infant Age	Infant Age (Weeks)	27	12.26	4.09	5.71 – 21.00

Measurements

Objective Sleep

Two types of actigraphy device were used as objective measures of overnight sleep and participants were not required to wear the device in the day, therefore not recording daytime naps. Devices were randomly assigned to participants at T1 based on availability. The present study had access to Ōura rings (n = 2; size 7 and size 8) and Actiwatch Pro devices (n = 4). Of the 27 participants, N = 8 wore an Ōura device and N = 19 wore an Actiwatch Pro.

Ōura rings (Ōura, Oulu, Finland) are small devices, worn on a finger that are non-invasive and do not require actions to initiate going to bed or periods of sleep detection. Ōura rings record heart rate, body temperature and respiration using infrared light photoplethysmography (PPG), and an internal accelerometer measures movement which is used to estimate sleep parameters including duration, quality, and overall efficiency. Ōura ring data were collected using the accompanying app and desktop interface which provided data for Total Sleep Time (TST), Waking after Sleep Onset (WASO), Sleep Onset Latency (SOL), and Sleep Efficiency (SE). Ōura ring data has been shown to significantly correlate with lab-based polysomnography (PSG) (de Zambotti et al., 2019), medically approved actigraphy devices (Asgari Mehrabadi et al., 2020) and commercially available actigraphy devices (Saganowski et al., 2020) regarding the estimation of total sleep time (TST), waking after sleep onset (WASO) and sleep onset latency (SOL). Participants were instructed to wear the device whilst sleeping, to keep it on charge during the day and to remove the device prior

to engaging in any activities that may involve the ring being submerged in water.

The Actiwatch Pro (Phillips Respironics Inc., Pittsburgh, PA) is a research-grade device used as an objective measure of sleep. The Actiwatch Pro also performs as a watch, with a light-up LCD face and an event-marker button on the side. Participants were advised to wear the Actiwatch device at night to record sleep and were made aware that it did not require charging. Actiwatch data were collected in 30-second epochs and scored using the Actiware software (version 6.0.9, Philips Respironics Inc, Pittsburgh, Pennsylvania). Total sleep time (TST) was calculated as the summation of sleep epochs within the designated sleep periods, and wake after sleep onset (WASO) as the summation of wake epochs between sleep onset and end. From this data, Sleep Onset Latency (SOL) and Sleep Efficiency (SE) were calculated.

Published methodological guidelines recommend a minimum of five consecutive nights of actigraphy recording in research to increase reliability of data (Sadeh, 2011) and attempts were made to follow this guidance, aiming to record a minimum of seven nights sleep per person in the present study. The mean number of nights of recorded for participants at T1 was 6.65 (*SD* = 1.03) The mean nights of sleep recorded for participants during T2 was 6.75 (*SD* = 0.78). Due to the small sample size in the present study, sleep data were included where the targeted seven nights were not achieved. Methodological guidelines also recommend that for traditional actigraphy, data should be cleaned using sleep diaries to ensure reliability of recordings (Sadeh, 2011). The objective sleep data was cleaned by the research team (CG, AC, EW, RM) following the data-cleaning protocol (see Appendix 15). Both in-person and virtual meetings were frequently held to discuss any queries or concerns regarding cleaning the data, with decisions being made as a group to establish a consensus on how to process sleep data in-line with the protocol.

Subjective Sleep

Alongside using actigraphy devices to measure sleep, participants recorded their subjective sleep experience using a paper sleep diary developed by Parsons (2020) (Appendix 3). Participants recorded the time they got into bed and an estimate of the time they fell asleep, recording any periods of night-time waking. Participants also recorded their final waking time and the time that they got out of bed. Raw sleep diary data was processed following the approach of Parsons (2020), with total sleep time (TST) being defined as the total time of asleep at night following the onset of sleep. TST did not include any periods of time during the night where participants recorded being awake. Waking after sleep onset (WASO) was defined as the total amount of time awake following the initial onset of sleep and SOL was defined as the time spent awake in bed prior to initial sleep onset. Sleep Efficiency was defined as the ratio of TST to time in bed (TiB), calculated using the formula TST/TiB (x100) as presented by Reed & Sacco (2016). Both the total and average data for TST, WASO, SOL and, Sleep Efficiency were calculated for all participants and were compared to the total for the same parameters as recorded using the Ōura ring and Actiwatch Pro. When using a sleep diary, it is recommended that a minimum of six nights sleep is recorded (Aili et al., 2017). In the present study, a mean average of 6.65 (*SD* = 1.03) nights of sleep data were collected by diary at T1 and a mean average of 6.75 (*SD* = 0.79) nights of sleep were collected by diary at T2.

Perinatal Anxiety Screening Scale (PASS)

The Perinatal Anxiety Screening Scale (PASS; Somerville et al., 2014; Somerville et al., 2015) is a 31-item self-rated questionnaire used to screen for anxiety disorders in the entire perinatal period (See Appendix 2). Each item is rated on a Likert 0–3 scale; the total score is the addition of scores on each item, with higher scores representing higher levels of anxiety. Scores may range from 0–93 with a cut off for clinical anxiety of ≥26, with scores ranging from ‘minimal anxiety/asymptomatic’ (scoring 0–20), ‘mild–moderate anxiety’ (21–

41), and 'severe anxiety' symptoms (42–93) (Somerville et al., 2015). The items are related to panic, general worry, specific phobias, OCD, PTSD, and social anxiety and the scale showed adequate test–retest reliability (*rho* = 0.74), a sensitivity of 70% and specificity of 30% at the 26 cut off (Somerville et al., 2015). Studies exploring the psychometric properties of the PASS have illustrated the validity and reliability of the measure in assessing anxiety symptoms and disorders (Amiri et al., 2022; Barros et al., 2021; Jradi et al., 2020; Koukopoulos et al., 2021 & Yazici et al., 2018).

Emotion Recognition Task

Participants completed an emotion recognition task that was adapted from Elliot et al., (2014) and developed by Parsons (2020) for use in this study. The task comprised of 48 colour images of infants under 3 months old, which were presented to participants in the size 15cm x 15cm and were cropped so that only the infant was in the photo. The 48 images were made up of an equal number of happy (n = 16), neutral (n = 16) and sad (n = 16) emotional expressions. An example of this can be seen in Figure 1, below.

Figure 1

Example pictures used in the emotion recognition task reproduced with permission from the parent

Left: Sad – Right: Neutral

The pictures were then loaded into the Qualtrics XM software platform (Qualtrics, Provo, UT) which is used to collect, manage, and act on experience data. Participants were shown one image at a time, placed in the centre of each page. The participants were presented with the image for three seconds and were instructed to select whether they thought the infant was expressing a 'Happy', 'Neutral' or 'Sad' emotion, before the page moved onto a question where participants rated their confidence in their decision on a scale of 0 [lowest] – 100 [highest]. Participants then selected 'next' to proceed to the next question item. Four practice items using stock images from Shutterstock were shown to participants prior to starting the task. The emotion recognition task was developed by Parsons (2020), and pictures were provided by parents who did not participate in the study. Each image was rated by four parents who were independent of the research to agree on the emotion expressed by the infant. Images were only included in the study where at least three of the independent reviewers reached an agreement. The final selection of 96 images were then randomised using a random number sequencer into two sets of 48. As per Parsons (2020), each set of 48 images was included once in its original order then again in a separate, reverse order, therefore producing four sets of images labelled 1a, 1b, 2a and, 2b. Pairs of sets of pictures were administered to participants with them completing either 1a or 1b at T1 and 2a or 2b at T2. The combinations of sets of pictures were therefore in the sequence listed above with the first participant rating set 1a and 2a., second participant 1b and 2a., third participant 1a and 2b and fourth participant 1b and 2b. When participant 4 rated the emotions of set 1b and 2b, the cycle would begin again with the next participant being administered 1a and 2a.

Twenty-seven participants completed data collection and assessment at T1 (pregnancy) and T2 (postpartum). Demographic characteristics of the participants at timepoint one are shown in table 1. All participants identified their gender as female, and participants had a mean age of 33.15 years (SD = 3.36). The average weeks gestation of

participants at T1 was 34.96 (*SD* = 3.04). Of the 27 participants in the study, 20 identified themselves as 'White – English, Welsh, Scottish, Northern Irish or British' (74.1%), four identified themselves as 'White – Any other background' (14.8%), one participant identified themselves as 'Asian or Asian British – Chinese' (3.7%) and one participant identified themselves as 'Any other mixed or multiple ethnic background' (3.7%). English was the first language spoken for most participants (85.2%), and Italian (n = 1), Polish (n = 1) and Russian (n = 1) were the first languages spoken of three participants (3.7% respectively). Most participants did not wear contact lenses or glasses (59.3%) and most of the participants were right-handed (92.6%). Adoptive and prospective adoptive parents were also eligible for the study, but none were recruited. At T2, the average age of the infant was 12.26 weeks, (*SD* = 4.09).

Control Participants

To control for potential learning effects, a control sample of participants over the age of 18, who were not pregnant and did not have any children under the age of one, completed the emotion recognition task at two time points, three months apart. The control participants were recruited through adverts (See Appendix 12) posted on social media, and through snowballing on social media. Recruitment took place between February 2022 and May 2022. The study was open to anyone residing in England, Wales, Scotland, and the Isle of Mann at the time of the study. As with the experimental participants, the control group were sent pairs of sets of pictures (1a or 1b at T1 and 2a or 2b at T2) with combinations of sets sequenced through control participants. At Time 1, 39 control participants completed the emotion recognition task (for demographic data see Table 2). At Time 2, 26 control participants completed the task. The attrition rate between time points was 13 participants (40.00%).

Table 2

Demographic characteristics of control participants at baseline (T1)

Item	Category	Number	Mean	Std. deviation	Percentage (%)
Gender	Male	11			28.2
	Female	27			69.2
	Non binary/Third Gender	1			2.6
Age	Age, Years	37	33.51	10.21	
	Missing	2			
Handedness	Right-handed	39			100
Ethnicity	White – English, Welsh, Scottish, Northern Irish or British	31			79.5
	Asian or Asian British – Chinese	2			5.1
	White – Any other Background	2			5.1
	Any other mixed or multiple ethnic background	1			2.6
	Missing	2			5.1
		1			2.6
First Language Spoken	English	36			92.3
	Welsh/English	1			2.6
	Slovenian	1			2.6
	Polish	1			2.6
Contact Lens/Glasses Wearer	Yes	22			56.4
	No	17			43.6

As all participants in the experimental group reported their gender as female, an independent samples t-test was conducted to explore differences in gender for the control group on the emotion recognition task, to assure that all control group participants could be included, as there were no restrictions placed on gender at the point of recruitment. For the purpose of the independent t-test, which explores differences between two groups, the participant who reported themselves as ‘Non binary/Third gender’ was excluded from analysis. The control group was included in further analysis as there was not a significant difference in accuracy or confidence across all emotional expressions between Males and Females (see Appendix 11).

Procedure

This study was approved by the University of Birmingham Science, Technology, Engineering and Mathematics ethics committee (ERN_21-1164; see Appendix 1). Each participant received a copy of the participant information sheet (Appendix 13) and was given the opportunity to ask any questions about the study either by email or phone. Participants then signed an electronic consent form (Appendix 14) confirming that they had read and understood the information provided and agreed to take part in the study. Participants who met the inclusion criteria completed the study at two time points; pregnancy (T1) and postpartum (T2). Prior to T2, participants were contacted via e-mail, sent the information sheet and consent form again and given the opportunity to ask questions prior to participating in the second part of the study. Each time point had two data collection phases. Firstly, recording sleep using the actigraphy device (Ōura ring/Actiwatch Pro) and a sleep diary. Following this, participants completed the perinatal anxiety screening scale (PASS) and an emotion recognition task (Parsons, 2020). All testing took place remotely with actigraphy devices and sleep diaries posted to participants. The emotion recognition task took place remotely over Qualtrics; software which could be accessed by an internet-compatible device: e.g., mobile phone, tablet, computer.

At both time points, actigraphy devices and sleep diaries were sent in the post. Participants receiving the Ōura ring were given instructions to charge the ring when it arrived and to charge it in the day and wear at night to record sleep. Participants who were sent the Actiwatch Pro were made aware that the device was pre-charged and programmed and would not require further charging during sleep data collection. During this time, participants also monitored their sleep using a paper diary and were asked to note when they started their first night of sleep recording on the sleep diary. Following seven nights of sleep recording, participants posted the actigraphy device and completed sleep diary back to the research team

using the pre-paid envelope provided.

Following the actigraphy device being sent, an e-mail was sent to each participant to confirm that the device had been posted, with a reminder of the tasks required by them. The e-mail contained a link and password to the online task, to be completed once via the Qualtrics platform; which incorporated the collection of demographic data, the perinatal anxiety screening scale and the emotion recognition task. Participants were advised to contact the research team if they had any difficulties with completing the task.

Recruitment, Retention and Missing Data

The research advert prompted potential participants to contact the research team for further information on the study. Following a request for information, the information sheet and consent form were e-mailed out. At T1, 33 participants completed the consent form. Of these 33 participants, 27 participants provided either full or partial data for the study. Reasons for attrition prior to T1 were that potential participants gave birth prior to completing T1 (n = 5) or contacted researchers to withdraw (n = 1). There were missing data regarding participant demographics (n = 1) and missing data regarding the anxiety measure and emotion recognition task at T1 (n = 2).

Missing data was a concern across each device. Of the 27 participants who completed T1, actigraphy data were not obtained for four participants due to the data not being recorded on the ring/actigraphy device upon its return and at T2, actigraphy data were not obtained for seven participants. Of note, Parsons (2020) identified in their research that Ōura rings can complete a 'hard reset' by being placed on the accompanying charger and being hit with force on a hard surface, and therefore it can be speculated that during transit a similar event may have occurred. It can be speculated that human error in terms of programming the Actiwatch Pro could have contributed to missing data. Additionally, the Actiwatch Pro was set to record data for a four-week period to manage delays in postage times however, due to

the nationwide postal strike in September 2022, the period for data collection may have elapsed for certain participants.

At T1, sleep diary data was not obtained for three participants and at T2, sleep diary data were not obtained for two participants. Regarding the anxiety and emotion recognition tasks, at T1, data were not obtained for two participants and demographic data were not obtained for one participant due to not completing prior to the online task. At T2, Anxiety data were not obtained for two participants and for the emotion recognition task at T2 and confidence data were not recorded for one participant (see table 3).

Table 3

Summary of missing data following consent to participate

	N	T1 - Percentage of original consenting sample	N	T2 - Percentage of original consenting sample
Withdrawal prior to T1	6	18.18%		
Demographic data	1	3.03%		
Actigraphy data	4	12.12%	7	21.21%
Diary data	3	9.09%	2	6.06%
Anxiety data	2	6.06%	2	6.06%
Emotion recognition data	2	6.06%	1	3.03%

Analysis

The data were analysed using IBM SPSS Statistics (Version 29). Continuous data were summarised using means and standard deviations (SDs) and categorical data were summarised using frequency distributions. Descriptive statistics were used to summarise the data (see table 3). Due to completion of multiple comparisons, the more conservative $p < .01$

was used throughout. This reflected a reasonable compromise between risk of type 1 error (reporting a spurious relationship) and type 2 error (missing a meaningful one). Results on which $.01 \leq p < .05$ were considered trends to lower the risk of not reporting potentially clinically significant results (Surtees et al., 2019).

Actigraphy sleep data were available for 23 participants at T1 and 20 participants at T2. Sleep diary data was available for 26 participants at T1 and 27 participants at T2. Anxiety data were available for 25 participants at T2 and 25 participants at T2. For the Emotion Recognition task, data was available for 25 experimental participants and 27 control participants. A further breakdown of the number demographics can be found in associated analysis tables in the results section.

Data were screened for normality and heterogeneity (see Appendix 7), to ensure they met the assumptions for ANOVA analysis.

Paired samples t-tests were conducted to explore changes in sleep data and anxiety data across time points. A repeated measures ANOVA was performed to compare the effect of time point on accuracy and confidence in the emotion recognition task, for both the experimental and control participants.

Correlation analysis was completed to examine the relationship between anxiety across time points and the relationship between sleep and anxiety across time points. Using the Schober et al., (2018) paper, for this study, a weak correlation has been defined as being between 0.10-0.39, a moderate correlation has been defined as being between 0.40-0.69 and a strong correlation has been defined as being between 0.70-0.89.

Results

Perinatal Sleep Parameters

The key characteristics of the data are recorded below. Table 4 shows a summary of Actigraphy sleep data across the two time points. Data for Sleep Efficiency are represented as percentages, WASO is represented as minutes and data for TST are represented as 'hours: minutes: seconds'.

Descriptive Statistics

Table 4

Summary of Actigraphy data across timepoints

	T1 Mean (SD)	T2 Mean (SD)	*t*	*p*
Days of sleep recorded	6.65 (1.03)	6.75 (0.79)		
TST[1]	7:18:17 (0:41:56)	7:27:25 (1:05:39)	-.61	.28
Sleep Efficiency	83.84 (3.86)	81.74 (4.77)	1.93	.04
WASO[2]	50.85 (15.05)	72.78 (31.20)	3.84	<.001*
N	23	20		

*Significant at the 0.01 level (1-tailed)

The key characteristics of the sleep diary data are recorded below. Table 5 shows a summary of sleep diary data across the two time points. Data for Sleep Efficiency are represented as percentages, WASO is represented as minutes and data for TST are represented as 'hours: minutes: seconds'.

[1] Total sleep time
[2] Waking after sleep onset

Table 5

Summary of Sleep Diary data across timepoints

	T1 Mean (SD)	T2 Mean (SD)	*t*	*p*
Days of sleep recorded	6.65 (1.03)	6.75 (0.79)		
N	26	27		
TST[3]	7:00:38 (0:50:32)	6:54:34 (1:04:18)	.45	.33
Sleep Efficiency	76.94 (8.83)	70.89 (11.75)	2.35	.02
WASO[4]	33.98 (25.78)	91.22 (46.48)	-4.57	<.001*
N	24	25		

*Significant at the 0.01 level (1-tailed)

Change in sleep

Actigraphy data

In the present study, sleep diary data was utilised to 'clean' the actigraphy data, and all subsequent analysis used solely actigraphy data. Paired samples t-tests were conducted to compare TST(Acti), WASO(Acti) and Sleep Efficiency (Acti) between T1 and T2. The data for this analysis were from a restricted sample of participants who had both T1 and T2 data. There was a trend for a difference in Sleep Efficiency between T1 (M = 83.98, SD = 4.12) and T2 (M = 81:60, SD = 4.70); $t(17) = 1.93$, $p = .04$, with new parents experiencing poorer Sleep Efficiency on average when compared to pregnancy. There was not a significant

[3] Total sleep Time
[4] Waking after sleep onset

difference in TST between T1 (*M* = 7:14:58, *SD* = 0:45:25) and T2 (*M* = 7:23:20, *SD* = 0:59:28); *t*(17) = -.61 , *p* = .28. There was a significant difference in WASO between T1 (*M* = 49.76, *SD* = 13.49) and T2 (*M* = 74.42 *SD* = 31.30); *t*(17) = -3.84 , *p* = <.001, with new parents experiencing longer periods of time awake following sleep onset when compared to pregnancy.

Diary data

Paired samples t-tests were conducted to compare $TST_{(Diary)}$, $WASO_{(Diary)}$ and Sleep efficiency $_{(Diary)}$ between T1 and T2. There was a trend for a difference in Sleep Efficiency between T1 (*M* = 76.94, *SD* = 8.83) and T2 (*M* = 70.72, *SD* = 11.97); *t*(23) = 2.35 , *p* = .02, with new parents experiencing lower Sleep Efficiency on average when compared to pregnancy. There was not a significant difference in TST between T1 (*M* = 7:00:38, *SD* = 0:50:32) and T2 (*M* = 6:53:55, *SD* = 1:05:36); *t*(23) = .45 , *p* = .33. There was a significant difference in WASO between T1 (*M* = 33.98, *SD* = 25.78) and T2 (*M* = 90.07 *SD* = 47.11); *t*(23) = -4.57 , *p* = <.001, with new parents experiencing longer periods of time awake following sleep onset when compared to pregnancy.

Anxiety and sleep

Perinatal Anxiety Parameters

Descriptive Statistics

Table 6 shows the data recorded across time points for anxiety, presenting the means and standard deviation for total anxiety score.

Table 6

Summary of anxiety data across timepoints

	T1 Mean (SD)	T2 Mean (SD)	T1 Percentage (%)	T2 Percentage (%)
Anxiety Total Score	20.60 (11.50)	24.56 (14.08)		
N	25	25		
Asymptomatic			56.0	40.0
N	14	10		
Mild-Moderate			40.0	48.0
N	10	12		
Severe			4.0	12.0
N	1	3		

Change and stability in Anxiety

Paired samples t-tests were conducted to compare total anxiety score between T1 and T2. There was a significant difference in anxiety between T1 (M = 20.60, SD = 11.50) and T2 (M = 24.56, SD = 14.08); $t(24) = -1.88$, $p = .04$, with new parents experiencing a trend for higher levels of anxiety when compared to pregnancy.

Correlation analysis was completed to examine the relationship between anxiety at T1 and T2. Given the normal distribution of the data, Pearson's r was used. There was a moderate, positive correlation between anxiety at T1 and T2, $r(25) = .680$, $p < .001$.

Perinatal Anxiety and Sleep

Correlation analysis was completed to examine the relationship between anxiety and sleep parameters; TST, WASO and Sleep Efficiency at both T1 and T2. Given the normal distribution of the data, Pearson's r was used (see table 7).

Table 7

Correlation coefficients for anxiety and sleep parameters for T1 and T2

		TST (Acti)[5]	Sleep Efficiency (Acti)	WASO (Acti)
T1	Anxiety	-.158 (*p* = .247)	-.165 (*p* = .238)	-.157 (*p* = .248)
T2	Anxiety	0.284 (*p* = .127)	.104 (*p* - .340)	-.075 (*P* = .384)
Change from T1 – T2	Anxiety	-.180 (*p* = .269)	-.234 (*p* = .210)	.033 (*p* - .455)

**. Correlation is significant at the 0.01 level (1-tailed)

There was not a significant correlation at T1 between anxiety and any of the sleep variables: TST, *r(21)* = -.158, *p* = .247, Sleep Efficiency *r(21)* = -.165, *p* = .238, WASO, *r(21)* = -.157, *p* = .248. Similarly, no significant correlations were identified at T2: TST, *r(18)* = -.284, *p* = .127, Sleep Efficiency *r(18)* = .104, *p* = .340, WASO, *r(18)* = -.075, *p* = .384. Correlation analysis was completed to examine the relationship between change in anxiety and change in TST, WASO and Sleep Efficiency across time points. Given the normal distribution of the data, Pearson's r was used. Again, no significant correlations were observed: TST, *r(14)* = -.180, *p* = .269, Sleep Efficiency *r(14)* = -.234, *p* = .210, WASO, *r(14)* = .033, *p* = .455.

Emotion Recognition and Sleep

Descriptive Statistics

The key characteristics of the emotion recognition task data for both the experimental and control group are recorded below. Table 8 shows a summary of accuracy and confidence ratings across the emotions of 'Happy', 'Neutral' and 'Sad'.

[5] Actigraphy data

Table 8

Summary of emotion recognition data across timepoints for experimental and control conditions

Variable		N Experiment /Controls	Mean (SD) Experiment (n = 25)	Mean (SD) Controls (n = 27)
Happy - Accuracy	T1	25/27	14.56 (1.53)	14.11(2.76)
	T2	25/27	13.84 (1.49)	13.44 (1.69)
Happy – Confidence %	T1	25/27	82.88 (8.57)	91.41(7.49)
	T2	25/26	90.30 (8.20)	83.39 (17.12)
Neutral - Accuracy	T1	25/27	14.32 (1.99)	13.63 (2.91)
	T2	25/27	13.64 (2.25)	13.85 (1.59)
Neutral – Confidence %	T1	25/27	80.94 (12.84)	87.76 (9.62)
	T2	25/27	83.98 (12.21)	87.09 (10.15)
Sad - Accuracy	T1	25/27	14.64 (1.44)	13.85 (3.18)
	T2	25/27	15.16 (1.28)	14.22 (0.93)
Sad – Confidence %	T1	25/27	87.12 (10.28)	90.46 (9.05)
	T2	25/26	91.71 (7.53)	92.97 (6.72)

Change and Stability in Emotion Recognition

An 2x3x2 mixed ANOVA was conducted on Accuracy of responses on the Emotion Recognition task, with the within subjects variables of Timepoint (Pre-birth, Post-Birth) and Emotion (Happy, Neutral, Sad), and the between subjects variable of Group (Mothers,

Control)[6]. There was no significant main effect of Timepoint, $F(1,50) = .34$, $p = .56$, $\eta p^2 = .007$, no significant main effect of Emotion, $F(1.67, 83.52) = 3.02$, $p = .063$, $\eta p^2 = .057$ and no significant main effect of Group $F(1,50) = 2.11$ $p = .15$, $\eta p^2 = .52$, $\eta p^2 = .041$. The two-way interaction between Group and Emotion, $F(1.67,50) = .755$ $p = .451$, $\eta p^2 = .017$, and the three-way interaction between Group, Emotion and Timepoint, $F(1.98,50) = 1.40$ $p = .25$, $\eta p^2 = .027$ were also not significant. The two-way interaction, between Timepoint and Emotion was, however, significant, $F(2,100) = 5.90$, $p = .004$, $\eta p^2 = .11$. Follow up on this interaction using Bonferroni Pairwise comparisons showed a trend for performance decreasing (across both parents and controls) for Happy stimuli, Mean Difference = .69, $p = .029$, whilst performance remained consistent for Sad, Mean Difference = -.44, $p = .20$, and Neutral, Mean Difference = .21, $p = .54$, stimuli.

An equivalent 2x3x2 mixed ANOVA was conducted on Confidence of responses on the Emotion Recognition task. Here, there was a significant main effect of Timepoint, $F(1,49) = 6.52$, $p = .014$, $\eta p^2 = .12$, T1 > T2, and a significant main effect of Emotion, $F(2, 98) = 34.02$, $p = .01$, $\eta p^2 = .41$, Sad > Happy > Neutral. There was no significant main effect of Group $F(1,49) = 1.76$ $p = .19$, $\eta p^2 = .035$. The two-way interaction between Group and Emotion, $F(2, 98) = 2.47$, $p = .09$, $\eta p^2 = .048$, was not significant, however, there was a significant interaction between Timepoint and Group, $F(1, 49) = 12.19$, $p = .001$, $\eta p^2 = .20$ and a trend for an interaction between Timepoint and Emotion , $F(2, 98) = 4.29$, $p = .016$, $\eta p^2 = .80$. The three-way interaction between Group, Emotion and Timepoint, $F(2,49) = 17.86$ $p = .01$, $\eta p^2 = .27$, was also significant.

[6] Given some data were not normally distributed for both parent and control participants, further consideration was made regarding analysis. No non-parametric equivalent to the mixed ANOVA exists. The planed omnibus ANOVA was conducted and is generally thought to be robust to deviations from normality. For completeness, non-parametric equivalents to all follow up analysis were conducted. None of these analysis suggested different conclusions from their parametric equivalents (see Appendices 8; 9; 10).

Further analyses on the three-way interaction between Group, Emotion and Timepoint was conducted through separate 2x3 ANOVAs for the parent and control groups, with the within-subjects variables of Timepoint (T1, T2) and Emotion (Happy, Neutral, Sad). For parents, there was a significant main effect of Timepoint ($F(1, 24) = 23.87$, $p = .<.001$, $\eta p^2 = .50$) and Emotion ($F(1, 48) = 22.50$, $p = .<.001$, $\eta p^2 = .48$). There was a trend toward a significant interaction between Timepoint and Emotion ($F(2, 48) = 4.98$, $p = .011$ $\eta p^2 = .17$). Follow up on this interaction using Bonferroni Pairwise comparisons showed that mothers became more confident in their performance on Happy stimuli, Mean Difference = 7.42, $p = <.001$, and Sad stimuli, Mean Difference = 4.60, $p = .002$, but not on Neutral stimuli, Mean Difference = 3.04, $p = .062$.

An equivalent 2x3 ANOVA was conducted for control participants. There was no significant main effect of Timepoint ($F(1, 25) = 3.63$, $p = .55$, $\eta p^2 = .01$). There was a significant main effect of Emotion ($F(2, 50) = 12.10$, $p = .<.001$, $\eta p^2 = .33$) and the two-way interaction between Timepoint and Emotion was significant ($F(2, 50) = 18.49$, $p = .<.001$, $\eta p^2 = .42$).

Follow up on this interaction using Bonferroni Pairwise comparisons showed confidence reducing for Happy, Mean Difference = 4.85, $p = .003$, whilst confidence remained consistent for Neutral stimuli, Mean Difference = -.34, $p = .84$. Confidence improved for Sad stimuli, Mean Difference = 2.85, $p = .035$.

Perinatal Anxiety and Sleep

Timepoint Specific Correlation

Correlation analysis was completed to examine the relationship between performance across the emotion recognition task (accuracy and confidence) and sleep parameters; TST, WASO and Sleep efficiency at both T1 and T2. Pearson's r was conducted and table 9

displays the correlation coefficients for T1, T2 and change across timepoints. A single, significant, negative correlation was identified between Anxiety and Accuracy at T2.

Table 9

Correlation coefficients for emotion recognition accuracy and confidence ratings, anxiety, and sleep parameters for T1 and T2

		TST (Acti)[7]	Sleep Efficiency (Acti)	WASO (Acti)	Anxiety
T1	Accuracy	-.002 (*p = .50)*	-.141 (*p = .24)*	.255 (*p = .10)*	-.008 (*p = .48)*
	Confidence	-.064 (*p = .38)*	.184 (*p = .18)*	-.033 (*p = .44)*	-.168 (*p = .15)*
T2	Accuracy	-.349 (*p = .08)*	-.062 (*p = .40)*	-.036 (*p = .44)*	-.553** (*p = .002)*
	Confidence	.268 (*p = .14)*	.318 (*p = .10)*	-.329 (*p = .10)*	-.302 (*p = .07)*
Change	Accuracy	.289 (*p = .16)*	.259 (*p = .19)*	-.392 (*p = .08)*	.242 (*p = .12)*
	Confidence	.091 (*p* = .38)	-.208 (*p* = .24)	.199 (*p* = .25)	-.056 (*p* = .40)

**. Correlation is significant at the 0.01 level (1-tailed)

Discussion

This study provides insights into the longitudinal relationship between sleep, perinatal anxiety, and emotion recognition across the perinatal period. It was the first study of its kind

[7] Actigraphy data

to be conducted in the United Kingdom and provides preliminary evidence into the nuanced relationship between sleep changes, mental health, and social cognition for new parents.

Summary of findings

Sleep Data

Sleep data was recorded at two time points; pregnancy (T1) and postpartum (T2), using diaries, Ōura rings, and the Actiwatch Pro. Data suggest that recording sleep using objective, sleep devices was feasible and tolerable for participants whilst pregnant and caring for an infant, however, a substantial amount of objective sleep data was missing across the two time points.

Analysis of the actigraphy data provided evidence for a trend for a difference between sleep efficiency from T1 to T2, with new parents experiencing lower sleep efficiency on average when compared to pregnancy. There were no significant differences highlighted for total sleep time between time points however, a significant difference was observed between timepoints for time awake following sleep onset with new parents experiencing longer periods of time awake when compared to pregnancy. The data provides partial support for the hypothesis that new mothers sleep will be worse than when tested in pregnancy, as evidenced by decreased sleep efficiency, and increased waking after sleep onset however, total sleep time did not significantly differ, supporting the null hypothesis. The data in the present study provides partial support for findings in the wider literature that suggest sleep difficulties in pregnancy continue through to the first few months following childbirth (Parsons et al., 2023; Zhang et al., 2021). Results of the present study do not support findings where a recovery of sleep patterns has been identified at 10-12 weeks postpartum (Kuo et al., 2014).

Perinatal Anxiety Scale

Perinatal anxiety was measured at both time points using the Perinatal Anxiety Screening Scale (PASS; Somerville et al., 2014; Somerville et al., 2015). Results of the present study observed a trend for a moderate increase in anxiety across the perinatal period, in support of the hypothesis that anxiety would increase from pregnancy to postpartum. Although not significant, a trend was observed for greater levels of anxiety to be associated with shorter periods of sleep, poorer sleep efficiency and longer periods of WASO across the perinatal period, consistent with some findings in the wider literature (Clout & Brown, 2015; Ozsoy et al., 2019; Qui et al., 2016; Teoh et al., 2021; MoghaddamHosseini et al., 2021; Morales-Munoz et al., 2018; Yildirim & Demir, 2019; Wang et al., 2022; Lin et al., 2021; Hall et al., 2009; Wang et al., 2021; Swanson et al., 2011) however, this is to be interpreted with caution due to the small sample size.

Emotion Recognition Task

It was hypothesised that new mothers' ability to recognise emotions in infants would be reduced in comparison to pre-partum abilities. A high level of accuracy was identified across the emotion recognition task for both experimental and control participants and there were no significant differences in accuracy and confidence ratings found between the groups. This high level of accuracy for experimental participants echoes previous findings by Parsons (2020). A significant main effect was identified for timepoint and emotion and the data suggest that all participants' performance decreased across the time points for Happy emotions, whereas no significant differences in performance were observed for Sad and Neutral emotions across time points. Confidence data showed a difference between parents and controls, with parents' confidence increasing across all emotions (Happy, Neutral and Sad) whereas data for control participants showed a trend for confidence reducing for Happy stimuli, remaining consistent for Neutral stimuli, and improving for Sad stimuli.

Further correlation analysis was conducted to examine the relationship between performance across the emotion recognition task (accuracy and confidence), sleep and anxiety at both timepoints. No significant correlations were identified between sleep parameters and anxiety however, a single, significant, and large, negative correlation was identified between anxiety and accuracy at postpartum, indicating that mothers with increased anxiety were likely to be less accurate in identifying emotions.

Limitations, Future Directions for Research and Clinical Implications

This study was the first longitudinal study to explore the relationship between changes in sleep, perinatal anxiety, and emotion recognition from pregnancy through to postpartum. The final sample represented a smaller data set than originally aimed for and it can be speculated that recruitment was impacted by the COVID-19 pandemic alongside the constraints of a ClinPsyD project and postal strikes. Several considerations can be drawn regarding conducting research of this nature.

Recruitment of Participants For a Longitudinal Study

Recruitment of participants took place through snowballing via adverts posted on social media with the support of the National Childbirth Trust (NCT). Although study adverts were frequently shared across social media, this did not translate directly into interest from potential participants. As this is the first piece of research recruiting for a longitudinal study exploring sleep, anxiety, and emotion recognition, it was unknown what level of interest would be received. All e-mails of interest were followed up by the information sheet and consent form, which translated into 33 participants consenting to take part in the study. The nature of recruiting for data collection in the third trimester of pregnancy meant that five participants were unable to take part due to having given birth prior to completing T1 (n = 5)

or contacting researchers to withdraw (n = 1). Working remotely within COVID-19 meant that equipment had to be cleaned and quarantined for several days prior to use and upon being returned prior to data extraction. The availability of equipment and added cleaning schedules contributed to the loss of potential data through consenting participants who gave birth earlier than expected and therefore could not continue with the study. In addition, throughout the period of recruitment, there was a substantial postal strike (September 2022) which led to a delay in equipment being sent to participants and returned in a timely manner.

As the study was remote, and social media is used by a majority of the public, there was an opportunity to recruit participants from a variety of locations within the United Kingdom, from a variety of backgrounds. Although positive steps through social media were made to include pregnant participants from a variety of backgrounds and locations, many participants found the study through the National Childbirth Trust (NCT) page. It is important to acknowledge that the National Childbirth Trust offer a series of antenatal classes which require payment, and therefore access to additional funds. It is likely that participants recruited through this advertising may be taking part in such courses and therefore findings from this sample may be less generalisable of the experience of pregnant women across the United Kingdom with differing levels of financial mobility. Future studies could benefit through recruiting through the National Health Service (NHS), which routinely offer antenatal and postnatal appointments to mothers across the United Kingdom and will capture a breadth of experiences.

Use of Actigraphy Devices and Sleep Diary

The present study used a subjective sleep diary alongside two objective measures of sleep (Ōura ring and Actiwatch Pro), all of which demonstrated strength in recording sleep, with an agreement between the devices (Asgari Mehrabadi et al., 2020; de Zambotti et al., 2019; Saganowski et al., 2020); however, the use of two devices, can be considered a

limitation due to differing algorithms for collecting sleep data. Future research comparing types of actigraphy devices would provide further insights into this confounding variable. The devices mirrored watch and ring devices which are commonly worn by the public. This provided a naturalistic context to record sleep changes in, which is likely to have produced data with greater accuracy, in comparison to formal research settings. For the present study, overnight sleep data was collected which limits a full understanding of sleep changes in the perinatal period due to not exploring the use of daytime sleeping/naps. Future research would benefit from measuring sleep over a 24-hour period, to explore the impact of napping on nighttime sleep as a confounding variable. Missing data was a concern across each device, and subsequent analysis was therefore limited.

A low agreement between subjective and objective measures has been identified when exploring the relationship between sleep and anxiety (Volkovich et al., 2016). This is likely related to different sleep constructs being measured, with subjective measures likely to explore sleep quality and objective measures likely to explore sleep quantity, including time taken to fall asleep and disrupted sleep.

Previous studies utilising both subjective and objective measures across the perinatal period have found an association between anxiety experienced during pregnancy and an over reporting of sleep difficulties as measured by subjective measures, which were not highlighted using objective tools (Gueron-Sela et al., 2021; Volkovich et al., 2016). Future research into sleep, anxiety and emotion recognition in the perinatal period could benefit from using both an objective and subjective measurement of sleep and comparing how perspective on sleep influences this nuanced relationship.

Perinatal Anxiety

The present study used the (PASS; Somerville et al., 2014; Somerville et al., 2015) which screens for anxiety disorders in the entire perinatal period. The measure is shown to

have adequate test–retest reliability and adequate convergent validity (Somerville et al., 2015) and has been illustrated validity and reliability in the measurement perinatal anxiety when compared with other measures assessing anxiety symptoms and disorders (Amiri et al., 2022; Barros et al., 2021; Jradi et al., 2020; Koukopoulos et al., 2021 & Yazici et al., 2018). The PASS is validated for use across the perinatal period whereas many typically used anxiety measures are not constructed and validated for the whole perinatal experience. This is the first study to use the PASS to explore the relationship between sleep changes and anxiety across the perinatal period however, it is not routinely used by health and social care professionals in the United Kingdom. Future research may benefit from using the PASS to contribute to the growing pool of literature using this measure and to highlight its potential clinical uses.

Emotion Recognition Task

The emotion recognition task was programmed into Qualtrics software, and was accessible remotely to participants via a phone, tablet, laptop, or computer with access to the internet. The data were accessible to the researcher throughout, so that individual responses could be verified. There was missing data for two participants at T1 and one participant at T2. This could be due to a participant not recording their responses, missing questions, or a technical fault. Future research could benefit from holding the emotion recognition task in person so that any technical concerns or difficulties with participants providing responses are better managed.

The procedure for the emotion recognition task was developed by Parsons (2020) who adapted a task by Elliot et al., (2014) with some key differences. In the study by Elliot et al, the stimulus included pictures of the participants own child which Parsons (2020) and the present study did not. Elliot et al., (2014) did however, identify that there were no systematic differences observed in parents' ability to accurately identify emotions in their own child and

others. Additionally, Elliot et al., used fewer images in their study, using 30 compared to the 48 used in this study and in Parsons (2020). A high level of performance in the present study is reflective of the performance observed in Parsons (2020). The task was time sensitive, with participants being shown each picture for three seconds which may have contributed to how participants then rated their confidence. Further research in this area would be beneficial to explore factors that may influence the emotion recognition of prospective and new parents in other unique contexts.

Further Clinical Implications

A trend was identified for anxiety increasing from pregnancy to postpartum for participants, which promotes the benefits for health and social care professionals to screen pregnant people for levels of anxiety during pregnancy and to signpost to appropriate avenues of support proactively and to offer timely reviews of mental health in the postpartum period. Based on actigraphy data, changes in sleep were identified in the present study, with sleep being less efficient, with greater periods of waking after sleep onset for new parents, however, total sleep time did not significantly differ from pregnancy. These changes in sleep did not significantly associate with changes in anxiety which contrast with findings in wider research (chapter 1). The present research did not use a validated psychometric measure to record subjective sleep data. A recent meta-analysis identified a moderate association between changes in sleep and anxiety in research that has largely used subjective, validated psychometric tests to explore sleep quality (chapter 1). Performance on such measures has been shown to be influenced by levels of anxiety (Volkovich et al., 2016), which highlights the role of perception of sleep, beliefs and expectations as confounding factors that could benefit from wider research and clinical focus.

In the present study, a high level of accuracy was observed across emotions, with participants' performance decreasing for Happy emotions, whilst remaining stable for Neutral

and Sad emotions. Confidence across all emotions was shown to increase from pregnancy to postpartum. It can be hypothesised that new parents are likely to be more attuned to neutral or negative emotional states which may reflect a need for parental intervention, as infants largely express the need for soothing, feeding and changing through crying. No significant associations were identified between performance on the emotion recognition task, sleep, and anxiety, other than one, single, significant, and large, negative correlation between anxiety and accuracy at postpartum, which suggests that mothers with increased anxiety may be less likely to accurately identify emotions. Such findings may be of interest to health and social care professionals, to promote the exploration of anxiety and assess any impact this may have on the parent-infant relationship, allowing for timely offers of intervention in health and social care settings.

Conclusions

The present study was the first study to explore the relationship between sleep changes, anxiety, and emotion recognition across the perinatal period. Both Actigraphy data and Sleep diary data highlighted that new parents experience greater sleep disruption than in pregnancy, as evidenced through less efficient sleep and greater periods of time awake after sleep onset when compared to pregnancy, although no difference was identified in total sleep time. Contrary to wider literature, sleep difficulties across the postnatal period were not significantly associated with changes in anxiety. Although performance on the emotion recognition task remained consistently high across groups, there was a trend for performance decreasing for both parents and controls for Happy stimuli, with performance remaining consistent for Neutral and Sad stimuli. Interestingly, differences in self-rated confidence on the emotion recognition task were observed between parent and control groups, with self-rated confidence improving across all emotions for parents. Comparatively, control

participants recorded higher confidence for Sad stimuli, lower confidence for Happy stimuli and confidence was consistent for Neutral stimuli. Overall, the findings from the present study seem to suggest that despite periods of sleep deprivation and experiences of anxiety, new mothers retain the ability to accurately identify an infant's emotions and experience an increase in confidence levels increase when compared to pregnancy by the third month postpartum.

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Chapter Three

Public Dissemination Document

Press Release for Literature Review

What's the relationship between sleep changes and anxiety in pregnancy and postpartum?

According to a new meta-analysis produced by the University of Birmingham, during pregnancy and the first year postpartum, disrupted sleep is associated with higher levels of anxiety.

Changes in sleep are expected in pregnancy with the birthing body going through a host of physical and emotional changes. Previous research has shown that disrupted sleep is most common in the third trimester of pregnancy, as mothers experience discomfort, pressure on the bladder and increased movements of a baby. When a baby is born, sleep dramatically changes, with a mother having to respond to a baby's needs in the night through meeting the demands for feeding and changing, whilst the body recovers from the birthing experience. Many studies have explored how disrupted sleep is associated with anxiety, finding that with increased periods of waking in the night and overall poorer sleep quality, anxiety levels are higher. In turn, anxiety has been shown to disrupt sleep, with people finding it harder to fall asleep and remain asleep. Many studies have explored the relationship between sleep and anxiety during pregnancy or during the postpartum period however, no review has been conducted to explore the literature across both periods to date.

This literature review looked at 32 studies, found from international research databases, which looked at sleep and anxiety in pregnancy and in the postpartum period. The current review provides insight into the relationship between changes in sleep and anxiety, finding that regardless of country of data collection, the time data was collected (whether in pregnancy or postpartum) or type of anxiety disorder, sleep difficulties are associated with higher anxiety levels.

Interestingly, a difference was identified between how sleep data was recorded, with most studies using sleep diaries and questionnaires to gather data regarding perceived sleep quality, whereas fewer studies used actigraphy devices to gather physiological sleep data. Subsequent analysis found that the relationship between sleep difficulties and anxiety was stronger when looking at subjective sleep diary/questionnaire data, and weaker when looking at said physiological data. This provokes the question, how does anxiety influence how we view our sleep? And should we view subjective sleep data or physiological sleep data as most reliable? Additionally, many differences were found across the studies, with variability in participant numbers, in the strategy to recruit participants and measures used to record anxiety and sleep data.

Lead author Catherine Gercs concluded "This is the first literature review looking at how changes in sleep and anxiety in this period are related, and the variability in studies suggests that further research into this relationship is required to broaden our understanding of what factors contribute to sleep changes and high level of anxiety. The more we know, the better healthcare professionals can screen for sleep problems and anxiety and therefore help mums to be".

Press Release for Empirical Project

Does sleep deprivation and anxiety make it harder to know that a baby is distressed?

According to research by the University of Birmingham, new parents experience poorer sleep and increased anxiety when compared to pregnancy, and a novel finding was that contrary to the current literature, new parents' confidence increases in selecting the emotional state of an infant.

The perinatal period is a time of biological, psychological, and social change which can influence sleep and mental wellbeing. Research has identified that such changes in sleep

and anxiety can impacts the development of bonding, with parents questioning what their baby needs in those early weeks, often impacting their confidence. Studies have explored the role between anxiety and sleep in either pregnancy or postpartum however, no research has been conducted following the same participants across this period. This novel study by a researcher at the University of Birmingham investigates the relationship between sleep deprivation, anxiety, and emotion recognition of infants across pregnancy into postpartum.

Although this study highlighted that parents experience poorer sleep and increased anxiety when compared to pregnancy, no significant relationship was identified between these two areas. Researchers also looked at how sleep changes and anxiety may influence a parents' ability to recognise the emotional state of an infant at three-months old, showing a series of 48 pictures of three-month old infants expressing 'Happy, 'Neutral' and 'Sad' emotions. Both accuracy and confidence scores were taken from this task, which was completed in the third trimester of pregnancy and repeated at 3 months postpartum. This task was also completed at two timepoints, three months apart, by a control group of participants who were not pregnant and did not have a child under the age of one.

The study found that across pregnancy and the postnatal period, parents were found to have high accuracy in recognising an infants' emotional state in a picture, with performance decreasing for 'Happy' emotions in the postnatal period, whilst performance remained consistent for 'Neutral' and 'Sad' emotions. Interestingly, confidence in making decisions regarding a baby's emotional state increased postnatally for all three emotional states, whilst they did not across the control group.

Overall, the findings from the present study seem to suggest that despite periods of sleep deprivation and experiences of anxiety, new mothers retain the ability to accurately identify an infant's emotions and experience an increase in confidence levels increase when compared to pregnancy by the third month postpartum.

Lead author Catherine Gercs concluded “This is the first study exploring how sleep, anxiety, and emotion recognition in an infant change over the perinatal period. Within this primary sample of participants, some new insights into how sleep and anxiety influence accuracy and confidence in understanding a baby’s needs have been highlighted. Further research would be beneficial to explore how this translates to a new parent’s developing bond with their own child and to explore what other factors may influence this.”

Appendix 1: Ethical approval e-mail following requested amendments

Application for Ethical Review ERN_21-1164

SC Susan Cottam (Research Support Services)
To: Andrew Surtees (Psychology)
Cc: Catherine Gercs (ClinPsyD Clinical Psychol FT); [redacted]
Wed 03/11/2021 15:23

Dear Dr Surtees

Re: "Relationship between sleep deprivation, perinatal anxiety, maternal mind-mindedness and emotional recognition in new mothers"
Application for Ethical Review ERN_21-1164

Thank you for your application for ethical review for the above project, which was reviewed by the Science, Technology, Engineering and Mathematics Ethical Review Committee.

On behalf of the Committee, I confirm that this study now has full ethical approval.

I would like to remind you that any substantive changes to the nature of the study as described in the Application for Ethical Review, and/or any adverse events occurring during the study should be promptly brought to the Committee's attention by the Principal Investigator and may necessitate further ethical review.

Please also ensure that the relevant requirements within the University's Code of Practice for Research and the information and guidance provided on the University's ethics webpages (available at https://intranet.birmingham.ac.uk/finance/accounting/Research-Support-Group/Research-Ethics/Links-and-Resources.aspx) are adhered to and referred to in any future applications for ethical review. It is now a requirement on the revised application form (https://intranet.birmingham.ac.uk/finance/accounting/Research-Support-Group/Research-Ethics/Ethical-Review-Forms.aspx) to confirm that this guidance has been consulted and is understood, and that it has been taken into account when completing your application for ethical review.

Please be aware that whilst Health and Safety (H&S) issues may be considered during the ethical review process, you are still required to follow the University's guidance on H&S and to ensure that H&S risk assessments have been carried out as appropriate. For further information about this, please contact your School H&S representative or the University's H&S Unit at healthandsafety@contacts.bham.ac.uk.

Kind regards

Mrs Susan Cottam
Research Ethics Manager
Research Support Group
University of Birmingham

Appendix 2: Meta-analysis Table of Effects

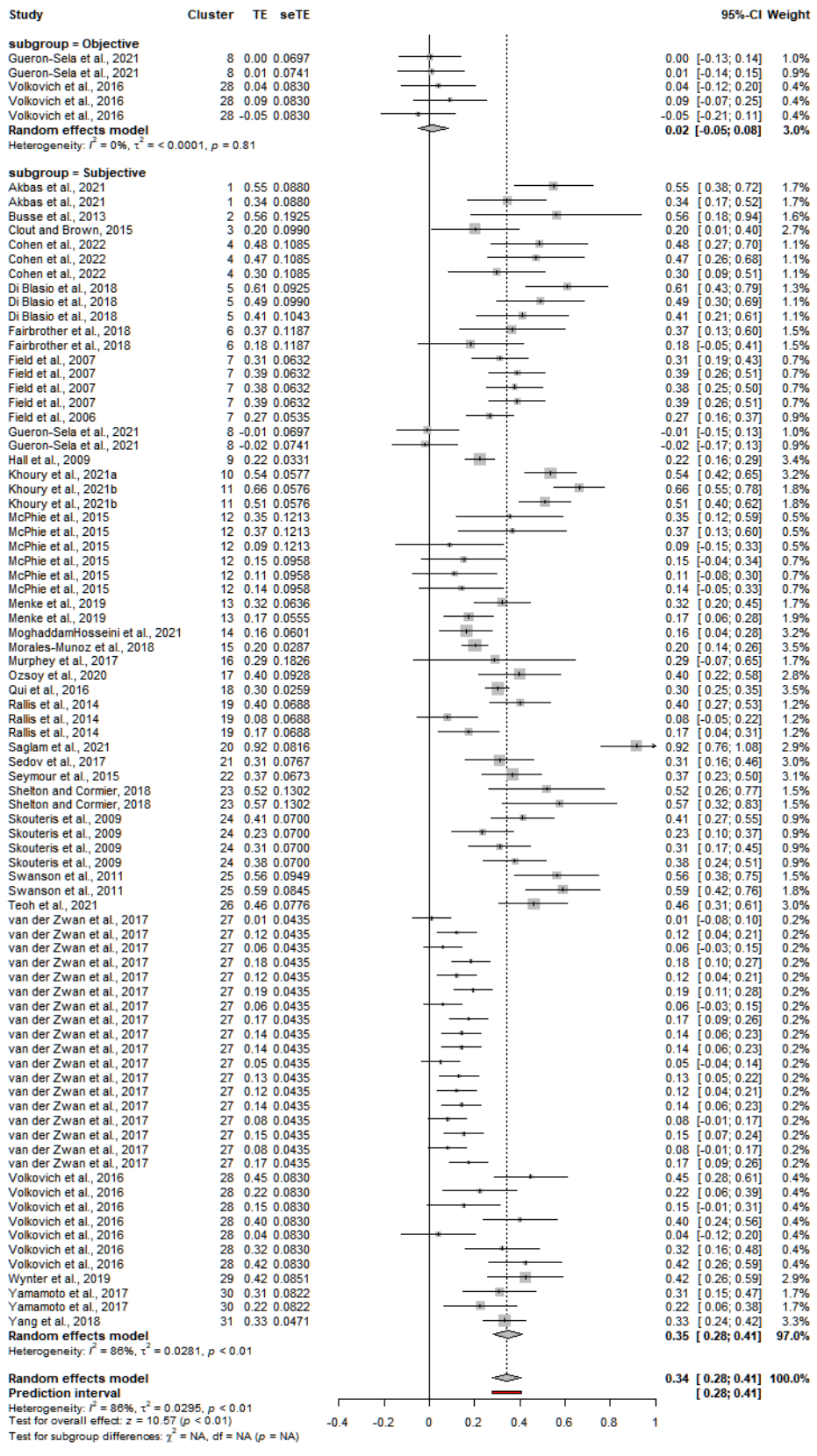
Table of effects

	Study	Effect	Std.Er	CI Lower	CI Upper	Weight(fixed)	Weight(random)
Akbas et al., *State Anxiety*	2021	0.55	0.088	0.38	0.72	129	27.59
Akbas et al., *Trait Anxiety*	2021	0.34	0.089	0.17	0.52	129	27.59
Busse et al.,	2013	0.56	0.19	0.18	0.94	27	15.26
Clout and Brown,	2015	0.20	0.099	0.0087	0.40	102	26.11
Cohen et al., *12w-12w postpartum*	2022	0.49	0.11	0.27	0.69	85	24.84
Cohen et al., *12w-24w postpartum*	2022	0.47	0.11	0.26	0.68	85	24.84
Cohen et al., *24w-24w postpartum*	2022	0.29	0.11	0.086	0.51	85	24.84
Di Blasio et al., *Pregnancy*	2018	0.61	0.092	0.43	0.79	117	26.99
Di Blasio et al., *Postpartum 1w*	2018	0.49	0.099	0.29	0.69	102	26.11
Di Blasio et al., *Postpartum 3w*	2018	0.41	0.10	0.21	0.61	92	25.4
Fairbrother et al., *Postpartum 4w*	2018	0.37	0.12	0.13	0.59	71	23.48
Fairbrother et al., *Postpartum 12w*	2018	0.18	0.12	-0.050	0.41	71	23.48
Field et al., *Pregnancy 22.3w*	2007	0.31	0.063	0.19	0.43	250	30.77
Field et al., *Pregnancy 32.4w*	2007	0.39	0.063	0.26	0.51	250	30.77
Field et al., Pregnancy 22.3w-32.4w	2007	0.38	0.063	0.25	0.50	250	30.77
Field et al., Pregnancy 32.4w-22.3w	2007	0.39	0.063	0.26	0.51	250	30.77
Field et al.,	2006	0.27	0.053	0.16	0.37	350	31.89
Gueron-Sela et al., *Pre Actigraphy*	2021	0.002	0.069	-0.13	0.14	206	29.98
Gueron-Sela et al., *Post Actigraphy*	2021	0.007	0.074	-0.14	0.15	182	29.42
Gueron-Sela et al., *Pre Diary*	2021	-0.01	0.069	-0.15	0.13	206	29.98
Gueron-Sela et al., *Post Diary*	2021	-0.02	0.074	-0.17	0.12	182	29.42
Hall et al.,	2009	0.22	0.033	0.16	0.29	913	33.79
Khoury et al.,	2021a	0.54	0.058	0.42	0.65	300	31.42
Khoury et al., *CWS scale*	2021b	0.66	0.058	0.55	0.77	301	31.43
Khoury et al., *GAD-7 scale*	2021b	0.51	0.058	0.39	0.62	301	31.43
McPhie et al., *With EGWG: T1 + T1*	2015	0.35	0.121	0.112	0.59	68	23.15
McPhie et al., *With EGWG: T2 + T2*	2015	0.36	0.121	0.13	0.60	68	23.15
McPhie et al., *With EGWG: T1 + T3*	2015	0.090	0.121	-0.15	0.33	68	23.15
McPhie et al., *Without EGWG: T1 + T1*	2015	0.15	0.096	-0.04	0.34	109	26.54
McPhie et al., *Without EGWG: T1 + T2*	2015	0.11	0.096	-0.08	0.29	109	26.54
McPhie et al., *Without EGWG; T1 + T3*	2015	0.14	0.096	-0.05	0.33	109	26.54
Menke et al., *GAD*	2019	0.32	0.064	0.19	0.44	247	30.73
Menke et al., *PTSD*	2019	0.17	0.055	0.063	0.28	325	31.67
MoghaddamHosseini et al.,	2021	0.16	0.060	0.044	0.28	277	31.15
Morales-Munoz et al.,	2018	0.20	0.029	0.14	0.26	1218	34.11
Murphey et al.,	2017	0.29	0.18	-0.070	0.64	30	16.17
Ozsoy et al.,	2020	0.39	0.093	0.22	0.58	116	26.94
Qui et al.,	2016	0.30	0.026	0.25	0.35	1485	34.28
Rallis et al., *Pre 16w + 16w*	2014	0.40	0.069	0.27	0.53	211	30.09
Rallis et al., *Pre 16w + 24w*	2014	0.080	0.069	-0.055	0.21	211	30.09
Rallis et al., *Pre 24w + 24w*	2014	0.17	0.069	0.037	0.30	211	30.09
Saglam et al.,	2021	0.92	0.082	0.76	1.08	150	28.44
Sedov et al.,	2017	0.31	0.077	0.16	0.46	170	29.09
Seymour et al.,	2015	0.37	0.067	0.23	0.49	221	30.28
Shelton and Cormier, *PSS*	2018	0.52	0.13	0.26	0.77	59	22
Shelton and Cormier, *PSI-SF*	2018	0.57	0.13	0.32	0.83	59	22
Skouteris et al., *T1 + T1*	2009	0.41	0.070	0.27	0.55	204	29.94
Skouteris et al., *T1 + T2*	2009	0.23	0.070	0.097	0.37	204	29.94
Skouteris et al., *T2 + T2*	2009	0.31	0.070	0.17	0.45	204	29.94
Skouteris et al., *T2 + T1*	2009	0.38	0.070	0.24	0.51	204	29.94
Swanson et al., *Pregnancy*	2011	0.56	0.095	0.38	0.75	111	26.66
Swanson et al., *Postpartum*	2011	0.59	0.085	0.42	0.75	140	28.06
Teoh et al.,	2021	0.46	0.078	0.31	0.61	166	28.97
van der Zwan et al., *T1 + Sleep duration*	2017	0.01	0.043	-0.075	0.095	529	32.91
van der Zwan et al., *T1 + Sleep quality*	2017	0.12	0.043	0.035	0.20	529	32.91
van der Zwan et al., *T2 + Sleep duration*	2017	0.060	0.043	-0.025	0.14	529	32.91
van der Zwan et al., *T2 + Sleep quality*	2017	0.18	0.043	0.0968	0.27	529	32.91
van der Zwan et al., *T3 + Sleep duration*	2017	0.12	0.043	0.035	0.20	529	32.91
van der Zwan et al., *T3 + Sleep quality*	2017	0.19	0.043	0.11	0.28	529	32.91
van der Zwan et al., *T1 + T2 Sleep duration*	2017	0.060	0.043	-0.02	0.14	529	32.91
van der Zwan et al., *T1 + T2 Sleep quality*	2017	0.17	0.043	0.09	0.26	529	32.91

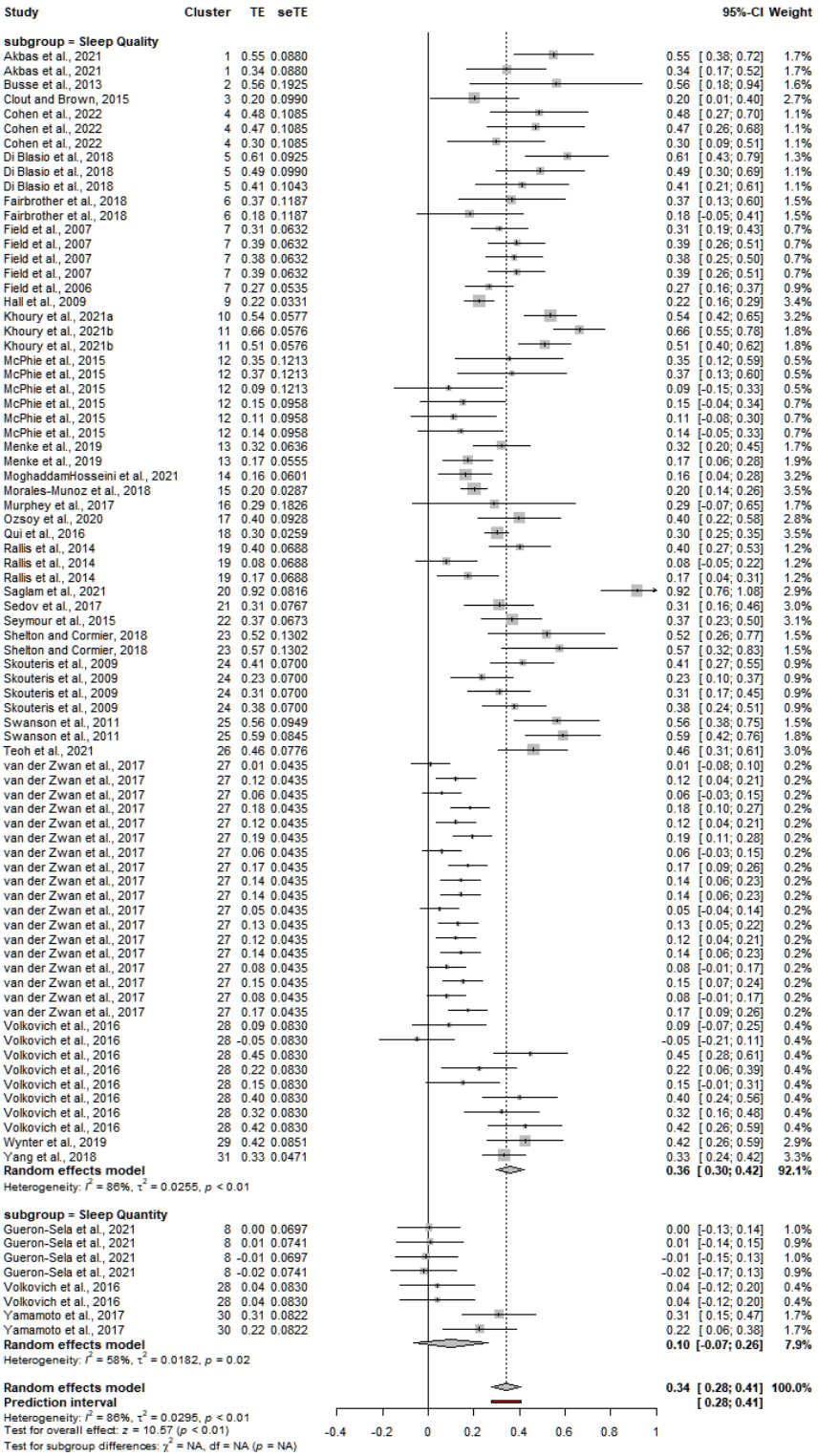
	Study	Effect	Std.Er	CI Lower	CI Upper	Weight(fixed)	Weight(random)
van der Zwan et al., *T1.+ T3 Sleep duration*	2017	0.14	0.043	0.06	0.23	529	32.91
van der Zwan et al., *T1.+ T3 Sleep quality*	2017	0.14	0.043	0.06	0.23	529	32.91
van der Zwan et al., *T2 + T1 Sleep duration*	2017	0.050	0.043	-0.035	0.13	529	32.91
van der Zwan et al., *T2 + T1 Sleep quality*	2017	0.13	0.043	0.045	0.21	529	32.91
van der Zwan et al., *T2 + T3 Sleep duration*	2017	0.12	0.043	0.035	0.20	529	32.91
van der Zwan et al., *T2 + T3 Sleep quality*	2017	0.14	0.043	0.056	0.23	529	32.91
van der Zwan et al., *T3 + T1 Sleep duration*	2017	0.080	0.043	-0.0050	0.16	529	32.91
van der Zwan et al., *T3 + T1 Sleep quality*	2017	0.15	0.043	0.066	0.24	529	32.91
van der Zwan et al., *T3 + T2 Sleep duration*	2017	0.080	0.043	-0.0050	0.17	529	32.91
van der Zwan et al., *T3 + T2 Sleep quality*	2017	0.17	0.043	0.086	0.26	529	32.91
Volkovich et al., *Actigraphy – Sleep duration*	2016	0.040	0.083	-0.12	0.20	145	28.25
Volkovich et al., *Actigraphy – Night wakings*	2016	0.090	0.083	-0.072	0.25	145	28.25
Volkovich et al., *Actigraphy = Sleep %*	2016	-0.050	0.083	-0.21	0.11	145	28.25
Volkovich et al., *PSQI – Sleep disturbance*	2016	0.45	0.083	0.28	0.61	145	28.25
Volkovich et al., *PSQI – Sleep Latency*	2016	0.22	0.083	0.061	0.39	145	28.25
Volkovich et al., *PSQI – Sleep efficiency*	2016	0.15	0.083	-0.011	0.31	145	28.25
Volkovich et al., *PSQI – Daytime dysfunction*	2016	0.40	0.083	0.24	0.56	145	28.25
Volkovich et al., *PSQI – Sleep duration*	2016	0.040	0.083	-0.12	0.20	145	28.25
Volkovich et al., *PSQI – Sleep quality*	2016	0.32	0.083	0.16	0.48	145	28.25
Volkovich et al., *Global PSQI score*	2016	0.42	0.083	0.26	0.59	145	28.25
Wynter et al.,	2019	0.42	0.085	0.26	0.59	138	27.98
Yamamoto et al., *State anxiety*	2017	0.31	0.082	0.15	0.47	148	28.37
Yamamoto et al., *Trait anxiety*	2017	0.22	0.082	0.062	0.38	148	28.37
Yang et al.,	2018	0.33	0.047	0.24	0.42	451	32.56

Note: CWS Scale: Cambridge Worry Scale, EGWG: Excessive Gestational Weight Gain, GAD/GAD-7: Generalised Anxiety Disorder/Generalised Anxiety Disorder Scale, 7 items, Post: Postpartum, Pre: Pregnancy, PTSD: Post-Traumatic Stress Disorder, PSS: Perceived Stress Scale, PSI-SF: Parenting Stress Index-Short Form, PSQI: Pittsburgh Sleep Quality Index, T1: Time 1, T2: Time 2, T3: Time 3, w: weeks,

Appendix 3: Meta-analysis – Forest plot of Subgroup analysis – Page 1



Appendix 3: Meta-analysis – Forest plot of Subgroup analysis – Page 2



Appendix 4: Meta-analysis Table of Study Characteristics

Table of Study Characteristics

First Author, Year	N	Pregnancy/ Postnatal	Design	Mean Age (years)	Mean/range Weeks (gestation / Trimester)	Mean Weeks (Infant Age)	Ethnicity	Country of Data Collection	Sleep: Objective/ Subjective	Sleep Measure	Sleep Construc
Akbas, 2021	132	Pregnancy + Postnatal	Longitudinal	31.3	Second + Third Trimester	-	-	Türkiye	Subjective	PSQI	Sleep Quality
Busse, 2013	30	Postnatal	Cross-Sectional	32.17	-	-	“White, Hispanic, Asian, Native American”	USA	Subjective	PROMIS	Sleep Quality
Clout, 2015	105	Postnatal	Cross-Sectional	31.8	-	4-6 months	“96, (91.4%) identified themselves as Caucasian, 3 identified as Asian, two as South-East Asian, one as Indigenous, and 3 as other“	Australia	Subjective	Likert Scale	Sleep Quality
Cohen, 2022	88	Postnatal	Longitudinal	25.45	-	12 + 24weeks	“African American /Black race/ethnicity = 100%”	USA	Subjective	PSQI	Sleep Quality
Di Blasio, 2018	105 (M)	Pregnancy + Postnatal	Longitudinal	32.62	32-40	4 + 12 weeks	“Italian (93%) “	Italy	Subjective	PSQI	Sleep Quality
Fairbrother, 2018	74	Postnatal	Longitudinal	32	-	4 + 12 weeks	“Caucasian (76%), Asian (13%) “	Canada	Subjective	PSQI	Sleep Quality
Field, 2007	253	Pregnancy	Longitudinal	-	22.2 + 32.4	-	“Hispanic (55%); African-American (23%); non-Hispanic White (22%) “	USA	Subjective	Likert Scale	Sleep Quality

Field, 2006	353	Pregnancy	Longitudinal	26.7	20 + 32	-	‘51% Hispanic, 21% African–American, 26% White non-Hispanic and 2% other“	USA	Subjective	Likert Scale	Sleep Quality
Gueron-Sela, 2021	196 (M)	Pregnancy + Postnatal	Longitudinal	-	34-37	12 weeks	-	Israel	Subjective + Objective	Actigraphy + Sleep Diary	Sleep Quality + Quantity
Hall, 2009	916	Pregnancy	Cross-Sectional	31.5	35	-	“Aboriginal (2%); African/Caribbean (2%); Asian Chinese (7.6%); Canadian (69.4%); European (12.6%); Latin (1.5%)“	Canada	Subjective	MSQ	Sleep Quality
Khoury, 2021a	303	Pregnancy	Cross-Sectional	32.13	21.47	-	“Caucasian (84.8%); Asian (6.9%); Native (0.7%); Mixed Race (3%); Other Race (4.6%)“	Canada	Subjective	ISI	Sleep Quality
Khoury, 2021b	304	Pregnancy	Cross-Sectional	32.09	21.44	-	“White (84.9%); Asian (6.9%); Indigenous (0.7%); Multiple ethnicities (3%); Other (4.6%)“	Canada	Subjective	ISI	Sleep Quality
McPhie, 2015	86 (M)	Pregnancy	Longitudinal	30.66	16.5 + 24.4	-	-	Australia	Subjective	PSQI	Sleep Quality
Menke, 2019	283 (M)	Pregnancy + Postnatal	Cross-sectional	-	Pregnant or child <12 m	Pregnant or child <12 m	“Caucasian (78.0); Minority (20.40%)“	USA	Subjective	PSQI	Sleep Quality
MoghaddamHosseini, 2021	280	Pregnancy	Cross-Sectional	32.41	36.98	-	-	Hungary	Subjective	PROMIS	Sleep Quality
Morales-Munoz, 2018	1221	Pregnancy	Cross-Sectional	30.61	32	-	-	Finland	Subjective	BNSQ	Sleep Quality

Murphey, 2017	33	Postnatal	Cross-Sectional	22.3	-	<12 months	“White (21%); Black/African American (9%); Hispanic/ Latina (64%); More than one ethnicity (6%)“	USA	Subjective	PSQI	Sleep Quality
Ozsoy, 2020	119	Pregnancy	Cross-Sectional	25.55	24-29	-	-	Türkiye	Subjective	PSQS	Sleep Quality
Qui, 2016	1488	Pregnancy	Cross-Sectional	33.4	20+	-	“81.5% (Non-Hispanic white); 1.4% (African American); 12.2% (Asian); 4.2% (Other)“	USA	Subjective	PSQI	Sleep Quality
Rallis, 2014	214	Pregnancy	Longitudinal	30.67	16 + 24	-	-	Australia	Subjective	PSQI	Sleep Quality
Saglam, 2021	153	Pregnancy	Cross-Sectional	27.7	27.85	-	-	Türkiye	Subjective	PSQI	Sleep Quality
Sedov, 2017	173	Pregnancy	Cross-Sectional	30.57	28.35	-	“70.4% White; 29.6% 'other'“	Canada	Subjective	ISI	Sleep Quality
Seymour, 2015	224	Postnatal	Cross-Sectional	32.57	-	6.09 months	-	Australia	Subjective	PSQI	Sleep Quality
Shelton, 2018	62	Postnatal	Cross-Sectional	29.9	-	6.5 months	“White/non-Hispanic (90.3%), African American (4.8%), Hispanic (4.8%)”	USA	Subjective	GSDS	Sleep Quality
Skouteris, 2009	207	Pregnancy	Longitudinal	31.74	18.32 + 34.63	-	-	Australia	Subjective	PSQI	Sleep Quality
Swanson, 2011	126	Pregnancy + Postnatal	Longitudinal	31.6	-	-	-	USA	Subjective	ISI	Sleep Quality
Teoh, 2021	169	Pregnancy	Cross-Sectional	28.4	18.7	-	“Malay 66.5%; Chinese 26.3%; Indian 4.5%; Others 2.8% “	Malaysia	Subjective	PSQI	Sleep Quality
Van der Zwan, 2017	532	Pregnancy	Longitudinal	31.6	14 + 24 + 32	-	-	Finland	Subjective	BNSQ	Sleep Quality
Volkovich, 2016	148	Pregnancy	Cross-Sectional	29	34-37	-	-	Finland	Subjective + Objective	Actigraphy + PSQI	Sleep Quality + Quantity

Wynter, 2019	141	Postnatal	Cross-Sectional	34.26	-	8.36	-	Australia	Subjective	PSQI	Sleep Quality
Yamamoto, 2017	151	Postnatal	Cross-Sectional	33.7	-	1 month	"Japanese"	Japan	Subjective	Self-report average sleep time	Sleep Quantity
Yang, 2018	454	Pregnancy	Cross-Sectional	-	-	-	-	China	Subjective	PSQI	Sleep Quality

Note M: Harmonic mean across multiple study effects where participant numbers differed, BAI: Beck Anxiety Inventory, BNSQ: The Basic Nordic Sleep Questionnaire, CWS: Cambridge Worry Scale, DASS-21: The Depression, Anxiety and Stress Scale, 21 items, GAD-7: Generalised Anxiety Disorder, 7 items, GSDS: General Sleep Disturbance Scale, HAM-A: Hamilton Anxiety Rating Scale, IES-R: Impact of Events Scale Revised, ISI: Insomnia Severity Index, LASC: The Los Angeles Symptoms Checklist, MSQ: Mindell's Sleep Questionnaire, OBQ-44: Obsessional Beliefs Questionnaire, 44 items, PRAQ-R2: Pregnancy Anxiety Questionnaire Revised, PRAS: Pregnancy Related Anxiety Symptoms, PROMIS: Patient-Related Outcomes Measurement Information System, PSS: Perceived Stress Scale, PSI-SF: Parenting Stress Index-Short Form, PSQI: Pittsburgh Sleep Quality Index, PSQS: Postpartum Sleep Quality Scale, PSWQ: Penn State Worry Questionnaire, STAI: The State-Trait Anxiety Index,, -: missing data.

Appendix 5: Perinatal Anxiety Screening Scale (Somerville et al., 2014) – Page 1

Name: _

DOB: _

PERINATAL ANXIETY SCREENING SCALE (PASS)

☐ ANTENATAL Weeks pregnant ( ) ☐ POSTNATAL Baby's age ( ) DATE: _____

OVER THE PAST MONTH, *How often* have you experienced the following? Please tick the response that most closely describes your experience for *every* question.

	Not at all	Some times	Often	Almost Always
1. Worry about the baby/pregnancy	0	1	2	3
2. Fear that harm will come to the baby	0	1	2	3
3. A sense of dread that something bad is going to happen	0	1	2	3
4. Worry about many things	0	1	2	3
5. Worry about the future	0	1	2	3
6. Feeling overwhelmed	0	1	2	3
7. Really strong fears about things, eg needles, blood, birth, pain, etc	0	1	2	3
8. Sudden rushes of extreme fear or discomfort	0	1	2	3
9. Repetitive thoughts that are difficult to stop or control	0	1	2	3
10. Difficulty sleeping even when I have the chance to sleep	0	1	2	3
11. Having to do things in a certain way or order	0	1	2	3
12. Wanting things to be perfect	0	1	2	3
12. Needing to be in control of things	0	1	2	3
14. Difficulty stopping checking or doing things over and over	0	1	2	3
15. Feeling jumpy or easily startled	0	1	2	3
16. Concerns about repeated thoughts	0	1	2	3
17. Being 'on guard' or needing to watch out for things	0	1	2	3
18. Upset about repeated memories, dreams or nightmares	0	1	2	3
	Not at all	Some times	Often	Almost Always

Continued on Back

Appendix 5: Perinatal Anxiety Screening Scale (Somerville et al., 2014) – Page 2

	Not at all	Some times	Often	Almost Always
19. Worry that I will embarrass myself in front of others	0	1	2	3
20. Fear that others will judge me negatively	0	1	2	3
21. Feeling really uneasy in crowds	0	1	2	3
22. Avoiding social activities because I might be nervous	0	1	2	3
23. Avoiding things which concern me	0	1	2	3
24. Feeling detached like you're watching yourself in a movie	0	1	2	3
25. Losing track of time and can't remember what happened	0	1	2	3
26. Difficulty adjusting to recent changes	0	1	2	3
27. Anxiety getting in the way of being able to do things	0	1	2	3
28. Racing thoughts making it hard to concentrate	0	1	2	3
29. Fear of losing control	0	1	2	3
30. Feeling panicky	0	1	2	3
31. Feeling agitated	0	1	2	3
	Not at all	Some times	Often	Almost Always
Global Score				

Clear fields Print / Save PDF

Reference:

Somerville, S., Dedman, K., Hagan, R., Oxnam, E., Wettinger, M., Byrne, S., Coo, S., Doherty, D., Page, A.C. (2014).

The Perinatal Anxiety Screening Scale: development and preliminary validation. *Archives of Women's Mental Health,* DOI: 10.1007/s00737-014-0425-8

Appendix 6: Sleep Diary

Sleep 1						
Time to bed	Time to bed	Time to bed	Time to bed	Time to bed	Time to bed	Time to bed
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Sleep 2						
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Sleep 3						
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Sleep 4						
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Sleep 5						
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Sleep 6						
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Sleep 7						
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Time out of bed	Time out of bed	Time out of bed	Time out of bed	Time out of bed	Time out of bed	Time out of bed

Appendix 7: Empirical Paper – Descriptive Statistics - Normality

Emotion Recognition Data - Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Happy - T1 - Total Accurate	.242	51	<.001	.651	51	<.001
Happy - T1 - Mean Confidence	.170	51	<.001	.910	51	<.001
Neutral - T1 - Total Accurate	.265	51	<.001	.728	51	<.001
Neutral - T1 - Mean Confidence	.114	51	.094	.935	51	.008
Sad - T1 - Total Accurate	.294	51	<.001	.590	51	<.001
Sad - T1 - Mean Confidence	.125	51	.047	.902	51	<.001
Happy - T2 - Total Accurate	.187	51	<.001	.899	51	<.001
Happy - T2 - Mean Confidence	.086	51	.200*	.953	51	.043
Neutral - T2 - Total Accurate	.216	51	<.001	.882	51	<.001
Neutral - T2 - Mean Confidence	.130	51	.030	.907	51	<.001
Sad - T2 - Total Accurate	.289	51	<.001	.848	51	<.001
Sad - T2 - Mean Confidence	.149	51	.006	.890	51	<.001

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Sleep Data - Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Total Sleep Time Average - T1	.118	17	.200*	.961	17	.651
Sleep Efficiency Average - T1	.100	17	.200*	.953	17	.501

Wake After Sleep Onset_Average - T1	.125	17	.200*	.972	17	.858
Total Sleep Time_Average - T2	.161	17	.200*	.964	17	.711
Sleep Efficiency_Average - T2	.209	17	.047	.835	17	.006
Wake After Sleep Onset_Average - T2	.210	17	.045	.778	17	.001
(Diary) Total Sleep Time_Average - T1	.196	17	.080	.901	17	.071
(Diary) Sleep Efficiency_Average - T1	.214	17	.037	.928	17	.203
(Diary) Wake After Sleep Onset_Average - T1	.174	17	.181	.888	17	.043
(Diary) Total Sleep Time Average - T2	.193	17	.091	.898	17	.064
(Diary) Sleep Efficiency_Average - T2	.219	17	.030	.868	17	.021
(Diary) Wake After Sleep Onset Average - T2	.234	17	.014	.850	17	.011

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Anxiety Data – Normality

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Time 1 - Total Anxiety Score	.173	25	.053	.937	25	.128
Time 2 - Total Anxiety Score	.139	25	.200*	.902	25	.020

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Appendix 8: Empirical Paper – Non-parametric post-hoc analysis (Wilcoxon) following significant interaction between timepoint x emotion recognition accuracy.

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Happy - T1 - Total Accurate	52	14.33	2.247	2	16
Neutral - T1 - Total Accurate	52	13.9615	2.51241	2.00	16.00
Sad - T1 - Total Accurate	52	14.2308	2.50971	1.00	16.00
Happy - T2 - Total Accurate	52	13.6346	1.59692	9.00	16.00
Neutral - T2 - Total Accurate	52	13.7500	1.91869	8.00	16.00
Sad - T2 - Total Accurate	52	14.6731	1.20002	11.00	16.00

Ranks

		N	Mean Rank	Sum of Ranks
Happy - T2 - Total Accurate - Happy - T1 - Total Accurate	Negative Ranks	31[a]	22.32	692.00
	Positive Ranks	11[b]	19.18	211.00
	Ties	10[c]		
	Total	52		
Neutral - T2 - Total Accurate - Neutral - T1 - Total Accurate	Negative Ranks	25[d]	19.32	483.00
	Positive Ranks	15[e]	22.47	337.00
	Ties	12[f]		
	Total	52		
Sad - T2 - Total Accurate - Sad - T1 - Total Accurate	Negative Ranks	18[g]	16.56	298.00
	Positive Ranks	19[h]	21.32	405.00
	Ties	15[i]		
	Total	52		

Test Statistics[a,c]

	Happy - T2 - Total Accurate - Happy - T1 - Total Accurate	Neutral - T2 - Total Accurate - Neutral - T1 - Total Accurate	Sad - T2 - Total Accurate - Sad - T1 - Total Accurate

Z			-3.046[b]	-.996[b]	-.827[d]
Asymp. Sig. (2-tailed)			.002	.319	.408
Monte Carlo Sig. (2-tailed)	Sig.		.002	.322	.420
	99% Confidence Interval	Lower Bound	.001	.310	.407
		Upper Bound	.003	.334	.432
Monte Carlo Sig. (1-tailed)	Sig.		.001	.162	.209
	99% Confidence Interval	Lower Bound	.000	.153	.199
		Upper Bound	.002	.172	.220

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on 10000 sampled tables with starting seed 2000000.

d. Based on negative ranks.

The Wilcoxon signed rank test indicated that there were significant differences between timepoints for Happy stimuli (Z = -3.05, Monte Carlo p = .001), with performance increasing at T2 compared with T1. No significant differences between timepoints were observed for Neutral stimuli (Z = -.99, Monte Carlo p = .322), and Sad stimuli (Z = -8.27 Monte Carlo p = .420).

Appendix 9: Non-parametric post-hoc analysis (Wilcoxon) following significant interaction between timepoint x emotion confidence for parent participants.

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Happy - T1 - Mean Confidence	25	82.8828	8.56860	67.50	93.19
Neutral - T1 - Mean Confidence	25	80.9449	12.83776	50.40	100.00
Sad - T1 - Mean Confidence	25	87.1200	10.27870	67.27	100.00
Happy - T2 - Mean Confidence	25	90.3040	8.19626	72.71	100.00
Neutral - T2 - Mean Confidence	25	83.9835	12.21113	58.38	100.00
Sad - T2 - Mean Confidence	25	91.7155	7.52651	76.13	100.00

Ranks

	Mean Rank
Happy - T1 - Mean Confidence	2.40
Neutral - T1 - Mean Confidence	2.00
Sad - T1 - Mean Confidence	3.76
Happy - T2 - Mean Confidence	4.64
Neutral - T2 - Mean Confidence	3.12
Sad - T2 - Mean Confidence	5.08

Test Statistics[a]

N			25
Chi-Square			54.336
df			5
Asymp. Sig.			<.001
Monte Carlo Sig.	Sig.		<.001
	99% Confidence Interval	Lower Bound	.000
		Upper Bound	.000

a. Friedman Test

A Friedman test was conducted and a significant difference was observed between the three emotion types at the two time points, $\chi^2(5) = 54.34$, Monte Carlo $p < 0.001$. To identify Pairwise differences a series of Wilcoxon signed ranks tests were undertaken.

Ranks

		N	Mean Rank	Sum of Ranks
Happy - T2 - Mean Confidence - Happy - T1 - Mean Confidence	Negative Ranks	2[a]	7.00	14.00
	Positive Ranks	23[b]	13.52	311.00
	Ties	0[c]		
	Total	25		
Neutral - T2 - Mean Confidence - Neutral - T1 - Mean Confidence	Negative Ranks	9[d]	9.22	83.00
	Positive Ranks	16[e]	15.13	242.00
	Ties	0[f]		
	Total	25		
Sad - T2 - Mean Confidence - Sad - T1 - Mean Confidence	Negative Ranks	4[g]	11.75	47.00
	Positive Ranks	20[h]	12.65	253.00
	Ties	1[i]		
	Total	25		

Wilcoxon Test Statistics[a,c]

			Happy - T2 - Mean Confidence - Happy - T1 - Mean Confidence	Neutral - T2 - Mean Confidence - Neutral - T1 - Mean Confidence	Sad - T2 - Mean Confidence - Sad - T1 - Mean Confidence
Z			-3.996[b]	-2.139[b]	-2.943[b]
Asymp. Sig. (2-tailed)			<.001	.032	.003
Monte Carlo Sig. (2-tailed)	Sig.		<.001	.033	.003
	99% Confidence Interval	Lower Bound	.000	.029	.001
		Upper Bound	.000	.038	.004
Monte Carlo Sig. (1-tailed)	Sig.		<.001	.017	.001
	99% Confidence Interval	Lower Bound	.000	.014	.000
		Upper Bound	.000	.021	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on 10000 sampled tables with starting seed 299883525.

The Wilcoxon signed rank test indicated that there were significant differences in confidence between T1 and T2, with performance increasing for all emotions; Happy stimuli, (Z = 3.99, Monte Carlo p = .<001), Neutral stimuli (Z = 2.14 Monte Carlo p = .017) and Sad stimuli (Z = 2.94, Monte Carlo p = .001).

Appendix 10: Non-parametric post-hoc analysis (Wilcoxon) following significant interaction between timepoint x emotion confidence for control participants.

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Happy - T1 - Mean Confidence	26	91.2149	7.56763	68.07	100.00
Neutral - T1 - Mean Confidence	26	87.4249	9.64921	58.81	100.00
Sad - T1 - Mean Confidence	26	90.1322	9.06561	56.53	100.00
Happy - T2 - Mean Confidence	26	86.3699	7.49178	71.00	95.20
Neutral - T2 - Mean Confidence	26	87.0859	10.15504	57.87	100.00
Sad - T2 - Mean Confidence	26	92.9777	6.72277	77.33	100.00

Ranks

	Mean Rank
Happy - T1 - Mean Confidence	4.04
Neutral - T1 - Mean Confidence	2.98
Sad - T1 - Mean Confidence	3.94
Happy - T2 - Mean Confidence	2.35
Neutral - T2 - Mean Confidence	2.92
Sad - T2 - Mean Confidence	4.77

Test Statistics[a]

N			26
Chi-Square			30.647
df			5
Asymp. Sig.			<.001
Monte Carlo Sig.	Sig.		<.001
	99% Confidence Interval	Lower Bound	.000
		Upper Bound	.000

a. Friedman Test

A Friedman test was conducted and a significant difference was observed between the three emotion types at the two time points, $\chi^2(5) = 30.65$, Monte Carlo $p < 0.001$. To identify Pairwise differences a series of Wilcoxon signed ranks tests were undertaken.

Ranks

		N	Mean Rank	Sum of Ranks
Happy - T2 - Mean Confidence - Happy - T1 - Mean Confidence	Negative Ranks	21[a]	15.19	319.00
	Positive Ranks	6[b]	9.83	59.00
	Ties	0[c]		
	Total	27		
Neutral - T2 - Mean Confidence - Neutral - T1 - Mean Confidence	Negative Ranks	13[d]	12.77	166.00
	Positive Ranks	12[e]	13.25	159.00
	Ties	1[f]		
	Total	26		
Sad - T2 - Mean Confidence - Sad - T1 - Mean Confidence	Negative Ranks	8[g]	10.63	85.00
	Positive Ranks	17[h]	14.12	240.00
	Ties	1[i]		
	Total	26		

Wilcoxon Test Statistics[a,c]

			Happy - T2 - Mean Confidence - Happy - T1 - Mean Confidence	Neutral - T2 - Mean Confidence - Neutral - T1 - Mean Confidence	Sad - T2 - Mean Confidence - Sad - T1 - Mean Confidence
Z			-3.123[b]	-.094[b]	-2.085[d]
Asymp. Sig. (2-tailed)			.002	.925	.037
Monte Carlo Sig. (2-tailed)	Sig.		.001	.938	.037
	99% Confidence Interval	Lower Bound	.000	.932	.033
		Upper Bound	.002	.944	.042
Monte Carlo Sig. (1-tailed)	Sig.		<.001	.470	.020
	99% Confidence Interval	Lower Bound	.000	.457	.016
		Upper Bound	.001	.483	.023

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on 10000 sampled tables with starting seed 334431365.

d. Based on negative ranks.

The Wilcoxon signed rank test indicated that there were significant differences in confidence between T1 and T2 for Happy stimuli, (Z = -3.12, Monte Carlo p = .<001), with confidence decreasing, and for Sad stimuli (Z = 2.09 Monte Carlo p = .020), with confidence increasing between timepoints. The difference between T1 and T2 for Neutral stimuli was not significant (Z = .094, Monte Carlo p = .45).

Appendix 11 – Control Participant: Gender differences T-test

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance		Mean	Std. Error	95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Difference	Difference	Lower	Upper
Happy – T1 – Total Accurate	Equal variances assumed	.649	.426	-.036	35	.486	.971	-.033	.916	-1.892	1.825
	Equal variances not assumed			-.050	33.336	.480	.960	-.033	.665	-1.385	1.318
Happy – T1 – Mean Confidence	Equal variances assumed	.093	.762	.487	35	.315	.629	1.33035	2.73020	-4.21225	6.87295
	Equal variances not assumed			.516	18.094	.306	.612	1.33035	2.57970	-4.08738	6.74808
Neutral – T1 – Total Accurate	Equal variances assumed	1.161	.289	.126	35	.450	.901	.14074	1.11861	-2.13016	2.41164
	Equal variances not assumed			.157	26.709	.438	.877	.14074	.89880	-1.70439	1.98587
Neutral – T1 – Mean Confidence	Equal variances assumed	.381	.541	1.334	35	.095	.191	5.29405	3.96847	-2.76238	13.35048
	Equal variances not assumed			1.518	21.350	.072	.144	5.29405	3.48730	-1.95095	12.53906
Sad – T1 – Total Accurate	Equal variances assumed	.438	.513	.239	35	.406	.813	.30741	1.28757	-2.30649	2.92131
	Equal variances not assumed			.291	25.346	.387	.773	.30741	1.05621	-1.86640	2.48121
Sad – T1 – Mean Confidence	Equal variances assumed	.586	.449	1.264	35	.107	.214	4.32679	3.42186	-2.61997	11.27354
	Equal variances not assumed			1.472	22.587	.077	.155	4.32679	2.93853	-1.75819	10.41177
Happy – T2 – Total Accurate	Equal variances assumed	.209	.652	1.037	24	.155	.310	.78947	.76132	-.78181	2.36076
	Equal variances not assumed			1.166	13.781	.132	.264	.78947	.67727	-.66529	2.24424
Happy – T2 – Mean Confidence	Equal variances assumed	8.744	.007	-1.053	24	.151	.303	-8.10751	7.69844	-23.99631	7.78130
	Equal variances not assumed			-.656	6.234	.268	.535	-8.10751	12.35048	-38.05527	21.84026
Neutral – T2 – Total Accurate	Equal variances assumed	.000	.983	.365	24	.359	.718	.26316	.72023	-1.22332	1.74964
	Equal variances not assumed			.351	9.999	.366	.733	.26316	.74977	-1.40744	1.93376
Neutral – T2 – Mean Confidence	Equal variances assumed	3.268	.084	.854	23	.201	.402	4.14774	4.85423	-5.89399	14.18947
	Equal variances not assumed			1.327	22.386	.099	.198	4.14774	3.12628	-2.32929	10.62478
Sad – T2 – Total Accurate	Equal variances assumed	.223	.641	-.160	24	.437	.874	-.06767	.42346	-.94165	.80631
	Equal variances not assumed			-.166	11.607	.435	.871	-.06767	.40720	-.95824	.82290
Sad – T2 – Mean Confidence	Equal variances assumed	8.780	.007	.657	23	.259	.517	2.04968	3.11745	-4.39925	8.49861
	Equal variances not assumed			1.035	22.715	.156	.312	2.04968	1.98091	-2.05100	6.15035

Appendix 12: Research Recruitment Advert

UNIVERSITY OF BIRMINGHAM

WHAT IS THE IMPACT OF SLEEP CHANGES IN NEW MOTHERS?

We're looking for participants to take part in a study on the impact of sleep loss on social abilities of new mothers

[ALL TESTING WILL BE COMPLETED REMOTELY]

You can participate if:

- You are expecting a baby before March 2023
- You are expecting your first child(ren)

If you participate you will:

- Complete a sleep diary for 1 week whilst wearing a sleep monitor (ring or a watch), before and after baby's arrival
- Complete a 20 minute online task
- Have the right to withdraw at any stage
- **Receive a £10 Amazon Voucher for your participation**

To participate, or for more information contact Cat Gercs (cjg045@student.bham.ac.uk), Angharad Chidgey (axc344@student.bham.ac.uk) or Dr Andrew Surtees (A.Surtees@bham.ac.uk, 0121 41 4 4934, @DrAndrewSurtees)

Appendix 13: Participant Information Sheet

UNIVERSITY OF BIRMINGHAM

PARTICIPANT INFORMATION SHEET
School of Psychology, University of Birmingham

Project title: WHAT IS THE IMPACT OF SLEEP DEPRIVATION ON NEW PARENTS?

Researcher: Catherine Gercs, Dr Andrew Surtees

What is the purpose of this study?
The purpose of the study is to examine the impact of sleep deprivation on new parents':

- Ability to recognize emotions in babies
- Understanding of their new baby
- Levels of anxiety

What does this study involve?
The study involves taking part in **two** testing sessions, 3 months apart.

For each session, you will:

- Keep a diary of your sleep

- Wear an actigraphy device on your finger for 7 nights. Much like a smart watch, this device has small sensors which monitor sleep/wake cycles – by recording your movement and heart rate.
  The sleep diary and actigraphy device will be sent to you via post. At the end of the week, you will return these materials through the post (in a stamped addressed envelope provided).

- Complete a short questionnaire about your level of anxiety.

- Complete a short task online in which you have to identify emotions in babies.

In the second session only, you will:

- Engage in a 5-minute free play session with your baby, which will be observed by a researcher over [Zoom]. This session will be video recorded and a written record

(transcript) of this session will be made for analysis purposes. The research team can offer evening and weekend slots for your convenience.

Even if you take part in the first session, you are under no obligation to take part in this second session or to provide reasons for not doing so. You will be provided with a stamped addressed envelope to request not to be contacted for the second session and can also do this via e-mail or telephone on the details below. Full consent will be sought for your participation in the second part of the study.

Other important things you should know:

- **Benefits from participation:** On completion of the second part of the study you will receive a £10 Amazon voucher. You will receive a short summary of your sleep. You will not receive feedback on your performance on the emotion task, anxiety questionnaire or the play session.

- **Risks associated with participation:** During participation in this study, you are unlikely to encounter any greater risks of discomfort than those incurred in routine daily activities.

- **Withdrawal from the study:** You may choose to stop your participation in this study at any time.

- **Data collection:** Your data will be managed in line with the General Data Protection Regulation Act (2018). Your data will be used only for the purpose described in this form. The data collected in this study will be your sleep diary, your actigraphy data – including sleep, movement and heart-rate data, questionnaire responses, a transcript of your play session, your responses on the emotion recognition task and basic demographic information about you (e.g., sex, ethnicity, age). These data will be stored anonymously. They will be processed by the research team and actigraphy data will be uploaded to an online website for processing. The data will then be stored in line with university regulations. Once the study is completed the anonymous version of the data, in which you cannot be identified, will be placed in an archive for use by other researchers, in line with good practice in open research. Data gathered from this study will be maintained as long as required by regulations, which is up to 10 years following the publication of empirical articles or communications describing the results of the study.

- **Data withdrawal:** You can choose to withdraw your data from the study up to one month after your session is completed.

- **Confidentiality**: Every effort will be taken to protect the names of the participants in this study. Your name and personal information will be stored separately from the research data, and will not be revealed in any publication that may result from this study. Your consent form will not be stored with your research data, to ensure that your identity cannot be linked in any way to your data. All personal information you provide will be kept confidential as per the General Data Protection Regulation Act (2018).

- **Safeguarding and well-being:** Very occasionally, researchers see things that make them worry about the safety of a child or parent. If this were to happen, we might have to contact someone to get you some help. If we were to do this, we'd almost always talk to you about it first. Collecting data on people's anxiety can mean we learn about people who are having difficulties. If we do, we will signpost you to appropriate support.

- **Who should you call with questions about this study?** Questions or concerns about this study can be directed to the staff member in charge of this research project: Dr. Andrew Surtees, [redacted], [redacted] If you have concerns about the conduct of this study, you can contact the head of the School of Psychology, Professor Edward Wilding, [redacted]

Appendix 14: Participant Consent Form

UNIVERSITY OF BIRMINGHAM

CONSENT TO PARTICIPATE IN RESEARCH
School of Psychology, University of Birmingham

Project title: WHAT IS THE IMPACT OF SLEEP DEPRIVATION ON NEW PARENTS?

Researcher: Dr Andrew Surtees, Catherine Gercs

CONSENT

- ☐ I have read the information about "**WHAT IS THE IMPACT OF SLEEP DEPRIVATION ON NEW PARENTS?**" and have been given an opportunity to ask questions.
- ☐ I agree to participate in this study.
- ☐ I give permission for the parent-child observation to be video recorded and stored locally until transcription.
- ☐ I give permission for my data to be published in an anonymized form.

Participant Name	Participant Signature and Date
Researcher Name	Researcher Signature and Date

Appendix 15: Actigraphy Sleep Data Cleaning Protocol

UNIVERSITY OF BIRMINGHAM

Actigraphy Cleaning Protocol VERSION 2 (modified by Dr. Andrew Surtees' research team)

Cerebra Network for Neurodevelopmental Disorders
School of Psychology
University of Birmingham

The purpose of this protocol is to remove the artefact associated with using activity as a proxy measure of sleep. Wherever possible, the intention is to keep the actigraphy data unchanged. However, where changes are necessary, the principles underpinning the nine steps can be applied to clean the data in a variety of situations. The three key principles of actigraphy cleaning are:

The exclusion principle (steps 1, 2, 3, 7)

The epochs principle (steps 4, 5, 6)

The congruence principle (steps 8, 9)

Cleaning Actiwatch Data

Materials needed to clean data:

1) Philips Actiware output
2) Child's sleep information (collected from paper sleep diary or mobile app diary).

The following pages include 9 steps to remove artefact from Actiware sleep data. These steps may or may not be applicable to each participant's data and need only be used when relevant (see corresponding worked examples). **Please keep records of your decision making using a 'cleaning log' on RDS.**

For clarity, the following definitions are used throughout:

- Actogram – This is a visual representation of the participant's sleep/wake across the data collection period as a whole.
- Automatically calculated sleep interval – This is the period of time automatically calculated within Actiware, in which the participant is assumed to be asleep. It appears as a rest interval within Actiware, and is indicated by sky blue shading.
- Lights out time – The time that the child is put to bed and the light turned off, ready to sleep (indicated by sleep diary or mobile app diary information).
- Sedentary activity – This refers to activities such as reading, or watching TV where the child is not moving much and thus may be interpreted as asleep. Periods of sedentary activity will be noted by the caregiver in the sleep diary or mobile app diary.
- Event marker – The event marker is a button on the actiwatch that the caregiver/child has been instructed to press to indicate the time of 'lights out' and 'get up'. It appears on the actogram as a dark blue triangle.

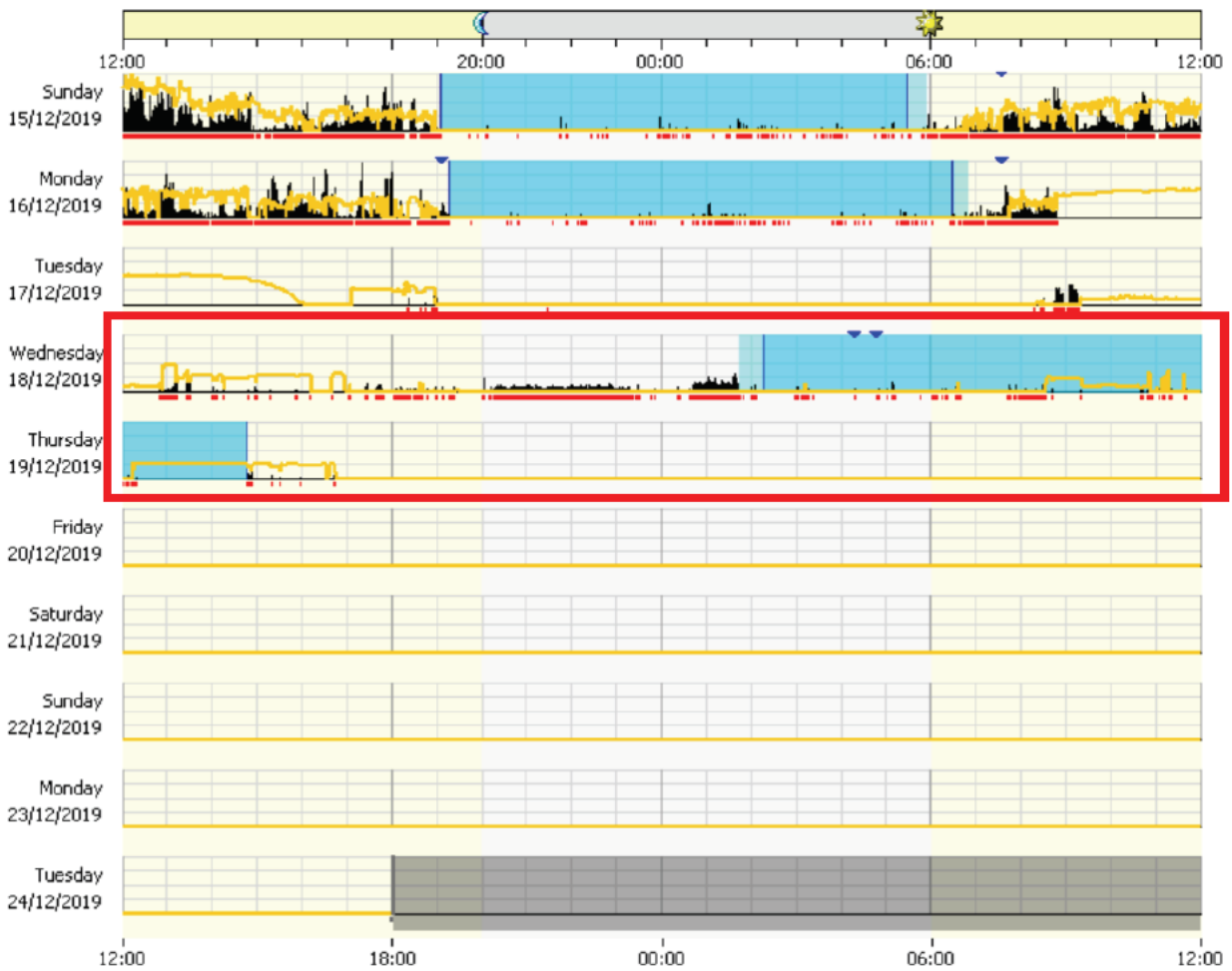
In order to follow these steps you will need to have the participant's Actiware sleep data (actogram) and diary data for the corresponding study period. Each night of actigraphy data is only eligible to be cleaned if there is corresponding diary data for that night. This need not be complete (i.e. does not need to include bed time, light out time, wake up time, get up time and all wakings – but at least one of these is necessary for the data to be cleaned). On the rare occasion that there is no diary data for a given night, but the event marker has been used appropriately (either according to the parent in the diary or confirmed by a member of the research team with the parent after the study period), the event marker may be used to indicate lights out and wake up time. If there is no diary data and no reliable event marker for a given night, this night should be excluded from the study period.

Step 1

Exclude any nights which appear on actogram that occur before or after data collection according to diary information (i.e. when actiwatch was in transit, if data collection was delayed).

a) First click the automatically calculated sleep interval that has erroneously been created before or after the sleep assessment dates, and click 'delete' (if applicable).
b) Enter exclusion interval(s) for days before and/or after data collection, when the watch was in transit or not worn by the child (Interval → Add interval → Interval

type: excluded). Exclude whole non-assessment day (from 12:00 – 12:00), even if there are black activity lines.



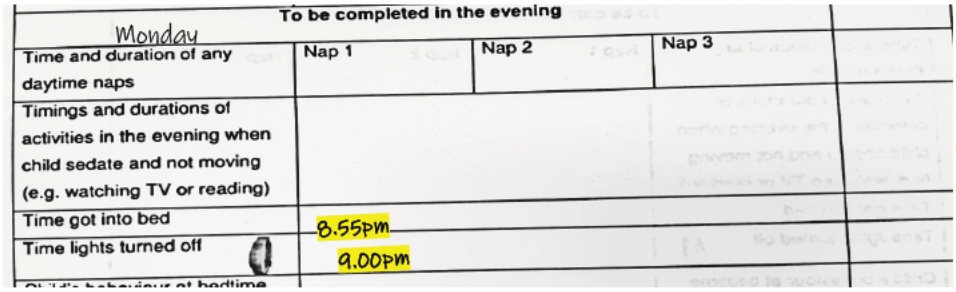
In the example above, a) delete automatically calculated sleep interval; b) enter exclusion interval from 12:00 (17/12/2019) to point at which watch stopped collecting data = 18:00 (24/12/2019).

Step 2

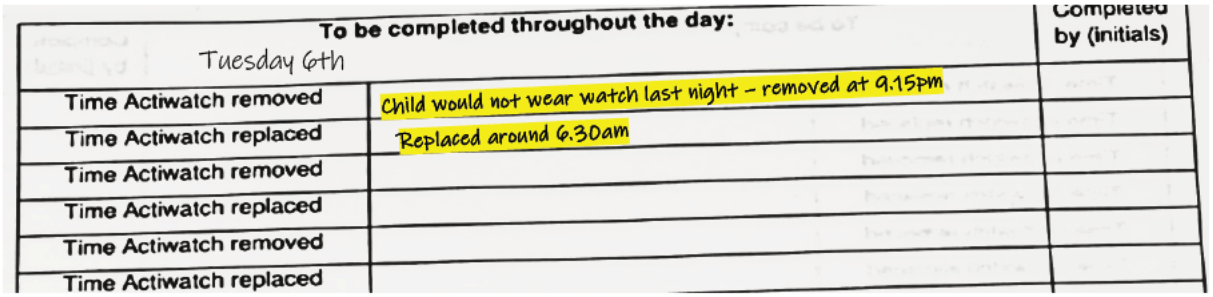
Check overlap between actiwatch removal times and "time lights turned off" in the child's sleep diary. Exclude any sleep intervals where the caregiver identifies that the watch has been taken off/removed for a **large proportion of the night (2 hours or more)**. Short actiwatch removals that overlap with the start time of the automatically calculated sleep interval (e.g. 20 minute watch removal during bath time) are not adjusted here (see Step 8).

a. If actiwatch removal is identified, check whether actiwatch removal occurs within the reported sleep period (i.e. between sleep diary lights out and wake up time). If actiwatch removal occurs before the automatically calculated sleep interval, adjustments are not to be made.
b. If any removal times are identified within the reported sleep period, check times against actogram for consistency by visually inspecting the specific night in question (i.e. no black lines of activity at this time).

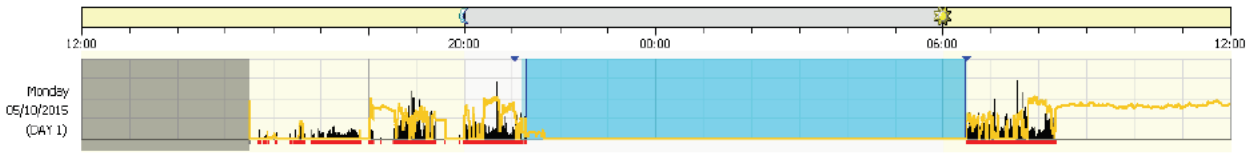
c. In Actiware, examine the night in question systematically. Click on the automatically calculated sleep interval for that night, and use the > key to scroll through the sleep interval. Examine the 'ac =' counter. If ac = 0 occurs continuously for a period of 2 hours or more between diary lights out and wake up time (check against time epochs when scrolling), exclude this 24 hour period. First delete this sleep interval, then enter exclusion period from 12:00 – 12:00 (Interval → Add interval → Interval type: excluded).
d. If parent reports that the actiwatch has been removed, but this is not evident on the actogram (i.e. evidence of movement and activity during this time, ac = 0 does not occur continuously for a period of 2 hours or more), keep the existing sleep interval as it is and continue to Step 3.



Monday	To be completed in the evening		
Time and duration of any daytime naps	Nap 1	Nap 2	Nap 3
Timings and durations of activities in the evening when child sedate and not moving (e.g. watching TV or reading)			
Time got into bed	8.55pm		
Time lights turned off	9.00pm		



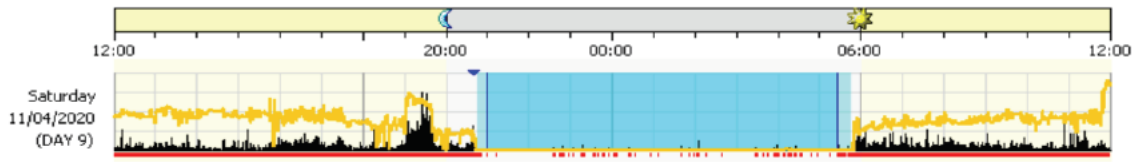
Tuesday 6th	To be completed throughout the day:	Completed by (initials)
Time Actiwatch removed	Child would not wear watch last night – removed at 9.15pm	
Time Actiwatch replaced	Replaced around 6.30am	
Time Actiwatch removed		
Time Actiwatch replaced		
Time Actiwatch removed		
Time Actiwatch replaced		



Parent reported that the actiwatch was removed during the night of Monday 5th. This occurred within the sleep period reported in the sleep diary. The actogram supports this information as there was no evidence of activity during this night. This is consistent with parent report. Therefore, data should be excluded for Monday .

Saturday 11th	To be completed in the evening			
Time and duration of any daytime naps	Nap 1	Nap 2	Nap 3	
Timings and durations of activities in the evening when child sedate and not moving (e.g. watching TV or reading)				
Time got into bed	8.45pm			
Time lights turned off	8.50pm			

Sunday 12th	To be completed throughout the day:	Completed by (initials)
Time Actiwatch removed	Think watch was taken off last night – wasn't wearing at breakfast	
Time Actiwatch replaced		
Time Actiwatch removed		
Time Actiwatch replaced		
Time Actiwatch removed		
Time Actiwatch replaced		



*Parent reported that the actiwatch was removed during the night of Saturday 11th. This occurred within the sleep period reported in the sleep diary. The actogram does not support this information as there was activity during this night. This is inconsistent with parent report. Therefore, this interval **should not** be excluded within this step.*

Step 3

Exclude any nights where the actiwatch appears to have been taken off but this **was not** noted in the sleep diary information.

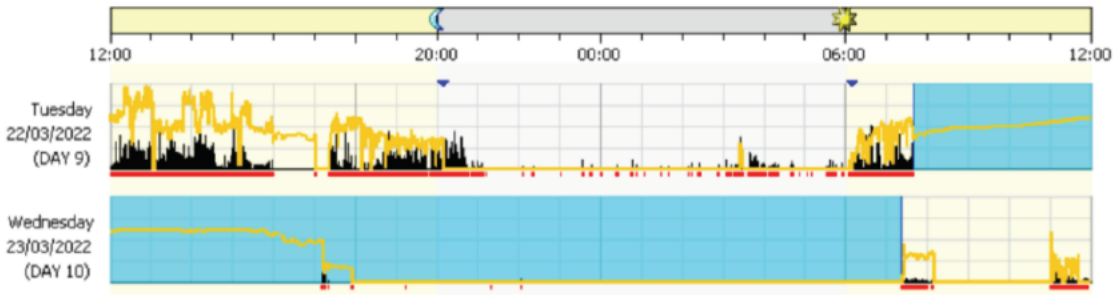
a. Initially, visually inspect the **entire actogram** at a glance and identify any overnight periods with continuous intervals where no black lines are present.
b. If any periods are identified, check whether these 'inactive' periods are within the reported sleep period (i.e. between sleep diary lights out and wake up time). If 'inactivity' occurs before the automatically calculated sleep interval, adjustments are not to be made in this step.
c. If 'inactive' periods are identified within the reported sleep period, examine the night in question systematically. Click on the automatically calculated sleep interval for that night, and use the > key to scroll through the sleep interval. Examine the 'ac =' counter. If ac = 0 occurs continuously for a period of 2 hours or more between diary lights out and wake up time (check against time epochs when scrolling), exclude this 24 hour period. First delete this sleep interval, then enter exclusion period from 12:00 – 12:00 (Interval → Add interval → Interval type: excluded).

d. If inactivity is suspected, but this is not evident on the actogram (i.e. evidence of movement and activity during this time, ac = 0 does not occur continuously for a period of 2 hours or more), keep the existing sleep interval as it is and continue to Step 4.

The parent did not report removal of the watch during the night of Monday 21st, but through visually inspecting the actogram, and systematically examining the activity count data, over 7 hours of inactivity (ac = 0) was confirmed (see section in red). As there is an inactive period of over 2 hours, this automatically calculated sleep interval would be deleted and replaced with an exclusion interval.

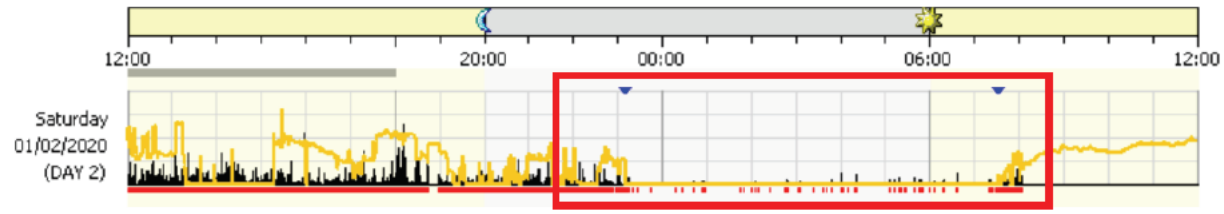
Step 4

Insert sleep intervals that are missing overnight. Use this step to correct any automatically calculated sleep intervals that are erroneously created **only within the daytime** or to insert sleep interval where **no data has automatically been calculated** (usually occurs when the watch has been removed for an extended period in the day, making it difficult to distinguish between sleep and wake). Please note, you can still follow this step if sleep diary information is missing following the epochs principle if necessary.

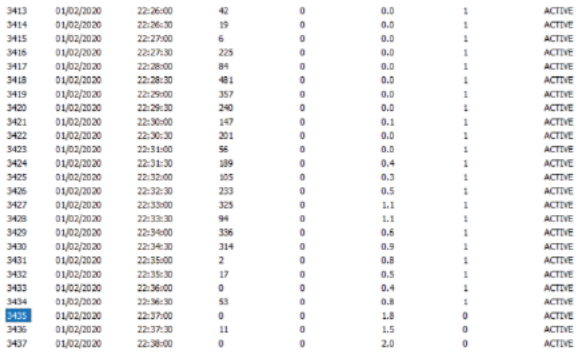


The sleep interval is missing for the night of Tuesday 22nd but has been created in they daytime, due to an extended actiwatch removal on Wednesday 23rd. Erroneous daytime automatically calculated sleep interval is to be deleted, and interval is to be inserted overnight following the epochs principle.

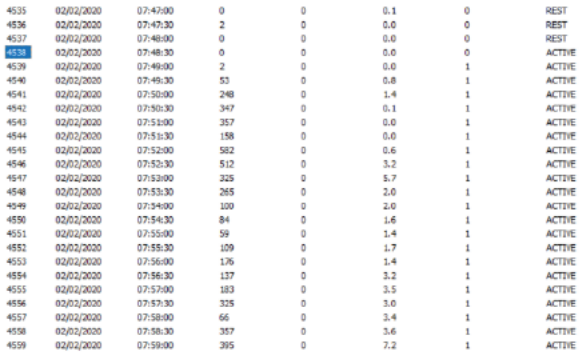
a. Note any occasions where sleep has erroneously been created in the daytime/sleep intervals are missing.
b. Check whether the erroneous daytime automatically calculated sleep interval both starts and ends outside of the sleep diary reported times. If so, proceed with this step following (c) below. If the sleep period start time overlaps with the start time according to the sleep diary information, do not adjust here (adjust in Step 6).
c. Creating a new sleep interval:
    - Delete the erroneous daytime automatically calculated sleep interval (if applicable).
    - To find the start time, use the data list function (View → Data List) to find the first 40 epochs coded as **0 in the sleep/wake column** after "time lights out" in child's sleep diary. From here, go back to the last 20 epochs coded as **1 in the sleep/wake column** in the data list. The new start time is the first 0 after the 20 epochs coded as **1 in the sleep/wake column**.
    - To find end time, use the data list to find the last 40 epochs coded as **0 in the sleep/wake column** before wake up time in child's sleep diary. From here, go forward to the first 20 epochs coded as **1 in the sleep/wake column** in the data list. The new end time is the last 0 before the 20 epochs coded as **1 in the sleep/wake column**.



Parent reports sleep period from 23.10pm to 07.22am. This has not been captured in the actogram, so a sleep interval needs to be created. 40 epochs coded as 0 closest to 23.10pm are located in the data list (start of 40 epochs at 00:59:00). From here 20 epochs coded as 1 before this time are located. First 0 after this sequence is recorded to indicate new start time of sleep interval = 22:37:00. 40 epochs coded as 0 closest to 07.22am are located in the data list (end of 40 epochs at 07:19:30). From here 20 epochs coded as 1 after this time are located. Last 0 before this sequence is recorded to indicate new end time of sleep interval = 07:48:30. See corresponding data lists below for clarification. PLEASE NOTE – this may not be the final sleep interval for this night, and these times may change according to principles implemented in later steps (i.e Step 9).



Start time of sleep interval = 22:37:00
End time of sleep interval = 07:48:30

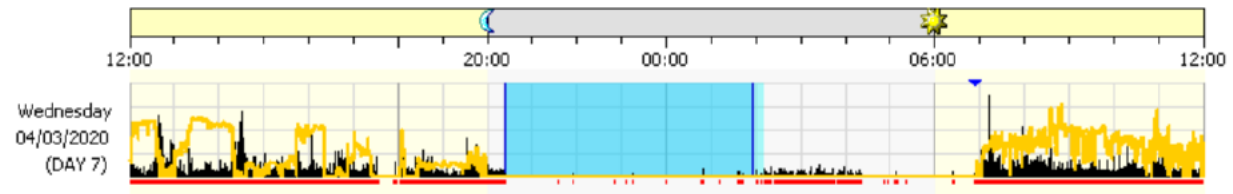


Step 5

Extend sleep intervals that have not captured the whole night reported in the sleep diary. To do this, use the data list to look for 40 epochs coded as **0 in <u>sleep/wake</u> column**, that have not been included within the automatically calculated sleep interval, but occur between lights out and wake up time in child's sleep diary. Please note, you can still follow this step if sleep diary information is missing following the epochs principle if necessary.

- WAKE UP TIME APPEARS 'TOO EARLY': If 40 epochs coded as **0 in <u>sleep/wake</u> column** are *after* the automatically coded sleep interval, look ahead for 20 epochs coded as **1 in <u>sleep/wake</u> column** and extend the sleep interval to last epoch coded as 0 before the 20 epochs coded as 1. When adjusting the sleep interval here, keep the original start time of the automatically calculated sleep interval.
- START OF SLEEP TIME APPEARS 'TOO LATE': If 40 epochs coded as **0 in <u>sleep/wake</u> column** are *before* the automatically coded sleep interval, look back to last 20 epochs coded as **1 in <u>sleep/wake</u> column** and extend interval to first epoch coded as 0 in sleep/wake column after the 20 epochs coded as 1. When adjusting the

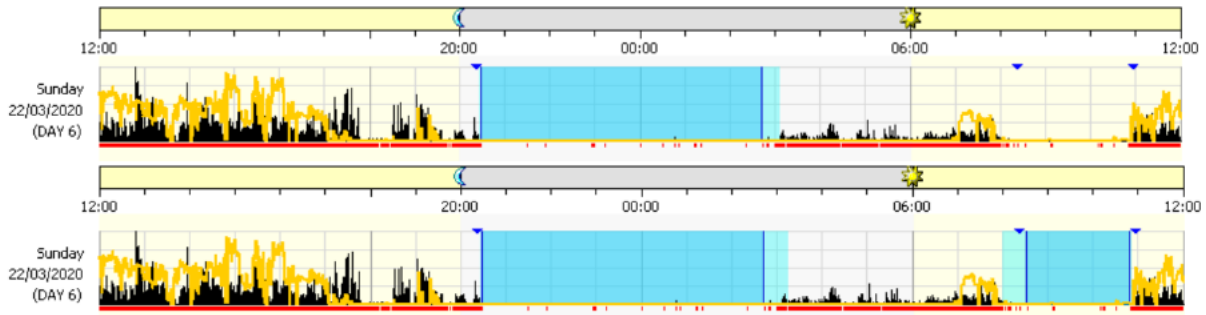
sleep interval here, keep the original end time of the automatically calculated sleep interval.



Parent reports sleep period as 19.56pm to 06.56am. The automatically calculated sleep interval as appeared to calculate the wake up time as being 'too early'. Here, 40 epochs coded as 0 are identified in the data list between the automatically coded end time (02:11:00), and the reported wake up time of 06:56:00. Looking ahead, 20 epochs coded as 1 are found. Last 0 before this sequence is recorded to indicate new end time of sleep interval = 06:52:00. Start time of sleep interval remains the same (20:24:00). PLEASE NOTE – this may not be the final sleep interval for this night, and these times may change according to principles implemented in later steps (i.e Step 9).

a. If automatically coded sleep interval looks short, but there are significant periods of late morning activity that indicates (1) waking, (2) waking activity and then (3) extended low activity – the child may have had a late morning nap after their first waking. Refer to information reported about naps/wakings within the sleep diary information. If parent reports a morning nap of more than 2 hours after a significant period of waking of more than 2 hours, you may wish to indicate two separate sleep intervals using the epochs principle **FOR THE PURPOSES OF THE FEEDBACK REPORT ONLY**.

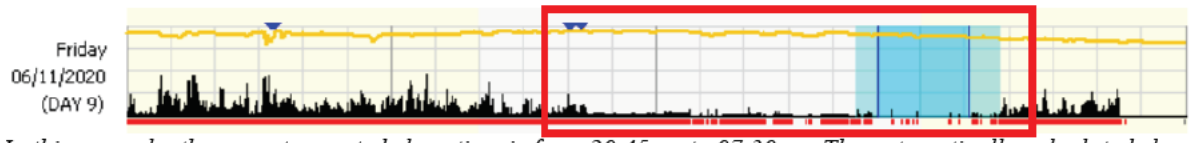
   The interval would not be extended within this step to incorporate the late morning nap as part of the actigraphy you would use for data analysis.



*In this example, the parent reports a morning nap of more than 2 hours after a significant period of waking of more than 2 hours. This is adjusted to indicate two separate sleep intervals using the epochs principle **FOR THE PURPOSES OF THE FEEDBACK REPORT ONLY**. The actigraphy used for the purposes of data analysis would not adjust/extend the automatically calculated sleep interval here.*

b. In some instances (due to a technical fault with older watches) the automatically calculated sleep interval may need to be extended, but this is not possible. If there are low level constant periods of activity that make it difficult to extend the sleep interval (40 epochs coded as **0 in the sleep/wake column** before or after sleep period reported in the child's sleep diary cannot be found) THIS DAY MUST BE

EXCLUDED. Exclusion interval would be inserted from 12:00 to 12:00 for the entire day.



In this example, the parent reported sleep time is from 20.45pm to 07.30am. The automatically calculated sleep interval has appeared to calculate the start of sleep time as being 'too late' and the sleep interval start time would be adjusted according to the epochs principle. However, there are constant periods of low level activity, which means 40 epochs of 0 between 20:45:00 and 04:32:30 cannot be found to adjust the sleep interval start time. Therefore, this assessment day must be excluded (12:00 to 12:00).
If this error is observed: a) do not send out this watch again for data collection with another family, b) report this faulty watch immediately to the Principal Investigator.

Step 6

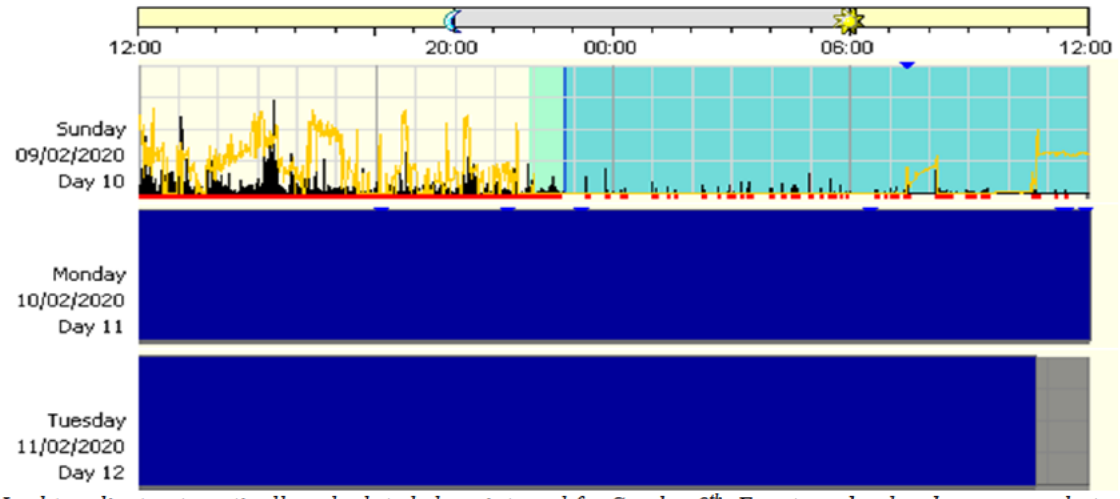
Adjust automatically calculated sleep intervals that have extended into daytime (beyond the wake up time reported in the sleep diary information). Visually determine in the actogram where the automatically coded sleep interval starts approximately around the time indicated by the sleep diary but continues beyond the wake up time reported in the sleep diary. Please note, you can still follow this step if sleep diary information is missing following the epochs principle if necessary.

- WAKE UP TIME APPEARS 'TOO LATE': Identify the last 40 epochs coded as **0 in <u>sleep/wake</u> column** that occur before the wake up time indicated in the sleep diary information. Look ahead for 20 epochs coded as **1 in <u>sleep/wake</u> column** and identify the last epoch coded as 0 before the 20 epochs coded as 1. When adjusting the sleep interval here, keep the original start time of the automatically calculated sleep interval.
- START OF SLEEP TIME APPEARS 'TOO EARLY': If 40 epochs coded as **0 in <u>sleep/wake</u> column** are *after* the start of sleep time indicated in the sleep diary information, look back to last 20 epochs coded as **1 in <u>sleep/wake</u> column** and shorten interval to first epoch coded as 0 in sleep/wake column after the 20 epochs coded as 1. When adjusting the sleep interval here, keep the original end time of the automatically calculated sleep interval.

- *Automatically calculated sleep interval has extended into the daytime, as an actiwatch removal occurred soon after waking. Although a wake up time is not indicated in the mobile app sleep diary (as it does not exist for the final morning of the ten day assessment) and the event marker has not been pressed, the sleep interval end time can be adjusted. Previous wake up times reported in the mobile app vary between 06.00am and 08.45am. Using this*

information as a guide, the data list is inspected. Around 06.00am on the morning of Friday 6th, 40 epochs coded as 0 are identified in the data list (end of 40 epochs at 05:53:00). Looking ahead, 20 epochs coded as 1 are found. Last 0 before this sequence is recorded to indicate new end time of sleep interval = 06:49:30.

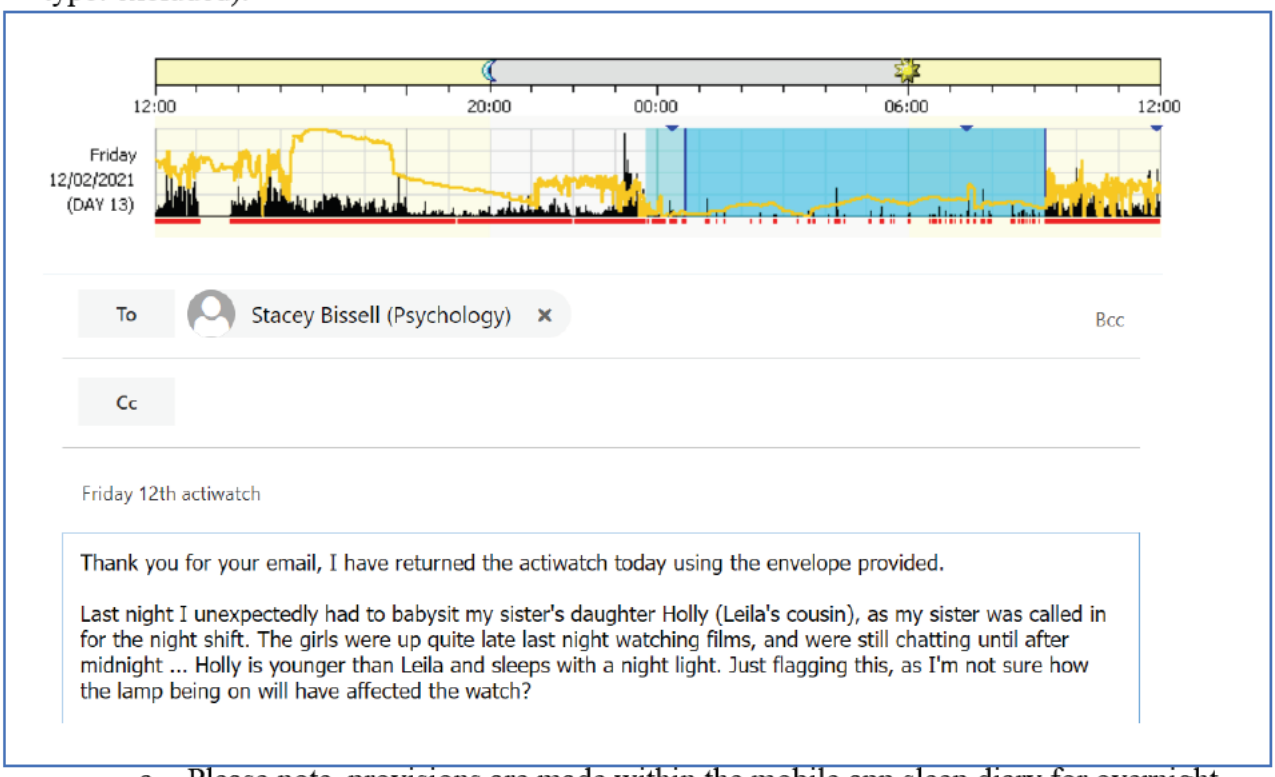
a. Please note, if the last epoch coded as 0 before the 20 epochs coded as 1 is *after* the original automatically coded sleep interval end time do not adjust the sleep interval.
b. If 20 epochs coded as 1 cannot be found to adjust the sleep interval end time (i.e an actiwatch removal occurs soon after waking), this sleep interval cannot be included. Exclude this 24 hour period from the actogram. First delete this sleep interval, then enter exclusion period from 12:00 – 12:00 (Interval → Add interval → Interval type: excluded).



Need to adjust automatically calculated sleep interval for Sunday 9th. Event marker has been pressed at 07:27:00. Previous wake up times reported in the mobile app vary between 07.00am and 08.30am. Using this information as a guide, the data list is inspected. Around 07.00am on the morning of Monday 10th, 40 epochs coded as 0 are identified in the data list (end of 40 epochs at 06:37:00). Looking ahead, 20 epochs coded as 1 cannot be found. Last 0 before this sequence cannot be recorded to indicate a new end time. This sleep interval needs to be deleted, and an exclusion interval entered from 12:00 – 12:00 on Sunday 9th.

Step 7

Exclude nights where parents reported that the child had a sleepover with a friend/experienced sleep that is not defined as 'typical' as part of their usual routine (see mock example below). Exclude this 24 hour period from the actogram. First delete this sleep interval, then enter exclusion period from 12:00 – 12:00 (Interval → Add interval → Interval type: excluded).



a. Please note, provisions are made within the mobile app sleep diary for overnight respite/overnight care by family members or relatives, if this is part of the child's usual routine (i.e sleeping overnight at grandparents, co-parenting arrangement). If sleep diary has been completed by parent/relative/professional according to pre-determined arrangements on these respite/alternative childcare nights, these nights do not need to be excluded.

Step 8

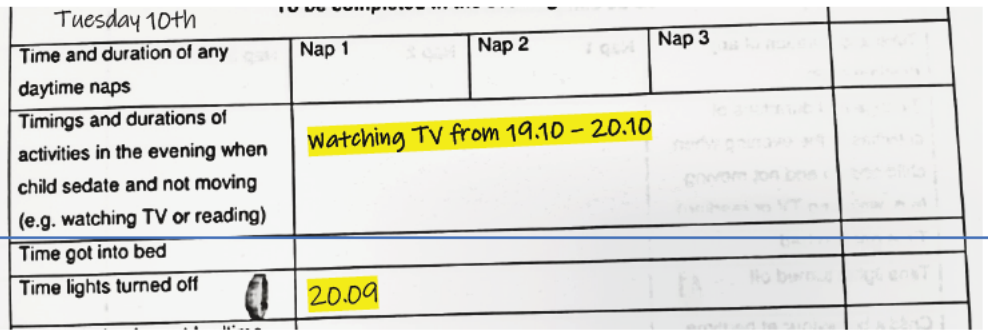
Adjust sleep intervals where automatically calculated interval start time overlaps with sedentary activity or short actiwatch removal (e.g. watch removal that coincides with bath time before bed) reported in the sleep diary information.

a. For each night, check if any of these activities/short removals overlap with the automatically calculated sleep interval for that night.

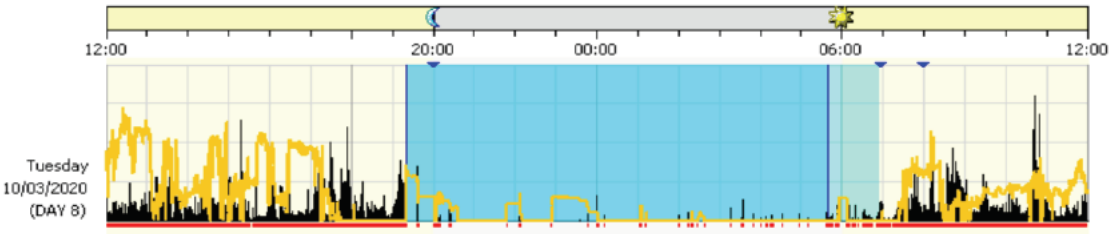
b. If the sedentary activity/short removal in the sleep diary ends before the automatically calculated sleep interval created in Actiware, do not change the sleep interval for this given night.
c. If the automatically calculated sleep interval starts during the period of sedentary activity/actiwatch removal, **keep the automatically coded end time**, but change the start time of the sleep interval according to the following guidance;
   - If the diary 'time lights turned off' and the event marker are congruent (+/- 15 minutes) use the time the event marker was pressed as the start of the adjusted sleep interval.
   - If the diary 'time lights turned off' and event marker are incongruent (> +/- 15 minutes) use the time the event marker was pressed as the start of the adjusted sleep interval.

The following actions apply if the event marker or sleep diary information cannot be used:

i. If the event marker was pressed before/during the sedentary activity or removal, use the diary 'time lights turned off' as the start of the adjusted sleep interval.
ii. If the event marker was not pressed, use parent reported 'time lights turned off' as the start of the adjusted sleep interval.
iii. If the 'time lights turned off' is +/- 15 minutes congruent with the **start time** of the sedentary activity (i.e event marker is being used to indicate when the child goes to lie in bed and watch television, not being used to indicate lights out to begin sleep), 'time lights turned off' cannot be used reliably. Use the **end time of the sedentary activity/short removal** in the sleep diary as the start of the adjusted sleep interval.
iv. If the event marker was not pressed and the sleep diary does not report 'time lights turned off' **use the end time of the sedentary activity/short removal** in the sleep diary as the start of the adjusted sleep interval.



Tuesday 10th			
Time and duration of any daytime naps	Nap 1	Nap 2	Nap 3
Timings and durations of activities in the evening when child sedate and not moving (e.g. watching TV or reading)	Watching TV from 19.10 – 20.10		
Time got into bed			
Time lights turned off	20.09		



Overlap between automatically calculated sleep interval (19:22:30-06:53:00) and sedentary activity reported in sleep diary. Event marker pressed at 20:02:00 – pressed during sedentary activity and cannot be used. Lights out information reported in sleep diary as 20.09pm. Adjust sleep interval to 20:09:00-06:53:00.

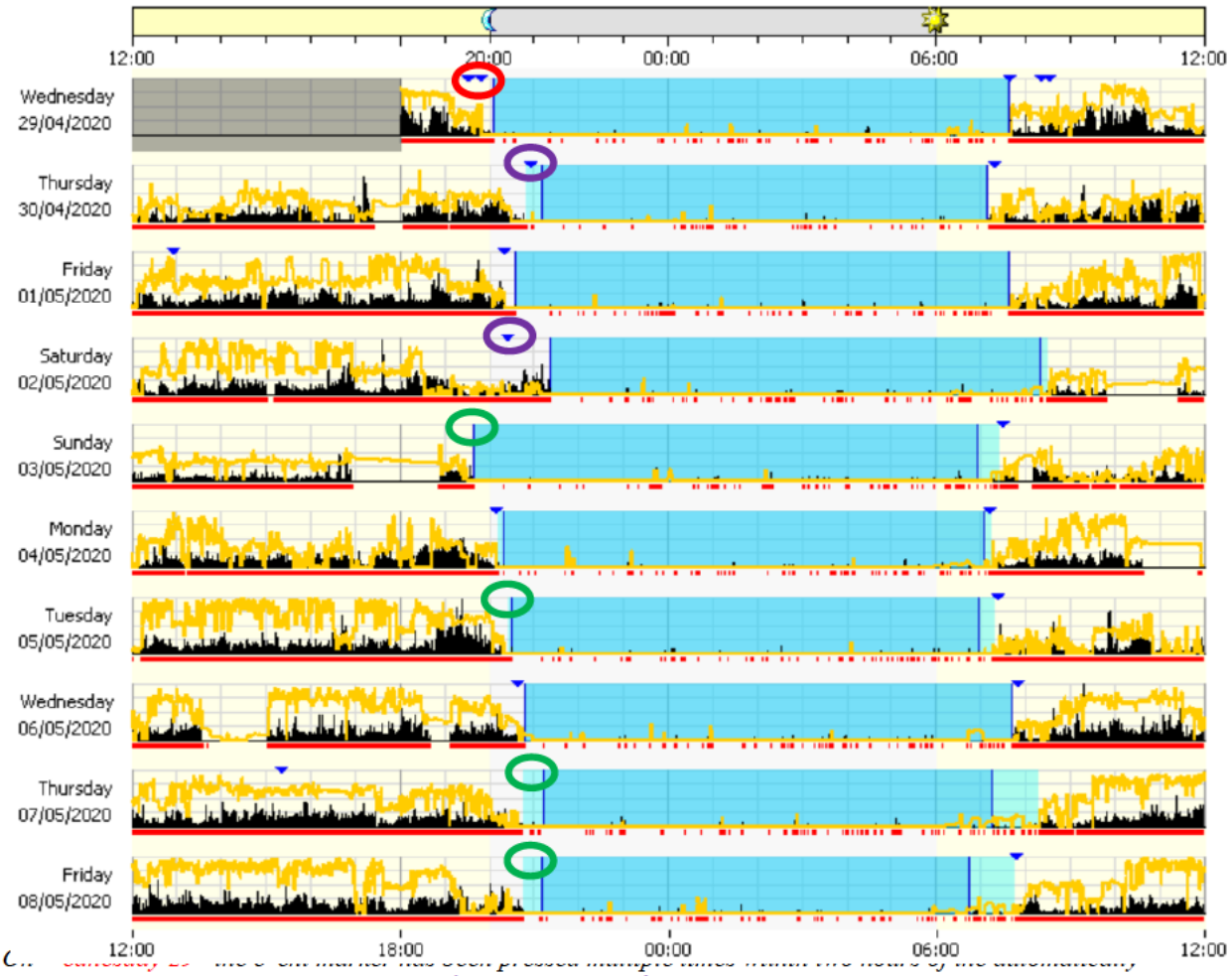
Step 9

Visually inspect the actogram and review the sleep diary information. Look over the whole data collection period and note the number of nights where:

a. The event marker is missing
b. The event marker has been pressed multiple times within two hours of the automatically calculated sleep interval start time
c. The sleep diary information indicates that the event marker was pressed at the incorrect time

<u>THE EVENT MARKER SHOULD BE DEEMED INACCURATE</u>

- If on half the nights or more (5/10, 4/7) any of these apply, the event marker is deemed inaccurate for the **whole sleep assessment**. Use the **alternative algorithm** to decide whether the start of the sleep interval needs to be changed FOR ALL NIGHTS OF THE SLEEP ASSESSMENT.
- If the event marker is deemed inaccurate for a minority of nights (1/10, 3/7), even if only on one night, use the **alternative algorithm** to decide whether the start of the sleep interval needs to be changed FOR EACH NIGHT SPECIFICALLY WHERE THE EVENT MARKER IS DEEMED INACCURATE.



calculated sleep interval. On Thursday 30th and Saturday 2nd, the event marker has been identified as inaccurate within the mobile app diary. On Sunday 3rd, Tuesday 5th, Thursday 7th and Friday 8th the event marker is missing. This means that the event marker is inaccurate for the majority of nights (7/10), and so the event marker should be discounted FOR ALL NIGHTS OF THE SLEEP ASSESSMENT. The alternative algorithm should be used for every night in the sleep assessment (including Friday 1st, Monday 4th and Wednesday 6th).

(If the event marker has been discounted on half the nights or more, do not follow these guidelines, follow the alternative algorithm for all nights).

Use the following guidelines to decide whether to change the start of the sleep interval, for nights when the event marker **has not** been discounted.

i. Look at the event marker, sleep diary and the automatically calculated sleep interval start time. If they are concordant (all three within +/-15 minutes of each other; SI – LO, SI – EM, EM – LO = +/-15 minutes) then leave the automatically calculated sleep interval.

ii. If the event marker and sleep diary are concordant but either are discordant with the automatically calculated sleep interval start

time, adjust the start time of the sleep interval to the event marker time.

iii. If the event marker is discordant with the sleep diary but concordant with the automatically calculated sleep interval start time, leave the automatically calculated sleep interval.

iv. If the sleep diary is discordant with the event marker but concordant with the automatically calculated sleep interval start time, leave the automatically calculated sleep interval.

v. If the sleep diary, event marker and automatically calculated sleep interval are all discordant, leave the automatically calculated sleep interval.

Sleep interval = 18:50:30
Event marker = 19:06:00
Sleep diary = 19:20:00
Event marker and sleep diary are concordant, event marker discordant with sleep interval = **Adjust to event marker**

Sleep interval = 18:55:00

Sleep interval = 20:28:00
Event marker = 20:24:30
Sleep diary = 20:45:00
Event marker and sleep diary are discordant, event marker concordant with sleep interval = **Do not adjust sleep interval**

ALTERNATIVE ALGORITHM

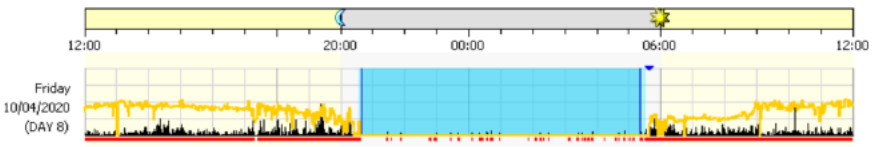
- Use when the event marker is deemed inaccurate for the **whole sleep assessment**. Use the **alternative algorithm** to determine whether changing the sleep interval is required FOR ALL NIGHTS OF THE SLEEP ASSESSMENT.
- If the event marker is deemed inaccurate for a minority of nights (even if this is just 1/10, 3/7) use the **alternative algorithm** to determine whether changing the sleep interval is required FOR EACH NIGHT SPECIFICALLY WHERE THE EVENT MARKER IS DEEMED INACCURATE.

Use the following guidelines to decide whether to change the start of the sleep interval, for nights when the event marker **cannot be considered**.

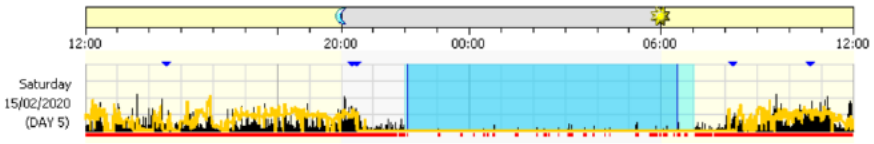
i. If the event marker has been identified as inaccurate, but the sleep diary "time lights out" and sleep interval start time are +/- 15 minutes **concordant**, leave the automatically calculated sleep interval for that night.

ii. If the event marker has been identified as inaccurate, and the sleep diary "time lights out" and sleep interval start time are +/- 15 minutes discordant,

use the child's sleep diary "time lights out" to change interval start time for that night.



EVENT MARKER IS MISSING
Sleep interval = 20:34:30
Sleep diary = 20:38:00
Sleep interval and sleep diary are concordant =
Do not adjust sleep interval



EVENT MARKER PRESSED MULTIPLE TIMES
Sleep interval = 22:00:00
Sleep diary = 20:30:00
Sleep interval and sleep diary are discordant =
Adjust to sleep diary

<u>General Principles/Notes</u>

- *When you make a change go to interval - add interval and indicate what you changed*
- *Record all data on excel sheets called T1 or T2 Sleep data collection (diary & watch 1) – pre means T1, post means T2. Only fill in raw data*
- *Code all data (less than or more than 7)*
- *Don't change if less than 15 mins between diary and actigraphy*
- *Save by clicking exit and then entering saving information*
- *Sending watch:*
  Plug into laptop. Press communications. Enter time point [e.g., T2], ID []. Select 21 days collection. Epoch 30 seconds. Then select all. Make sure to save data if previous. Place watch and sleep diary in brown envelope and include silver envelope inside with addresses on.