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# **University of Southampton**

Faculty of Environmental and Life Sciences

School of Psychology

## **The Wake-Up Call We Keep ‘Snoozing’: The Role of Sleep and Circadian Factors in Adolescent Anxiety**

by

**Hannah Ravenhall**

Thesis for the degree of Doctorate in Educational Psychology

September 2025

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# University of Southampton

## Abstract

Faculty of Environmental and Life Sciences

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Adolescent mental health is a rising concern, with anxiety presenting as the most prevalent need. As onset during adolescence can present long-term challenges, early identification and intervention is key. Concurrently, sleep problems alongside biological changes in sleep, such as a shift towards ‘eveningness’ (i.e., becoming more of a ‘night owl’) is prevalent. This shift creates tensions with societal demands like early school start times, leading to weekday sleep deprivation and compensatory weekend lie-ins – a pattern known as ‘social jetlag’.

Given the bidirectional relationship between sleep and anxiety, this thesis explores their association in greater depth. A systematic literature review and meta-analysis explores the magnitude of the relationship between social jetlag and anxiety in adolescence. A multi-level random-effect meta-analysis found a small, positive, significant association, suggesting that adolescents experiencing greater social jetlag are likely to report higher anxiety.

An empirical study explores the extent to which sleep and circadian factors influence anxiety and emotional processing – an underlying mechanism of anxiety. Participants aged 16-18 completed an online survey consisting of self-report measures of sleep (quality, latency, duration, efficiency, disturbance, daytime dysfunction, circadian regularity, sleep continuity, chronotype, sleep inertia, insomnia) and mental health (generalised anxiety, state anxiety, depression, quality of life), alongside two emotional processing tasks (emotional classification task, emotional flanker task). Correlational analyses showed that insomnia, daytime dysfunction, sleep quality, sleep disturbance, sleep latency, circadian regularity, sleep continuity, and sleep inertia significantly correlated with anxiety. Hierarchical regressions identified sleep disturbance, sleep inertia, and insomnia as significant contributors of anxiety. Whilst sleep/circadian factors did not explain additional variance in anxiety beyond depression, many mediated the relationship between depression and anxiety. In the tasks, sleep/circadian factors influenced sensitivity to fear and correct-response reaction times to happy and sad emotional expressions. Circadian regularity arose as the most consistently associated variable across mental health and task outcomes, highlighting its importance in promoting adolescent wellbeing.

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## Research Thesis: Declaration of Authorship

Print name: Hannah Ravenhall

Title of thesis: The Wake-Up Call We Keep 'Snoozing': The Role of Sleep and Circadian Factors in Adolescent Anxiety

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission

Signature: ..... Date: 18.06.2025.....

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Lastly, I think it is important to acknowledge the irony of a caffeine-fuelled, sleep-deprived night owl conducting a thesis on the importance of sleep and mental wellbeing – let's hope that that combination hasn't negatively impacted the outcomes here too significantly!

## Definitions and Abbreviations

| Term or Abbreviation | Definition                                                                                                        |
|----------------------|-------------------------------------------------------------------------------------------------------------------|
| Chronotype           | The extent to which an individual is an ‘early bird’ or a ‘night owl’                                             |
| Circadian Regularity | The consistency of sleep-wake timing                                                                              |
| Daytime Dysfunction  | Difficulties associated with daytime wakefulness, alertness, and/or energy levels                                 |
| GAD-7                | Generalized Anxiety Disorder – 7-item scale (to measure anxiety)                                                  |
| ISI                  | Insomnia Severity Index                                                                                           |
| KIDSCREEN-10         | KIDSCREEN-10 – a 10-item questionnaire measuring quality of life                                                  |
| T1                   | Time 1                                                                                                            |
| T2                   | Time 2                                                                                                            |
| T3                   | Time 3                                                                                                            |
| MEQ                  | Morningness-Eveningness Questionnaire                                                                             |
| PHQ-9                | Patient Health Questionnaire – 9-item Scale (to measure depression severity)                                      |
| PSQI                 | Pittsburgh Sleep Quality Index                                                                                    |
| TIB                  | Time In Bed (including time spent awake or trying to get to sleep)                                                |
| TST                  | Total Sleep Time (referring specifically to the time spent asleep, as opposed to time in bed)                     |
| SJL                  | Social Jetlag                                                                                                     |
| Sleep Continuity     | The extent to which sleep is smooth, stable, and uninterrupted                                                    |
| Sleep Disturbance    | The extent to which factors disrupt an adolescent’s ability to fall asleep, stay asleep, or achieve restful sleep |
| Sleep Duration       | The total amount of time spent sleeping within a 24-hour period                                                   |
| Sleep Efficiency     | The amount of time spent asleep (in comparison to the amount of time spent in bed)                                |
| Sleep Inertia        | The transitional state from sleep to wake, characterized by ‘grogginess’ and low arousal                          |
| Sleep Latency        | The time it takes an individual to fall asleep                                                                    |
| Sleep Quality        | An individual’s subjective assessment of how well they slept                                                      |

## Definitions and Abbreviations

|               |                                                                                                                                                                                             |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Social Jetlag | A mismatch between internal circadian rhythm and external demands, which leads to a discrepancy in weekday-weekend sleep (similar to being 'jetlagged' but without leaving your time zone). |
| SRQ           | Sleep Regularity Questionnaire                                                                                                                                                              |
| STAI          | Spielberger State Anxiety Scale                                                                                                                                                             |

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# Chapter 1    Introductory Chapter

## Context: Why this, why now?

Adolescents are vulnerable to developing mental health difficulties (Blakemore, 2019), with anxiety presenting as the most prominent mental health need within the adolescent population (Institute of Health Metrics and Evaluation, 2021; Rapee et al., 2023). As the onset of anxiety in adolescence poses risks related to future mental health needs (including anxiety, depression, and suicidal ideation), poorer academic outcomes, and nicotine, alcohol, and recreational drug use (Woodward & Fergusson, 2001), early identification and intervention is key.

Similarly, sleep problems have also been found to be prevalent within the adolescent population, with 37.8% of 8-16 year-olds and 64.9% of 17-23-year-olds experiencing problems with their sleep (Newlove-Delgado et al., 2022). For individuals with mental health needs, sleep difficulties are even more likely, with 76.5% of 8–16-year-olds and 91.4% of 17–23-year-olds with mental health conditions experiencing problems with their sleep.

Aside from sleep problems, adolescents adopt sleep behaviours that are governed by biological developmental factors meaning that their environments are not always conducive to their sleep needs. For example, ‘chronotype’ is an individual’s tendency towards an earlier or later sleep-wake cycle within a 24-hour period; this is often referred to as being a ‘morning person’ (i.e., ‘early bird’) or a ‘evening person’ (i.e., a ‘night owl’). Adolescents experience a shift towards ‘eveningness’ (Randler et al., 2017), meaning that they are inclined to stay up later and sleep in later than younger children or adults. As well as the biological factors at play, this shift is also influenced by academic and social demands (Gau & Soong, 2003); for example, embarking on formal qualifications (such as GCSEs), a decrease in parent/carer set bedtimes, an increased use of technology at nighttime, and an increased drive for independence. Chronotype has also been found to be a correlate of mental health (Taylor & Hasler, 2018), with ‘night owls’ being more at risk for mental health difficulties (Randler et al., 2017). This poses further risks for the adolescent population.

Here, it is valuable to draw upon the two-process model of sleep proposed by Borbély (1982). This outlines how two processes interact to promote a healthy sleep-wake cycle:

- Process S – the homeostatic sleep drive (i.e., the accumulation of ‘sleep pressure’ throughout the waking period – the longer you are awake, the stronger the sleep pressure becomes)
- Process C – the circadian arousal drive (i.e., our internal clock which approximately follows a 24-hour cycle, and is influenced by external cues)

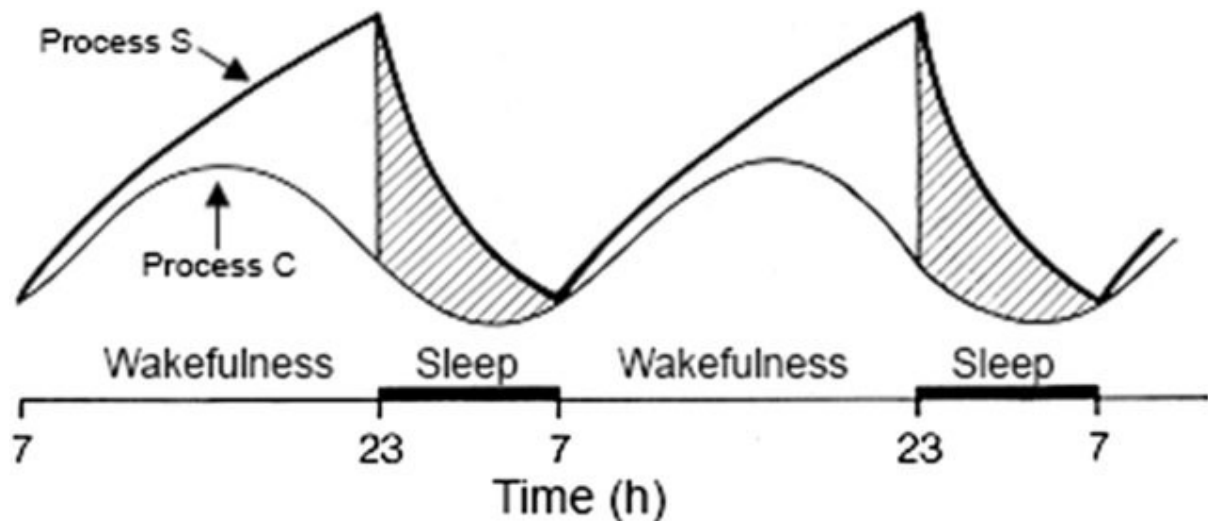


Figure 1.1: The two-process model of sleep

*Note. Reprinted from “Assessing the management of excessive daytime sleepiness by napping benefits,” \*by E. Murillo-Rodríguez et al., 2020, Sleep and Vigilance, 4(2), p. 119 (<https://doi.org/10.1007/s41782-020-00090-9>). © 2020 The Author(s). Licensed under CC BY 4.0.*

When adolescents experience a shift towards eveningness, they feel more alert later into the evenings, when they may be expected to go to bed in order to wake up in time for school. This may lead to them going to bed later, leaving them without sufficient sleep during the week. As such, they then sleep in at the weekend, and experience a discrepancy in their weekday-weekend sleep patterns; this further perpetuates a misalignment between their circadian drive (i.e., Process C) and external demands. This discrepancy between weekend and weekday sleep is known as ‘social jetlag’, which is when their internal clock is mismatched to external demands. Thus, it felt valuable to

draw upon the two-process model of sleep when exploring the concept of social jetlag, considering the impact of quality of life for adolescents who experience that circadian shift. Chapter 2 seeks to explore the magnitude of the link between these two variables. As social jetlag is a relatively new construct, a systematic review and meta-analysis was carried out to explore existing findings to date, gain a deeper understanding of the literature to inform future research, and to begin to consider effective practice to support adolescents.

As indicated, it is evident that a bidirectional relationship is present between sleep/circadian factors and mental health, which can lead to a ‘vicious cycle’ whereby mental health problems worsen sleep and problematic sleep exacerbates mental health difficulties (Meyer et al., 2024). As such, Chapter 3 seeks to gain a deeper understanding of *which* sleep and circadian factors, and to what extent, play a role in anxiety, and to identify where intervention can have the most impact for adolescents.

Sleep is a multidimensional process (Dzierzewski et al., 2021), characterised by a range of factors including:

- Those that focus on the period of sleep itself, such as sleep duration and sleep quality;
- Those that focus on the period of being awake, for example, daytime functioning;
- Those that focus on circadian rhythm, such as sleep regularity;

Alongside the two-process model (Borbély, 1982), Buysse (2014) offers a framework of sleep health which captures six dimensions: regularity, satisfaction, alertness, timing, efficiency, and duration. This framework was proposed with a positive psychological lens of shifting away from a focus on sleep problems and towards the promotion of sleep health. I felt that this approach aligned with my practice as a trainee educational psychologist, as it is solution focused and is underpinned by the notion of promoting wellbeing as opposed to ‘treating’ problems (often from a within-person perspective). In combination, these two models captured the wide range of sleep and circadian factors upon which to explore in relation to anxiety.

From a clinical perspective, it is noted that sleep is referenced in measures of depression such as the PHQ-9, and whilst it is alluded to in similar anxiety scales (e.g.,

asking respondents whether they experience restlessness in the GAD-7), it is not as prominent. This suggests that sleep and circadian factors may not be considered as significant when considering anxiety needs within individuals. Similar to previous findings (Qiu & Morales-Muñoz, 2022), this research seeks to inform the practice of health practitioners in that sleep and circadian factors should be considered when assessing anxiety within adolescence.

More broadly, this research seeks to challenge perceptions of adolescent sleep behaviours as an indication of ‘laziness’ or being ‘moody’, and instead frame them as experiences of sleepiness due to sleep problems, and differences in sleep-wake schedules which are driven by biological, social, and environmental factors (Moore & Meltzer, 2008). Once this is recognised by adults who support adolescents, particularly educators and policy makers, it has the capacity to drive forward structural changes, such as delaying school start times, to better align with adolescent sleep-wake cycles.

In summary, adolescence is a period of significant physical, behavioural, social, emotional, cognitive, and moral development (Tsagem, 2022), marked by an increased vulnerability to anxiety and sleep difficulties. This research seeks to explore this relationship to better understand the nuances and most influential sleep/circadian factors to inform evidence-based intervention promoting adolescent wellbeing and supporting the adults who care for them. Findings will have implications for educational psychologists, educators, health practitioners, parents/carers, and adolescents by contributing to a deeper understanding of sleep health, sleep behaviours, and appropriate and effective interventions.

## **Personal Motivation for Research**

Fuelled by a personal interest in the influence of sleep and circadian factors, I was drawn to the book *‘Why We Sleep’* written by Matthew Walker (2017). Walker makes a powerful claim in this book that *“there does not seem to be one major organ within the body, or process within the brain, that isn’t optimally enhanced by sleep (and detrimentally impaired when we don’t get enough)”* (Walker, 2017, p. 6). This highlights the universal importance of sleep for human beings, and encouraged me to reflect on my own sleep and the young people with whom I work in my practice. Personally, I would identify as a ‘night owl’, recognising that my productivity levels often come alive

at nighttime, however, I have always felt that by working late into the evening, this is perceived by society as working ‘last minute’ due to having not completed work earlier in the waking day. Whereas, individuals who wake early to begin work (perhaps ‘early birds’) are perceived as productive and opportunistic, perhaps even envied by those whose sleep-wake cycles do not align with this rhythm. Upon learning that there is a shift to eveningness within adolescents – and not just in human beings (a similar shift has been seen in rodents and other primates; Hagenauer & Lee (2013), suggesting that an evolutionary function is at play) – I wondered how perceptions of adolescent sleep may be shifted to support them. With a shift in perspective, I hope that this leads to positive change for young people, to enable them to reap the wide range of benefits that healthy sleep brings.

Furthermore, within my practice as a trainee educational psychologist and in speaking to other educational psychologists, I have noticed that children/young people’s sleep problems often arise within casework. As such, I feel that educational psychologists are well placed to offer evidence-informed provision and training to educators/parents regarding sleep behaviours to promote positive outcomes for children and young people. Whilst I feel that recommendations regarding sleep duration are widely recognised (i.e., the recommended sleep duration is 8-10 hours for adolescents and 7-9 hours for adults; Hirshkowitz et al., 2015), I feel that recommendations about sleep timing and regularity are less widespread. Yet, circadian regularity arose as one of the prominent influential factors within this research, highlighting its importance in the plethora of sleep and circadian factors. As such, within my future role as an educational psychologist, I would love to continue to promote knowledge, understanding, and implementation of healthy sleep-related behaviours and environments for children, young people, and their families.

### **Ontology and Epistemology**

A critical realist ontological stance is taken within this research, which aligns with a post-positivist epistemology. Both chapters employ quantitative methodology, and it is recognised that whilst an objective ‘reality’ is being explored (for example, sleep-wake patterns), our understanding of them is shaped by the measurement tools (e.g., self-report questionnaires), theory (i.e., those outlined above), and contextual factors (i.e.,

the environments in which we exist). Constructs such as sleep and circadian factors, mental health, and task performance are treated as measurable and quantifiable, whilst acknowledging that they will not be captured ‘perfectly’ (Van Den Berg & Jeong, 2022).

Through a positivist lens, there is an assumption that an objective reality can be measured and known, and therefore, by taking a post-positivist epistemological stance, there is an acceptance that the measures and tools utilised in research are fallible (Maksimović & Evtimov, 2023), resulting in limitations and bias which are acknowledged within the papers. For example, questionnaires that were regarded as valid and reliable were employed with the aim of accessing the ‘truth’ of participant experiences; it was recognised that the selected tools were just one way of obtaining such data.

Within this stance, the goal was to minimise bias whilst recognising that complete neutrality was not possible (Van Den Berg & Jeong, 2022). For example, some of the free-text items in the questionnaires required my interpretation of their responses, and therefore, a ‘rule book’ was created to ensure that a consistent approach was employed (e.g., if a participant said that they took 15-30 minutes to fall asleep, the midpoint was recorded, and this ‘midpoint’ rule was followed to interpret all participant responses).

## **Ethical Considerations**

As participants were recruited online, measures were put in place to deter against bots completing questionnaire responses. Similarly, efforts were made to ensure that language was straightforward and without jargon, with posters created to appeal visually, and Word documents created to enable the text-to-speech function.

Researchers’ contact details were provided to enable participants the opportunity to reach out and ask questions. Information was also provided to ensure that it was clear that participants understood their right to withdraw. Furthermore, participants were encouraged to complete the study in a quiet and confidential space, however, it is recognised that this was dependent upon their own autonomy and choice.

Participants were required to have access to a laptop/desktop computer and the internet, and it was recognised that not all adolescents have access to such resources, and so efforts were made to recruit through educational settings, where they are more readily available. Furthermore, they were required to provide approximately 35 minutes

of their time, which may have led to some discomfort, inconvenience, or inattention. Participants were provided with the opportunity to enter a prize draw for an Amazon voucher, and personal data was collected separately from the data via a separate online survey. Measures were put in place to ensure that only participants who had completed the survey had access to the prize draw.

It is recognised that in order to explore sleep and circadian factors and adolescent mental health, sensitive questionnaires regarding these topics were required within the scope of this research. It was also possible that the emotional flanker task could have caused discomfort or distress due to the negative images presented. As participation was anonymous, participants were encouraged to seek support from adults they knew and trusted, and were signposted to organisations which could support them, should they experience any discomfort or distress.

Anonymous participation in the research was prioritised in order to protect the information provided by the adolescents, and to promote honest responses to questionnaires. Nwanaji-Enwerem et al. (2022) found evidence to suggest that stigma is associated with self-report characteristics of sleep deficiency, and so it was outlined to participants that no judgements would be made about the answers they provided in the hope that this would support them to provide accurate and honest answers. When reaching out to educational settings to recruit participants, one teacher asked what would happen if participants scored highly on the GAD-7. Here, I explained that anonymous participation was prioritised within data-collection as it protects participant identity, respects their autonomy, and reduces social desirability bias through promoting honest and true responses. Anonymous participation also means that it is not possible to provide direct support for any participants who present with high GAD-7 scores. I explained to the teacher that as this was the case, the debrief encourages participants to seek support from an adult they know and trust, and signposts organisations which can support them. This response was recognised and accepted by the teacher, and I felt it was important to hold open and honest communication with them about the pros and cons of anonymous participation.

Furthermore, concerns were raised from educators with regards to parental consent. Participants were aged 16-18 years old, meaning that they were eligible to give their own consent, and this appeared to lead to some discomfort among educational settings,

and potentially contradict their policies. I was required to explain that it would be ethically challenging to seek consent from parents or carers, because participants would be at liberty to provide consent independently, regardless of parent/carers approval. It was, however, made clear that whilst participant autonomy was respected, parents/carers could still be informed of the research and the young person's invitation to take part. For example, many educational settings decided to advertise the study via their parent/carers newsletter.

## **Dissemination Plan**

This thesis comprises of two research papers completed with the intention of submitting to peer-reviewed journals. I intend to publish the systematic literature review and meta-analysis in *Sleep Medicine*, a journal considered to be a leading platform within the field of clinical sleep research, primarily focusing on the human aspect of sleep. It has a five-year impact factor of 4.0, and a current impact factor of 3.8. I intend to publish the empirical research paper in *SLEEP* – an international journal of sleep and circadian science. It has a five-year impact factor of 5.7 and its current impact factor is 5.3. As such, the papers have been written in the style required for publication to those journals, with final amendments to be made in due course.

Further to the intention to publish the papers that I have written, I am also delivering a presentation of my findings at the University of Southampton Postgraduate Conference and presenting research posters at the 46th Annual Conference of the International School Psychology Association (ISPA) 2025. When recruiting participants for the empirical research, I offered schools and services the opportunity for me to present my findings once complete, and some settings have requested that I share my research outcomes and/or present them to staff. I will also be disseminating my research findings to educational psychologists within my placement as part of my role as a Trainee Educational Psychologist. Relatedly, I have been contacted by educational psychologists who also conducted their doctoral research in sleep, and I have been invited to join a community of educational psychologists who would like to develop a special interest group which I am excited to join. Whilst I mark a significant milestone in submitting this thesis, I feel that future work focusing on disseminating findings and continuing to explore the most effective ways in which individuals can be supported to

develop beneficial sleep health is yet to come, and I look forward to embarking on the next stage of this journey.

**Chapter 2 Out of Sync and Overlooked: Exploring the Relationship between Social Jetlag and Anxiety within the Adolescent Population – A Systematic Literature Review and Meta-Analysis**

## Abstract

**Importance:** Mental health needs are prevalent amongst adolescents, with anxiety being the most prominent. Adolescence is a period characterised by change and transition, including a shift towards an eveningness chronotype. A combination of this eveningness preference, and social and environmental factors, results in adolescents going to bed later but societal demands require them to wake for early school start times. This leaves them with a sleep ‘debt’ which they are inclined to ‘catch up’ on at the weekend, leading to ‘social jetlag’. Social jetlag refers to a mismatch between an individual’s internal circadian rhythm and external demands, which leads to a discrepancy in weekday-weekend sleep (similar to feeling ‘jetlagged’ but without leaving your time zone).

**Objective:** The present PRISMA-compliant systematic review investigates the relationship between social jetlag and anxiety in adolescents.

**Data Sources:** Whole text searches were conducted in PsycINFO, Web of Science, Embase, PubMed, MEDLINE, and ProQuest Dissertations & Theses Global on 14<sup>th</sup> November 2024 to retrieve studies analysing the relationship between social jetlag and anxiety in the adolescent population.

**Study Selection:** Inclusion criteria consisted of quantitative studies obtaining data on social jetlag and anxiety levels for participants aged 12-18 years old, living in any country.

**Data Extraction and Synthesis:** Findings synthesize data through multi-level random-effect meta-analysis to estimate the magnitude of the association between social jetlag and anxiety, and through narrative synthesis. Further analyses explored heterogeneity.

**Main Outcomes:** Data were obtained from 12 studies, yielding 29 effect sizes, and comprising 235, 526 participants. A further six studies were included in the narrative review. A small and positive significant association was found between social jetlag and anxiety ( $z = 0.614$ , 95% CI [0.0268, 0.0961],  $p = .0001$ ).

**Conclusions and relevance:** Implications of these findings include increasing awareness of the importance of circadian rhythm and supporting adolescents directly

and through the wider contexts in which they live to promote healthy sleep and mental health.

## Introduction

The growing prevalence of mental health needs is presenting as a public health issue worldwide (Huang et al., 2023). The period of adolescence presents vulnerability to mental health difficulties (Blakemore, 2019), and anxiety is the most prominent mental health need within the adolescent population (Rapee et al., 2023). The World Health Organisation estimate that, globally, 4.4% of 10-14 year olds, and 5.5% of 15-19 year olds experience an anxiety disorder, whilst depression rates are estimated to be 1.4% and 3.5% respectively (Institute of Health Metrics and Evaluation, 2021), and Bie et al. (2024) state that the global incidence of anxiety disorders among those aged 10-24-years-old increased by 52% from 1990 to 2021. Due to the onset of anxiety in adolescence posing risks into adulthood (Blakemore, 2019; Clark et al., 2007; Pine et al., 1998), early identification and intervention is vital. Without intervention, longitudinal studies have shown detrimental long-term consequences of anxiety in adolescents, including continuation of anxiety into adulthood, risk of depression, nicotine, alcohol, and recreational drug dependence, suicidal ideation and poorer academic outcomes (Woodward & Fergusson, 2001).

Mental health, sleep, and circadian factors present a bidirectional relationship, which can result in a 'vicious cycle' whereby mental health symptoms can worsen sleep, and disruption to sleep quality, continuity, or timing can exacerbate mental health difficulties (Meyer et al., 2024). It seems that co-occurrence between mental health needs and sleep disorders is the norm, rather than the exception (Harvey, 2022) and it is often the case that questionnaires identifying mental health needs include questions related to sleep. For example, the Patient Health Questionnaire-9 (Kroenke & Spitzer, 2002) asks respondents to reflect on symptoms including 'trouble falling or staying asleep, or sleeping too much', and the Beck Depression Inventory (Beck et al., 1996) includes a question about changes in sleep patterns. Whilst widely used anxiety scales may indirectly address sleep through questions associated with restlessness (e.g., the Generalized Anxiety Disorder-7; Spitzer et al., 2006) or an inability to relax (e.g., the Beck Anxiety Inventory; Beck et al., 1988), reference to sleep appears less common.

The two-process model of sleep (as proposed by Borbély, 1982) outlines two distinct and related biological processes involved in regulating individuals' sleep-wake cycle: (1) the sleep-wake homeostasis (i.e., the accumulation of sleep pressure throughout the

waking day – the longer you are awake, the stronger the sleep pressure); (2) circadian rhythm (i.e., an individuals' internal clock that follows an approximate 24-hour cycle, which is influenced by external cues such as light, exercise, and mealtimes).

Chronotype refers to individual differences in sleep timings, and alertness and energy levels throughout the day (Taylor & Hasler, 2018). Human beings range on a spectrum of morningness to eveningness (i.e., a natural preference to be awake later into the evening), and whilst it is considered relatively stable, there is a significant shift towards eveningness in adolescence (Randler et al., 2017). In addition to biological shifts, adolescent sleep is impacted by environmental factors, such as academic and social demands (Gau & Soong, 2003). For example, the use of screen-based media devices at night can increase arousal levels and introduce light disturbance (Mireku et al., 2019), and extracurricular activities (e.g., volunteering, sports clubs, music groups), paid jobs, and academic demands (e.g., homework) often compete for adolescent free time, leading to later bedtimes (Short et al., 2013). Adolescents demonstrate a drive for independence, including the autonomy to choose their own bedtimes (Carskadon, 2011), and school start times often result in adolescents needing to wake during their biological night (Wahistrom, 2002). Carskadon (2011) describes these contributors as the 'perfect storm' in limiting sleep duration for adolescents. Furthermore, these factors may also lead to 'social jetlag' (SJL) – a mismatch between internal circadian rhythm and external demands, which leads to a discrepancy in weekday-weekend sleep (similar to being 'jetlagged' but without leaving your time zone).

Chronotype is increasingly being recognised as an important correlate of mental health (Taylor & Hasler, 2018), with research indicating eveningness as a potential risk factor for mental health difficulties (Randler, 2011). Evening types are more prone to experiencing SJL (Martínez-Lozano et al., 2020), likely due to being woken before their preferred waking time, and being more alert later into the evening. It may be, therefore, that SJL plays a key role in the relationship between chronotype and mental health.

Adolescence is regarded as a transitional phase (Ko et al., 2024), characterised by a high prevalence of anxiety (Blakemore, 2019) and a shift towards an evening chronotype (Randler et al., 2017). Due to a range of aforementioned contributors, circadian rhythm disruption, such as SJL, is often observed during adolescence, however, no previous evidence synthesis study has investigated whether there is a link between SJL and

anxiety within adolescents. Via systematic review and meta-analysis, this research aims to investigate the association between the two variables. If such an association is found, sleep schedules could be considered a modifiable factor influencing mental health (Waters et al., 2023), and therefore, a potential target for interventions to promote positive outcomes for adolescents.

## Method

### 2.1 Search Strategy and Selection Criteria

This systematic review and meta-analysis followed the 2020 PRISMA guidelines (Page et al., 2021) and the protocol was pre-registered on Prospero (available from <https://www.crd.york.ac.uk/PROSPERO/view/CRD42024611935>). Whole text searches were conducted in PsycINFO, Web of Science, Embase, PubMed and MEDLINE on 14<sup>th</sup> November 2024. To reduce the risk of publication bias, grey literature searches were also conducted via ProQuest Dissertations & Theses Global. The key components of the systematic search strategy were considered using the SPIDER tool (Cooke et al., 2012), and study eligibility was assessed using its framework:

Table 2.1: Systematic search strategy using the SPIDER tool

| SPIDER Element              | Criteria                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| S - Sample                  | Adolescent participants (aged 12-18 years old ) living in any country                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| PI - Phenomenon of Interest | Studies measuring social jetlag (i.e., a discrepancy between weekday and weekend sleep). It is noted that social jetlag is operationalised in varying ways across the literature. In this review, social jetlag is referred to broadly as a 'discrepancy' in order to accommodate all definitions. It is recognised that social jetlag is conceptually related to sleep regularity, however it specifically captures a difference in weekday and weekend sleep, whereas sleep regularity refers to consistency across all days (Windred et al., 2024).                                                                                                |
| D - Design                  | Quantitative data collection, including longitudinal, cross-sectional, case control or cohort studies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| E - Evaluation              | Studies that gathered data on sleep regularity/circadian rhythm through self-report measures, actigraphy, wrist-worn wearables, or EEG to determine participant experiences of social jetlag. It is noted that social jetlag is currently measured via the Munich Chronotype Questionnaire (MSTQ; McGowan et al., 2016), however, there are other means through which studies calculate social jetlag, and this evidence synthesis aims to capture all methods.<br><br>Self-report data on participant anxiety, for example, via the Generalized Anxiety Disorder 7-item (GAD-7) or studies including participants diagnosed with an anxiety disorder |
| R - Research                | Quantitative empirical studies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

The search terms referred to (a) participant age (e.g., adolescen\*), (b) social jetlag (e.g., “social jetlag” OR “circadian misalignment”), and (c) anxiety (e.g., anxi\*). For the full search strategy and terms, see Appendix A.

## **Data Selection, Extraction, and Quality Rating**

Titles and abstracts of retrieved studies were independently screened by three reviewers to identify those that met inclusion criteria. Full texts of potentially eligible studies were assessed by two authors. Disagreements were resolved through discussion, with final decisions being made by the lead author. Data extraction and assessment of data quality was performed by the lead author. Extracted information included study design, sample characteristics (including sample size, participant age, participant gender, and ethnicity where reported), country of origin, anxiety measure, definition/measure of SJL, and relevant statistical results (see Table 2.2). Data which were not available from the published reports were requested from authors via email request.

Study quality was assessed via the Newcastle-Ottawa Scale (NOS; Wells et al., 2014). The NOS is a widely used tool that provides an evaluation of the overall quality of non-randomised studies based on three main criteria: a) selection of groups, b) comparability of the study groups, c) ascertainment of exposure for case-control studies, or study outcomes for cohort studies (see Appendix B).

## **Data Synthesis and Analysis**

To explore the association between SJL and anxiety, studies were included in the meta-analysis if they reported data or statistical analyses assessing the relationship between these two variables. Studies that offered meaningful information about this relationship, but did not include relevant statistical analyses, were included in the narrative synthesis.

A meta-analysis was conducted in RStudio 2024.12.1 (Posit team, 2025) to estimate the pooled effect size across studies. All effect sizes were transformed into Fisher’s  $z$  to allow for consistent comparison across studies that used different statistical metrics. Effect sizes were calculated using a combination of base R functions and the `esc`

package (Lüdtke, 2016). For studies that reported correlations between social jetlag and anxiety, Pearson's  $r$  coefficients or Spearman's rank correlation coefficients were converted into Fisher's  $z$  effect sizes, along with their standard errors and variances, using the *esc* package in R (via the *esc\_rpb* function). For studies that reported linear regressions between two groups of participants (e.g., severe vs. moderate-to-low anxiety) standardized or unstandardized  $\beta$  coefficients were converted into Fisher's  $z$  using *esc\_beta* or *esc\_B*. Chi-square statistics were converted using *esc\_chisq*, and independent  $t$ -tests were converted using *esc\_t*. Where necessary, odds ratios and  $\eta^2$  values were also transformed into Pearson's  $r$  and subsequently into Fisher's  $z$ .

Standard errors were calculated using the formula  $SE\ z = \frac{1}{\sqrt{N-3}}$ ; this calculation was implemented in R using base functions.

A multi-level random-effects meta-analytic model was fitted using the *metafor* package (Viechtbauer, 2010) in R, with effect sizes nested within studies to account for the non-independence of multiple outcomes reported within the same study. As between-study heterogeneity was anticipated, a random-effects meta-analysis estimated the pooled effect size using the *meta* package in R. The model was estimated using the Restricted Maximum Likelihood (REML) estimator (Viechtbauer, 2005) and confidence intervals were adjusted using the Knapp-Hartung method (Knapp & Hartung, 2003). This approach was used to estimate heterogeneity variance  $\tau^2$  and reduce the risk of Type I error when interpreting the pooled effect size. Heterogeneity was assessed using Cochran Q test. Publication bias was assessed visually, using funnel plots, and statistically, using the rank correlation test for funnel plot asymmetry (a version of the Egger, 1997, test, suitable for multivariate meta-analytic models). On identification of significant heterogeneity, further exploratory analyses were planned to investigate potential influential factors. Raw data and R codes are available on request to the corresponding author.

## Results

The aim of this systematic review and meta-analysis was to explore the relationship between social jetlag and anxiety within the adolescent population.

### Characteristics of studies included in the review

The initial search retrieved 5508 references, of which 3370 were duplicates and 1831 did not reach eligibility criteria based on title and abstract screening. A total of 307 papers underwent full-text screening, and 39 papers met inclusion criteria. The 39 studies were re-assessed to ensure that they met the specific inclusion criteria for quantitative or qualitative synthesis by directly addressing the relationship between social jetlag and anxiety. Studies providing relevant statistical data were included in the meta-analysis and those that contributed meaningful insights but did not include the required statistical data were incorporated in the narrative synthesis. Figure 2.1 displays the systematic search strategy based on the PRISMA template (Page et al., 2021).

Of the 39 studies, 12 were deemed eligible for inclusion in the meta-analysis on the basis that they provided statistical analyses (e.g., correlations or regressions) which directly examined the relationship between social jetlag and anxiety (total  $N = 235, 526$ ); extracted data were either stated in the journal article or provided following an email request. A further 6 studies were included in the narrative review. Of the 18 included papers, 14 were cross-sectional and four were longitudinal. Table 2.2 outlines a summary.

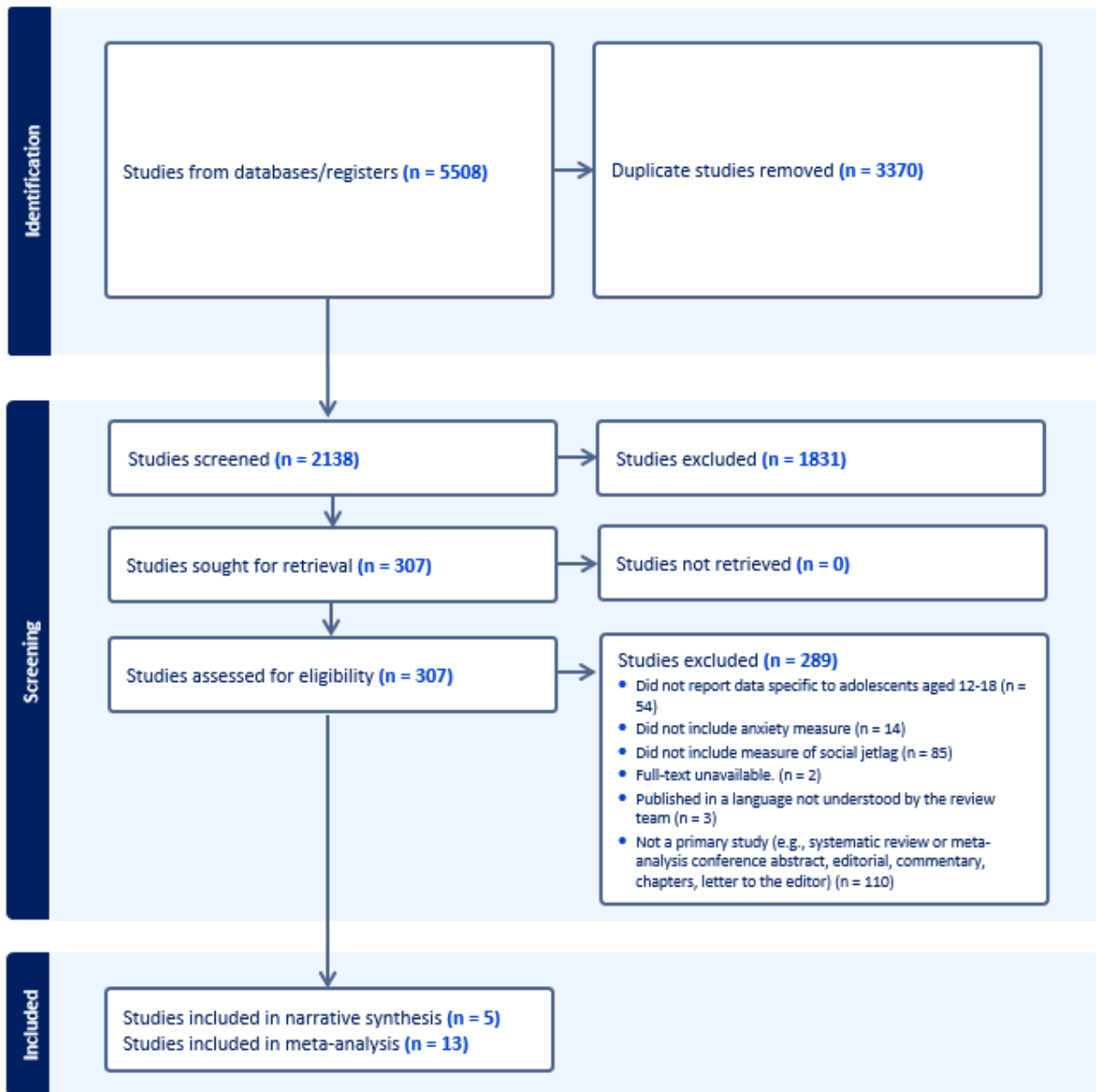


Figure 2.1: PRISMA flowchart

Table 2.2: Characteristics of included studies

| Author                        | Inclusion           | Sample Characteristics                                                                                                                                | Country of Origin | Social Jetlag Calculation*                                       | Anxiety Measure                                                              | Summary of Findings                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-------------------------------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Alvaro et al. (2014)</b>   | Narrative synthesis | n = 318 (mean age: 14.96 years, 48.4% F, 51.6% M)<br><br>Ethnicity not reported                                                                       | Australia         | TST                                                              | Revised Child Anxiety Depression Scale (RCADs; Chorpita et al., 2000)        | The difference between total sleep time (TST) on weekdays and weekends was significantly correlated with panic disorder (PD), social phobia (SP), and obsessive-compulsive disorder (OCD), as assessed by the Revised Child Anxiety Depression Scale (RCADs; Chorpita et al., 2000), corresponding with diagnostic categories of the DSM-IV. Authors describe PD, SP and OCD as subtypes of anxiety, thus, suggesting a relationship between SJL and anxiety. |
| <b>Bauducco et al. (2024)</b> | Meta-analysis       | n = 2781 (mean age: 12.6 years, 51.6% F, 47% M, 1.4% prefer not to say)<br><br>86.2% born in Australia, 6.9% born in other English-speaking countries | Australia         | 'Weekend sleep in' = weekend wake up time - weekday wake up time | PROMIS Anxiety Paediatric (Irwin et al., 2010)                               | At T1, no significant differences were found between weekend sleep-in times and anxiety symptom trajectories. At T2, adolescents with average-increasing trajectory for anxiety had significant longer weekend sleep-in times compared to the low-stable trajectory. At T3, the differences in weekend sleep-in times between anxiety trajectories were not significant.                                                                                      |
| <b>Chung et al. (2020)</b>    | Narrative synthesis | n = 765 (mean age: 15.07, 39.08% F, 60.92% M)<br><br>Ethnicity not reported                                                                           | Korea             | Weekend/weekday bedtime, wake time, and TST discrepancy          | The Revised Children's Manifest Anxiety Scale (RCMAS) (March & Albano, 1996) | No significant differences in anxiety levels across evening types, mid types, and morning types experiencing different amounts of SJL (it is noted that they all experienced >2 hr SJL).                                                                                                                                                                                                                                                                      |

|                                   |                     |                                                                                         |             |                  |                                                                 |                                                                                                                                                                                                                                                                                                                                     |
|-----------------------------------|---------------------|-----------------------------------------------------------------------------------------|-------------|------------------|-----------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Díaz-Morales J.F. (2016)</b>   | Meta-analysis       | n = 1406 (mean age: 13.95, 50.9% F, 49.1% M)<br><br>Ethnicity not reported              | Spain       | Midpoint         | State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1970) | No significant correlations between anxiety and SJL.                                                                                                                                                                                                                                                                                |
| <b>Ko et al. (2024)</b>           | Meta-analysis       | n = 106, 513 (age range: 12-18, 48.5% F, 51.5% M)<br><br>Ethnicity not reported.        | South Korea | Corrected SJL    | GAD-7 (Spitzer et al., 2006)                                    | The odds of developing anxiety increased in girls in the groups of no, low, and high SJL (in that order).                                                                                                                                                                                                                           |
| <b>Kuula et al., (2020)</b>       | Narrative synthesis | n = 1374 (mean age: 16.9 years, 66% F, 34% M)<br><br>Ethnicity not reported.            | Finland     | TST and midpoint | GAD-7 (Spitzer et al., 2006)                                    | Results indicated gender differences: anxiety scores in girls significantly related to sleep mid-point across weekdays, weekends, and all days, however, in boys, whilst anxiety scores significantly correlated with self-reported later sleep timing, actigraphy (including midpoint data) did not correlate with anxiety scores. |
| <b>Li et al. (2024)</b>           | Meta-analysis       | n = 106, 979 (mean age: 13.0 ± 1.8 years, 45.5% F, 54.5% M)<br><br>Ethnic Majority: Han | China       | Midpoint         | GAD-2 (Katon & Roy-Byrne, 2007)                                 | Adolescents with ≥2h SJL were more likely to experience anxiety compared to those with < 1h SJL. When adjusting for demographics, lifestyles, and sleep characteristics, the associations remained significant for ‘sleep corrected’ SJL (SJLsc). Adolescents with ≥2h SJLsc had an increased risk of anxiety.                      |
| <b>Magnusdottir et al. (2024)</b> | Meta-analysis       | n = 65 (mean age: 17.3, 72.3% F, 27.7% M)<br><br>Ethnicity not reported.                | Iceland     | Midpoint         | GAD-7 (Spitzer et al., 2006)                                    | A weak positive association was found between SJL and anxiety; this was not statistically significant.                                                                                                                                                                                                                              |

|                                  |               |                                                                                                                                                                                                                                                           |               |          |                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|----------------------------------|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|----------|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Mathew et al. (2019)</b>      | Meta-analysis | n = 3097 (mean age: 15.59, 48% F, 52% M)<br><br>Ethnicity: 46.4% 'Black/African American'; 23.9% 'Hispanic and/or Latino'; 17.5% 'White/Caucasian'; 12.1% 'other, mixed, or none'                                                                         | United States | Midpoint | 6-item anxiety subscale of the Brief Symptoms Inventory 18 (BSI-18) (Derogatis, 2000) | Results showed that greater SJL was significantly associated with greater anxiety. Shorter TST and greater SJL were independently associated with anxiety. No significant interaction was found between TST and SJL. SJLsc was also found to be associated with greater anxiety, independent of TST. Categories of low, moderate, and high SJL were examined in association with anxiety, and authors found that adolescents with high SJL reported higher anxiety than low and moderate. |
| <b>Rojo-Wissar et al. (2021)</b> | Meta-analysis | n = 817 (mean age: 15 years, 43.16% F, 56.84% M)<br><br>Ethnicity: Non-Hispanic White: 216 participants (40.95%); Non-Hispanic Black: 317 participants (18.86%); Hispanic/Latino: 213 participants (29.08%); Non-Hispanic Other: 71 participants (11.10%) | United States | Midpoint | Brief Symptoms Inventory 18 (BSI-18) (Derogatis, 2000)                                | Correlation data provided by Rojo-Wissar indicated a weak, positive correlation between SJL and anxiety.                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Singh et al. (2023)</b>       | Meta-analysis | n = 1753 (mean age: 16 years, 100% F)<br><br>Ethnicity not reported                                                                                                                                                                                       | India         | Midpoint | Depression Anxiety Stress Scale (DASS-21) (Lovibond & Lovibond, 1995)                 | A (weak) significant relationship was found between SJL and anxiety; urban students experienced higher SJL than rural students and lower anxiety symptoms, suggesting that work is similar every day in rural households in North India. A significant positive correlation was found between chronotype and SJL.                                                                                                                                                                         |

|                             |                     |                                                                                                                                                                                                                                                               |               |                                                             |                                                                 |                                                                                                                                                                                                                                                                                                                                                  |
|-----------------------------|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-------------------------------------------------------------|-----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Stein et al. (2002)</b>  | Narrative synthesis | n = 144 (age range: 13-16, 100% M)<br><br>Ethnicity: European descent: medicated (46%), nonmedicated (47%), control (45%); Middle eastern descent: medicated (54%), nonmedicated (53%), control (55%)                                                         | Israel        | TST                                                         | State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1970) | No significant differences were found in medicated/ nonmedicated participant sleep duration for weekdays-holidays. No significant relationship was found between medicated and nonmedicated sleep duration during weekdays and holidays and anxiety.                                                                                             |
| <b>Stone et al. (2021)</b>  | Narrative synthesis | n = 53 (mean age: 12.8, 62.26% F, 37.74% M)<br><br>Ethnicity not reported                                                                                                                                                                                     | Australia     | Weekend/weekday sleep onset, wake time, and TST discrepancy | PROMIS Pediatric Anxiety Scales (Quinn et al., 2014)            | Research was conducted during COVID-19. Data suggested that adolescents experienced greater SJL during in-person learning compared to remote learning. Anxiety levels were lower during remote learning compared to in-person learning. Further analysis showed that anxiety levels were due to remote learning, as opposed to sleep parameters. |
| <b>Troxel et al. (2024)</b> | Meta-analysis       | Baseline: n = 142 (mean age: 14.0 years, 59% F, 41% M)<br><br>Follow-up: n = 114 (mean age: 14.1 years, 62% F, 38% M)<br><br>Ethnicity at baseline: American Indian and Alaska Native Adolescents (more than 40 tribes represented which were not reported to | United States | Midpoint                                                    | GAD-7 (Spitzer et al., 2006)                                    | Greater SJL was not significantly associated with anxiety symptoms at follow-up, with results suggesting a very small positive association.                                                                                                                                                                                                      |

protect confidentiality), 51% Hispanic

|                             |                     |                                                                                                                                                                                                                                                                     |               |                                                                                               |                                                                                                     |                                                                                                                                                                                                                                                                                                                                        |
|-----------------------------|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Wang et al. (2021)</b>   | Meta-analysis       | baseline: n = 1957 (mean age: 13.6 years, 49.2% F, 50.8% M)<br><br>Ethnicity: 66.1% White, 4.2% Black, 16.7% Hispanic, 3.7% Asian, 9.3% Multiracial/Other                                                                                                           | China         | Weekday-weekend catch-up sleep (CUS) = absolute value of weekend TST and weekday TST          | GAD-7 (Spitzer et al., 2006) Chinese Version (Liu et al., 2020; Zeng et al., 2013)                  | Longer weekday-weekend catch-up sleep (CUS) was a risk factor for anxiety symptoms. Longer weekday-weekend CUS was significantly associated with subsequent anxiety symptoms.                                                                                                                                                          |
| <b>Waters et al. (2023)</b> | Meta-analysis       | n = 709 (mean age: 16.13 years for females, 16.55 years for males, 56.7% F, 43.3% M)<br><br>Ethnicity not reported                                                                                                                                                  | Australia     | 'Short increasing sleep pattern' = fewer than 8h during weekday, more than 8 hours at weekend | The Revised Children's Anxiety and Depression Scale – Short Version (RCADS; Ebesutani et al., 2012) | Short increasing sleepers (i.e., those sleeping less than 8h in the week and more than 8h at weekends) had higher anxiety than average stable sleepers (8-10 hr each night). Providing adolescents have 8-10 hours' sleep during the week, variation in nightly sleep duration at the weekend may not adversely impact anxiety levels. |
| <b>Wesley et al. (2023)</b> | Narrative synthesis | n = 3494 (mean age: 16.24 years, 65.4% F, 29.2% M, 5.4% Other)<br><br>Ethnicity: American Indian or Alaska Native – 0.744%; Asian – 1.97%; Black – 1.35%; More than one race – 10.6%; Native Hawaiian or Pacific Islander – 0.0572%; Unknown – 12.7%; White – 72.7% | United States | Midpoint                                                                                      | PROMIS Anxiety short form measure (Irwin et al., 2012)                                              | Anxiety PROMIS score was not significantly associated with SJL during COVID-19. It is noted that participants' current levels of social jetlag were adjusted for pre-COVID levels of social jetlag.                                                                                                                                    |

## Chapter 2

|                            |               |                                                                                   |       |                                                                       |                                                                                                                                                      |                                                                                                                                                                                                                                                  |
|----------------------------|---------------|-----------------------------------------------------------------------------------|-------|-----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Zhang et al. (2017)</b> | Meta-analysis | n = 10123 (age range: 13-18, gender not specified)<br><br>Ethnicity not reported. | China | 'Weekend oversleep' = weekend sleep duration - weekday sleep duration | Structured World Health Organization Composite International Diagnostic Interview to assess DSM-IV criteria (American Psychiatric Association, 1994) | When compared to weekend oversleep of 1.01-2 hours, participants with $\leq 0$ h of weekend oversleep experienced higher levels of anxiety, whereas those experiencing $> 2$ h of weekend oversleep did not experience higher levels of anxiety. |
|----------------------------|---------------|-----------------------------------------------------------------------------------|-------|-----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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\*'Midpoint' refers to papers that have calculated SJL as the absolute difference between the midpoints of weekday and weekend sleep

'TST' refers to papers that have calculated SJL as the difference between weekend and weekday 'total sleep time'

'Corrected SJL' refers to papers that have calculated SJL as the absolute value of difference between weekday and weekend sleep start time

DSM-IV refers to Diagnostic and Statistical Manual of Mental Disorders, fourth edition (American Psychiatric Association, 1994)

## Meta-Analysis

A multi-level random-effects meta-analytic model was fitted using the *metafor* package (Viechtbauer, 2010) in R, with effect sizes nested within studies to account for the non-independence of multiple outcomes reported within the same study. The analysis included 12 studies, yielding 29 effect sizes. The pooled effect size was  $z = 0.0614$ , 95% CI [ 0.0268, 0.0961], which was statistically significant ( $p = 0.0011$ ). When converted back to Pearson's  $r$ , this corresponds to  $r \approx 0.06$ , indicating a small, positive, and statistically significant association between social jetlag and anxiety. Substantial heterogeneity was observed across studies, with  $Q(28) = 684.5990$ ,  $p < .0001$ . Variance decomposition indicated that most of the heterogeneity was attributable to between-study differences ( $\tau^2 = 0.0021$ ), with minimal within-study variance ( $\tau^2 = 0.0008$ ). These findings suggest the observed variability is due to true difference between studies, rather than sampling error.

## Forest Plot

A forest plot (Figure 2.2) was generated to visually summarise the effect sizes and 95% confidence intervals. Each study contributed either a single or aggregated effect size, expressed as Fisher's  $z$ . The effect sizes ranged from small negative to large positive associations between social jetlag and anxiety, with Waters et al. (2023) reporting the largest effect size ( $z = 0.19$ , 95% CI [0.09, 0.29] and Troxel et al. (2024) reporting the smallest, non-significant effect ( $z = 0.01$ , 95% CI [-0.01, 0.03]. Most studies show small-to-moderate positive effect sizes, with only Singh et al. (2024) showing a significant negative effect ( $z = -0.07$ , 95% CI [-0.12, -0.02]). Wide confidence intervals ( $z = 0.05$ , 95% CI [-0.20, 0.29]) presented by the Magnúsdóttir et al. (2024) study indicate high variability which may reflect the small sample size in this pilot study [ $N = 65$ ] which can lead to greater uncertainty around the effect estimates (Patole, 2021). The small square block, however, indicates that this study contributes less weight in the meta-analysis (Patole, 2021).

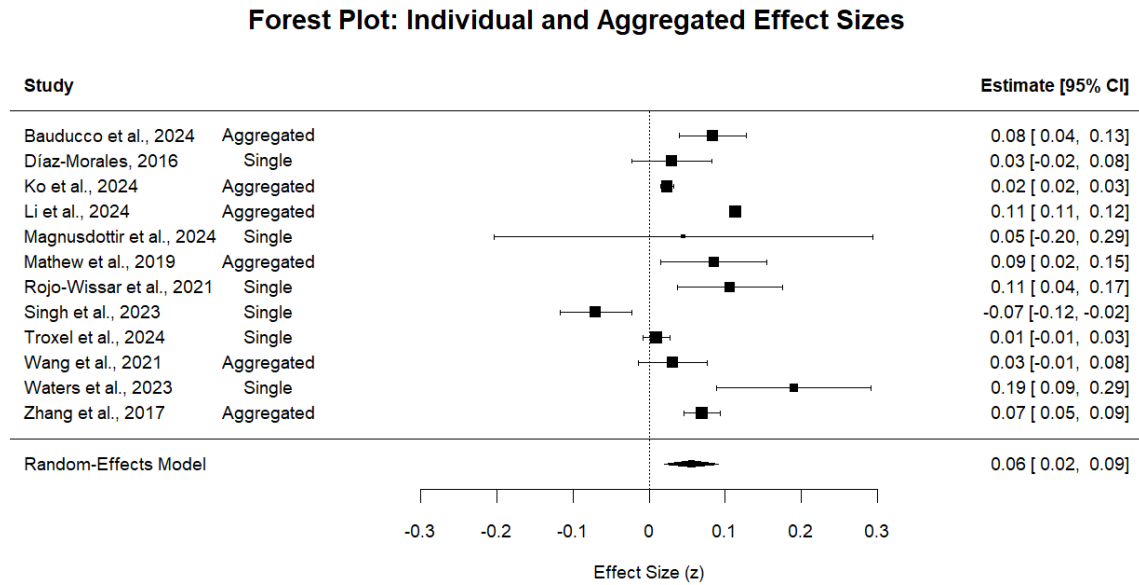


Figure 2.2: Forest plot of individual and aggregated effect sizes

## Publication Bias

A funnel plot was generated to visually assess the presence of publication bias (Figure 2.3). Visual inspection of the funnel plot showed one study positioned away from the main cluster of data points, potentially suggesting publication bias. As such, Egger's regression test was conducted to statistically test for funnel plot asymmetry. The results indicated no significant evidence of funnel plot asymmetry, suggesting that publication bias was unlikely to influence findings,  $z = 0.7271$ ,  $p = .47$ . These outcomes strengthen the validity of the overall findings. The data points positioned away from the main cluster may instead represent variability in study design or sample characteristics.

Figure 2.3: Funnel plot of the individual and aggregated effect sizes

## Outlier Analysis

Studentized residuals were examined to identify potential outliers, using the *rstandard* function from the *metafor* package (Viechtbauer, 2010) in R. A threshold of  $z > 2$  flagged studies with particularly large residuals. All studies had residuals within the acceptable

range of  $\pm 2$ , suggesting that no individual effect size deviated substantially from the model, and thus suggesting no outliers.

To assess the influence of individual studies on the overall meta-analytic findings, a leave-one-out sensitivity analysis was conducted. The resulting estimates ranged from 0.0545 to 0.0724, with deviations from the full model ( $z = 0.0614$ ) not exceeding 0.01. These results indicate that no single study disproportionately influenced the overall findings.

## Meta-Regression

On account of the high level of heterogeneity, which suggests that other sources of variability are contributing to the outcome, a meta-regression was carried out to investigate a factor that may have affected the pooled effect size: the methodological method for calculating social jetlag. The model included 29 effect sizes drawn from 12 independent studies, with random effects specified at the study level (i.e., author) and effect size level (i.e., study ID). Of the total 29 effect sizes, 9 identified the discrepancy between weekday and weekend midpoint, 12 calculated waketime discrepancy, five calculated duration discrepancy, and three calculated sleep onset discrepancy.

The overall model revealed a non-significant effect of measurement method on the strength of the association between social jetlag and anxiety, ( $QM(3) = 0.932$ ,  $p = .4399$ ) suggesting that the way in which social jetlag is calculated did not significantly moderate the effect size. The estimated overall effect size for sleep duration discrepancy was  $z = 0.0833$ , 95% CI  $[-0.0007, 0.1673]$ ,  $p = 0.0518$ , suggesting a small and non-significant positive association. Comparisons with other measurement methods yielded the following results, none of which reached statistical significance:

- Midpoint vs Duration:  $\Delta z = -0.0236$ , 95% CI  $[-0.1255, 0.0783]$ ,  $p = .637$
- Onset vs Duration:  $\Delta z = -0.0701$ , 95% CI  $[-0.1817, 0.0416]$ ,  $p = .2079$
- Waketime vs Duration:  $\Delta z = -0.0004$ , 95% CI  $[-0.1547, 0.1539]$ ,  $p = .9958$

All confidence intervals included zero, indicating no meaningful differences in effect sizes across measurement methods. Furthermore, substantial residual heterogeneity

remained,  $QE(25) = 325.43$ ,  $p < .0001$ , suggesting that other factors are contributing to the variability in effect sizes.

## Narrative Synthesis

A synthesis of the five studies not included in the meta-analysis begin to shed light on other factors that may be contributing to heterogeneity. Studies present mixed findings with regards to the relationship between SJL and anxiety.

Alvaro et al. (2014) support a positive association between SJL and anxiety as they found that the difference between weekday-weekend TST was significantly correlated with panic disorder (PD), social phobia (SP), and obsessive-compulsive disorder (OCD), as assessed by the Revised Child Anxiety Depression Scale (RCADs; Chorpita et al., 2000). As Alvaro and colleagues describe PD, SP and OCD as subtypes of anxiety, corresponding to diagnostic categories of the DSM-IV (American Psychiatric Association, 1994; Regier et al., 2013), thus suggesting a link between SJL and anxiety.

Findings from Kuula et al. (2020) suggest that gender-specific differences may be at play when considering the relationship between SJL and anxiety. Kuula and colleagues reported that anxiety scores in girls were significantly associated with sleep mid-point across weekdays, weekends, and all days. In boys, however, whilst anxiety scores significantly correlated with self-reported later sleep timing, actigraphy measures including sleep midpoint data, did not correlate with anxiety scores. This highlights that potential gender differences warrant further exploration.

Chronotype may also influence the relationship between SJL and anxiety. Chung et al. (2020) explored differences in sleep, depression, anxiety, and Internet addiction in Korean adolescents with different circadian preferences. Information provided in the paper enables for calculation of the difference in weekday-weekend midpoint discrepancy. Morning types were experiencing an average of 2 hours 18 mins, neutral types were experiencing an average of 2 hours 42 mins, and evening types were experiencing an average of 3 hours 2 minutes. Chung et al. (2020) found there to be no significant differences in anxiety levels across chronotypes, suggesting that there may not be a significant relationship between SJL and anxiety. It should be noted, however,

that whilst the evening types appeared to experience higher levels of SJL, statistical analyses did not confirm significant differences in SJL.

Stein et al. (2002) explored sleep patterns in adolescents with symptoms of Attention-Deficit/Hyperactivity Disorder (ADHD) and found that, regardless of medication status, there was no significant relationship between participants' weekday-weekend sleep duration and anxiety. Whilst these findings suggest that there is no significant relationship between SJL and anxiety within this population, this research brings to light another potential moderating factor: neurodiversity. Research shows that sleep problems are highly prevalent within the neurodivergent population, impacting emotional regulation, peer relationships, and structural language (Bettencourt et al., 2024). This suggests that neurodiversity may introduce variance when considering the relationship between sleep and mental health, highlighting the importance of continuing to explore neurodiversity within sleep and mental health research.

Finally, Stone et al. (2021) and Wesley et al. (2023) conducted research during the COVID-19 pandemic. These studies were excluded from the meta-analysis due to the unique and confounding contextual factors associated with the pandemic which would limit the validity of cross-study comparison; however, the studies provide data that is important to acknowledge within the broader narrative review. Stone and colleagues assessed anxiety levels and sleep-wake timings using actigraphy and sleep diaries across periods of in-person, remote learning, and school holidays. Data collected on sleep parameters suggested that adolescents were experiencing greater SJL during in-person learning compared to remote learning. Anxiety levels were found to be significantly lower during remote learning. Whilst this could suggest a relationship between SJL and anxiety, Stone and colleagues tested mediation models for sleep parameters and found that the indirect effect was null, suggesting that changes in anxiety symptoms were due to the remote learning environment and reduced perceived stress as opposed to changes in sleep. This highlights that various other factors could be contributing to the relationship between SJL and anxiety during the COVID-19 pandemic.

Wesley and colleagues examined participants' current social jetlag based on anxiety diagnoses and PROMIS anxiety categories (high, moderate, or below) adjusting for pre-COVID social jetlag. As they adjusted for pre-COVID social jetlag, this complicates

making a direct comparison with studies that did not need to account for pandemic-related changes. The study found that anxiety PROMIS scores were not significantly associated with social jetlag during the pandemic, which may suggest an influence of confounding variables in the relationship between social jetlag and anxiety; for example, Wesley and colleagues note that more participants reported increased sleep opportunities during the COVID-19 pandemic, and fewer participants reported a difference of more than 2-hours between their weekday-weekend sleep schedules (suggesting a more regular sleep/wake schedule during the pandemic). In relation to anxiety levels, Wesley and colleagues report that adolescents with severe symptoms of anxiety significantly shifted their sleep/wake schedules later during the pandemic compared to those in the 'moderate' or 'below' range, and that those with a reported diagnosis of anxiety spent an increased time in bed during COVID-19. Furthermore, physical activity was found to be associated with changes in sleep patterns. It is noted that Wesley and colleagues report that participants experienced less social jetlag during the pandemic compared to their retrospective report of their sleeping behaviours pre-COVID-19, and, as such, it is important to note that retrospective reports can be inaccurate, especially when participants need to report on extended time periods (Schwarz, 2007; Walentynowicz et al., 2018). Finally, Wesley and colleagues highlight that whilst the context of this study is unique to the COVID-19 pandemic, it remains relevant in that it highlights how later school start times provide more sleep opportunity for adolescents.

In summary, these studies contribute to a nuanced understanding of the complex interplay between adolescent SJL and anxiety. The narrative synthesis provides contextual insights to explain the high levels of heterogeneity observed in the meta-analysis whilst also highlighting the importance of greater consistency in study design to inform future research.

## Discussion

This novel systematic literature review and meta-analysis explores the relationship between social jetlag and anxiety within the adolescent population. A multi-level meta-analysis found a small, positive association between social jetlag and anxiety, which was statistically significant. This means that adolescents experiencing greater social jetlag are likely to report higher levels of anxiety. While this relationship only appears marginal, suggesting that social jetlag does not explain a large proportion of the anxiety experienced, it is statistically significant, indicating that it is unlikely to be due to chance, and is sufficiently prevalent across studies to suggest an association between these two variables. It is, therefore, likely to be one of the factors that can influence anxiety within adolescents.

Substantial heterogeneity was observed, which was not explained fully by the subgroup analysis that explored differences in the way in which social jetlag was calculated across studies. A narrative synthesis provided further insight into the between-study diversity. While heterogeneity was explored both statistically and within the narrative synthesis, additional factors that may influence the relationship between social jetlag and anxiety are considered and discussed in turn.

## Defining Social Jetlag and Anxiety

A range of data collection methods were used to determine both social jetlag and anxiety. Whilst statistically, the difference in measurement methods did not account for the high levels of heterogeneity, it is important to explore this further. Nine papers defined social jetlag as the difference between weekday and weekend sleep midpoints whilst some authors calculated 'sleep-corrected social jetlag' which aims to isolate the effects of social jetlag from other sleep-related variables, such as duration, in the hope to understand the sole impact of circadian misalignment. Furthermore, some authors categorise social jetlag into groups, for example, Li et al. (2024) grouped participants into low, moderate, and high social jetlag (<1h, 1-2h, ≥2h, respectively), and Wesley et al. (2024) only regarded participants with a weekend-weekday discrepancy of two or more hours between midpoints as those experiencing SJL.

Jankowski (2017) outlines that when using the original formula, social jetlag is calculated as the difference between the midpoint of sleep on free days (MSF) and the midpoint of sleep on weekdays:

$$\text{Social jetlag} = \text{midsleep on free days} - \text{midsleep on weekdays}$$

$$\text{SJL} = \text{MSF} - \text{MSW}$$

As such, this formula captures the misalignment of weekday-weekend sleep schedules as well as inadvertently calculating sleep debt, which are two interrelated but different sleep phenomena. Calculating ‘sleep-corrected social jetlag’, however, aims to remove the effects of sleep debt from social jetlag in order to explore the concept of weekday-weekend sleep discrepancy in isolation. Sleep-corrected social jetlag assumes that an individual’s average sleep duration reflects their true sleep need, and, therefore, their average weekly sleep duration is calculated. Half of this average is added to their sleep onset on free days with the other half being added to their sleep onset on weekdays. As subtracting half of the average weekly sleep duration from the other half creates a mathematical constant, the formula for sleep-corrected social jetlag (SJLsc), comprises:

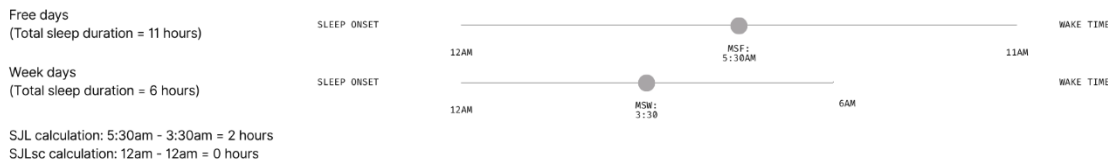
$$\text{Sleep-corrected SJL} = \text{sleep onset on free days (MSFsc)} - \text{sleep onset on week days (MSWsc)}$$

$$\text{SJLsc} = \text{MSFsc} - \text{MSWsc}$$

Figure 2.4 highlights this visually. In Example 1, the individual goes to bed at the same time each night, but sleeps in longer on free days. They experience a 2-hour difference between the midpoint of their sleep on free days vs. weekdays, and they also appear to be compensating for a weekday sleep-debt. In Example 2, the individual also has a social jetlag calculation of 2 hours, however, they experience the same sleep duration each night. As such, the figure highlights how the original social jetlag formula may not reflect only a misalignment in their weekday-weekend sleep patterns, but also captures sleep debt (which may be contributing independently to participant anxiety levels). Alternatively, calculating ‘sleep-corrected social jetlag’ enables the effects of sleep

debt to be excluded in order to isolate the effects of weekend-weekday misalignment.

#### Example 1



#### Example 2

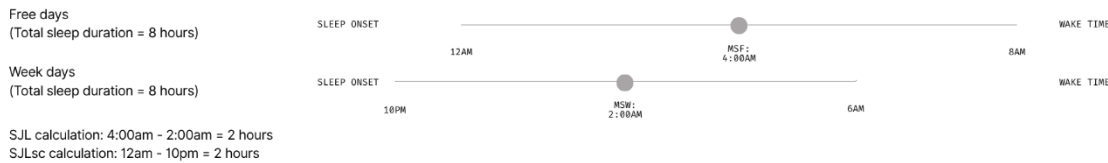


Figure 2.4: A visual representation of social jetlag and sleep-corrected social jetlag calculations

Including studies with a range of definitions brings advantages and disadvantages.

Firstly, including papers with differences in the social jetlag measurements allowed for a larger proportion of the final papers to be included in the analysis, thus expanding the sample size and increasing statistical power to detect significant associations between social jetlag and anxiety. It therefore enabled for a comprehensive analysis of the concept of the mismatch between social and biological clocks, prevalent across the adolescent population. By incorporating social jetlag, sleep-corrected social jetlag, and the categories of social jetlag as set out by various authors, a nuanced analysis of the concept of social jetlag is explored within this review, enabling for generalisability within the complexities of adolescent sleep. It is, however, important to highlight the limitations of including varied definitions and measurement methods of social jetlag as it introduces conceptual inconsistency which may introduce ‘noise’ to the overall analysis. Future research is needed to clarify the association between anxiety and the definitions of social jetlag outlined by the studies within this review (for example, by midpoint, onset, duration, or waketime) as this could help distinguish between cases whereby sleep duration interacts with circadian rhythm to affect anxiety.

Additionally, a broad range of anxiety measures were utilised across included studies. As a construct, anxiety can be difficult to define, and as such, measures of anxiety likely vary in their focus (Wall & Lee, 2022). Advantageously, drawing upon a range of anxiety assessment tools has potential to enhance the robustness of the findings, providing a

comprehensive exploration of the complexities of anxiety and reducing risk of bias by only drawing upon a single measure to enable generalisability. Conversely, whilst the broad range of anxiety measures aim to measure the same construct, they likely introduce heterogeneity, which can make it more challenging to compare and synthesize the results. Indeed, Wall and Lee (2022) found that anxiety scales are often heterogeneous in their content, meaning that caution should be taken when interpreting results.

## **Subjective and Objective Assessment Methods**

Further to the array of measures employed for anxiety and social jetlag, it is also important to consider subjective and objective assessment methods. All included studies utilised self-report measures of anxiety whilst a broader range of assessment approaches, such as actigraphy, were implemented for measuring sleep. Haeffel and Howard (2010) describe self-report measures as widely used, and also widely criticised, within the field of psychology, largely due to the potential for individuals to be inaccurate when reporting their own experiences (for example, they may not recognise or understand their own symptoms, leading to limitations in self-report measures). Advantages such as ease of use and low administration costs can enable accessibility, however, self-report measures can also introduce biases such as demand characteristics (i.e., cues in the environment that lead participants to behave in a way that aligns with the research hypothesis), recall bias (i.e., difficulties accurately remembering experiences related to mood or sleep) or social desirability bias (i.e., individuals reporting what they feel to be more socially acceptable). However, Haeffel and Howard (2010) conclude that self-report tools are well-placed to measure constructs such as emotions and moods, and can be valuable when measuring behaviours. Personal perceptions of experiences such as anxiety and sleep can be valuable within research (e.g., the individual's emotional experiences or perception of their sleep quality), however, discrepancies have been found between subjective and objective sleep assessments (Masaki et al., 2025).

Whilst objective measures of sleep, such as actigraphy and polysomnography, may eradicate some of the limitations of self-report data, they come with their own barriers within research. For example, whilst polysomnography is often regarded as the 'gold

standard' measurement for sleep (Rupp & Balkin, 2011), offering the most comprehensive and accurate data, it often requires a laboratory setting which introduces an artificial setting for sleep and may lead to 'first night' effect (whereby a participant's sleep is atypical during their first night in a novel environment; Byun et al., 2019; Scholle et al., 2003). Further to this, polysomnography is expensive meaning that it is often conducted over short periods, which may not lend itself to measuring a whole week of sleep or more for research related to social jetlag. Actigraphy offers a more cost effective and less invasive option (Alakuijala et al., 2021), enabling participants to wear this technology within their natural environment (therefore, promoting ecological validity), with research suggesting that the results produced by actigraphy are reasonably reliable for measurements of sleep/wake parameters (Rupp & Balkin, 2011). There are, however, questions related to its accuracy and consistency, especially in populations experiencing poor sleep or sleep-related disorders (Sadeh, 2011). Furthermore, Sewell et al. (2025) found that self-report sleep measures provide insights, such as long periods of still wakefulness, that actigraphy-measured sleep did not. Actigraphy technology continues to progress, with recent developments extending to detect limb movements (Sadeh, 2011), and therefore, it will be important to continue to assess its accuracy. Considering the current context, recognising the unique information brought by subjective and objective measures of sleep is advisable as they offer complementary insights.

## **Cultural Differences**

Having stood the test of time throughout evolution, sleep is a biological process experienced by all human beings. As such, it felt important to ensure that studies included within this review extended across the globe. The inclusion of globally conducted research on social jetlag and anxiety encompasses a diverse, cross-cultural sample, naturally bringing differences to the studies which may have contributed to heterogeneity in the meta-analysis. Furthermore, despite the universality of sleep, it varies across sociocultural contexts. Therefore, it is important to consider the wider context in which sleep research is conducted, with the vast majority of studies being disproportionately based on WEIRD (Western, Educated, Industrialized, Rich, Democratic societies) populations, which raises concerns regarding the generalisability of findings due to constructs and measurements being grounded within 'WEIRD'

epistemologies (Beebe, 2016). Furthermore, even within 'WEIRD' populations, differences in sleep patterns and behaviours have been observed, with Short et al. (2013) finding that, after controlling for age and gender, Australian adolescents slept on average 47 minutes longer than adolescents from the United States.

The very nature of social jetlag is shaped by the misalignment of biological circadian rhythm and social schedules, highlighting the importance of cultural and environmental factors within this phenomenon. Owens (2004) discusses that whilst some studies carried out across Europe, Asia, and America demonstrate cross-cultural similarities in sleep behaviours (for example, sleep latency, sleep disturbance, daytime wakefulness), the sleep habits of adolescents residing in countries such as India, Italy, Korea, China, and Japan reflect early school start times, which are often before 7:30am. Owens also highlights that even considering what is regarded as a 'problem' is subjective and dependent on culture. Furthermore, Singh et al. (2023) found that a morning chronotype was more prevalent amongst rural populations whilst an evening chronotype was more common for urban populations in North India. It is, therefore, important to demonstrate an appreciation for social, environmental, and cultural contexts and nuances when exploring the relationship between social jetlag and anxiety within the adolescent population. As such, findings should be interpreted within the context of the studies and may not extend universally across diverse cultures or socioeconomic contexts. Similarly, sleep recommendations need to take such contexts into consideration.

### **Other considerations**

It is noted that Zhang and colleagues (2017) found that, when compared to weekend oversleep of 1.01-2 hours, participants with  $\leq 0$  hours of weekend oversleep experienced higher levels of anxiety, whereas those undergoing  $>2$  hours of weekend oversleep did not. As this may be contrary to expected findings, thoughtful reflection has been given to the concept of 'recovery sleep'. If adolescents are experiencing sleep deprivation during the week, they may accumulate a 'sleep debt', which has been found to have a neurobiological 'cost' (Van Dongen et al., 2003); therefore, experiencing social jetlag may mean that they are able to 'recover' this accumulated 'sleep debt', and reverse any detrimental effects. Whilst some research suggests that just one night of 'recovery sleep' can begin to demonstrate improvements, for example in cognitive performance

(Drummond et al., 2006), other findings, such as that which is related to biological functions, indicate that one hour of potential sleep debt can take four days to recover to optimal levels (Kitamura et al., 2016). Lo et al. (2016) explored cognitive performance, sleepiness, and mood in adolescents, and found that whilst working memory and executive functions recovered to baseline levels after one night of recovery sleep, subjective sleepiness and sustained attention did not return to baseline levels even after two nights of recovery sleep. Mood explored via anxiety and depression scales and found that whilst positive mood declined during periods of sleep restriction, it recovered after one night of recovery sleep. Negative mood, however, remained low and unchanged. These findings shed light on the complexities of potential effects of experiencing social jetlag and indicate why research outcomes may vary.

### **Key Implications**

This systematic review and meta-analysis synthesise existing research related to the association between social jetlag and anxiety, providing a robust evidence base for sleep-related behaviour changes for adolescents and for policy decision-making. By the very nature of exploring correlations and relationships, this review is not intended to seek causation, and it cannot be determined whether social jetlag causes heightened anxiety, or vice versa, however, it does indicate that there is an association between these two variables.

As such, it will be important to endorse sleep hygiene behaviours such as regular bedtimes (even at the weekends) and combine them with the application of theories of behavioural change to promote effective sleep-related interventions for adolescents. For example, the Stages of Change Model (Prochaska & DiClemente, 1983) highlights the importance of recognising the individual's position in relation to change. If an individual is in the 'pre-contemplation' stage, for instance, they may not intend to change any of their sleep-related behaviours. In such cases, it will be important for parents/carers and educational settings to provide age-appropriate information to raise awareness and increase their knowledge about the link between social jetlag and anxiety. As such, it will be important for parents/carers and educational settings to have up-to-date and accessible information. If, however, an individual is presenting behaviours suggesting that they are already taking action, it may be more important to

provide maintenance support, for example, reinforcing behaviours through parent/carer or teacher praise, rewards, and encouragement. Moreover, the COM-B model (Michie et al., 2011) highlights the importance of three components for behaviour change: Capability (C), Opportunity (O), and Motivation (M). Therefore, if we were to apply the COM-B model to a young person changing their bedtime routine, they would need to be in a position where they feel that they are physically and psychologically able to engage in this behaviour; for example, they will be able to physically fall asleep at their desired bedtime, they understand the benefits of this behaviour change, and they have the planning and self-monitoring skills to support themselves to reach this goal. When considering their opportunity to change, they may need encouragement from parents or peers to engage in this behaviour, and wider systems such as school-based interventions or adjusted school start times to enable them to sleep in alignment with their chronotype. Finally, a conscious willingness and drive to engage in this behaviour will be important, particularly if other appealing activities or habits coincide with their new desired behaviour.

Furthermore, it is important to look beyond the individual adolescent and recognise that their sleep-related behaviours are shaped by broader interconnected societal systems. Here, it may be valuable to consider Bronfenbrenner's (1979) Ecological Systems, which provides a framework upon which to consider how multiple systemic layers may shape adolescent sleep behaviours. This model refers to five systems that are linked to one another: the microsystem, mesosystem, exosystem, macrosystem, and chronosystem. The 'microsystem' considers the adolescent's immediate surrounding systems, such as family, peer, and school support. Peltz et al. (2020) highlight that an adolescent drive for independence can result in a decline in bedtimes set by parents/caregivers which can impact adolescent sleeping behaviours. Their findings support bedtimes set by parents/carers, however, they acknowledge that this may be unrealistic within households. Furthermore, they highlight the importance of promoting healthy sleep in line with adolescent developmental changes in sleep timings, and suggest that imposing bedtimes before adolescents are biologically ready for sleep may be problematic, for example, resulting in longer sleep latency. It may be more effective to consider the interplay of multiple sleep hygiene factors, and ways of supporting adolescent sleep-wake schedule through continued communication regarding the importance of sleep hygiene. Similarly, educational settings have autonomy over school

start times, and it will be important for them to consider sleep research to inform their decisions, whilst balancing other demands such as parental expectations, local authority expectations, and the demands of the curriculum. The ‘mesosystem’ considers the interactions between the microsystems demonstrating the importance of a shared understanding between home and school with regards to sleep-related behaviours. Within the ‘exosystem’ is it important to consider how indirectly influential systems, such as communities or parental workplaces, may adjust their expectations to recognise and value the importance of adolescent sleep. The ‘macrosystem’ refers to broader cultural and societal perspectives, for example, as highlighted by Orzech (2013), the adolescent shift to a later chronotype is often associated with ‘laziness’, whereas it will be valuable to promote a reframe in this thinking and a deeper understanding of adolescent sleep schedules, and how they can be supported by society through shifts in expectations. Orzech (2013) promotes the importance of a cultural shift in how healthy sleep in adolescence is conceived and prioritised by schools, families, and adolescents themselves. Finally, the ‘chronosystem’ refers to changes over time, and thus it will be important to consider the impact of societal trends such as social media. With a total of 5.64 billion internet users globally in April 2025 (68.7% of the world’s population), reflecting a 2.6% annual growth rate (Kepios, 2024) it is important to consider the impact of the increasing prevalence of internet-based activities on sleep.

These systems demonstrate the complex interplay around sleep-related behaviours for adolescents and highlight the importance of wider decision-making to support and promote healthy adolescent sleep behaviours. When promoting healthy sleep behaviours within the adolescent population, it will be important for supporting adults to consider reasonable and effective recommendations. For example, recommendations for stark behavioural changes are often ineffective as they do not take into account the complexities of behaviour and the contextual factors discussed above. For example, Osman et al. (2020) suggest that a behavioural intervention may be ineffective due to being rigid and lacking contextual sensitivity, and Michie et al. (2018) emphasise the importance of tailoring recommendations to individuals. As such, an expectation to go to bed at the same time every night, including weekends, is likely to be an unrealistic recommendation, and therefore, flexible and supportive alternatives can be promoted. For example, Furihata et al. (2023) found that individualised sleep

schedules promoting gradual sleep extension in university students promoted a statistically significant change in social jetlag experiences compared to a control group. Therefore, promoting a gradual sleep extension (e.g. going to bed 15 minutes earlier every night) to better align with societal demands may be more effective. Similarly, Illingworth et al. (2025) found that weekend bedtime setting, frequency of social media use and videogaming before sleep were the strongest predictors of social jetlag, and that household rules related to weekend bedtimes and limiting the use of electronics before bed may be effective in promoting regular sleep timing. As such, it may be most effective to provide adolescents with information about social jetlag and the impact of pre-sleep screentime on social jetlag, to inform their own decision-making regarding bedtimes.

Finally, from a clinical perspective, whilst commonly used measures of depression, such as the PHQ-9 asks about sleep, these findings could influence the development of commonly used anxiety measures, such as the GAD-7, which does not currently ask directly about sleep or circadian rhythm.

### **Limitations**

This evidence synthesis suggests that social jetlag is one of the mechanisms underpinning anxiety within the adolescent population. It is important, however, to recognise that social jetlag is a single component in the plethora of sleep and circadian factors that change within the period of adolescence (Colrain & Baker, 2011) and have been shown to influence anxiety (Coles et al., 2015). Furthermore, this systematic review and meta-analysis focused only on the adolescent population, whereas young adults (aged 18-25) are among those who are vulnerable to experiencing high levels of social jetlag (Wittmann et al., 2006). As such, findings and implications can only be applied to the adolescent population and cannot be extended to the young adults or beyond; this may pose ethical challenges if young adults experience negative outcomes related to social jetlag. As such, further evidence synthesis should look to review studies exploring the impact of social jetlag in young adults. Furthermore, it is recognised that there are fundamental differences throughout early, mid, and late adolescence, and some of the key environmental influences of social jetlag, such as parent/carers set bedtimes and academic demands, may shift throughout adolescence.

Future research should therefore look to differentiate adolescents into developmental stages to best capture any nuanced differences in social jetlag and reported levels of anxiety. Additionally, studies of longitudinal design would serve to monitor changes in sleep patterns and potentially identify key stages for intervention to support mental health outcomes.

## Conclusion

This systematic review and meta-analysis found evidence of a positive relationship between social jetlag and anxiety, meaning that adolescents experiencing a discrepancy in their weekday and weekend sleep are more likely to report higher levels of anxiety. As such, it is important that recommendations promoting sleep health for teenagers emphasise the importance of consistent sleep timing and sleep hygiene, recognising that sleep is a multi-faceted construct which is impacted by its regularity. Adolescents will require support from parents/carers, educators, and healthcare providers to guide and reinforce positive sleep behaviours, and facilitate structural and societal changes necessary to create environments that are conducive to their wellbeing (e.g., later school start times to align with evening chronotypes). Future research is needed to further develop our understanding of the relationship between social jetlag and anxiety, when controlling for other sleep parameters such as duration and quality, for instance that which is measured by 'sleep-corrected' social jetlag. As this review focused on the correlational relationship between these two variables, longitudinal research is required to explore its directionality. This would promote the development of targeted interventions for adolescents, who, in the current climate not only undergo significant changes in sleep patterns but also experience a high prevalence of anxiety. Shaping recommendations and targeted interventions would, therefore, help to address the relationship between sleep and mental health difficulties through informed action and early intervention to prevent long-term adverse outcomes.

# **Chapter 3    In the Dark about Sleep: Examining Sleep and Circadian Influences on Emotional Processing and Anxiety in Late Adolescence**

## Abstract

Mental health needs and sleep difficulties are prevalent among adolescents. Additionally, adolescents experience biologically driven sleep-changes which are also influenced by social factors (such as a decline in parent/carer set bedtimes and increases in academic demands). The literature indicates a bidirectional link between mental health and sleep; therefore, this current study seeks to explore the extent to which sleep and circadian factors influence anxiety and emotional processing – an underlying mechanism of anxiety, which can be described as the ability to absorb emotional disruption. Participants aged 16-18 completed an online survey consisting of self-report measures of sleep and circadian factors (quality, latency, duration, efficiency, disturbance, daytime dysfunction, circadian regularity, sleep continuity, chronotype, sleep inertia, insomnia) and mental health (generalised anxiety, state anxiety, depression, quality of life), alongside two emotional processing tasks (emotional classification task, emotional flanker task). Correlational analyses showed that insomnia, daytime dysfunction, sleep quality, sleep disturbance, sleep latency, circadian regularity, sleep continuity, and sleep inertia significantly correlated with anxiety. Hierarchical regressions identified sleep disturbance, sleep inertia, and insomnia as significant contributors of anxiety. Whilst sleep and circadian factors did not explain additional variance in anxiety beyond depression, many mediated the relationship between depression and anxiety. In the emotional processing tasks, sleep/circadian factors influenced sensitivity to fear and correct-response reaction times to happy and sad emotional expressions. Circadian regularity arose as the most consistently associated variable across mental health and task performance outcomes, highlighting the significance of sleep-wake timings when promoting sleep health recommendations for adolescents. Findings emphasise the importance of recognising the critical role of sleep and circadian factors when supporting our understanding of adolescent anxiety, and in shaping strategies and interventions to promote their wellbeing.

## Introduction

Sleep and its advantages have been evident throughout evolution among every studied species (Walker, 2017). For instance, sleep has been shown to be essential for human functions in relation to development, cognition, energy conservation, performance, and psychological state (Zielinski et al., 2016). Despite the benefits of sleep, it was found that 37.8% of children and young people aged 8 to 16 years, and 64.9% of young people aged 17 to 23 years, in England, experienced sleep problems (Newlove-Delgado et al., 2022). Furthermore, of those with a probable mental health condition, 76.5% and 91.4% respectively, experienced sleep problems. Whilst the prevalence of sleep difficulties may be higher in adolescents experiencing mental health difficulties (74.2%; Newlove-Delgado et al., 2021), it is apparent that many young people are experiencing sleep problems. Further to this, the number of young people in the UK experiencing mental health problems is growing, with mental health services being unable to meet the rising needs (Grimm et al., 2022). Amongst 17-19-year-olds, 23.3% were identified as having a probable mental health disorder in 2023, with anxiety being among the most prevalent (Newlove-Delgado et al., 2022). As the onset of anxiety in adolescence can present a risk of continued experiences of anxiety into adulthood (Blakemore, 2019; Clark et al., 2007; Pine et al., 1998), early intervention is important to improve overall quality of life. Identifying modifiable sleep and circadian factors that contribute to anxiety could inform public health interventions to reduce their rising incidence.

Stages of adolescence (early, mid, and late) are characterised by differences in physical, behavioural, social, emotional, cognitive, and moral development (Tsagem, 2022). As well as being a period of vulnerability to mental health difficulties such as anxiety, late adolescence is marked by significant structural neural changes (Baker et al., 2015) and is coined as “the passage to adulthood” by Zarrett and Eccles (2006), highlighting a time of social change and transition. Furthermore, academic pressure has been found to be a common source of stress for young people (Steare et al., 2023), and it should be noted that, in the United Kingdom, late adolescence is a period associated with high academic demands due to formal qualifications and entering the world of work. As such, the period of late adolescence was selected for this present research.

The literature indicates a bidirectional link between emotions and sleep, i.e., poor sleep impacts emotional wellbeing, and experiencing heightened emotions leads to

problematic sleep (Kahn et al., 2013). As such, this present research seeks to explore the link between anxiety and sleep in further detail by exploring which sleep and circadian factors are most influential within this relationship. While change can be challenging to implement, sleep can be considered a modifiable factor (Waters et al., 2023), and if the most influential sleep and circadian factors related to anxiety are identified, then these findings will contribute to the construction and implementation of supportive strategies and interventions that can support adolescents, promoting a positive quality of life.

Neuroimaging studies have consistently highlighted the amygdala as a key brain region associated with anxiety (Rauch et al., 2003). The amygdala is understood to be involved in processing emotionally salient external stimuli and initiating a behavioural response (Martin et al., 2009). Given its involvement in both anxiety and emotional processing, it serves as a critical neural marker for understanding the underpinning functions within mental health needs in the adolescent population. Emotional processing refers to the ability to absorb emotional disruption, enabling individuals to continue their day without experiencing significant distress or disruption (Rachman, 1980, 2001). Furthermore, Tempesta et al. (2018) highlight the critical role of sleep in emotional processing. For example, Ricketts et al. (2018) found vigilant attention to threat to be associated with longer sleep latency and decreased sleep maintenance (i.e., sleep disruption and sleep efficiency) in early adolescents. Furthermore, Goldstein-Piekarski et al. (2015) found that sleep deprivation compromised adult participants' ability to process complex social signals, such as facial expressions. Similarly, Killgore et al. (2017) found that emotional processing is particularly sensitive to sleep deprivation, particularly for prosocial emotional expressions (i.e., happy and sad). The current study seeks to gain a deeper understanding of late adolescent responses to emotional discrimination and threat processing tasks, and to understand which sleep and circadian factors are most influential. By investigating participant behavioural responses in emotional processing tasks, it was hypothesised that short sleep duration, longer sleep latency, more sleep disruption, and lower sleep efficiency would be associated with lower task performance outcomes. These findings could subsequently help to inform effective strategies to modify sleep that promote emotional wellbeing and overall quality of life. To measure emotional processing, tasks sought to capture everyday experiences of adolescents: the emotional classification task was selected to replicate experiences of individuals

interpreting facial expressions with varying degrees of intensity within their everyday lives. Deficits in emotional recognition have been found to be associated with anxiety disorders (Button et al., 2013; Garner et al., 2009), making this task a relevant choice for addressing the study aims. Further, (Goldstein-Piekarski et al. (2015) state that facial expressions represent one of the most important cues within our environment and our interpretation of them is key in social interactions. Secondly, the emotional flanker task sought to explore participants' emotional attentional control. Mathews et al. (1997) describe the existence of cognitive biases in anxiety as "well established" (p. 340), with individuals interpreting ambiguous stimuli negatively and presenting as more vigilant and focused on threat-related cues. Furthermore, whilst Wieser and Keil (2020) highlight the value of selective attention in that it enables individuals to efficiently and accurately detect and identify threat, they outline that in anxiety, this mechanism can be unhelpful as it leads to an exaggeration of threat processing. As such, attentional bias presents as a key mechanism of anxiety maintenance. This task, therefore, explores participant attentional threat bias. Together, the tasks provide a comprehensive assessment of emotional discrimination and threat processing by capturing the identification of emotional expressions and the capacity to regulate attention in response to emotional distractions.

Given that sleep is a multidimensional process (Dzierzewski et al., 2021), two key frameworks are drawn upon to provide a comprehensive structure through which to explore such factors: the two-process model of sleep (Borbély, 1982) and Buysse's (2014) multidimensional model of sleep. The two-process model of sleep (Borbély, 1982) demonstrates that the circadian process (i.e., the internal body clock, approximately following a 24-hour cycle) and the homeostatic drive (i.e., 'sleep pressure' that builds throughout the day) work together to optimise daytime functioning and sleep quality. It appears that there is a period directly after waking which is characterised by 'sleep inertia', which is defined by Trotti (2017) as the transitional state between sleep and wake, characterised by impaired performance, reduced vigilance, and a desire to fall back to sleep. Sleep inertia is emerging as being independent of circadian drive and homeostatic processes, and therefore, a third mechanism at play. Below, Figure 3.1 shows the model (Hilditch & McHill, 2019) outlines this three-process model of sleep regulation, with the green line representing sleep inertia:

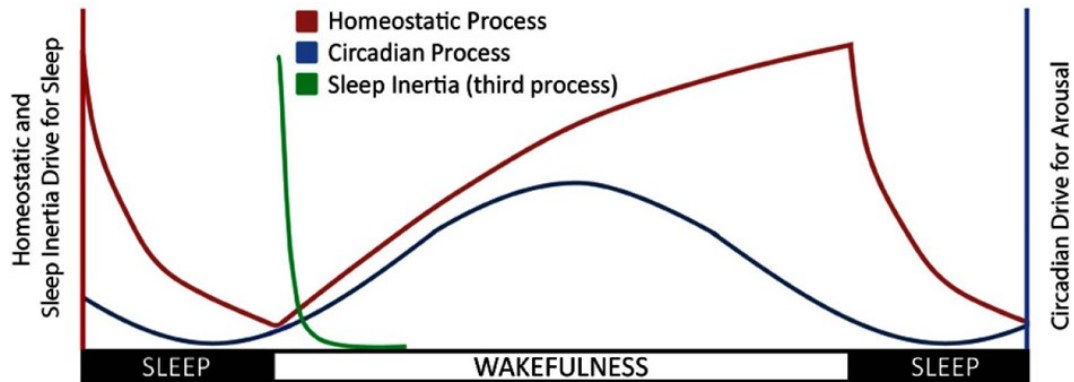


Figure 3.1: The three-process model of sleep regulation. This model, proposed by Hilditch and McHill (2019) integrates the homeostatic process, circadian process, and sleep inertia.

*Note.* Reprinted from “*Sleep inertia: current insights*,” by C. J. Hilditch & A. W. McHill, 2019, *Nature and Science of Sleep*, pp. 155–165. Copyright 2019 by Dove Medical Press Limited.

Furthermore, Buysse (2014) offers five dimensions of sleep health to shift the focus away from sleep disorders and towards the promotion of sleep health (which is not simply the absence of a sleep problem). Subsequently, an additional factor, regularity, (Morrison et al., 2023) has contributed to the ‘RU-SATED’ model consisting of six dimensions of sleep health:

- **Regularity:** the consistency of sleep/wake times.
- **Satisfaction:** an individual’s subjective assessment and perception of the quality of their sleep.
- **Alertness:** the ability to maintain attentive wakefulness.
- **Timing:** the placement of an individual’s sleep within the 24-hour day; this is often considered as an individual’s ‘chronotype’ (i.e., whether someone is an ‘early bird’ or a ‘night owl’).
- **Efficiency:** the ease of falling asleep, and falling back to sleep (e.g., ‘sleep latency’ refers to how long it takes someone to fall asleep).
- **Duration:** the amount of sleep an individual obtains within a 24-hour period.

This paper aims to explore the multi-dimensional concept of sleep health and its relationship with psychological measures and adolescent quality of life. These models allow for a meaningful framework through which to base this exploration, and through carefully selected questionnaires, the following areas (outlined in Table 3.1) are explored:

Table 3.1: Sleep and circadian factors explored in the current study, including definitions and questionnaires through which they were measured

| <b>Dimension</b>            | <b>Explanation</b>                                                                                                | <b>Questionnaire</b>                                           |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|
| <b>Global PSQI Score</b>    | Overall sleep health                                                                                              | The Pittsburgh Sleep Quality Index (Buysse et al., 1989)       |
| <b>Sleep Quality</b>        | The individual's subjective assessment of how well they slept                                                     |                                                                |
| <b>Sleep Latency</b>        | The time it takes an individual to fall asleep                                                                    |                                                                |
| <b>Sleep Duration</b>       | The total time spent sleeping                                                                                     |                                                                |
| <b>Sleep Efficiency</b>     | The amount of time spent asleep (in comparison to the amount of time spent in bed)                                |                                                                |
| <b>Sleep Disturbance</b>    | The extent to which factors disrupt an individual's ability to fall asleep, stay asleep, or achieve restful sleep |                                                                |
| <b>Daytime Dysfunction</b>  | Difficulties associated with daytime wakefulness, alertness and/or energy levels                                  |                                                                |
| <b>Sleep Regularity</b>     | The extent to which individuals engage in consistent sleep behaviours                                             | Sleep Regularity Questionnaire (Dzierzewski et al., 2021)      |
| <b>Circadian Regularity</b> | The consistency of sleep-wake timings (aligning with circadian rhythm; Dzierzewski et al., 2021)                  |                                                                |
| <b>Sleep Continuity</b>     | The extent to which sleep is smooth, stable, and uninterrupted                                                    |                                                                |
| <b>Chronotype</b>           | The extent to which an individual is an 'early bird' or a 'night owl'                                             | Morningness-Eveningness Questionnaire (Horne & Ostberg, 1976)  |
| <b>Sleep Inertia</b>        | The transitional state from sleep to wake, characterised by grogginess and low arousal                            | Subset of items from the Morningness-Eveningness Questionnaire |

|                 |                                                                                                           |                         |
|-----------------|-----------------------------------------------------------------------------------------------------------|-------------------------|
| <b>Insomnia</b> | Sleep which is characterised by difficulty falling asleep or staying asleep, despite opportunity to sleep | Insomnia Severity Index |
|-----------------|-----------------------------------------------------------------------------------------------------------|-------------------------|

This study employs a cross-sectional design to evaluate the relationship between self-reported sleep and circadian factors, anxiety (and other psychological measures assessing depression symptomology and quality of life), and emotional processing through behavioural tasks. It was hypothesised that a relationship between anxiety and sleep/circadian factors will be found, with aspects of sleep (e.g., duration, quality) and sleep timing (e.g., chronotype, circadian regularity) contributing in varying degrees to this relationship. It is hypothesised that anxiety symptoms and sleep/circadian factors will be associated with decreased accuracy and speed in emotional processing tasks (i.e., tasks examining emotional discrimination and threat processing). It is predicted that the ‘flanker effect’ (i.e., slower and less accurate responses in incongruent conditions in the flanker tasks) will be found in adolescents with lower sleep quality and/or impaired sleep regularity, and that participants with higher sleep inertia will demonstrate decreased accuracy and speed in the emotional processing tasks.

The aims of this current study are:

- To examine the associations between anxiety and the multidimensional concept of sleep
- To understand the extent to which self-reported sleep and circadian factors impact emotional processing task performance
- To explore the impact of sleep inertia on emotional processing.

The findings will have important implications for adolescent mental health, specifically anxiety, and in informing policy and strategies to support young people.

## Methodology

Adolescents living in the United Kingdom aged 16-18 years old were invited to take part in an online survey consisting of questionnaires and behavioural tasks. Ethical approval for this study was granted by the University of Southampton (ERGO number: 100209.A1). Participants gave their consent electronically and anonymously ahead of their involvement. Following their participation, volunteers were given the opportunity to enter a prize draw of which there were 10 x £20, 5 x £50, and 1 x £100 vouchers available. Participant responses were not linked to the personal data provided in order to enter the prize draw.

Participants were recruited through convenience sampling. The lead researcher contacted educational settings (including secondary schools, sixth forms, and universities), professionals working within the education sector (including teachers, lecturers, educational psychologists), and their wider network. The following questionnaires and tasks were administered to participants via the online platform, Qualtrics.

## Demographics

Participants were asked questions related to the following: age, gender, ethnicity, geographical location, educational status, alcohol and caffeine consumption, smoking/vaping behaviour, physical and mental health needs, sleep disorders, rise time that morning, and use of medication.

## Sleep and Circadian Measures

- **The Pittsburgh Sleep Quality Index (PSQI;** Buysse et al., 1989): a 19-item self-report questionnaire measuring sleep quality through seven subcategories: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleeping medication, and daytime dysfunction. As per Raniti and colleagues' (2018) research, the wording on item 8 was changed from “while driving” to “during class” to remain developmentally relevant to the adolescent population. Buysse and colleagues found an internal reliability of  $\alpha = .83$  and a test–retest reliability of .85 for the global scale. Further to this, the

PSQI is a widely used measure of sleep quality in adolescents (de la Vega et al., 2015) and Raniti et al. (2018) found an acceptable level of internal consistency for the seven components (Cronbach's  $\alpha = 0.73$ ) and that no item should be removed to improve reliability.

- **The Sleep Regularity Questionnaire** (SRQ; Dzierzewski et al., 2021): a 6-item self-report questionnaire measuring sleep regularity (i.e., the degree to which their circadian drive and homeostatic processes are aligned), which examines circadian regularity and sleep continuity regularity.
- **The Morningness-Eveningness Questionnaire** (MEQ; developed by Horne & Ostberg, 1976): a 19-item self-report questionnaire measuring circadian preferences for morningness or eveningness, as well as exploring experiences of sleep inertia. Panjeh et al. (2021) outline that the MEQ is a widely used questionnaire which measures three constructs: dissipation of sleep pressure, build-up of sleep pressure, and peak time of cognitive arousal. The MEQ was also selected due to its relevance to sleep inertia; a range of items on the questionnaire refer to participant experiences upon awakening, enabling the concept to be explored, without an additional questionnaire (which could result in respondent fatigue).
- **Insomnia Severity Index** (ISI; Morin, 1993): a 7-item questionnaire used to determine whether participants were experiencing insomnia sleep disorders.

## Mental Health Measures

- **Generalized Anxiety Disorder Assessment** (GAD-7; Spitzer et al., 2006)<sup>1</sup>: a 7-item questionnaire based on the DSM-IV (Diagnostic and Statistical Manual of Mental Disorders, fourth edition; American Psychiatric Association, 1994) criteria for Generalised Anxiety Disorder (Mossman et al., 2017). The GAD-7 determines levels of anxiety: *mild* (5-9 points), *moderate* (10-14 points) or *severe* (15+), and

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<sup>1</sup> The GAD-7 was duplicated in error in the online survey. Only data from the first record was used in scoring and analysis.

has been found to be valid and reliable for assessing anxiety symptoms in the adolescent population (Mossman et al., 2017).

- **Spielberger State Anxiety Scale** (STAI-6; Marteau & Bekker, 1992): a 6-item version of the State Trait Anxiety Index (STAI) measuring state anxiety (i.e., how participants felt in the moment, determining their current feelings). State anxiety is considered different from trait anxiety or an anxiety disorder which are thought to be more long-standing. When compared to the full version, Marteau and Bekker (1992) found that the STAI-6 is brief yet sustains acceptable reliability and validity levels. Participants were encouraged to answer these 6 questions straightaway and without too much thought to provide a snapshot of their current emotionality.
- **Patient Health Questionnaire** (PHQ-9; Kroenke & Spitzer, 2002): a 9-item questionnaire for screening the severity of depression. The PHQ-9 is regarded as a valid and reliable measure (Cronbach's  $\alpha = 0.89$ ; Kroenke et al., 2001) and has been validated in adolescent samples (e.g., Fonseca-Pedrero et al., 2023).
- **KIDSCREEN-10** (Ravens-Sieberer et al., 2010): a 10-item questionnaire assessing self-reported health and psychological, mental and social wellbeing of children and adolescents. It is a global Health-Related Quality of Life (HRQoL) measure for monitoring and screening purposes (Cronbach's  $\alpha = 0.82$ ). This measure was included as it is thought that quality of life is impacted by anxiety, depression, and sleep/circadian factors.

## Emotional Processing Behavioural Tasks

### Emotional Classification Task

The Emotion Classification Task presents facial expressions (derived from the facial features of real individuals) along a continuum of expression magnitude for six emotions: sadness, happiness, fear, anger, disgust, and surprise. Bamford et al. (2015) outlined that the facial expression stimuli were created from photographs of 12 young adult males taken under controlled conditions (i.e., in a booth painted Munsell N5 grey, illuminated with 3 Verivide F20 T12/D65 daylight simulation bulbs in high-frequency fixtures to reduce effects of flicker). The individuals posed the six expressions and

composite images of each emotion were constructed. A prototypical ‘emotional’ face was constructed by compositing the 12 individuals in each emotion with a neutral expression to create emotional ambiguity. A continuum from each emotion at ‘full-intensity’ to the emotionally ambiguous prototype was created, and six 15-image morph sequences were created to run along this continuum, consisting of 90 trials (15 per emotional continua). Figure 3.2 provides the six 15-image morph sequence.

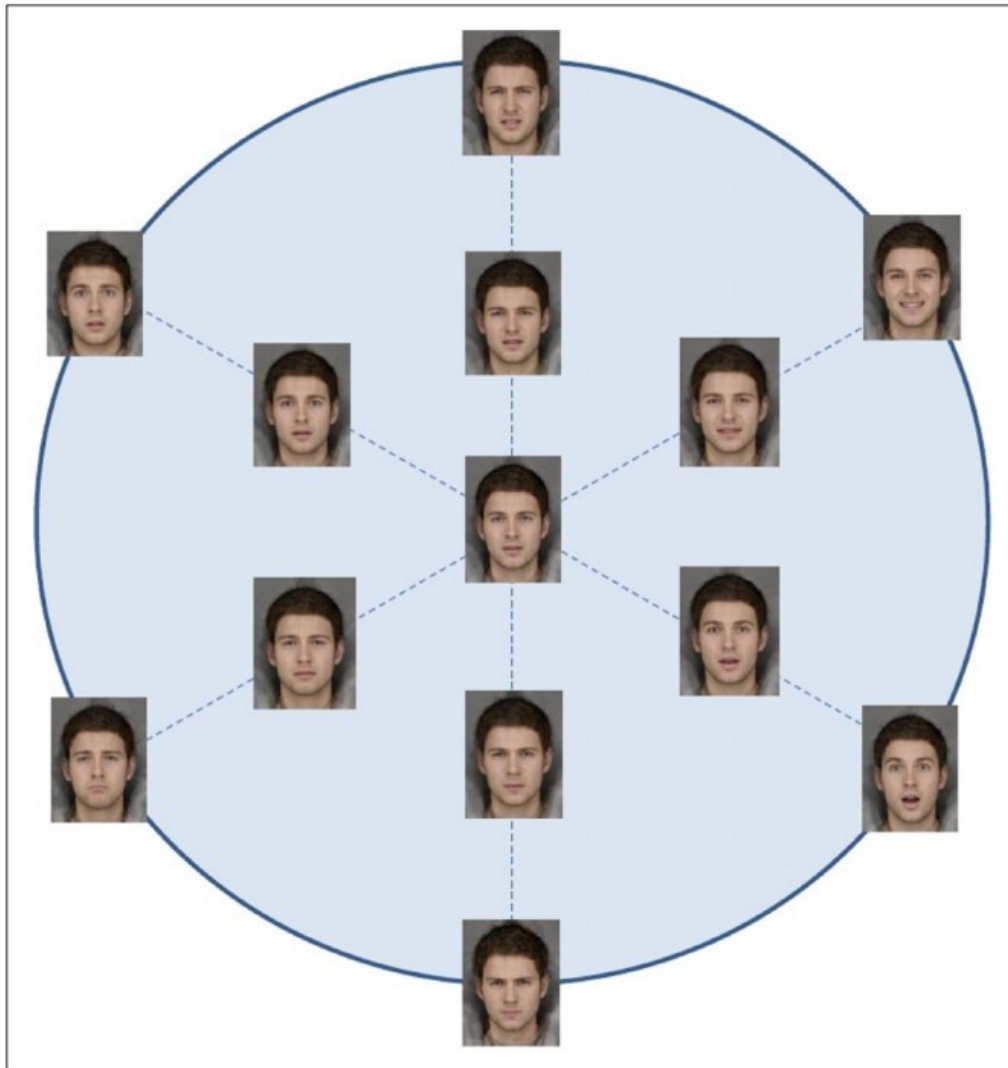


Figure 3.2: Emotional facial expressions in the ‘Emotion Classification Task’

Note. Reprinted from “*Early effects of duloxetine on emotion recognition in healthy volunteers*” by S. Bamford, I. Penton-Voak, V. Pinkney, D. S. Baldwin, M. R. Munafò, & M. Garner, 2015, *Journal of Psychopharmacology*, 29(5), p. 634–641. Copyright 2015 by Sage Publications.

The purpose of the task was to provide a measure of perceptual sensitivity to negative emotions of which there were two primary scores:

- **Sensitivity score** i.e., a participant's sensitivity score for anger would account for their hit rate (correct identification of anger) minus their false alarm rate (misidentification of other emotional expressions as anger)
- **Correct response reaction time:** the time it takes the participant to accurately identify the emotion presented

### **Emotional Flanker Task (adapted from the Eriksen Flanker Task; Eriksen & Eriksen, 1974)**

The emotional flanker task, designed to assess attentional bias to threat, was selected as the second task. Participants were presented with a row of three images, simultaneously, from the International Affective Picture System (IAPS; Lang et al., 1988) database. Images were presented for 500ms and they adhered to one of the four conditions outlined in Figure 3.3: negative incongruent, neutral incongruent, negative congruent, neutral congruent. The three images in the congruent trials all presented with the same affective value, whilst target images within the incongruent trials presented different affective value to the images either side (i.e., the 'flankers'). The target image was positioned centrally and 'flanked' by non-target stimuli. Participants were required to press the left arrow key if the target image was negative, and the right arrow key if the target image was neutral. There were 128 experimental trials, 32 trials per condition outlined in Figure 3.3.

Prior to the experimental trials, participants completed a round of 'training' with non-affective stimuli including a row of three shapes. They were required to attend to the colour of the central shape and ignore the colour of the flankers. This enabled them to become familiar with what was required of them in the experimental trials; there were 28 practice trials.

Flanker tasks aim to measure attentional bias by presenting central stimuli and flankers simultaneously, causing them to compete for the participant's attention (Tannert & Rothermund, 2020). The extent to which participants performed quickly and accurately, suppressing emotional responses to the flankers, was measured. Two bias scores were analysed:

- A negative distractor bias score, whereby a positive score demonstrated slower reaction times on trials where negative flankers interfered with a neutral target, suggesting a bias to threat.
- A negative target bias score, whereby a positive score indicated faster classification of negative vs. neutral congruent stimuli, suggesting a bias to threat.



Figure 3.3: Emotional flanker task conditions

## Data Analysis

Spearman's rank-order correlations were conducted to assess the associations between anxiety, sleep/circadian factors, and psychological measures. Hierarchical regression models were performed to determine the extent to which sleep and circadian factors contribute to variance in anxiety and predict performance in emotional processing behavioural tasks, while accounting for demographic factors. Demographic data included gender, age, alcohol consumption, caffeine consumption and smoking status. Further explorations were conducted to consider participant depression and quality of life scores. The effect sizes for each were determined by  $R^2$  values. A mediation analysis was conducted using RStudio 2024.12.1 (Posit team, 2025) with the lavaan package (version 0.6-19, Rosseel, 2012) to identify whether sleep/circadian factors mediated the relationship between anxiety and depression.

## Results

### Preliminary Analyses

Missing data were assessed using frequency analysis. Of the 456 participants who started the survey, the number of valid responses per variable ranged. A total of 312 (68.42%) participants completed the full battery of questionnaires, whilst 149 (32.68%) participants completed the final behavioural task. Participant numbers decreased throughout the survey (see Table 3.2), and as such, it is important to recognise that analyses including task data or questionnaires completed later in the survey may not be representative of the full sample. Pairwise deletion was applied in order to maximise sample size for each analysis.

Table 3.2: Participant questionnaire and behavioural tasks completion rates

| Questionnaire                                           | N   | %      |
|---------------------------------------------------------|-----|--------|
| Number of participants who completed the first question | 456 | 100%   |
| Pittsburgh Sleep Quality Index (PSQI)                   | 351 | 76.73% |
| Sleep Regularity Questionnaire (SRQ)                    | 348 | 76.32% |
| State-Trait Anxiety Scale (STAI-6)                      | 348 | 72.15% |
| Morningness-Eveningness Questionnaire                   | 329 | 72.15% |
| Insomnia Severity Index                                 | 327 | 71.71% |
| Generalized Anxiety Disorder Scale (GAD-7)              | 322 | 70.61% |
| Patient Health Questionnaire (PHQ-9)                    | 319 | 69.96% |
| KIDSCREEN-10                                            | 312 | 68.42% |
| Emotion Classification Task                             | 149 | 32.68% |
| Emotional Flanker Task                                  | 152 | 33.33% |

The final analytical sample consisted of 312 adolescents who completed the full battery of questionnaires, and a subsample of 149 participants who also completed the behavioural tasks. Demographic information is outlined in Table 3.3 and descriptive statistics are outlined in Table 3.4 and 3.5. An independent-samples t-test was

conducted to compare the generalised anxiety levels (i.e., GAD-7 scores) between participants who completed only the questionnaires and those who proceeded to complete the full survey consisting of all questionnaires and the behavioural tasks. There was no significant difference in anxiety scores between the groups,  $t(251) = 0.01$ ,  $p = 0.996$ , Cohen's  $d < 0.01$ , 95% CI [-0.32, 0.32]. It is important to note, however, that participants needed to have completed 93% of the survey to have provided a GAD-7 score, and therefore, generalised anxiety levels of those who dropped out earlier cannot be assessed. Furthermore, the sample size of participants who completed the full survey ( $n = 229$ ) was much larger than those in the questionnaire-only group ( $n = 24$ ) which may limit the sensitivity of the test in detecting subtle group differences. It does not appear, however, that participant anxiety levels were associated with completion rates.

Table 3.3: Demographic data of participants completing the full battery of questionnaires

Demographic data of participants completing the full battery of questionnaires

| Demographics                                                          | N          | %      |
|-----------------------------------------------------------------------|------------|--------|
| <b>Age</b>                                                            | <b>312</b> |        |
| 16                                                                    | 113        | 34.44% |
| 17                                                                    | 141        | 45.67% |
| 18                                                                    | 58         | 19.89% |
| <b>Gender</b>                                                         | <b>312</b> |        |
| Female                                                                | 227        | 72.76% |
| Male                                                                  | 78         | 25.00% |
| Non-binary                                                            | 3          | 0.96%  |
| Prefer to self-describe                                               | 4          | 1.28%  |
| <b>Ethnicity</b> (as per the INCLUDE framework; Treweek et al., 2021) | <b>312</b> |        |
| White                                                                 | 224        | 71.79% |
| Asian/Asian British                                                   | 29         | 9.29%  |
| Mixed/Multiple ethnic groups                                          | 24         | 7.69%  |
| Black/African/Caribbean/Black British                                 | 17         | 5.45%  |
| Other ethnic group                                                    | 15         | 4.81%  |

|                                    |            |        |
|------------------------------------|------------|--------|
| Unspecified                        | 1          | 0.32%  |
| <b>Geographical Location</b>       | <b>312</b> |        |
| Greater London (England)           | 27         | 8.65%  |
| South East (England)               | 70         | 22.44% |
| South West (England)               | 1          | 0.32%  |
| West Midlands (England)            | 15         | 4.81%  |
| North West (England)               | 0          | 0.00%  |
| North East (England)               | 1          | 0.32%  |
| Yorkshire and the Humber (England) | 5          | 1.60%  |
| East Midlands (England)            | 38         | 12.18% |
| East of England (England)          | 152        | 48.72% |
| Wales                              | 3          | 0.96%  |
| <b>Alcohol Consumption</b>         | <b>312</b> |        |
| No                                 | 172        | 55.13% |
| Yes                                | 140        | 44.87% |
| <3                                 | 100        | 32.05% |
| 3-5                                | 29         | 9.29%  |
| 6-10                               | 7          | 2.24%  |
| >10                                | 4          | 1.28%  |
| <b>Caffeine Consumption</b>        | <b>312</b> |        |
| No                                 | 104        | 33.33% |
| Yes                                | 208        | 66.67% |
| <3                                 | 179        | 57.37% |
| 3-4                                | 21         | 6.73%  |
| >4                                 | 8          | 2.56%  |
| <b>Smoking Status</b>              | <b>312</b> |        |
| No (do not smoke or vape)          | 283        | 90.71% |
| Yes (smoking)                      | 3          | 0.96%  |

|                                                                                  |            |        |
|----------------------------------------------------------------------------------|------------|--------|
| Yes (vaping)                                                                     | 19         | 6.09%  |
| Yes (smoking and vaping)                                                         | 7          | 2.24%  |
| <b>Health Status</b>                                                             | <b>311</b> |        |
| Health issues (e.g., cardiovascular, diabetes, gastrointestinal disease, others) |            |        |
| Yes                                                                              | 34         | 10.90% |
| No                                                                               | 278        | 89.10% |
| Depression/anxiety/anxiety-related disorders                                     |            |        |
| Yes                                                                              | 85         | 27.33% |
| No                                                                               | 226        | 72.67% |
| Insomnia                                                                         |            |        |
| Yes                                                                              | 57         | 18.27% |
| No                                                                               | 255        | 81.73% |
| Medication (e.g., sleeping pills, heart medication, anti-allergic, others)       |            |        |
| Yes                                                                              | 92         | 29.49% |
| No                                                                               | 220        | 70.51% |

Cronbach's alpha coefficients (see Table 3.4) indicated acceptable to excellent internal consistency for all scales for which it was possible to compute: SRQ (6 items;  $\alpha = .74$ ), STAI-6 (6 items;  $\alpha = .87$ ), MEQ (19 items;  $\alpha = .97$ ) ISI (7 items;  $\alpha = .81$ ), GAD-7 (7 items;  $\alpha = .93$ ), PHQ-9 (9 items;  $\alpha = .93$ ), KIDSCREEN-10 (11 items;  $\alpha = .98$ ). It was not possible to calculate reliability coefficients for the PSQI as it included open-ended responses.

Normality was assessed using the Shapiro-Wilk test and as the majority of variables significantly deviated from normality ( $p < 0.05$ ), non-parametric tests (e.g., Spearman's rho) were selected for subsequent analysis.

Table 3.4: Descriptive statistics and internal consistency of each questionnaire and subscale

| Questionnaire and Subscales                  | N   | Mean | Median | SD   | IQR   | $\alpha$ |
|----------------------------------------------|-----|------|--------|------|-------|----------|
| <b>Pittsburgh Sleep Quality Index (PSQI)</b> | 309 | 9.7  | 10.00  | 7.43 | 12.00 |          |
| Sleep Quality (PSQI-1)                       | 456 | 0.92 | 1.00   | 0.74 | 1.00  |          |

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|                                                        |     |       |       |      |       |      |
|--------------------------------------------------------|-----|-------|-------|------|-------|------|
| Sleep Latency (PSQI-2)                                 | 453 | 2.09  | 2.00  | 1.99 | 4.00  |      |
| Sleep Duration (PSQI-3)                                | 451 | 1.39  | 1.00  | 1.21 | 3.00  |      |
| Sleep Efficiency (PSQI-4)                              | 279 | 1.18  | 1.00  | 1.34 | 3.00  |      |
| Sleep Disturbance (PSQI-5)                             | 456 | 4.81  | 4.00  | 4.31 | 6.75  |      |
| Medication (PSQI-6)                                    | 456 | 0.11  | 0.00  | 0.47 | 0.00  |      |
| Daytime Dysfunction (PSQI-7)                           | 456 | 2.46  | 3.00  | 1.92 | 4.00  |      |
| <b>Sleep Regularity Questionnaire (SRQ)</b>            | 456 | 11.47 | 13.00 | 7.47 | 12.00 | 0.74 |
| Circadian Regularity (SRQ-1)                           | 456 | 8.00  | 10.00 | 5.23 | 8.75  |      |
| Sleep Continuity (SRQ-2)                               | 456 | 3.48  | 3.50  | 2.75 | 6.00  |      |
| <b>Morningness-Eveningness Questionnaire (MEQ)</b>     | 345 | 47.62 | 47.00 | 9.13 | 11.00 | 0.97 |
| Sleep Inertia (items 4-7 on MEQ)                       | 456 | 1.62  | 2.00  | 1.05 | 1.50  |      |
| <b>Insomnia Severity Index (ISI)</b>                   | 456 | 6.85  | 6.00  | 6.09 | 12.00 | 0.81 |
| <b>Generalized Anxiety Disorder Assessment (GAD-7)</b> | 456 | 5.84  | 4.50  | 5.97 | 10.00 | 0.93 |
| <b>Spielberger State Anxiety Scale (STAI-6)</b>        | 348 | 12.52 | 12.00 | 3.79 | 5.00  | 0.87 |
| <b>Patient Health Questionnaire (PHQ-9)</b>            | 456 | 7.81  | 6.00  | 7.63 | 13.00 | 0.93 |
| <b>Measure of Quality of Life (KIDSCREEN-10)</b>       | 313 | 32.12 | 32.00 | 6.16 | 8.50  | 0.98 |

Note. *N* = number of participants; *SD* = standard deviation; *IQR* = interquartile range;  $\alpha$  = Cronbach's alpha. All values are based on responses to each questionnaire.

Table 3.5: Descriptive statistics of task performance

| Task                                 | N   | Mean | Median | SD   | IQR  |
|--------------------------------------|-----|------|--------|------|------|
| <b>Emotional Classification Task</b> |     |      |        |      |      |
| Sensitivity to Anger                 | 154 | 0.53 | 0.56   | 0.13 | 0.16 |
| Sensitivity to Disgust               | 154 | 0.62 | 0.63   | 0.13 | 0.19 |
| Sensitivity to Fear                  | 154 | 0.37 | 0.37   | 0.23 | 0.37 |
| Sensitivity to Happy                 | 154 | 0.75 | 0.77   | 0.12 | 0.14 |

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|                                                                                                                      |     |         |         |        |        |
|----------------------------------------------------------------------------------------------------------------------|-----|---------|---------|--------|--------|
| Sensitivity to Sad                                                                                                   | 154 | 0.64    | 0.65    | 0.13   | 0.16   |
| Sensitivity to Surprise                                                                                              | 154 | 0.64    | 0.66    | 0.11   | 0.16   |
| Correct-Response Reaction Time to Anger                                                                              | 154 | 1306.97 | 1242.60 | 433.40 | 492.21 |
| Correct-Response Reaction Time to Disgust                                                                            | 154 | 1388.99 | 1324.25 | 412.83 | 560.37 |
| Correct-Response Reaction Time to Fear                                                                               | 154 | 1433.17 | 1335.62 | 577.69 | 707.39 |
| Correct-Response Reaction Time to Happy                                                                              | 154 | 1063.82 | 1035.43 | 287.37 | 357.52 |
| Correct-Response Reaction Time to Sad                                                                                | 154 | 1422.25 | 1412.69 | 398.69 | 550.45 |
| Correct-Response Reaction Time to Surprise                                                                           | 154 | 1169.51 | 1121.64 | 355.81 | 421.28 |
| <b>Emotional Flanker Task</b>                                                                                        |     |         |         |        |        |
| Negative Incongruent Condition                                                                                       | 149 | 629.09  | 613.05  | 143.65 | 684.85 |
| Negative Congruent Condition                                                                                         | 151 | 622.81  | 598.47  | 138.46 | 161.62 |
| Neutral Incongruent Condition                                                                                        | 151 | 641.44  | 611.84  | 151.94 | 163.15 |
| Neutral Congruent Condition                                                                                          | 150 | 621.76  | 602.39  | 136.92 | 144.04 |
| Negative Distractor Bias (i.e., overall performance in negative incongruent trials)                                  | 150 | 21.06   | 17.79   | 69.27  | 49.32  |
| Negative Target Bias (i.e., ability to detect centrally presented targets when they have negative emotional valence) | 150 | -0.87   | 1.50    | 66.59  | 67.16  |

*Note.* *N* = number of participants; *SD* = standard deviation; *IQR* = interquartile range

An overview of responses showed that it took participants an average of 35 minutes to fall asleep. A sleep latency of  $\leq 30$  minutes suggests appropriate indication of sleep health (Ohayon et al., 2017), and so as this average sleep latency is a fraction higher, then this could be an indication of difficulty falling asleep. With an average bedtime of 00:52 and average wake-up time of 7:08am, the average sleep duration of participants in the sample was 6 hours 55.2 minutes. A one-sample t-test showed that the average sleep duration of 359 participants ( $M = 6.92$ ,  $SD = 21.98$ ) was significantly lower than the

recommended average of 8-10 hours (i.e., 9 hours; Hirshkowitz et al., 2015)) sleep for adolescents,  $t(358) = 27.97$ ,  $p < .001$ .

## Correlational Analysis

### Exploring the Relationship between Anxiety and Sleep, Circadian, and Psychological Measures

Spearman's rank-order correlations were conducted to explore the relationship between sleep, circadian and psychological measures, and anxiety (see Appendix E). Anxiety scores indicated by the GAD-7 (Spitzer et al., 2006) provided generalised anxiety symptoms associated with longer-term feelings of worry. Anxiety scores presented by the STAI-6 (Court et al., 2010) provided information about participants' state anxiety, i.e., the anxiety experienced temporarily, in the moment. Figure 3.3 provides a visual presentation of the correlations. Due to higher scores on the PSQI indicating poorer sleep quality, they have been reversed for the purposes of visually aligning with the SRQ scores, whereby higher scores indicate more consistent sleep regularity.

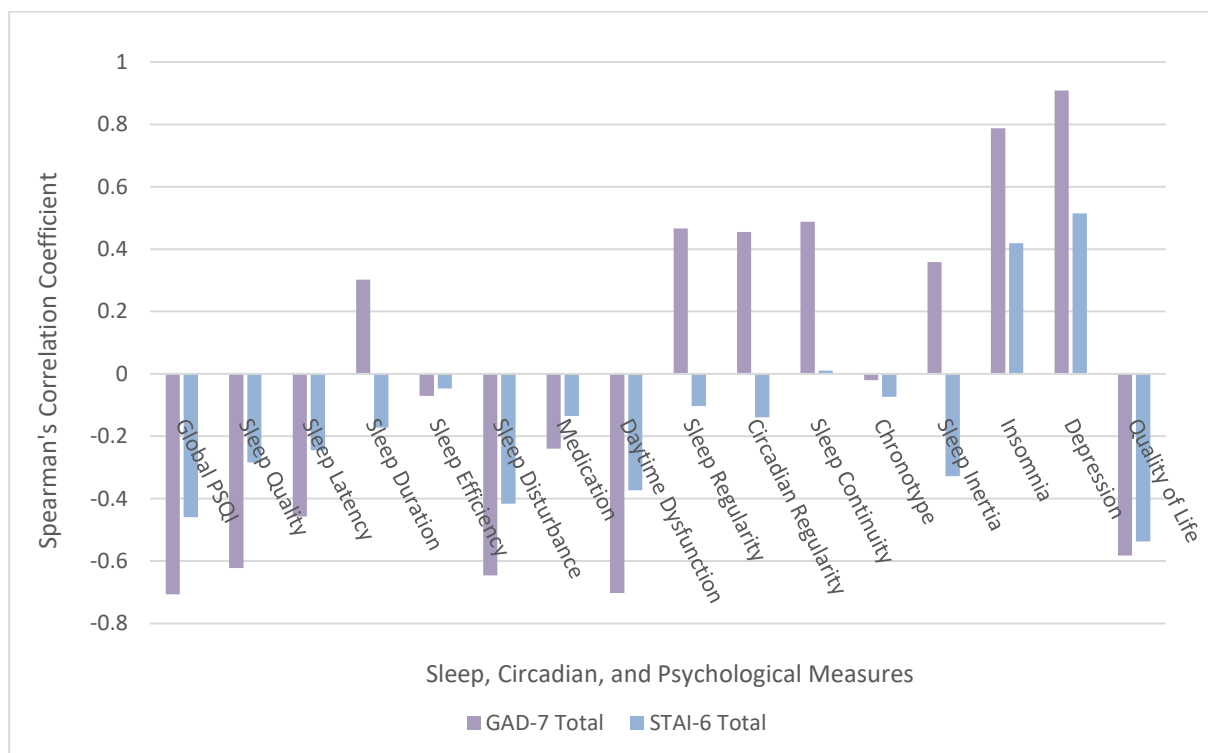


Figure 3.4: Bar graph showing correlations between anxiety scores and sleep/circadian and psychological measures

The figure illustrates the strength and direction of correlations between GAD-7 scores and STAI-6 scores and various sleep-related and psychological measures.

Note. PSQI = Pittsburgh Sleep Quality Index

Generalised anxiety scores (GAD-7) and acute anxiety (STAI-6) moderately correlated with each other ( $r = 0.52, p < 0.001$ ), suggesting that individuals experiencing ongoing heightened levels of anxiety were more likely to be experiencing anxiety at the time of completing the questionnaire, but not in all cases. A moderate correlation highlights that generalised and acute anxiety are related, but distinct, constructs.

Strong, positive associations were found between anxiety and depression scores, as measured by the GAD-7 ( $r = 0.91, p < 0.001$ ) and the STAI-6 ( $r = 0.51, p < 0.001$ ), showing that higher anxiety levels correlate with higher depression symptoms. A significant negative correlation was found between quality of life and anxiety, as measured by the GAD-7 ( $r = -0.59, p < 0.001$ ) and the STAI-6 ( $r = -0.54, p < 0.001$ ), indicating that higher levels of anxiety correlate with lower quality of life. Furthermore, very strong, positive correlations were found between generalised anxiety and global sleep health score (as per the PSQI) ( $r = 0.71, p < 0.001$ ), daytime dysfunction ( $r = 0.7, p < 0.001$ ), and insomnia severity ( $r = 0.79, p < 0.001$ ), whilst moderate positive relationships were found between state anxiety and global sleep health ( $r = 0.46, p < 0.001$ ), sleep disturbance ( $r = 0.42, p < 0.001$ ), daytime dysfunction ( $r = 0.37, p < 0.001$ ), and insomnia ( $r = 0.42, p < 0.001$ ). Further strong significant positive correlations were found between generalised anxiety and sleep quality, where higher scores indicate worse sleep quality, ( $r = 0.62, p < 0.001$ ), and sleep disturbance, where higher scores indicate more sleep disturbance ( $r = 0.65, p < 0.001$ ). Significant moderate and positive correlations were found between generalised anxiety and sleep latency ( $r = 0.46, p < 0.001$ ), overall sleep regularity ( $r = 0.47, p < 0.001$ ), circadian regularity ( $r = 0.46, p < 0.001$ ), and sleep continuity ( $r = 0.49, p < 0.001$ ).

Four questions from the Morningness-Eveningness Questionnaire (MEQ) were identified as being relevant to the concept of sleep inertia (see Appendix C), and a Spearman's rank-order correlation was conducted to assess the relationship between anxiety and the scores of these questions as a combined new variable. Interestingly, significant moderate correlations were found in opposing directions between sleep inertia and generalised anxiety ( $r = 0.36, p < 0.001$ ) and state anxiety ( $r = -0.33, p < 0.001$ ), which is explored further in the discussion.

## **Exploring the Relationship between Anxiety and Sleep/Circadian Factors and Behavioural Task Performance**

Correlation analyses were conducted to explore sleep/circadian factors, anxiety, and behavioural task performance, revealing numerous statistically significant, weak relationships. Whilst the relationships were found to be statistically significant, and thus unlikely to have occurred by chance, they were limited in strength. It is noted, however, that some associations provided insight into the relationship between sleep and anxiety, which merit further exploration and reflection in the discussion.

## **Hierarchical Regression Models and Mediation Analyses**

This section presents the results of hierarchical regressions and mediation analyses conducted to examine the relationships between sleep/circadian factors, anxiety, and participant performance on behavioural tasks.

### **Sleep/Circadian Factors and Anxiety**

A hierarchical regression was conducted to determine whether sleep/circadian factors were significantly associated with anxiety (GAD-7), after controlling for participant demographics. Model 1 included demographic data containing age, gender, ethnicity, smoking status, alcohol consumption, caffeine consumption, and health needs. This model was not statistically significant, explaining only 3% of the variance in anxiety scores  $F(7,203) = .99, p = .441, R^2 = 0.033$ .

Model 2 included sleep and circadian factors, including the Pittsburgh Sleep Quality Index (PSQI) global score and subscale, the Sleep Regularity Questionnaire (SRQ) total score and subscale, the Insomnia Severity Index (ISI), the Morningness-Eveningness Questionnaire (MEQ), and the 'Sleep Inertia' variable which was created with items from the MEQ. The MEQ score and the 'Sleep Inertia' variable showed high multicollinearity ( $VIF > 10$ ). Whilst a statistical overlap here was understandable due to the manner in which the 'Sleep Inertia' variable was created, it meant that it was difficult to determine which influenced anxiety scores. As such, a residualized variable was created by regressing sleep inertia on MEQ and saving the unstandardized residuals. This residualized variable was used in the model in order to isolate the unique contribution of sleep inertia independent of chronotype. This decision was theoretically driven, with

the exploratory research question regarding sleep inertia in mind. Furthermore, SPSS excluded variables due to multicollinearity and redundancy and it is noted that the Global PSQI Score and SRQ Total score were not included in the final model due to their variance being accounted for by their subscales.

Model 2 was statistically significant, explaining 64% of the variance  $F(19,191) = 17.92$ ,  $p < .001$ ,  $R^2 = 0.641$  and representing a substantial significant contribution to anxiety levels, above demographics,  $\Delta R^2 = .608$ . Significant sleep and circadian predictors of anxiety included:

Table 3.6: The standardized indirect effects and p-values of significant sleep and circadian factors contributing to anxiety

| Sleep/Circadian Factor | Standardized indirect effect ( $\beta$ ) | p-value |
|------------------------|------------------------------------------|---------|
| Sleep Disturbance      | .222                                     | < .001  |
| Insomnia               | .387                                     | < .001  |
| Sleep Inertia          | -.175                                    | .022    |

These findings suggest that increased sleep disturbance and insomnia are associated with higher levels of anxiety. Greater sleep inertia was associated with lower levels of anxiety, which potentially suggests an inverse relationship.

### **Sleep/Circadian Factors, Anxiety, and Performance on Behavioural Tasks**

A series of hierarchical regressions were conducted to determine whether sleep and circadian factors, or anxiety levels, impacted task performance in the emotional flanker tasks or the facial recognition task. Bias scores were outputted from the Emotional Flanker Task in the form of reaction time and proportion of accuracy scores for distractibility (i.e., the impact of negative stimuli on accuracy) and target bias (i.e., the tendency to classify neutral stimuli as negative). Sensitivity scores and correct response reaction time outcomes were devised for each of the six emotions (anger, disgust, fear, happiness, sadness, surprise) in the Emotional Classification Task. Furthermore, the proportion of correctly identified facial expression for each level of emotional intensity (low, medium, high) was identified. As such, 16 separate hierarchical regressions were conducted with each as the dependent variable. Results showed that anxiety (GAD-7) was not significantly associated with any of the dependent variables. Sleep and

circadian factors, however, were found to explain variation in participant performance on the Emotional Classification Task, specifically related to fear, happiness, and sadness. Each are discussed in turn:

### **Sensitivity to Fear**

Model 1, which included demographics as above, was not statistically significant,  $F(7,88) = .150$ ,  $p = .993$ ,  $R^2 = 0.012$ . Model 2 showed sleep and circadian factors as a predictor of sensitivity to fear (that is high accuracy when correctly identifying fear and low rates of misidentifying other emotions as fear),  $F(19,76) = 2.37$ ,  $p < .001$ ,  $R^2 = 0.372$ . Significant sleep and circadian predictors in order of strength include:

Table 3.7: The standardized indirect effects and p-values of significant sleep and circadian factors contributing to sensitivity to fear

| Sleep/Circadian Factor | Standardized indirect effect ( $\beta$ ) | p-value |
|------------------------|------------------------------------------|---------|
| Circadian Regularity   | -1.389                                   | < .001  |
| Sleep Inertia          | .740                                     | < .001  |
| Daytime Dysfunction    | .690                                     | < .001  |
| Insomnia               | .520                                     | .006    |
| Sleep Duration         | .402                                     | .002    |
| Chronotype             | .400                                     | .009    |
| Sleep Efficiency       | .221                                     | .022    |

### **Correct Response Reaction Time to Sad Expressions**

Model 1, which included demographics as above, was not statistically significant,  $F(7,88) = .225$ ,  $p = .979$ ,  $R^2 = 0.018$ . Model 2 showed sleep and circadian factors as a predictor of participant ability to quickly and correctly identify happy facial expressions,  $F(19,76) = 1.85$ ,  $p < .004$ ,  $R^2 = 0.316$ . Significant sleep and circadian predictors in order of strength include:

Table 3.8: The standardized indirect effects and p-values of significant sleep and circadian factors contributing to correct-response reaction time to sad expressions

| Sleep/Circadian Factor | Standardized indirect effect ( $\beta$ ) | p-value |
|------------------------|------------------------------------------|---------|
|------------------------|------------------------------------------|---------|

|                      |        |        |
|----------------------|--------|--------|
| Circadian Regularity | -1.159 | < .001 |
| Sleep Continuity     | .530   | < .001 |
| Sleep Inertia        | .442   | .010   |
| Chronotype           | .343   | .031   |
| Sleep Efficiency     | .262   | .009   |

### Correct Response Reaction Time to Happy Expressions

Model 1, including demographics, was not statistically significant,  $F(7,88) = .468, p = .855, R^2 = 0.036$ . Model 2 showed sleep and circadian factors as a predictor of participant ability to quickly and correctly identify sad facial expressions,  $F(19,76) = 2.29, p < .001, R^2 = 0.364$ . Significant sleep and circadian predictors in order of strength include:

Table 3.9: The standardized indirect effects and p-values of significant sleep and circadian factors contributing to correct-response reaction time to happy expressions

| Sleep/Circadian Factor | Standardized indirect effect ( $\beta$ ) | p-value |
|------------------------|------------------------------------------|---------|
| Sleep Continuity       | 4.458                                    | < .001  |
| Sleep Efficiency       | 3.621                                    | < .001  |
| Circadian Regularity   | -1.995                                   | .050    |

### Sleep/Circadian Factors, Depression and Anxiety

As indicated by the correlational analyses, anxiety is associated with depression. Furthermore, items on questionnaires assessing depression, such as the PHQ-9, refer to sleep. As such, it was important to explore whether sleep and circadian factors were statistically associated with anxiety, when controlling for depression (model 1: demographics, as above; model 2: PHQ-9 scores; model 3: sleep/circadian factors, as above). As before, Model 1 was not statistically significant,  $F(7,203) = .99, p = .441, R^2 = 0.033$ . Model 2 demonstrated the significant contribution of depression in predicting anxiety scores  $F(8,202) = 81.96, p = .193, R^2 = 0.765$ . Above and beyond depression, sleep and circadian factors did not significantly contribute to anxiety levels,  $F(20,190) =$

33.65,  $p = .360$ ,  $R^2 = 0.780$ . The final model explained 78% of the variance in anxiety ( $R^2 = 0.780$ , Adjusted  $R^2 = 0.757$ ).

Mediation analyses were conducted in RStudio 2024.12.1 (Posit team, 2025) with the lavaan package (version 0.6-19, Rosseel, 2012) to explore whether sleep and circadian factors influence the relationship between anxiety and depression. The models included anxiety (GAD-7) as the predictor, depression (PHQ-9) as the outcome variable, and one of the 11 sleep and circadian factors as the potential mediator. Standardized indirect effects and 95% confidence intervals were estimated using bootstrapping, with 4989 bootstrap samples. Results (Table 3.4) show that several sleep variables significantly mediated the relationship between anxiety and depression.

Table 3.10: The standardized indirect effects and p-values of sleep and circadian factors mediating the relationship between anxiety (GAD-7) and depression (PHQ-9).

| Mediator             | Standardized indirect effect ( $\beta$ ) | p-value |
|----------------------|------------------------------------------|---------|
| Sleep Quality        | 0.093                                    | < .001* |
| Sleep Latency        | 0.044                                    | < .001* |
| Sleep Duration       | -0.001                                   | 0.833   |
| Sleep Efficiency     | 0.003                                    | 0.458   |
| Sleep Disturbance    | 0.111                                    | < .001* |
| Medication           | 0.018                                    | 0.013*  |
| Daytime Dysfunction  | 0.200                                    | < .001* |
| Circadian Regularity | 0.046                                    | < .001* |
| Sleep Continuity     | 0.034                                    | 0.001*  |
| Chronotype           | -0.001                                   | 0.828   |
| Sleep Inertia        | 0.046                                    | 0.002*  |

Note. An \* indicates significant value  $p = 0.05$

These results indicate that several sleep and circadian factors significantly mediate the relationship between anxiety (GAD-7) and depression (PHQ-9). Specifically, daytime dysfunction, sleep disturbance, and sleep quality ( $\beta = .20$ ,  $.11$ , and  $.09$  respectively, all  $p < .001$ ), suggesting that they are key pathways through which anxiety may influence depressive symptoms. Whilst marginal, circadian regularity, sleep inertia, sleep latency,

sleep continuity, and medication status also had significant mediational influence. Contrastingly, chronotype, sleep duration, and sleep efficiency did not show significant mediation effects, suggesting that they may not play a key role in the relationship between anxiety and depression within this sample.

### **Sleep/Circadian Factors, Anxiety, and Quality of Life**

Correlational analyses indicated a negative correlational association between anxiety and quality of life i.e., as anxiety levels increase, quality of life decreases. A hierarchical regression model was conducted to determine whether sleep and circadian factors were statistically associated with quality of life, over and above that of anxiety. Due to the high levels of multicollinearity between MEQ total and the 'Sleep Inertia' variable, it was necessary to remove 'Sleep Inertia' from this model as the inclusion of both introduced redundancy and inflated variance inflation factors, which distorted regression estimates. Model 1, which included demographics as above, was not statistically significant,  $F(7,182) = 1.70$ ,  $p = .112$ ,  $R^2 = 0.061$ . Model 2 showed anxiety as a strong predictor of quality of life,  $F(8,181) = 14.1$ ,  $p < .001$ ,  $R^2 = 0.384$ . Model 3 demonstrated that sleep and circadian factors significantly contributed uniquely to quality of life, over and above anxiety levels  $F(19,170) = 52.56$ ,  $p < .001$ ,  $R^2 = 0.855$ , accounting for 47% more variance. The final model explained 86% of the variance in anxiety ( $R^2 = 0.855$ , Adjusted  $R^2 = 0.839$ ). Significant sleep and circadian predictors of quality of life in order of strength included:

Table 3.11: The standardized indirect effects and p-values of significant sleep and circadian factors contributing to quality of life, beyond anxiety

| Sleep/Circadian Factor | Standardized indirect effect ( $\beta$ ) | p-value |
|------------------------|------------------------------------------|---------|
| Circadian Regularity   | .913                                     | < .001  |
| Daytime Dysfunction    | .674                                     | < .001  |
| Sleep Quality          | -.240                                    | < .001  |
| Insomnia               | .189                                     | .002    |
| Sleep Disturbance      | -.158                                    | < .001  |
| Medication Use         | -.077                                    | < .001  |

## Overall Influence of Sleep/Circadian Factors

A summary of the influence of each sleep/circadian factor is outlined in Table 3.5 below:

Table 3.12: Summary of the impact of sleep/circadian factors on anxiety, quality of life, mediating the relationship between anxiety and depression, and participant performance on emotional processing tasks

| Dimension                  | Definition                                                                                                        |                                                                                      |
|----------------------------|-------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| <b>Sleep Quality</b>       | The individual's subjective assessment of how well they slept                                                     | Correlated significantly with generalised anxiety (GAD-7) and acute anxiety (STAI-6) |
|                            |                                                                                                                   | Associated with quality of life (over and above anxiety)                             |
|                            |                                                                                                                   | A mediating factor between anxiety and depression                                    |
| <b>Sleep Latency</b>       | The time it takes an individual to fall asleep                                                                    | Correlated significantly with generalised anxiety (GAD-7) and acute anxiety (STAI-6) |
|                            |                                                                                                                   | A mediating factor between anxiety and depression                                    |
| <b>Sleep Duration</b>      | The total time spent sleeping                                                                                     | Correlated significantly with acute anxiety (STAI-6)                                 |
|                            |                                                                                                                   | Associated with task performance: fear sensitivity                                   |
| <b>Sleep Efficiency</b>    | The amount of time spent asleep (in comparison to the amount of time spent in bed)                                | Associated with task performance: fear sensitivity                                   |
|                            |                                                                                                                   | Associated with task performance: correct response reaction time (sadness)           |
|                            |                                                                                                                   | Associated with task performance: correct response reaction time (happiness)         |
| <b>Sleep Disturbance</b>   | The extent to which factors disrupt an individual's ability to fall asleep, stay asleep, or achieve restful sleep | Correlated significantly with generalised anxiety (GAD-7) and acute anxiety (STAI-6) |
|                            |                                                                                                                   | Associated with variance in anxiety when other variables controlled                  |
|                            |                                                                                                                   | Associated with quality of life (over and above anxiety)                             |
| <b>Daytime Dysfunction</b> | Difficulties associated with daytime wakefulness, alertness and/or energy levels                                  | A mediating factor between anxiety and depression                                    |
|                            |                                                                                                                   | Correlated significantly with generalised anxiety (GAD-7) and acute anxiety (STAI-6) |
|                            |                                                                                                                   | Associated with task performance: fear sensitivity                                   |
|                            |                                                                                                                   | Associated with quality of life (over and above anxiety)                             |

A mediating factor between anxiety and depression

|                             |                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-----------------------------|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Circadian Regularity</b> | The consistency of sleep-wake timing                                                     | <p>Correlated significantly with generalised anxiety (GAD-7)</p> <p>Associated with task performance: fear sensitivity</p> <p>Associated with task performance: correct response reaction time (sadness)</p> <p>Associated with task performance: correct response reaction time (happiness)</p> <p>Associated with quality of life (over and above anxiety)</p> <p>A mediating factor between anxiety and depression</p> |
| <b>Sleep Continuity</b>     | The extent to which sleep is smooth, stable, and uninterrupted                           | <p>Correlated significantly with generalised anxiety (GAD-7)</p> <p>Associated with task performance: correct response reaction time (sadness)</p> <p>Associated with task performance: correct response reaction time (happiness)</p> <p>A mediating factor between anxiety and depression</p>                                                                                                                           |
| <b>Chronotype</b>           | The extent to which an individual is an 'early bird' or a 'night owl'                    | <p>Associated with task performance: fear sensitivity</p> <p>Associated with task performance: correct response reaction time (sadness)</p>                                                                                                                                                                                                                                                                               |
| <b>Sleep Inertia</b>        | The transitional state from sleep to wake, characterised by 'grogginess' and low arousal | <p>Correlated in opposite directions with generalised anxiety (GAD-7) and acute anxiety (STAI-6)</p> <p>Associated with variance in anxiety when other variables controlled</p> <p>Associated with task performance: fear sensitivity</p> <p>Associated with task performance: correct response reaction time (sadness)</p> <p>A mediating factor between anxiety and depression</p>                                      |

## Discussion

This study explores the relationship between sleep and circadian factors, mental health (focusing on anxiety), and performance in emotional processing tasks within the late adolescent population.

### Sleep and Circadian Factors and Mental Health

In line with previous research (Qiu & Morales-Muñoz, 2022), results indicated a relationship between sleep/circadian factors and anxiety, with an increase in insomnia showing the strongest correlation after increased depression. Correlations also showed strong significant relationships between anxiety and increased daytime dysfunction, decreased sleep quality, and increased sleep disturbance. Moderate correlational relationships were also found between anxiety and increased sleep latency, decreased circadian regularity, decreased sleep continuity, and increased sleep inertia.

Hierarchical regression analyses showed that sleep and circadian factors (sleep disturbance, sleep inertia, and insomnia) significantly contribute to variance of anxiety.

Sleep and circadian factors did not significantly contribute to variability in anxiety over and above that of depression. Due to the strong relationship between anxiety and depression ( $r = 0.91$ ,  $p < 0.001$ ), further analyses exploring the mediational role of sleep and circadian factors in this relationship was carried out. Analyses highlighted the mediational role of sleep, specifically daytime dysfunction, sleep disturbance, and sleep quality. Furthermore, hierarchical regression showed circadian regularity and daytime dysfunction to be particularly strong contributors to adolescent quality of life, when accounting for anxiety.

With evidence of comorbidity of anxiety and depression within the adolescent population (Cummings et al., 2014; Konac et al., 2021; Melton et al., 2016), a strong correlation between anxiety and depression scores was expected. Interestingly, whilst the PHQ-9 for depression includes items related to sleep, there are no questions in the GAD-7 which directly ask about sleep. It appears evident from these findings, however, that there is a strong relationship between anxiety and experiences of insomnia, with other sleep and circadian factors also demonstrating strong correlational relationships (e.g., sleep quality, daytime dysfunction, and sleep disturbance). In a similar vein to the

conclusions formed by Qiu & Morales-Muñoz, such findings suggest that sleep problems should be considered when assessing mental health in adolescence.

## **Anxiety and Chronotype**

As previous findings (including studies investigating the adolescent population) show a relationship between anxiety and late chronotype (Antypa et al., 2016; Diaz-Morales, 2016), it is important to take particular note of the findings in the present study.

Correlation analyses indicated no significant relationship between anxiety and chronotype ( $r = -.020$ ,  $p = 0.714$ ), therefore, to explore the possibility of a nonlinear relationship between these two variables (e.g., severe morning and evening types experiencing higher levels of anxiety), a scatter plot was generated to visually inspect the distribution points. Visual inspection corroborated there to be no significant relationship between these two variables. A correlation was conducted to explore the relationship between anxiety and item 19 which asks participants directly whether they identify as a ‘morning person’ or an ‘evening person’; this indicated a moderate positive relationship between anxiety and chronotype preference ( $r = 0.38$ ,  $p < 0.001$ ). Whilst chronotype itself did not appear to correlate significantly with anxiety, it arose as one of the stronger, significant predictors of anxiety within the hierarchical regression ( $\beta = 0.19$ ,  $p = .006$ ). This suggests a potential suppression effect in that, when controlling for all other variables, chronotype contributes uniquely to the variability in anxiety. As adolescents demonstrate a shift towards an eveningness preference (Randler et al., 2017), this suggests that consideration should be given to adolescent chronotype, independently of other sleep or circadian factors at play. Future research could explore which variables are interacting with chronotype to better understand the mechanisms underpinning this relationship with anxiety. If research continues to show a consistent link between anxiety and evening chronotype, then consideration should be given to related interventions (such as adjusting sleep schedules) and environmental changes (such as later school start times to accommodate their eveningness).

## **Sleep Inertia**

One of the exploratory aims of this study was to investigate adolescent experiences of sleep inertia. The Morningness-Eveningness Questionnaire (MEQ) was selected due to it containing several items which were suited to examining the concept of sleep inertia.

Conducting the Spearman's correlations was an opportunity to begin to explore the concept of sleep inertia and its relationship with anxiety. Whilst a significant correlation was not found between anxiety and chronotype (measured by the MEQ), outcomes suggested a moderate positive relationship between anxiety and sleep inertia, indicating that the identified questions within the MEQ had provided insight to a distinct, unique concept of sleep inertia. It poses a question around whether an eveningness chronotype is associated with anxiety, or whether experiencing sleep inertia as a result of those with an eveningness preference being awoken in their biological night is the key factor associated with anxiety levels. It is recommended that future research conducts a factor analysis on the MEQ to examine its constructs and establish whether a sleep inertia subscale fits within the 19-item questionnaire. Furthermore, further exploration of the relationship between sleep inertia and anxiety, as well as other concepts, can be conducted.

As defined by the four identified questions within the MEQ, sleep inertia was found to show significant moderate correlations with anxiety, in opposing directions depending on the type of anxiety measured (i.e., generalised and acute). Higher generalised anxiety (GAD-7) was positively associated, suggesting that ongoing feelings of anxiety leads to increased experiences of grogginess upon awakening. On the other hand, state anxiety (STAI-6) was negatively associated, suggesting heightened levels of arousal upon awakening. It may be that acute anxiety reflects situational feelings associated with a particular event, such as an exam (which may be a common experience of academic pressure for adolescents). As such, individuals may feel more alert upon awakening, whereas those who are experiencing persistent anxiety may feel fatigued or have more impacted sleep. Additionally, findings from the hierarchical regression models showed that greater sleep inertia was associated with lower levels of anxiety. Further research is recommended to explore the distinction between acute and generalised anxiety and its relation to sleep inertia to enable firmer conclusions and considerations for supporting adolescents.

In relation to task performance, sleep inertia arose as one of the strongest contributing factors to participants' sensitivity to fear and correct response reaction time to sad and happy facial expressions. This suggests a key role in emotional processing, and indicates that this may be particularly prominent upon awakening. Crucially, for many

adolescents, this is when they are expected to start their school day, which involves social interactions and starting to engage in academic tasks. As such, it is important to consider the appropriateness of early school start times, and what tasks are expected of young people when sleep inertia is at its peak.

### **Task Performance, Sleep/Circadian Factors, and Anxiety**

Numerous statistically significant, weak relationships were found in correlational analyses exploring task performance, sleep/circadian factors, and anxiety. In hierarchical regression models, anxiety was not significantly associated with task performance, and sleep/circadian factors did not contribute to participant performance in the emotional flanker task. However, hierarchical regression models demonstrated that sleep and circadian factors played a key role in task performance on the Emotional Classification Task, specifically in relation to identifying fearful, happy, and sad emotional expressions. Circadian regularity and sleep efficiency played key roles in relation to fear, happy, and sad expressions, sleep continuity and chronotype were key to identifying happy and sad expressions, and sleep inertia played a key role in responding to fear and sadness.

In relation to participant performance on the emotional flanker task, a statistically significant but weak correlation ( $r = 0.17$ ,  $p = 0.039$ ) indicated that longer sleep duration was associated with a reduced impact of negative distractors on reaction time; that is to say, participants were less impacted by negative distractors when they had experienced longer sleep duration. Whilst marginal, this could suggest that these individuals are demonstrating better emotional regulation and attentional control when responding to emotional stimuli.

Interestingly, a weak positive correlation was found between participant sleep quality scores and correct response reaction time to fear ( $r = 0.19$ ,  $p = 0.021$ ), meaning that participants with higher sleep quality scores took longer to correctly identify fear. This may suggest that those with better quality sleep are less alert to threat-related responses or that they are more deliberate in their response whereas those with lower quality sleep are quicker to alert to fear. Contrastingly, however, correlations between sleep disturbance and correct response reaction time of fear ( $r = 0.18$ ,  $p = 0.028$ ) suggest that individuals who have experienced more disturbed sleep take longer to

correctly identify fear. Here, it may be that a slowed response to threat-related stimuli is due to attentional lapses or longer time required to process information. Furthermore, correlations suggested that higher levels of insomnia ( $r = 0.17$ ,  $p = 0.04$ ) and increased daytime dysfunction ( $r = 0.18$ ,  $p = 0.028$ ) promoted participant accuracy in correctly identifying medium-intensity fearful facial expressions. Overall, whilst disturbed sleep may hinder processing speed, it appears that impaired sleep can ultimately increase an individual's threat response, and well-rested adolescents experience a reduced attentional bias to threat. This likely supports adolescent quality of life, contributing to a more positive outlook. Furthermore, correlations suggested that participants with longer sleep duration were more accurate in identifying low-intensity surprised expressions ( $r = 0.16$ ,  $p = 0.048$ ) and less accurate in identifying low-intensity disgusted expressions ( $r = 0.2$ ,  $p = 0.012$ ). This suggests that they were more attuned to the facial expressions which may be regarded as more positive.

Similar findings came to light when exploring the correlations between anxiety and performance in the Emotional Classification Task. Higher anxiety scores (according to both GAD-7 and STAI-6) were associated with a greater attunement to 'disgust'. Higher GAD-7 scores meant that participants were marginally more accurate in correctly identifying low-intensity disgust ( $r = 0.18$ ,  $p = 0.027$ ), and the higher the anxiety score on the STAI-6, the higher participant sensitivity towards facial expressions showing disgust (that is, higher accuracy in correctly identifying disgust, and lower misidentification of other facial expression as disgust) ( $r = -0.21$ ,  $p$ ). This suggests that those with heightened anxiety may be more alert to socially negative responses. The correlational data suggests only marginal relationships between anxiety and task performance, and hierarchical regression models found that anxiety scores did not predict task performance. As such, it is important that these marginal correlations are interpreted with curiosity and caution.

More broadly, previous findings associated with sleep and emotional processing are mixed. For example, Goldstein-Piekarski et al. (2015) found that sleep deprivation significantly impacts individuals' next-day ability of emotional discrimination, as participants categorised more stimuli as threatening. Davidson et al. (2016), however, found no difference in the generalisation of fear learning between those who had slept well and those who were sleep-deprived. It is noted that participants in these studies

were young adults, and the focus of the current research is on adolescent emotional processing. Tempesta and colleagues (2017) also note that the methodology within the studies producing mixed results varies in type of stimuli, sleep deprived and well-slept participants, and ‘immediate vs. delay extinction’ procedure. The current research continues to explore performance in tasks related to emotional processing, building a more comprehensive picture within the literature of behaviours presented by individuals varying in levels of anxiety, experiences of depressive symptoms, and in sleep/circadian factors.

## **Implications**

This research begins to shed light on which sleep and circadian factors may be most influential within adolescent mental health, specifically anxiety and emotional processing. Circadian regularity (i.e., the consistency of adolescent sleep-wake times) arose as the most common significant sleep/circadian factor throughout analyses, highlighting it as a key area of focus for intervention. Sleep disturbance, daytime dysfunction, and sleep inertia also presented as contributors to anxiety levels and participant performance in emotional processing tasks. Whilst sleep duration influenced the fewest outcome variables, it still significantly impacted acute anxiety and participants’ sensitivity to fear. Similarly, chronotype was found to be associated only with participant sensitivity to fear and correct response reaction time for sadness. This means that all tested sleep and circadian factors influenced areas which contribute to adolescent quality of life (e.g., anxiety levels, emotional processing behaviours, or quality of life scores). As such, it is important to educate adolescents and adults who support them (e.g., parents/carers, educators, medical professionals) to ensure that information regarding sleep health and mental wellbeing reflects the significant influences of sleep. Godsell and White (2019) found that adolescents presented an understanding of the recommended 8-10 hours of sleep and that many routinely engaged in weekend catch-up sleep to counter their sleep debt. Furthermore, perceptions of sleep health portrayed in their findings appeared to centre predominantly around sleep duration, rather than other sleep and circadian factors, suggesting that there may be a need to increase adolescent understanding of the breadth and depth of sleep health.

It is important that information and resources are accessible in order to provide helpful interventions (e.g., sleep hygiene interventions that support circadian regularity), and that adaptations are made to the environments where possible (e.g., school start times, exam start times, bedtime expectations). Educational psychologists are well-placed to provide information through training sessions, workshops, and individual reports to provide up-to-date research and evidence-based strategies that are conducive to adolescent sleep needs. They can also assess individual adolescent sleep and circadian factors through consultation with young people, families, and school professionals, to raise awareness of the importance of sleep-wake schedules and to offer support through evidence-informed recommendations. It should also be acknowledged that sleep is influenced by cultural factors such as beliefs and practices, like bedtime routines, and it is important that any recommendations for sleep health consider cultural differences (Jeon et al., 2021).

It is recognised that there is sometimes concern associated with moving school start times later. Evidence suggests, however, that even modest delays of 25-30 minutes can improve adolescent sleep duration, satisfaction with sleep, school attendance, academic performance, mood, and motivation, whilst reducing their daytime sleepiness, fatigue, and caffeine use (Boergers et al., 2014; Dunster et al., 2018; Owens et al., 2010). This highlights that whilst the present research explores the relationship between sleep/circadian factors and adolescent mental wellbeing, and potential benefits for delayed school start times, such delays have also been found to positively impact other areas, encompassing academic and psychosocial outcomes. In many local authorities, educational psychologists are allocated to specific schools or colleges to promote long-term, collaborative relationships with school communities. In such cases, educational psychologists can be influential in offering support to the wider school system. Through system-level consultation, educational psychologists can present research that demonstrates the biological shifts in the adolescent sleep-wake cycle and the importance of sleep and circadian factors, such as circadian regularity, in order to consider shifting school start times later and evaluating the impact of this change. Furthermore, in the present sample, most participants chose to start a five-hour working day at 9am (Figure 3.4), which is not considerably later than many school start times.

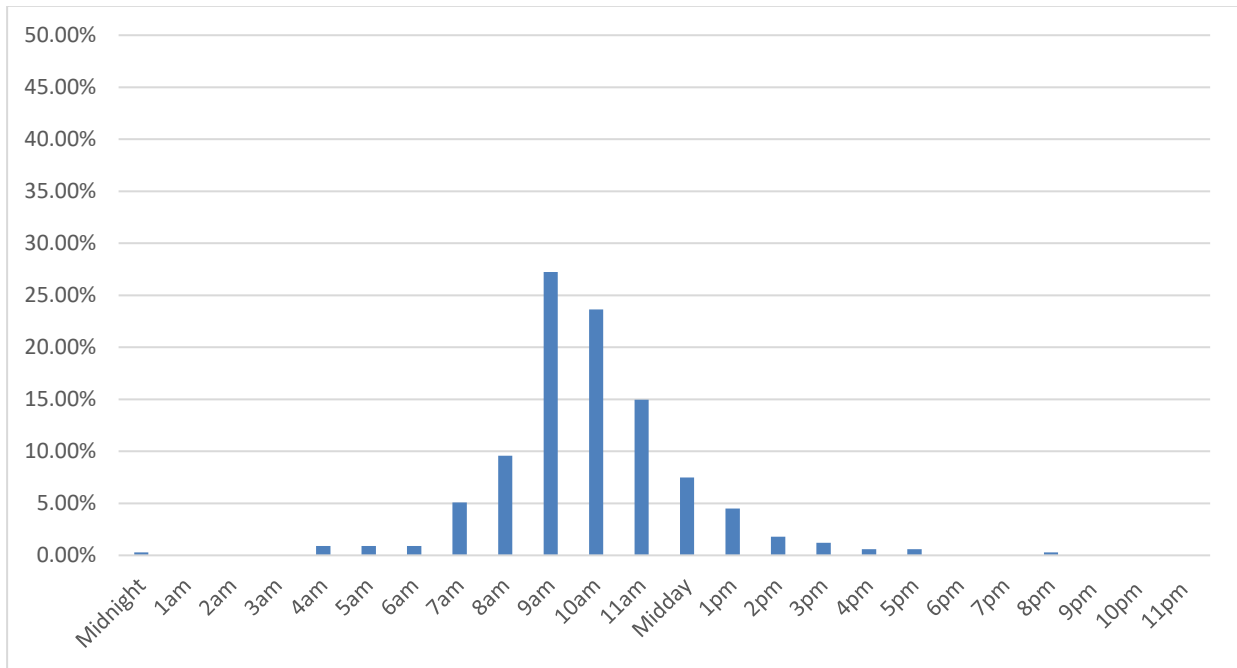


Figure 3.5: Participant responses to MEQ item: ‘Suppose that you can choose your own work hours. Assume that you work a five hour day (including breaks) and that your job was interesting and paid by results. Which hour would you choose to start your five hour shift (if you have to complete all five hours in one go)?’

Whilst disseminating these research findings would provide insights into adolescent sleep health for adolescents and the adults supporting them, it is important to acknowledge that knowledge itself is not always sufficient in promoting behaviour change. For example, Cain et al. (2011) found that whilst a sleep intervention improved adolescent understanding and knowledge of healthy sleep behaviours, such knowledge did not have the desired impact on behavioural changes. As such, when promoting interventions and strategies for sleep health, consideration should be given to long-term behavioural change, including the identification of barriers to change (Cain et al., 2011). In light of this, it is helpful to draw upon theories and models of behavioural change, such as the COM-B model (Michie et al., 2011), which highlights three components: Capability (C), Opportunity (O), and Motivation (M). For example, to support a consistent sleep-wake schedule for a teenager, they would need to be in a position where they felt capable of achieving this goal (i.e., being physically able to fall asleep at their desired bedtime), had the opportunity to engage in it (i.e., assurance that social or academic demands will not create barriers), and the motivation to do so (i.e., encouragement, a willingness to engage in this behavioural change, an understanding of the benefits associated with a consistent

sleep-wake schedule). In order to facilitate meaningful change, adolescents need coordinated support from their families, schools, and broader societal perspectives, which starts with an understanding and acceptance of the biological changes and needs related to adolescent sleep (i.e., a shift towards a later sleep-wake schedule and a need for 8-10 hours of sleep a night). From this understanding and acceptance, open conversations can be held with adolescents about the benefits of a good night's sleep, healthy sleep routine (including consistent sleep-wake schedules at the weekend), and the effects of screen time and caffeine on sleep. Adults should model healthy sleep behaviours (e.g., maintaining a consistent sleep-wake routine, limiting screen time and caffeine before bed) to promote a culture which benefits the sleep health of the community. Furthermore, qualitative research would lend itself to developing an understanding of adolescent perception of sleep health and sleep behaviours to inform future practice.

## **Limitations and Future Directions**

It is important to consider the representativeness of the sample. Firstly, the majority of the sample identified as female (72.76%) demonstrating an over-representation within this sample, which may be due to recruiting psychology students as participants, as such groups are predominately populated by females (Fowler et al., 2018; Johnson et al., 2020). Geographically, participants were primarily from the East of England (48.72%) and the South East (22.44%), which reflects participant recruitment channels. This may limit generalisability to other areas within the UK, particularly areas such as the North West and North East which were not represented, or minimally represented, within this sample. Participant ethnicity was categorised into five broad categories outlined by the INCLUDE framework (Treweek et al., 2021) to promote inclusive research (outlined in Table 3.3). Compared to the national population as outlined in the 2021 Census data for England and Wales (Office for National Statistics, 2021; Office for National Statistics, 2022), the sample shows a marginal underrepresentation of White individuals (71.79% vs. 81.7%) and an overrepresentation of Mixed/Multiple ethnic groups (7.69% vs. 2.9%) and Other ethnic groups (4.81% vs. 2.1%). Representation of Asian/Asian British (9.29% vs. 9.3%) and Black/African/Caribbean/Black British (5.45% vs. 4%) was broadly

comparable. This suggests that the sample is reflective of the ethnicity of the UK population. In relation to lifestyle behaviours, data were collected on participant alcohol and caffeine consumption, smoking and vaping behaviours, mental health diagnoses, and medication use. Data on national smoking and vaping habits of 16–18-year-olds does not appear to be readily available, but some survey data provides indicative rates of such behaviours. A report by Action on Smoking and Health (2025) reports that, in 2025, 30% of 16-17-year-olds and 28% of 18-year-olds reported that they had tried vaping, with 12% of 16-17-year-olds and 15% of 18-year-olds reported to be current vape-users, which is considerably higher than the 6.09% in the current sample. The Action on Smoking and Health survey outlines that, in line with the current sample, vaping rates are higher than smoking rates, reporting that 4.2% of 11-17 year-olds currently vape but do not smoke, 2.8% currently vape and smoke, and 2.6% smoke but do not vape. The report does not outline specific figures for 16-18-year-olds. Other reports state that 12% of 16-17-year-olds smoke across the United Kingdom (Department of Health and Social Care, 2024), and 15% of 15-year-olds vape in the United Kingdom (NHS Digital, 2024). In the current sample, smoking and vaping rates were considerably lower (0.96% and 6.09%, respectively) which may reflect a particularly health-conscious sample, or an underreporting of smoking and/or vaping. Given that these demographics were entered into Model 1 of the hierarchical regression models, the low reported rates of these behaviours within the sample may have limited their explanatory power in predicting outcome variables, reducing the sensitivity of the model in detecting associations, which could have influenced the outcomes. This should be considered when interpreting the contribution of these demographics within the hierarchical regression analyses.

Whilst an online survey enables geographical scope of participants, allowing for opportunistic and convenience sampling through the use of the internet, it also creates barriers for individuals with limited access to technology. The behavioural tasks were required to be completed on a desktop computer or laptop due to their compatibility and considerable dropout rate between the completed battery of questionnaires and the behavioural tasks is noted. It is predicted that more adolescents will not only have access to mobile devices, but also, easier accessibility to such devices. As technology continues to develop, future research should explore tasks which can be completed on

mobile devices to enable further reach to a wider range of participants to promote a more representative sample.

Data collected on participant sleep/circadian and psychological factors (e.g., anxiety, depression, quality of life) were via self-report measures. It is acknowledged that self-report measures are both widely used and widely criticised within psychological research, often due to potential inaccuracies within participant reporting (Haeffel & Howard, 2010). Self-report measures offer direct insight into participant experiences, and the use of such tools promoted accessibility through being low in cost and easy to administer via online surveys, limitations may involve factors such as bias, distractibility, or misunderstanding of questions. Surveys were anonymous and participants were asked to share open and honest responses that would be received with no judgement, however, there remains possibility for biases such as social desirability bias (i.e., individuals reporting what they feel to be more socially acceptable) or recall bias (i.e., difficulties accurately remembering experiences related to mood or sleep). The aim was to capture adolescent sleep as they are experiencing it in their everyday lives, and so aside from the expense of polysomnography, it would not have been an appropriate measure for this research due to the requirement to carry out assessments in a laboratory setting. Whilst actigraphy may have offered a less expensive and less invasive alternative, enabling adolescent sleep to be captured in their everyday environment, the accuracy and consistency of data obtained via these methods is disputed (Sadeh, 2011). Future research should look to explore sleep/circadian factors and their impact on mental health and emotional processing through a range of subjective and objective measures in order to offer complementary insights into late adolescent experiences.

The cross-sectional design of this study does not establish the causal links between the variable explored as they reflect a single point in time. To address the limitations of this design, future research should consider longitudinal or intervention-based studies to explore causal relationships or changes over time. These findings would complement the current research paper and extend findings.

Finally, this research focuses on the experiences of the late adolescent population in the United Kingdom. This is a period associated with high academic demands due to completing formal qualifications, and as such, questionnaires were selected to be

appropriate and relevant to them. Research suggests differences between early, mid, and late adolescence (Tsagem, 2022) and therefore it is important to take caution when generalising these findings more broadly within the adolescent population.

Furthermore, sleep and circadian factors are strongly governed by natural daylight, meaning that these findings are most relevant to those exposed to daylight patterns in the United Kingdom at the time of data collection. It is important to note that the period of data collection (from February to April 2025) stretched across the daylight saving time (DST) 1-hour clock change, which could have impacted results as DST has been found to have adverse effects on adolescent sleep (Medina et al., 2015). Future researchers may wish to replicate this study with participants across different stages of adolescence, and across different seasons within the calendar year, to explore similarities and differences in findings.

## **Conclusion**

To conclude, this empirical research found evidence to show that sleep and circadian factors contribute to the mental health and wellbeing of the late adolescent population. Circadian regularity arose as the variable which most commonly demonstrated statistical associations with mental health measures (e.g., GAD-7) and participant performance in emotional processing tasks (specifically in relation to fearful, happy, and sad emotional expressions). This highlights the importance of considering sleep-wake timings when promoting sleep health recommendations for adolescents and when adapting environments to best suit adolescent sleep health. This research suggests that such adaptations would have a positive influence on adolescent mental health and wellbeing, including anxiety and quality of life.

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## Appendix A      Search Terms

|                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Age</b>                                    | adolescen* OR youth* OR teen* OR "young person" OR "young people" OR child*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>AND</b>                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Sleep<br/>Regularity/Social<br/>Jetlag</b> | "sleep regularity" OR "sleep regulation" OR "social jetlag" OR "social jet lag" OR "social jet-lag" OR "delayed sleep phase" OR "sleep pattern*" OR "behavio*rally induced insufficient sleep" OR "sleep duration" OR "sleep discrepant*" OR "sleep debt" OR "sleep-debt" OR "sleep deficit" OR "sleep compensation" OR "catch up sleep" OR "weekday-weekend" OR "weekend-weekday" OR "weekend oversleep" OR "morningness" OR "eveningness" OR chronotyp* OR chronobiology OR chronodisruption OR "circadian preference" OR "circadian rhythm* disturbance*" OR "circadian disturbance*" OR "circadian disrupt*" OR "circadian misalignment" OR "sleep inconsistency" OR "sleep variability" OR "intraindividual variability" OR "insomnia" OR "sleep inertia" |
| <b>AND</b>                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Anxiety</b>                                | anxi*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

## Appendix B    Quality Assurance: Newcastle-Ottawa Scale

| Author                     | Study Design    | Item 1 | Item 2 | Item 3 | Item 4 | Item 5 | Item 6 | Item 7 | Item 8 | Total | Rating       |
|----------------------------|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|-------|--------------|
| Alvaro et al. (2014)       | Cross-Sectional | 1      | 1      | 1      | 0      | 2      | 2      | 1      |        | 8     | Good         |
| Bauducco et al. (2024)     | Longitudinal    | 1      | 1      | 0      | 0      | 2      | 0      | 1      | 0      | 5     | Satisfactory |
| Chung et al. (2020)        | Cross-Sectional | 1      | 1      | 1      | 0      | 2      | 1      | 1      |        | 7     | Good         |
| Díaz-Morales J.F. (2016)   | Cross-Sectional | 0      | 1      | 1      | 0      | 2      | 1      | 1      |        | 6     | Satisfactory |
| Ko et al. (2024)           | Cross-Sectional | 1      | 1      | 1      | 0      | 2      | 1      | 1      |        | 7     | Good         |
| Kuula et al., (2020)       | Cross-Sectional | 1      | 1      | 1      | 0      | 2      | 2      | 1      |        | 8     | Good         |
| Li et al. (2024)           | Cross-Sectional | 1      | 1      | 1      | 0      | 2      | 1      | 1      |        | 7     | Good         |
| Magnusdottir et al. (2024) | Cross-Sectional | 0      | 0      | 1      | 0      | 2      | 1      | 1      |        | 5     | Satisfactory |
| Mathew et al. (2019)       | Cross-Sectional | 1      | 1      | 1      | 0      | 2      | 1      | 1      |        | 7     | Good         |
| Rojo-Wissar et al. (2021)  | Cross-Sectional | 1      | 1      | 1      | 0      | 2      | 1      | 1      |        | 7     | Good         |
| Singh et al. (2023)        | Cross-Sectional | 1      | 1      | 1      | 0      | 2      | 1      | 1      |        | 7     | Good         |
| Stein et al. (2002)        | Cross-Sectional | 0      | 1      | 1      | 0      | 2      | 2      | 1      |        | 7     | Good         |
| (Stone et al., 2021)       | Longitudinal    | 1      | 1      | 1      | 0      | 2      | 1      | 1      | 1      | 8     | Good         |
| Troxel et al. (2024)       | Longitudinal    | 0      | 1      | 0      | 0      | 2      | 0      | 1      | 1      | 5     | Satisfactory |

## Appendix B

|                             |                 |   |   |   |   |   |   |   |   |   |              |
|-----------------------------|-----------------|---|---|---|---|---|---|---|---|---|--------------|
| <b>Wang et al. (2021)</b>   | Longitudinal    | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 1 | 5 | Satisfactory |
| <b>Waters et al. (2023)</b> | Cross-Sectional | 0 | 1 | 1 | 0 | 2 | 1 | 1 |   | 6 | Satisfactory |
| <b>Wesley et al. (2023)</b> | Cross-Sectional | 1 | 1 | 1 | 0 | 2 | 1 | 1 |   | 7 | Good         |
| <b>Zhang et al. (2017)</b>  | Cross-Sectional | 1 | 1 | 1 | 1 | 2 | 1 | 1 |   | 8 | Good         |

| <b>Item</b> | <b>Cohort/Longitudinal Studies</b>                                          | <b>Adapted Newcastle-Ottawa Scale for Cross-Sectional Studies</b>                                                                   |
|-------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| <b>1</b>    | Representativeness of the exposed cohort                                    | Representativeness of the sample                                                                                                    |
| <b>2</b>    | Selection of the non-exposed cohort                                         | Sample Size                                                                                                                         |
| <b>3</b>    | Ascertainment of exposure                                                   | Ascertainment of exposure                                                                                                           |
| <b>4</b>    | Demonstration of that outcome of interest was not present at start of study | Non-respondents                                                                                                                     |
| <b>5</b>    | Comparability of cohorts on basis of design or analysis                     | The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled. |
| <b>6</b>    | Assessment of outcome                                                       | Assessment of outcome                                                                                                               |
| <b>7</b>    | Was follow-up long enough for outcomes to occur?                            | Statistical test                                                                                                                    |
| <b>8</b>    | Adequacy of follow-up of cohort                                             |                                                                                                                                     |

## **Appendix C    Questions from the Morningness- Eveningness Questionnaire identified as relevant to the concept of ‘Sleep Inertia’**

Question 4: Assuming adequate environmental conditions, how easy do you find getting up in the mornings?

Question 5: How alert do you feel during the first half hour after having woken up in the mornings?

Question 6: How is your appetite during the first half hour after having woken up in the mornings?

Question 7: During the first half hour after having woken in the morning, how tired do you feel?

## Appendix D Advertisement Poster

# Exploring Sleep and Emotions in Adolescence

Are you aged between 16-18? Would you like to take part in an online research project?

**What is the research about?**

We are exploring the relationship between sleep and emotions in late adolescence. How much impact does a bad night's sleep have on our ability to process emotions?

We are looking for 16-18 year olds living in the UK and we welcome those from all backgrounds to take part.

Whilst lots of us know that sleep is important (especially for teens), scientists are still learning about how sleep impacts our lives. By participating in this study, you will be helping to contribute to the scientific understanding of sleep!

**Who is conducting this research?**

My name is Hannah and I'm a Trainee Educational Psychologist at the University of Southampton. I am interested in learning more about sleep and its impact on adolescents. You are welcome to email me if you have any questions:

✉ [H.L.Ravenhall@soton.ac.uk](mailto:H.L.Ravenhall@soton.ac.uk)

The University of Southampton Research Ethics Committee has granted ethical approval for this research, ERGO-II number: 100209  
Version 4.0 • Date: 17/01/2025

**For taking part, you will have the chance to win a £20, £50 or £100 Amazon voucher!**

**Tasks**

If you would like to take part, you will need to:

- 1) Log onto a laptop/computer (unfortunately, this cannot be done on a mobile phone or tablet)
- 2) Scan the QR code or follow the link: <https://tinyurl.com/teen-sleep-research>
- 3) If you choose to take part in the study, you will:
  - Answer questions about yourself (e.g., your age, gender, lifestyle)
  - Answer questions about your sleep
  - Answer questions about your feelings and emotions
  - Complete tasks which involve recognising emotions

**30 MIN** We expect this to take about half an hour.

Following your participation, you can enter the prize draw by providing your email address. (please note, your personal information will not be held for more than 12 months after the study)

## Appendix E Correlation Matrix Heat Map

|                              | Global PSQI | Sleep Quality (PSQI-1) | Sleep Latency (PSQI-2) | Sleep Duration (PSQI-3) | Sleep Efficiency (PSQI-4) | Sleep Disturbance (PSQI-5) | Medication (PSQI-6) | Daytime Dysfunction (PSQI-7) | Sleep Regularity Questionnaire (SRQ Total) | Circadian Regularity (SRQ-1) | Sleep Continuity Regularity (SRQ-2) | State Anxiety (STAI-6) | Morningness-Eveningness Questionnaire (MEQ) | Insomnia Severity Index (ISI) | Generalised Anxiety (GAD-7) | Depression (PHQ-9) | Quality of Life (KIDSCREEN-10) | Sleep Inertia (items 4-7 on MEQ) |
|------------------------------|-------------|------------------------|------------------------|-------------------------|---------------------------|----------------------------|---------------------|------------------------------|--------------------------------------------|------------------------------|-------------------------------------|------------------------|---------------------------------------------|-------------------------------|-----------------------------|--------------------|--------------------------------|----------------------------------|
| Global PSQI                  | 0.78**      | 0.80**                 | -0.27**                | -0.08                   | 0.93**                    | 0.30**                     | 0.79**              | 0.38**                       | 0.40**                                     | 0.41**                       | 0.46**                              | -0.23**                | 0.79**                                      | 0.71**                        | 0.75**                      | -0.45**            | 0.30**                         |                                  |
| Sleep Quality (PSQI-1)       | 0.78**      |                        | 0.60**                 | -0.21**                 | -0.10                     | 0.67**                     | 0.23**              | 0.69**                       | 0.43**                                     | 0.44**                       | 0.46**                              | 0.28**                 | -0.16**                                     | 0.77**                        | 0.62**                      | 0.64**             | -0.35**                        | 0.38**                           |
| Sleep Latency (PSQI-2)       | 0.80**      | 0.60**                 |                        | -0.20**                 | -0.07                     | 0.65**                     | 0.19**              | 0.50**                       | 0.29**                                     | 0.30**                       | 0.30**                              | 0.25**                 | -0.18**                                     | 0.56**                        | 0.46**                      | 0.48**             | -0.19**                        | 0.25**                           |
| Sleep Duration (PSQI-3)      | -0.27**     | -0.21**                | -0.20**                |                         | 0.04                      | -0.29**                    | 0.00                | -0.25**                      | -0.55**                                    | -0.55**                      | -0.49**                             | 0.17**                 | -0.32**                                     | -0.24**                       | -0.30**                     | -0.27**            | -0.20**                        | -0.55**                          |
| Sleep Efficiency (PSQI-4)    | -0.08       | -0.10                  | -0.07                  | 0.04                    |                           | -0.04                      | 0.02                | -0.09                        | 0.02                                       | 0.00                         | -0.02                               | 0.05                   | 0.14*                                       | -0.09                         | -0.07                       | -0.10              | 0.06                           | -0.04                            |
| Sleep Disturbance (PSQI-5)   | 0.93**      | 0.67**                 | 0.65**                 | -0.29**                 | -0.04                     |                            | 0.23**              | 0.65**                       | 0.34**                                     | 0.36**                       | 0.36**                              | 0.42**                 | -0.09                                       | 0.70**                        | 0.65**                      | 0.66**             | -0.47**                        | 0.31**                           |
| Medication (PSQI-6)          | 0.30**      | 0.23**                 | 0.19**                 | 0.00                    | 0.02                      | 0.23**                     |                     | 0.21**                       | 0.02                                       | 0.02                         | 0.06                                | 0.14*                  | -0.13*                                      | 0.22**                        | 0.24**                      | 0.27**             | -0.17**                        | -0.04                            |
| Daytime Dysfunction (PSQI-7) | 0.79**      | 0.69**                 | 0.50**                 | -0.25**                 | -0.09                     | 0.65**                     | 0.21**              |                              | 0.44**                                     | 0.43**                       | 0.48**                              | 0.37**                 | -0.30**                                     | 0.75**                        | 0.70**                      | 0.77**             | -0.47**                        | 0.32**                           |

# Appendix E

|                                             |         |         |         |         |       |         |         |         |        |         |        |         |        |         |         |         |         |         |
|---------------------------------------------|---------|---------|---------|---------|-------|---------|---------|---------|--------|---------|--------|---------|--------|---------|---------|---------|---------|---------|
| Sleep Regularity Questionnaire (SRQ Total)  | 0.38**  | 0.43**  | 0.29**  | -0.55** | 0.02  | 0.34**  | 0.02    | 0.44**  |        | 0.93**  | 0.89** | -0.10   | 0.27** | 0.44**  | 0.47**  | 0.47**  | 0.19**  | 0.68**  |
| Circadian Regularity (SRQ-1)                | 0.40**  | 0.44**  | 0.30**  | -0.55** | 0.00  | 0.36**  | 0.02    | 0.43**  | 0.93** |         | 0.69** | -0.14** | 0.30** | 0.45**  | 0.46**  | 0.46**  | 0.19**  | 0.70**  |
| Sleep Continuity Regularity (SRQ-2)         | 0.41**  | 0.46**  | 0.30**  | -0.49** | -0.02 | 0.36**  | 0.06    | 0.48**  | 0.89** | 0.69**  |        | 0.01    | 0.12*  | 0.46**  | 0.49**  | 0.49**  | 0.11*   | 0.59**  |
| State Anxiety (STAI-6)                      | 0.46**  | 0.28**  | 0.25**  | 0.17**  | 0.05  | 0.42**  | 0.14*   | 0.37**  | -0.10  | -0.14** | 0.01   |         | -0.07  | 0.42**  | 0.52**  | 0.51**  | -0.54** | -0.33** |
| Morningness-Eveningness Questionnaire (MEQ) | -0.23** | -0.16** | -0.18** | -0.32** | 0.14* | -0.09   | -0.13*  | -0.30** | 0.27** | 0.30**  | 0.12*  | -0.07   |        | -0.09   | -0.02   | -0.10   | 0.13*   | 0.59**  |
| Insomnia Severity Index (ISI)               | 0.79**  | 0.77**  | 0.56**  | -0.24** | -0.09 | 0.70**  | 0.22**  | 0.75**  | 0.44** | 0.45**  | 0.46** | 0.42**  | -0.09  |         | 0.79**  | 0.84**  | -0.46** | 0.36**  |
| Generalised Anxiety (GAD-7)                 | 0.71**  | 0.62**  | 0.46**  | -0.30** | -0.07 | 0.65**  | 0.24**  | 0.70**  | 0.47** | 0.46**  | 0.49** | 0.52**  | -0.02  | 0.79**  |         | 0.91**  | -0.58** | 0.36**  |
| Depression (PHQ-9)                          | 0.75**  | 0.64**  | 0.48**  | -0.27** | -0.10 | 0.66**  | 0.27**  | 0.77**  | 0.47** | 0.46**  | 0.49** | 0.51**  | -0.10  | 0.84**  | 0.91**  |         | -0.63   | 0.34**  |
| Quality of Life (KIDSCREEN-10)              | -0.45** | -0.35** | -0.19** | -0.20** | 0.06  | -0.47** | -0.17** | -0.47** | 0.19** | 0.19**  | 0.11*  | -0.54** | 0.13*  | -0.46** | -0.58** | -0.63** |         | 0.37**  |
| Sleep Inertia (items 4-7 on MEQ)            | 0.30**  | 0.38**  | 0.25**  | -0.55** | -0.04 | 0.31**  | -0.04   | 0.32**  | 0.68** | 0.70**  | 0.59** | -0.33** | 0.59** | 0.36**  | 0.36**  | 0.34**  | 0.37**  |         |

## **Appendix F    Participant Information Sheets**

## Participant Information Sheet

**Study Title:** Exploring the relationship between sleep and emotional processing in late adolescence.

**Researcher:** Hannah Ravenhall

**ERGO number:** 100209

This information is designed to help you decide whether you would like to take part in this study. It is important that you understand why the research is being done and what it will involve. You are encouraged to read the information carefully and ask questions if anything is unclear. You are welcome to discuss it with others, but it is up to you to decide whether or not to take part. If you are happy to participate, you will be asked to sign a consent form.

My name is Hannah and I am completing a doctorate in Educational Psychology at the University of Southampton. If you are aged between 16 - 18, living in the UK, I invite you to participate in this research project about sleep and emotional processing/mental health. We are hoping to recruit around 200 participants.

### What will happen if I take part?

1. If you wish to participate after reading the information, you will be asked to provide consent.
2. Then, you will be asked to spend approximately 30 minutes completing:
  - a. Questions about yourself (e.g., your age, gender, lifestyle)
  - b. Questions about your sleep
  - c. Questions about your feelings and emotions
  - d. Tasks involving recognising emotions

### Are there any benefits in my taking part?

Whilst you will not receive direct benefits for taking part, your participation will contribute to the knowledge of sleep and mental health/wellbeing in adolescence. If you wish, you can also provide your email address to enter a prize draw and the chance of winning a £20, £50 or £100 Amazon voucher.

### Are there any risks involved?

We note that some of the questionnaires address sensitive or personal information, for example, regarding how you feel and your sleep patterns, and therefore, there is a possibility that it might induce some psychological discomfort or distress. Should you feel uncomfortable at any time, you can leave the survey at any time without having to give a reason. If you require any further support, you are encouraged to speak to supportive adults you know. You may also find these links to organisations helpful:

- NHS (<https://www.nhs.uk/live-well/sleep-and-tiredness/> or <https://www.nhs.uk/every-mind-matters/mental-health-issues/sleep/>)
- ChildLine (<https://www.childline.org.uk/info-advice/your-feelings/feelings-emotions/problems-sleeping/>)
- YoungMinds (<https://www.youngminds.org.uk/young-person/my-feelings/sleep-problems/>)

### What data will be collected?

All information collected will be stored securely on a password protected computer and backed up on a secure server. The information collected will be analysed, pooled, and compiled into data summaries or reports. The University of Southampton conducts research to the highest standards of ethics and research integrity. In accordance with our Research Data Management Policy, data will be held for 10 years after the study when it will be securely destroyed. Data will be anonymised and will not be linked to your personal data i.e., you will not be able to be singled out from the research data. Any identifiable personal information (i.e., your email address) will not be held for more than 12 months.

### Will my participation be confidential?

Your participation and the information we collect about you during the course of the research will be kept strictly confidential. Only members of the research team and responsible members of the University of Southampton may be given access to data about you for monitoring purposes and/or to carry out an audit of

the study to ensure that the research is complying with applicable regulations. Individuals from regulatory authorities (people who check that we are carrying out the study correctly) may require access to your data. All of these people have a duty to keep your information, as a research participant, strictly confidential.

#### **Do I have to take part?**

No, it is entirely up to you to decide whether or not to take part. If you decide you want to take part, you will need to sign a consent form to show you have agreed to take part.

#### **What happens if I change my mind?**

You have the right to change your mind and withdraw at any time without giving a reason and without your participant rights being affected. You can do this by leaving the online survey. Once you have submitted your survey, you will need to provide your participant ID to withdraw, otherwise, it will be not be possible to identify your responses. If you are not able to provide your participant ID, we will keep the information that you have already provided for the purposes of achieving the objectives of the study only.

#### **What will happen to the results of the research?**

Your personal details will remain strictly confidential. Research findings made available in any reports or publications will not include information that can directly identify you without your specific consent.

#### **Where can I get more information?**

If you would like any further information, please contact a member of the research team (details can be found at the bottom of this document).

#### **What happens if there is a problem?**

If you are unhappy or have a concern about any aspect of this study, you should speak to the researchers who will do their best to answer your questions via [h.l.ravenhall@soton.ac.uk](mailto:h.l.ravenhall@soton.ac.uk). If you remain unhappy or have a complaint about any aspect of this study, please contact the University of Southampton Head Research Ethics and Governance (023 8059 5058, [rginfo@soton.ac.uk](mailto:rginfo@soton.ac.uk)). Please quote the ERGO-II number and note that by making a complaint, you might no longer be anonymous. More information on your rights as a study participant is available via this link: <https://www.southampton.ac.uk/about/governance/participant-information.page>

#### **How will we use information about you?**

For the purposes of data protection law, the University of Southampton is the 'Data Controller' for this study, we will need to use information that you provide us for this research project. People will use this information to do the research or to check your records to make sure that the research is being conducted properly. We will keep all the information about you safe and secure. Once we have finished the study, we will keep some of the data so that we can check the results. The write up will ensure that no-one can work out that you took part in the study.

- You can stop being part of the study at any time, without giving a reason. If you want to withdraw after submitting your questionnaire, you will need to provide your participant ID.
- We need to manage your records in specific ways for the research to be reliable. This means that we won't be able to let you see or change the data we hold about you.

#### **Where can you find out more about how your information is used?**

You can find out more about how we use your information:

- by sending an email to University's Data Protection Officer ([data.protection@soton.ac.uk](mailto:data.protection@soton.ac.uk)).
- by asking one of the research team or from our general privacy policy.
- by sending an email to a member of the research team: Hannah Ravenhall – [h.l.ravenhall@soton.ac.uk](mailto:h.l.ravenhall@soton.ac.uk), Professor Matthew Garner ([m.j.garner@soton.ac.uk](mailto:m.j.garner@soton.ac.uk)) or Dr Sarah Chellappa – [s.l.chellappa@soton.ac.uk](mailto:s.l.chellappa@soton.ac.uk)

**Thank you** for taking the time to read this information and for considering taking part in this study.

## Appendix G Qualtrics Survey: Participant Information

### Welcome to the research study!

Ethics/ERGO number: 100209 Version and date: Version 2.0, 19/12/2024

Thank you for your interest in this study. **We are exploring the relationship between sleep and emotional processing in late adolescence.** Your participation in this research is voluntary.

Please be assured that your responses will remain confidential and will be received without judgement. You have the right to withdraw at any point during the study without needing to provide a reason. If you would like to withdraw after you have submitted your answers, you must provide your Participant ID (which is provided once you have given consent). If you would like to contact the lead researcher to discuss this research, please email: h.l.ravenhall@soton.ac.uk.

**Overview:** Your participation should take you about **30 minutes**. After completion, you will then have the option to be entered into a prize draw for the opportunity to win an Amazon voucher (of which there will be 10 x £20, 5 x £50, and 1 x £100). At the end of the survey, you will be automatically directed to the prize draw (you may exit the survey at this stage if you do not wish to enter the draw). It is very important to us to conduct our studies in line with ethics principles, and the Consent Form asks you to confirm if you agree to take part in the above study. Please carefully consider the statements. Only tick the boxes if you agree to participate in this research and understand what this will mean for you. Please complete this on a **laptop OR desktop computer**. Please **do NOT complete it on a mobile phone or tablet** as some features will not be compatible. Please note, you will not be able to go back and change your answers throughout the survey.

Q2 First, please take time to read (or listen to via a text-to-speech function on your device) the Participant Information Sheet. Both documents contain the same information in different formats.

Participant Information Sheet Word document

Participant Information Sheet PDF Poster

Q3 I confirm that I read or listened to the Participant Information Sheet, explaining the study above and I understand what is expected of me.

☐

Tick the box to confirm

## Appendix H Qualtrics Survey: Consent Form

**Q4 Please tick the following boxes if you agree with the statements:**

Q5 I was given the opportunity to consider the information, ask questions about the study, and all my questions have been answered to my satisfaction.

☐ Tick the box to confirm

Q6 I agree to take part in this study and understand that data collected during this research project will be used for the purpose of this study.

☐ Tick the box to confirm

Q7 I understand that my participation is voluntary and that I am free to withdraw from this study at any time without giving a reason.

☐ Tick the box to confirm

Q8 I understand that if I withdraw from the study after I have submitted my survey, it may not be possible to remove my data as my personal information will not be linked to the study data.

☐ Tick the box to confirm

Q9 I understand that all personal information collected about me (e.g., contact details) will be kept confidential (i.e., will not be shared beyond the study team) unless required by law or relevant regulations (e.g., for the purpose of monitoring the safety of this study).

☐ Tick the box to confirm

Q10 I understand that my anonymised data collected during this study will be shared with research partners collaborating on this research.

☐ Tick the box to confirm

Q11 I understand that the information I provide on this consent form will not be linked to the study data, and therefore, my answers and responses in the questionnaires and tasks will be kept anonymous.

☐ Tick the box to confirm

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Q12 I understand that if I choose to enter the prize draw for one of the Amazon vouchers, then my personal details will be kept separately from the study and not be linked to the study data.

☐ Tick the box to confirm

Q13 I confirm that I would like to participate in this research.

☐ Yes, I wish to participate.

☐ No, I do not wish to participate.

***If 'No, I do not wish to participate' is selected, the survey ends.***

## Appendix I      Qualtrics Survey: Participant ID Generation

**Welcome to the research project!**    Here is your participant ID  
number: \${e://Field/Login%20ID}

Please type the participant ID number into the box below:

---

---

---

---

---

Please write this number down on a piece of paper or in the 'Notes' section of your phone. You will need this participant ID number later on in the study. You will also need this information if you wish to later withdraw from the study. Remember, you will not be able to go back to this page.

☐ I have taken note of my participant ID number

## Appendix J      Qualtrics Survey: Demographics and Pre-Survey Information

Please answer these pre-survey questions about yourself. Make sure you check your response before you click 'next' as you will not be able to go back and change your answers.

Age: How old are you?

- ☐ 16
- ☐ 17
- ☐ 18
- ☐ Other

***If 'Other' is selected, the survey ends.***

Q274 Select your date of birth:

|                    | Month                             | Day                | Year                     |
|--------------------|-----------------------------------|--------------------|--------------------------|
| Please Select: (1) | ▼ January (1 ...<br>December (12) | ▼ 1 (1 ... 31 (31) | ▼ 1900 (1 ... 2049 (150) |

## Appendix J

Q275 What time did you wake up this morning?

|                                | Hour / Minutes |    | AM/PM                 |                       |
|--------------------------------|----------------|----|-----------------------|-----------------------|
|                                | HH             | MM | AM                    | PM                    |
| Enter time (e.g.,<br>07 35 AM) |                |    | <input type="radio"/> | <input type="radio"/> |

Please outline your current education status

- ☐ I attend school, college or Sixth Form full-time
- ☐ I am completing an apprenticeship, internship or traineeship
- ☐ I am working or volunteering for 20 hours or more while in part-time education or training
- ☐ Other (please specify)

Which year are you in?

- ☐ Year 11
- ☐ Year 12/Lower Sixth/First Year of College
- ☐ Year 13/Upper Sixth/Second Year of College
- ☐ Other (please outline) \_\_\_\_\_

How do you describe yourself?

- ☐ Male
- ☐ Female
- ☐ Non-binary
- ☐ Prefer to self-describe \_\_\_\_\_

How would you best describe your ethnic origin?

\_\_\_\_\_

Where are you located? (Please enter your nearest town or city e.g. Southampton)

\_\_\_\_\_

Do you drink alcohol?

- ☐ Yes
- ☐ No

*Display this question:*

*If = Yes*

How many units do you have a week?

- ☐ Less than 3
- ☐ 3 - 5

- ☐ 6 - 10
- ☐ More than 10

Do you drink caffeinated drinks?

- ☐ Yes
- ☐ No

*Display this question:*

*If = Yes*

How many cups/cans do you drink per day?

- ☐ Less than 3
- ☐ 3 - 4
- ☐ More than 4

Do you smoke cigarettes or vape?

- ☐ Yes, I smoke
- ☐ Yes, I vape
- ☐ Yes, I smoke and I vape
- ☐ No, I do not smoke or vape

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Do you have any health issues (e.g., cardiovascular, diabetes, gastrointestinal disease, others)?

☐ Yes

☐ No

*Display this question:*

*If = Yes*

If yes, please describe

---

Do you have depression, anxiety, or an anxiety-related disorders?

☐ Yes

☐ No

*Display this question:*

*If = Yes*

If yes, please describe

---

Do you experience insomnia?

☐ Yes

☐ No

*Display this question:*

*If = Yes*

If yes, please describe

---

Do you take any medication (e.g., sleeping pills, heart medication, anti-allergic, others)?

☐ Yes

☐ No

*Display this question:*

*If = Yes*

If yes, please describe

---

## Appendix K    Qualtrics Survey: The Pittsburgh Sleep Quality Index (PSQI)

INSTRUCTIONS First, you will be asked questions about your sleep. If you share your bedroom with at least one other person, it will be helpful if they can answer some questions about your sleeping too. *(Make sure you check your responses before your click 'next' as you will not be able to go back and change your answers.)*

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

Q1 During the past month, what time have you usually gone to bed at night?

---

Q2 During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

---

Q3 During the past month, what time have you usually got up in the morning?

---

Q4 During the past month, how many hours of actual sleep did you get at night? (This might be different than the number of hours you spent in bed).

---

For each of the remaining questions, tick the one best response. Please answer all questions.

Q5a During the past month, how often have you had trouble sleeping because you **cannot get to sleep within 30 minutes?**

- ☐ Not during the past month
- ☐ Less than once a week
- ☐ Once or twice a week

- ☐ Three or more times a week

Q5b During the past month, how often have you had trouble sleeping because you **wake up in the middle of the night or early morning?**

- ☐ Not during the past month
- ☐ Less than once a week
- ☐ Once or twice a week
- ☐ Three or more times a week

Q5c During the past month, how often have you had trouble sleeping because you **have to get up to use the bathroom?**

- ☐ Not during the past month
- ☐ Less than once a week
- ☐ Once or twice a week
- ☐ Three or more times a week

Q5d During the past month, how often have you had trouble sleeping because you **cannot breathe comfortably?**

- ☐ Not during the past month
- ☐ Less than once a week
- ☐ Once or twice a week
- ☐ Three or more times a week

Q5e During the past month, how often have you had trouble sleeping because you **cough or snore loudly?**

- ☐ Not during the past month
- ☐ Less than once a week
- ☐ Once or twice a week
- ☐ Three or more times a week

Q5f During the past month, how often have you had trouble sleeping because you **feel too cold**?

- ☐ Not during the past month
- ☐ Less than once a week
- ☐ Once or twice a week
- ☐ Three or more times a week

Q5g During the past month, how often have you had trouble sleeping because you **feel too hot**?

- ☐ Not during the past month
- ☐ Less than once a week
- ☐ Once or twice a week
- ☐ Three or more times a week

Q5h During the past month, how often have you had trouble sleeping because you **had bad dreams**?

- ☐ Not during the past month
- ☐ Less than once a week
- ☐ Once or twice a week

- ☐ Three or more times a week

Q5i During the past month, how often have you had trouble sleeping because you **have pain**?

- ☐ Not during the past month

- ☐ Less than once a week

- ☐ Once or twice a week

- ☐ Three or more times a week

Q5j During the past month, have you had trouble sleeping because of other reasons?

- ☐ Yes

- ☐ No

*Display this question:*

*If Q5j = Yes*

Q5j Please describe the other reason(s) below:

---

*Display this question:*

*If Q5j = Yes*

Q5j How often during the past month have you had trouble sleeping because of this?

- ☐ Not during the past month

- ☐ Less than once a week

- ☐ Once or twice a week

- ☐ Three or more times a week

Q6 During the past month, how would you rate your sleep quality overall?

- ☐ Very good
- ☐ Fairly good
- ☐ Fairly bad
- ☐ Very bad

Q7 During the past month, how often have you taken medicine to help you sleep (prescribed or over-the-counter medicines)?

- ☐ Not during the past month
- ☐ Less than once a week
- ☐ Once or twice a week
- ☐ Three or more times a week

Q8 During the past month, how often have you had trouble staying awake during class, eating meals, or engaging in social activity?

- ☐ Not during the past month
- ☐ Less than once a week
- ☐ Once or twice a week
- ☐ Three or more times a week

Q9 During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

- ☐ No problem at all

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- ☐ Only a very slight problem
- ☐ Somewhat of a problem
- ☐ A very big problem

## Appendix L    Qualtrics Survey: Sleep Regularity

### Questionnaire

Instructions: Thinking about how you usually sleep, how much do you agree with the statements below. There are no right or wrong answers. Don't spend too much time on any one statement. *(Make sure you check your responses before your click 'next' as you will not be able to go back and change your answers.)*

|                                                           | Not at all            | A little bit          | Somewhat              | Moderately            | Very much             |
|-----------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| I go to bed at about the same time every night            | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I wake for about the same number of times each night      | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I spend about the same amount of time awake each night    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I wake up at about the same time each morning             | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I get out of bed at about the same time each morning      | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I am asleep for about the same amount of time every night | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

## Appendix M Qualtrics Survey: Spielberg State Anxiety Scale

Please state how you feel **right now**: *(Make sure you check your responses before your click 'next' as you will not be able to go back and change your answers.)*

|                          | Not at all            | Somewhat              | Moderately            | Very much             |
|--------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Right now I feel calm    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Right now I am tense     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Right now I feel upset   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Right now I am relaxed   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Right now I feel content | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Right now I am worried   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

## Appendix N Qualtrics Survey: Morningness-Eveningness Questionnaire

**Instructions:** Please read each question carefully before answering. Each question should be answered independently of others - you will NOT be able to go back and check or change your answers. Please answer each question as honestly as possible and make any comments in the section provided below.

1 Considering only your own 'feeling best' rhythm, at what time would you get up if you were entirely free to plan your day?

|     | Before<br>5am         | 5am                   | 5:30am                | 6am                   | 6:30am                | 7am                   | 7:30am                | 8am                   | 8:30am                | 9am                   | 9:30am                | 10am                  | 10:30am               | 11am                  | 11:30am               | Midday                | Later<br>than<br>midday |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-------------------------|
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   |

2 Considering only your own 'feeling best' rhythm, at what time would you go to bed if you were entirely free to plan your evening?

|     | Before<br>8pm         | 8pm                   | 8:30pm                | 9pm                   | 9:30pm                | 10pm                  | 10:30pm               | 11pm                  | 11:30pm               | Midnight              | 12:30am               | 1am                   | 1:30am                | 2am                   | 2:30am                | 3am                   | Later<br>than<br>3am  |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

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3 If there is a specific time at which you have to get up in the morning, to what extent are you dependent on being woken up by an alarm?

|     | Not at all dependent  | Slightly dependent    | Fairly dependent      | Very dependent        |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

4 Assuming adequate environmental conditions, how easy do you find getting up in the mornings?

|     | Not at all easy       | Not very easy         | Fairly easy           | Very easy             |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

5 How alert do you feel during the first half-hour after having woken in the mornings?

|     | Not at all alert      | Slightly alert        | Fairly alert          | Very alert            |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

6 How is your appetite during the first half-hour after having woken in the mornings?

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|     | Very poor             | Fairly poor           | Fairly good           | Very good             |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

7 During the first half-hour after having woken in the morning, how tired do you feel?

|     | Very tired            | Fairly tired          | Fairly refreshed      | Very refreshed        |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

8 When you have no commitments the next day, at what time do you go to bed compared to your usual bedtime?

|     | Seldom or never<br>later | Less than one hour<br>later | 1-2 hours later       | More than two<br>hours later |
|-----|--------------------------|-----------------------------|-----------------------|------------------------------|
| (1) | <input type="radio"/>    | <input type="radio"/>       | <input type="radio"/> | <input type="radio"/>        |

9 You have decided to engage in some physical exercise. A friend suggests that you do this one hour, twice a week, and the best time for them is between 7am and 8am. Bearing in mind nothing else but your own 'feeling best' rhythm, how do you think you would perform?

|     | Would be on good form | Would be on reasonable form | Would find it difficult | Would find it very difficult |
|-----|-----------------------|-----------------------------|-------------------------|------------------------------|
| (1) | <input type="radio"/> | <input type="radio"/>       | <input type="radio"/>   | <input type="radio"/>        |

10 At what time in the evening do you feel tired and, as a result, in need of sleep?

|     | Before 8pm            | 8pm                   | 8:30pm                | 9pm                   | 9:30pm                | 10pm                  | 10:30pm               | 11pm                  | 11:30pm               | Midnight              | 12:30am               | 1am                   | 1:30am                | 2am                   | 2:30am                | 3am                   | Later than 3am        |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

## Appendix N

11 You wish to be at your peak performance for a test which you know is going to be mentally exhausting and lasting for two hours. You are entirely free to plan your day and considering only your own 'feeling best' rhythm, which ONE of the four testing times would you choose?

|     | 8am - 10am            | 11am - 1pm            | 3pm - 5pm             | 7pm - 9pm             |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

12 If you went to bed at 11pm, at what level of tiredness would you be?

|     | Not at all tired      | A little tired        | Fairly tired          | Very tired            |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

13 For some reason, you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which ONE of the following events are you most likely to experience?

- ☐ Will wake up at usual time and will NOT fall back to sleep
- ☐ Will wake up at usual time and will doze thereafter
- ☐ Will wake up at usual time but will fall asleep again
- ☐ Will not wake up until later than usual

14 One night, you have to remain awake between 4am and 6am in order to carry out a night watch. You have no commitments the next day. Which ONE of the following alternatives will suit you best?

- ☐ Would NOT go to bed until the watch was over
- ☐ Would take a nap before and sleep after
- ☐ Would take a good sleep before and nap after
- ☐ Would take ALL sleep before watch

## Appendix N

15 You have to do two hours of hard physical work. You are entirely free to plan your day and considering only your own 'feeling best' rhythm, which ONE of the following times would you choose?

|     | 8am - 10am            | 11am - 1pm            | 3pm - 5pm             | 7pm - 9pm             |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

16 You have decided to engage in some physical exercise. A friend suggests that you do this one hour, twice a week, and the best time for them is between 10pm and 11pm. Bearing in mind nothing else but your own 'feeling best' rhythm, how do you think you would perform?

|     | Would be on good form | Would be on reasonable for | Would find it difficult | Would find it very difficult |
|-----|-----------------------|----------------------------|-------------------------|------------------------------|
| (1) | <input type="radio"/> | <input type="radio"/>      | <input type="radio"/>   | <input type="radio"/>        |

17 Suppose that you can choose your own work hours. Assume that you work a **five** hour day (including breaks) and that your job was interesting and paid by results. Which hour would you choose to **start** your five hour shift (if you have to complete all five hours in one go)?

|     | Midnight              | 1am                   | 2am                   | 3am                   | 4am                   | 5am                   | 6am                   | 7am                   | 8am                   | 9am                   | 10am                  | 11am                  | Midday                | 1pm                   | 2pm                   | 3pm                   | 4pm                   | 5pm                   | 6pm                   | 7pm                   | 8pm                   | 9pm                   | 10pm                  | 11pm                  |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

18 At what time of the 24 hour day do you think that you reach your 'feeling best' peak?

Appendix N

|     |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |                       |
|-----|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|     | Midnight              | 1am                   | 2am                   | 3am                   | 4am                   | 5am                   | 6am                   | 7am                   | 8am                   | 9am                   | 10am                  | 11am                  | Midday                | 1pm                   | 2pm                   | 3pm                   | 4pm                   | 5pm                   | 6pm                   | 7pm                   | 8pm                   | 9pm                   | 10pm                  | 11pm                  |
| (1) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

19 You might have heard about 'morning' and 'evening' types of people. Which ONE of these types do you consider yourself to be?

|     |                                  |                                                                  |                                                                  |                                   |
|-----|----------------------------------|------------------------------------------------------------------|------------------------------------------------------------------|-----------------------------------|
|     | Definitely a<br>'morning' person | Rather more a<br>'morning' person<br>than an 'evening'<br>person | Rather more an<br>'evening' person<br>than a 'morning'<br>person | Definitely an<br>'evening' person |
| (1) | <input type="radio"/>            | <input type="radio"/>                                            | <input type="radio"/>                                            | <input type="radio"/>             |

## Appendix O    Qualtrics Survey: Insomnia Severity Index

For each statement, select the option that best describes you. Please state your **current severity** (i.e., the last two weeks). *(Make sure you check your responses before your click 'next' as you will not be able to go back and change your answers.)*

|                              | None                  | Mild                  | Moderate              | Severe                | Very Severe           |
|------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Difficulty falling asleep    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Difficulty staying asleep    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Problems waking up too early | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

How **satisfied/dissatisfied** are you with your **current** sleep pattern?

- ☐ Very Satisfied
- ☐ Satisfied
- ☐ Moderately Satisfied
- ☐ Dissatisfied
- ☐ Very Dissatisfied

How **noticeable** to others do you think your sleep problem (if any) is in terms of impairing the quality of your life?

- ☐ Not at all noticeable

## Appendix O

- ☐ A Little
- ☐ Somewhat
- ☐ Much
- ☐ Very Much Noticeable

How **worried/distressed** are you about your current sleep problem?

- ☐ Not at all worried
- ☐ A Little
- ☐ Somewhat
- ☐ Much
- ☐ Very Much Worried

To what extent do you consider your sleep problem (if you have one) to **interfere** with your daily functioning (e.g., daytime fatigue, mood, ability to function, concentration, memory, mood, etc.) **currently**?

- ☐ Not at all interfering
- ☐ A Little
- ☐ Somewhat
- ☐ Much
- ☐ Very Much Interfering

## Appendix P    Qualtrics Survey: Generalized Anxiety Disorder Scale (GAD-7)

Q1 Over the last two weeks, how often have you been bothered by the following problems?  
*(Make sure you check your responses before your click 'next' as you will not be able to go back and change your answers.)*

|                                                    | Not at all            | Several days          | More than half the days | Nearly every day      |
|----------------------------------------------------|-----------------------|-----------------------|-------------------------|-----------------------|
| Feeling nervous, anxious, or on edge               | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Not being able to stop or control worrying         | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Worrying too much about different things           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Trouble relaxing                                   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Being so restless that it is hard to sit still     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Becoming easily annoyed or irritable               | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Feeling afraid, as if something awful might happen | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |

## Appendix P

Q308 Over the last two weeks, how often have you been bothered by the following problems?  
*(Make sure you check your responses before your click 'next' as you will not be able to go back and change your answers.)*

|                                                    | Not at all            | Several days          | More than half the days | Nearly every day      |
|----------------------------------------------------|-----------------------|-----------------------|-------------------------|-----------------------|
| Feeling nervous, anxious, or on edge               | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Not being able to stop or control worrying         | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Worrying too much about different things           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Trouble relaxing                                   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Being so restless that it is hard to sit still     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Becoming easily annoyed or irritable               | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Feeling afraid, as if something awful might happen | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |

## Appendix Q    Qualtrics Survey: Patient Health

### Questionnaire (PHQ-9)

Over the last two weeks, how often have you been bothered by the following problems? (Make sure you check your responses before you click 'next' as you will not be able to go back and change your answers.)

|                                                                                                  | Not at all            | Several Days          | More than half the days | Nearly every day      |
|--------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-------------------------|-----------------------|
| Little interest or pleasure in doing things.                                                     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Feeling down, depressed, or hopeless.                                                            | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Trouble falling or staying asleep, or sleeping too much.                                         | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Feeling tired or having little energy.                                                           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Poor appetite or overeating.                                                                     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Feeling bad about yourself - or that you are a failure or have let yourself or your family down. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |
| Trouble concentrating on things, such as treading the                                            | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> |

## Appendix Q

newspaper or  
watching television.

Moving or speaking  
so slowly that other  
people could have  
noticed, or the  
opposite - being so  
fidgety or restless  
that you have been  
moving around a  
lot more than  
usual.

Thoughts that you  
would be better off  
dead or hurting  
yourself in some  
way.

☐☐☐☐☐☐☐☐

If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?

☐

Not difficult at all

☐

Somewhat difficult

☐

Very difficult

☐

Extremely difficult

## Appendix R Qualtrics Survey: KIDSCREEN-10

Thinking about the **last week...**

|                                                                                           | Never/Not at<br>all   | Seldom/Slightly       | Moderately/Quite<br>Often | Very/Very<br>Often    | Always/Extremely      |
|-------------------------------------------------------------------------------------------|-----------------------|-----------------------|---------------------------|-----------------------|-----------------------|
| Have you felt<br>fit and well?                                                            | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Have you felt<br>full of<br>energy?                                                       | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Have you felt<br>sad?                                                                     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Have you felt<br>lonely?                                                                  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Have you had<br>enough time<br>for yourself?                                              | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Have you<br>been able to<br>do the things<br>that you want<br>to do in your<br>free time? | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Have your<br>parent(s)<br>treated you<br>fairly?                                          | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Have you had<br>fun with your<br>friends?                                                 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |

## Appendix R

Have you got  
on well at  
school?

☐☐☐☐☐

Have you  
been able to  
pay  
attention?

☐☐☐☐☐

In general, how would you say your health is?

☐

Excellent

☐

Very good

☐

Good

☐

Fair

☐

Poor

## Appendix S    Qualtrics Survey: Emotional Tasks

Now, click this **link** which will take you to your first task. The task will open in a separate window. Once you have completed the task, please return here to confirm you have completed the task before moving on to the next section.

☐ I confirm I have completed Task

Now, click this **link** which will take you to your second task. The task will open in a separate window. Once you have completed the task, please return here to confirm you have completed the task before moving on to the next section.

☐ I confirm I have completed Task 2

## Appendix T Qualtrics Survey: Debrief

### Debrief

**Thank you for taking part in this project.**

Please read this debrief which outlines more information about your participation. You can also download the debrief poster, if you wish to read it later.

**Once you have read the debrief information, click the 'next' arrow in the survey and you will be directed to the prize draw. If you do not wish to enter the prize draw, you may exit the survey after this page.**

The **main aims** of this research were to explore the relationship between your sleep quality and the regularity of your sleep patterns with emotional processing (i.e., how well people manage and understand emotions) as it may be linked to the prevalence of anxiety in the adolescent population. We are also hoping to understand more about 'sleep inertia' (which is the grogginess some of us experience when we wake up in the mornings).

We are expecting that:

- if you have poorer quality sleep, you will show decreased accuracy and/or speed in emotional processing tasks
- if you have more irregular sleeping patterns, you will show decreased accuracy and/or speed in emotional processing tasks
- if you experience more sleep inertia, you will show decreased accuracy and/or speed in emotional processing tasks

By analysing your responses, we can learn more about the link between sleep and emotions, which can help to inform future recommendations about sleep and mental health/wellbeing. Your data will help our understanding of this. The results of this study will not include your name or any other identifying information. If you would like to see the final report when it is complete, please email us. Please note that by providing your contact details, your participation in the study might no longer be anonymous (however, the researcher/s will not know what information you provided as it will not be linked to your data within the larger field of information). If taking part in this study caused you any discomfort or distress, we recommend you speak to an adult you know and trust. You may also find these links to organisations helpful:

- NHS (sleep: <https://www.nhs.uk/live-well/sleep-and-tiredness/> or mental health: <https://www.nhs.uk/every-mind-matters/mental-health-issues/sleep/>),

- ChildLine: <https://www.childline.org.uk/info-advice/your-feelings/feelings-emotions/problems-sleeping/>
- YoungMinds: <https://www.youngminds.org.uk/young-person/my-feelings/sleep-problems/>

If you would like to learn more about this area of research, you can refer to these papers:

- Sleep and emotional processing (a link to: Tempesta, D., Socci, V., De Gennaro, L., & Ferrara, M. (2018). Sleep and emotional processing. *Sleep medicine reviews*, 40, 183-195.)
- Associations between social jetlag and mental health in young people (a link to: Henderson, S. E., Brady, E. M., & Robertson, N. (2019). Associations between social jetlag and mental health in young people: A systematic review. *Chronobiology international*, 36(10), 1316-1333.)
- Sleep inertia: current insights (a link to: Hilditch, C. J., & McHill, A. W. (2019). Sleep inertia: current insights. *Nature and science of sleep*, 155-165.)

If you have any concerns or questions about this study, please contact Hannah Ravenhall (lead researcher: [h.l.ravenhall@soton.ac.uk](mailto:h.l.ravenhall@soton.ac.uk)) who will do their best to help. If you remain unhappy or would like to make a formal complaint, please contact the Head of Ethics and Governance, University of Southampton (email: [rgoinfo@soton.ac.uk](mailto:rgoinfo@soton.ac.uk) or phone: + 44 2380 595058) and quote the Ethics/ERGO number: 100209 Please note: there is some information in this document that we chose not to share with you prior to the study as it may have impacted your actions and response. **We, therefore, ask that you do not discuss or show this information to anyone who is yet to complete the study as it could impact the results.**

**Thank you again for your participation in this research.**

Researchers: Hannah Ravenhall ([h.l.ravenhall@soton.ac.uk](mailto:h.l.ravenhall@soton.ac.uk)), Professor Matthew Garner ([m.j.garner@soton.ac.uk](mailto:m.j.garner@soton.ac.uk)), Dr Sarah Chellappa ([s.l.chellappa@soton.ac.uk](mailto:s.l.chellappa@soton.ac.uk))

Version and date: Version 2.0, 18/12/2024

# Debrief

## Thank you for taking part in this project!

Your contribution is valuable and greatly appreciated.

Once you have read the debrief information, click the 'next' arrow in the survey and you will be directed to the prize draw. If you do not wish to enter the prize draw, you can exit after this page.

### Purpose of this study

The main aims of this research were to explore the relationship between your sleep quality and the regularity of your sleep patterns with emotional processing (i.e., how well people manage and understand emotions) as it may be linked to the prevalence of anxiety in the adolescent population.

We are also hoping to understand more about 'sleep inertia' (which is the grogginess some of us experience when we wake up in the mornings).

### What are we expecting?

We are expecting that:

- if you have poorer quality sleep, you will show decreased accuracy and/or speed in emotional processing tasks.
- if you have more irregular sleeping patterns, you will show decreased accuracy and/or speed in emotional processing tasks
- if you experience more sleep inertia, you will show decreased accuracy and/or speed in emotional processing tasks

By analysing your responses, we can learn more about the link between sleep and emotions, which can help to inform future recommendations about sleep and mental health/wellbeing. Your data will help our understanding of this.

Please note: there is some information in this document that we chose not to share with you prior to the study as it may have impacted your actions and responses. We, therefore, ask that you do not discuss or show this information to anyone who is yet to complete the study as it could impact the results.

### Results

The results of this study will not include your name or any other identifying information. If you would like to see the final report when it is complete, please email us. Please note that by providing your contact details, your participation in the study might no longer be anonymous (however, the researcher/s will not know what information you provided as it will not be linked to your data within the larger field of information).

### Further info

If taking part in this study caused you any discomfort or distress, we recommend you speak to an adult you know and trust. You may also find these links to organisations helpful: NHS ([sleep](#) or [mental health](#)), [ChildLine](#) or [YoungMinds](#).

If you would like to learn more about this area of research, you can refer to these papers:

- [Sleep and emotional processing](#)
- [Associations between social jetlag and mental health in young people](#)
- [Sleep inertia: current insights](#)

If you have any concerns or questions about this study, please contact Hannah Ravenhall (lead researcher: [h.j.ravenhall@soton.ac.uk](mailto:h.j.ravenhall@soton.ac.uk)) who will do their best to help. If you remain unhappy or would like to make a formal complaint, please contact the Head of Ethics and Governance, University of Southampton (email: [rginfo@soton.ac.uk](mailto:rginfo@soton.ac.uk) or phone: + 44 2380 595058) and quote the Ethics/ERGO number: 100209. Please note that if by making a complaint, you might be no longer anonymous.

Ethics/ERGO-II number: 100209

Researchers: Hannah Ravenhall, Professor Matthew Garner, Dr Sarah Chellappa

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Version and date: Version 2.0, 18/12/2024

Thank you again for your participation in this research.