Thesis

The Relationship Between Sleep, Interoception, and Autistic Traits – What Role Does Thermoregulation Play?

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‘Recharge’

“Sleep will recharge

The body and the mind

But nothing restores the heart

Except goodness

So let no good thing

Pass unnoticed

And let every great thing

Be celebrated

For all its worth and wonder

To keep your heart renewed”

by David Gate (2025 - used with permission)

Abstract

Autistic individuals often experience differences in interoception, including difficulties perceiving or interpreting bodily signals (Shah et al., 2016), and commonly report sleep disturbances (Pavlopoulou, 2020). Thermoregulation, which depends on interoceptive feedback, plays a key role in sleep onset and maintenance (Harding et al., 2020). Although interoception is closely linked to sleep regulation (Wei & Van Someren, 2020), no research has directly examined the relationship between sleep, interoception, and thermoregulation in autism. This study investigated whether interoceptive abilities, thermoregulation, and autistic traits predict sleep difficulties in adults.

A general population sample (N = 234) completed an online survey assessing global sleep difficulty (GSD) (measure: PSQI), alongside measures of interoceptive attention (IAT), interoceptive accuracy (IAS), temperature sensitivity (STRAQ-1), trait anxiety (GAD-7), and autistic traits (AQ-28).

FDR-corrected correlations showed that GSD was positively associated with trait anxiety ($r = .436$, $p < .001$), interoceptive attention ($r = .195$, $p = .019$), and high temperature sensitivity ($r = .227$, $p = .022$), and negatively associated with interoceptive accuracy ($r = –.178$, $p = .028$). Hierarchical regression for GSD showed that trait anxiety ($\beta = .46$, $p < .001$) and age ($\beta = .24$, $p < .001$) were the only significant predictors, explaining 27% of the variance in GSD ($F(9, 224) = 9.39$, $R^2 = .27$, $p < .001$). A separate regression model predicting sleep latency (SOL) found that trait anxiety was the only

significant predictor, though the model explained a modest amount of variance ($F(1, 232) \approx 3.66$, $R^2 = .031$, $p = .027$).

These findings underscore the central role of anxiety in sleep disturbance and support further research into interoceptive profiles in autistic and sensory-sensitive individuals. Interventions targeting anxiety and interoception may offer novel pathways for improving sleep in neurodivergent populations.

Table of Contents

1.1.1. Positionality Statement

As an allistic person who has worked with autistic people for over 20 years, I have had the opportunity to spend a lot of time with experts by experience. I have learned a lot and am still learning from autistic clients, colleagues, friends, and family. The privilege of spending this amount of time with autistic people, has meant I have been able to get to know many autistic people well, and see their unique personalities and gifts, and value the importance of their contribution to my life and to the communities they are a part of. Working primarily in social care support-worker roles with autistic adults who also have an intellectual disability, I value the social model of disability, having seen first-hand the barriers that there are to neurodivergent people who want to engage in employment, education, community, and citizenship. While I see importance in diagnosis, and acknowledge the multitude of difficulties autistic people face, I believe that the DSM-5 and ICD-11 parameters for autism have a solely deficit focus and this may overlook the inherent strengths that an autistic person may have. Having supported individuals in seeking help with their health and mental health, I have seen how our systems, interventions, and approaches to autistic people can lack a fundamental understanding of their experiences and needs. I believe clinicians and mental health organisations need to continually engage in evaluating whether interventions, theories, and processes can be further adapted to improve their efficacy

and accessibility for individuals who can often be misunderstood, mistreated, and overlooked.

Having spent the majority of my career working overnight shifts in supported living settings, I have seen first-hand how sleep difficulties can impact a person's life, and how sensory issues and adaptations can make significant differences to people. As a practitioner, the concept of interoception has been an incredibly useful additional lens for understanding the experiences of people with neurodevelopmental conditions. My motivation in doing this research is that we might take steps towards greater understanding of the processes and difficulties relating to sleep and interoception. I hope increased research in this area will contribute to better informed interventions, more collaboration, and more peaceful sleep.

1.1.2 Statement on Terminology

This thesis uses identity-first language (IFL) and adopts terminology recommended by autistic individuals during a pre-study public and patient involvement (PPI). While preferences for terminology vary across regions and individuals (Bury et al., 2023; Taboas et al., 2023), the terms 'autistic people' and 'autism' will be used throughout this thesis to refer to individuals and the condition, respectively. These were the preferred terms of the autistic contributors consulted for this project and are also supported in recent empirical research. For example, Amaral et al. (2023) conducted a large international study and found that nearly four-fifths of participants approved of identity-first terminology. Similarly, Botha et al. (2023) and Flowers et al. (2023) argue

that IFL is more affirming and aligns with a neurodiversity-affirming perspective, while person-first language (PFL) can inadvertently pathologise autistic identity.

Despite this preference among autistic individuals, recent reviews of published literature indicate that PFL remains dominant in academic publishing (Zajic & Gudknecht, 2024; Grech et al., 2023). This discrepancy highlights the importance of aligning research language with the voices of the community being studied. As Vivanti (2020) and Botha (2021) argue, language is not neutral; it reflects underlying values and has implications for stigma, autonomy, and inclusion in research.

The term ‘allistic’ is used here to describe people who are not autistic. This is preferred over neurotypical, as not all non-autistic individuals are neurotypical. Additionally, the term neurodivergent is not used synonymously with autism in this thesis. While autism is one kind of neurodivergence, the term also encompasses other neurodevelopmental differences, such as ADHD, dyspraxia, or dyslexia.

In summary, the language used in this thesis reflects both the preferences of autistic individuals consulted during the research design and a growing consensus in the literature advocating for identity-affirming terminology. By being intentional with language, this study aims to align with ethical, respectful, and neurodiversity-informed research practice.

1.1.2.1 Glossary: Definitions and Acronyms

Definitions:

Interoception – The process by which the nervous system senses, interprets, and integrates signals originating from within the body, such as hunger, heart rate, and body temperature. The parameters and limitations of interoception are much debated, as will be discussed in section 1.1.6. In this study, I am taking a definition of interoception that includes cutaneous termperature and pain signals alongside visceral afferents when they carry homeostatic information (Crucianelli & Ehrsson, 2022). In considering interoceptive processes, I am also including processing from preconscious to metacognitive levels (Suksasilp & Garfinkel, 2022).

Interoceptive Attention – The tendency to notice or focus on internal bodily sensations, such as heartbeat or breathing.

Interoceptive Accuracy – The objective ability to correctly perceive internal bodily signals, often measured by behavioural tasks. Also used to refer to the subjective beliefs about that ability. Subjective interoceptive accuracy is measured in the current study.

Thermoregulation – The physiological process by which the body maintains a stable internal temperature through autonomic and behavioural responses. The overall process of thermoregulation includes, and is dependent on, thermoception. Thermoregulation processes involve both conscious and unconscious thermoception, and autonomic processes, as well as conscious and unconscious behavioural

processes. References to thermoregulation within this thesis include thermoceptive processes as well as thermoregulatory behaviours. The term thermoception will be used when referring solely to the perception of body temperature.

Thermoception – The sensory perception of temperature changes on or within the body.

Sleep Onset – The transition from wakefulness to sleep, typically marked by the first occurrence of non-REM Stage 1 sleep.

Sleep Latency – The length of time it takes to fall asleep after attempting to do so. This is also referred to as sleep onset latency in some literature (SOL).

REM Sleep – Rapid Eye Movement sleep; a sleep stage associated with vivid dreams and heightened brain activity.

NREM Sleep – Non-Rapid Eye Movement sleep; encompasses sleep stages 1–4, including deep slow-wave sleep important for physical restoration.

Autism – A neurodevelopmental condition characterised by difficulties in social communication and interaction, along with restricted and repetitive behaviours or interests.

Sensory Sensitivity – Heightened or reduced sensitivity to sensory stimuli, including touch, sound, light, or internal bodily signals.

Alexithymia – A trait characterised by difficulty identifying and describing one's own emotional states, often associated with interoceptive difficulties.

Acronyms

PSQI – Pittsburgh Sleep Quality Index; a self-report questionnaire assessing sleep quality and disturbances over a one-month period.

AQ-28 – Autism Spectrum Quotient (28-item version); a self-report measure used to assess traits associated with autism in adults.

IAT – Interoceptive Attention Task or Scale; refers to the measure used to assess self-reported attention to bodily signals.

IAS – Interoceptive Accuracy Scale; a self-report measure of confidence in accurately interpreting bodily signals.

GAD-7 – Generalized Anxiety Disorder 7-item scale; a validated screening tool for anxiety symptoms.

STRAQ-1 – Self-Thermoregulatory Questionnaire version 1; a measure assessing thermoregulatory behaviours and sensitivities.

GSD – Global Sleep Difficulty; an index or score reflecting overall sleep disturbance, typically derived from PSQI scores.

SOL – Sleep Onset Latency; the time it takes to fall asleep, often self-reported or measured in sleep studies. The literature refers to this delay between trying to sleep, and falling asleep as sleep latency, or sleep onset latency.

EEG – Electroencephalogram; a method of measuring electrical activity in the brain, commonly used in sleep and neuroscience research.

CBT-i – Cognitive Behavioural Therapy for Insomnia; an evidence-based psychological intervention targeting sleep difficulties.

ACT-i – Acceptance and Commitment Therapy for insomnia. ACT is a ‘third-wave’ approach that combines cognitive and mindful approaches in order to promote psychological flexibility.

1.1.3 Clinical Importance of Understanding Autistic Sleep Difficulties and Mental Health Difficulties.

Autistic individuals often experience sleep difficulties, such as insomnia, night-time waking and reporting poor sleep quality (Pavlopoulou et al, 2020). General clinical approaches to sleep difficulties may involve a sleep hygiene approach, or treatment with cognitive behavioural therapy for insomnia (CBT-i) which has a good evidence base in treating the general population. Despite there being a wide range of published articles exploring the efficacy of CBT-i when applied to autistic children, to date there are currently no published peer reviewed articles in English investigating CBT-i for autistic adults (Lawson et al, 2023; and my own literature search). Sleep hygiene approaches are also not sufficiently tailored to autistic populations with research indicating that autistic people often find these approaches ineffective (Pavlopoulou et al, 2020).

Autistic people are more likely to be affected by mental health difficulties that the general population (Jolliffe et al., 2023). They are also more likely to experience sleep difficulties and have difficulty accessing mental health treatments (Mandy, 2022). There is a pressing need for clinical interventions into sleep to be better-informed and more effective for this population. (Nijhof et al., 2024; Pavlopoulou, 2020).

Clinical psychologists and other mental health professionals frequently ask their patients about sleep and aim to support individuals in overcoming sleep difficulties (Alfano et al., 2009). Sleep and mental health are deeply interrelated, with disturbances in one domain often influencing the other (Alfano et al., 2009; Arora et al., 2021; Freeman et al., 2017). Poor sleep can increase vulnerability to stress, reduce emotional resilience, and exacerbate symptoms of anxiety and depression (Baglioni et al., 2016; Gregory & Sadeh, 2016). Conversely, mental health difficulties—especially anxiety and mood disorders—can disrupt sleep through mechanisms such as hyperarousal, intrusive thoughts, and dysregulated circadian rhythms (Harvey, 2002; Riemann et al., 2010). This bidirectional relationship creates a feedback loop: poor sleep undermines mental health, and psychological distress further impairs sleep quality. Clinicians therefore often undertake sleep interventions not only to improve rest, but also to reduce psychological symptoms and enhance the effectiveness of broader therapeutic work. These issues are especially pertinent for autistic adults, who are more likely to experience sleep difficulties than the general population, and yet there is a lack of published informing how their sleep difficulties should be treated ((Lawson, 2024; Pavlopoulou, 2020).

UK national guidance reflects the importance of recognising and treating sleep problems as a key component of mental health care. The NICE guidelines on insomnia recommend Cognitive Behavioural Therapy for Insomnia (CBT-i) as the first-line treatment for chronic sleep problems (NICE CKS, 2024). The British Psychological Society (BPS) also acknowledges the relevance of sleep in psychological wellbeing and

encourages psychologists to integrate sleep formulation into therapeutic practice where appropriate (BPS, 2022). Additionally, NHS England's long-term plan emphasises the integration of physical and mental health, with sleep recognised as a relevant factor in both domains. For autistic individuals, where sleep problems are particularly common and persistent, this guidance supports the need for autism-informed, individually tailored interventions.

Mental health interventions conducted by clinical psychologists should be grounded in psychological formulation (Thrower et al., 2024). Formulation involves the collaborative development of a shared understanding of a client's difficulties, based on psychological theory and individual context. It is not a one-off process but a dynamic, evolving hypothesis that helps guide assessment and treatment. In autism, formulation must consider neurodevelopmental factors, sensory differences, communication preferences, and autistic identity (Maddox et al., 2020). There is growing awareness that interventions must be adapted for autistic people in order to be effective, rather than assuming that generic models will be equally valid across neurotypes (Crane et al., 2019; Cooper et al., 2022).

Research shows that autistic people are more likely than allistic people to experience trauma (Kerns et al., 2015, 2020), mental health difficulties (Kelly et al., 2008), and sleep disruption (Morgan et al., 2020; Nijhof et al., 2024). However, despite the high prevalence and interconnectedness of these challenges, research and intervention often address them in isolation. In order to provide comprehensive, autism-

informed care, a deeper understanding is required of how these domains are related for autistic people—and how interventions can best support them in real-world settings.

Historically, a large proportion of autism research has focused on the aetiology and diagnosis of autism rather than the lived experiences of autistic individuals. More recent calls from the autistic community and neurodiversity-informed researchers (Botha et al., 2023; Milton, 2012) stress the importance of participatory research that centres autistic perspectives and priorities. Understanding sleep is one of these priorities. Sleep plays a critical role in emotional regulation, mental health, learning, and overall quality of life (Alfano et al., 2009; Buysse et al., 1989; Chokroverty, 2017; Freeman et al., 2017). If we are to develop more effective interventions for sleep in autistic adults, we must start by improving our understanding of both autism and the ways in which sleep processes may differ for this population.

Autistic people are more likely to experience mental health difficulties than the general population (Kelly, et al., 2008; Rumball, 2019). They are also more likely to experience trauma and post-traumatic stress (Kerns et al., 2020; Kerns et al., 2015) and this experience of trauma has gone unrecognised for a long time (Rumball, 2019). Autistic people can also have difficulty engaging with institutions in order to access services (Shaw et al., 2023; Maddox et al., 2020), and engaging in talk-therapies (Schwartzman et al., 2023; Maddox et al, 2020). These difficulties, along with problems in attaining an accurate diagnosis, are contributors to the current mental health crisis for autistic people (Mandy, 2022). There is a need for clinical psychologists and other

mental health clinicians to increase their awareness of autism, their understanding of the challenges autistic people experiences, and the ways interventions may need to be adapted for autistic individuals (Maddox et al., 2020). This need extends to the need for clinicians to understand sleep difficulties for autistic people and to adapt interventions appropriately for each autistic individual. Given the increased awareness of the importance of autistic sensory differences (Lawson, 2024; Shah et al., 2016), it is important that efforts to understand sleep difficulties also include understanding the role that sensory differences might have in sleep processes, and in any possible sleep interventions.

1.1.4 Autism as a complex and evolving construct

Autism is a neurodevelopmental condition that can present in a wide variety of ways, affecting cognition, sensory processing, and social interaction. Autistic people often have a highly focussed area of interest or expertise (Murray et al., 2005). Their focus maybe be hard for others to understand (Milton et al., 2023). Allistic and autistic people can often have difficulties understanding each other (Milton et al., 2023). According to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; American Psychiatric Association [APA], 2013), Autism Spectrum Disorder (ASD) is defined by:

- Persistent deficits in the reciprocation of social interactions and communication.
- Restricted or repetitive patterns of behaviour, interests, or activities.

The DSM-5 stipulates that signs from these two categories of symptoms must have been present early on in childhood development and must cause a significant impairment to functioning in social, occupational or other spheres of life. The International Classification of Diseases, 11th Revision (ICD-11) also describes two similar symptom categories for Autism Spectrum Disorder. The ICD-11 specifically mentions sensory processing difficulties under the category of restricted, repetitive behaviours, whereas the DSM-5 mentions sensory sensitivities without mention of processing difficulties. Both diagnostic manuals differ in how they organise the variety of possible presentations and resulting difficulties, with the latest version of the DSM proposing levels of severity and relating this to support needs, whereas the ICD-11's approach considers the presence of absence of language difficulties and intellectual disabilities that may co-occur with autistic symptoms.

1.1.4.1 Historical and Conceptual Evolution

Autism is a construct that has evolved over time. While our understanding of the features of autism continues to develop, theories of its aetiology and frameworks for understanding autism also continue to be debated and updated. The discovery of what is now referred to as autism is usually credited to 1940s researchers Leo Kanner and Hans Asperger, who separately used the terms 'autism' and 'autistic psychopathology' respectively (Baron-Cohen, 2015; Rosen et al., 2021). However, there are some indications that previous researchers had noticed shared autistic features but had not popularised a term to refer to this condition. In particular, Grunya Efimovna Sukhareva, published case studies in 1926 describing six cases of children with socialising

differences and also atypical sensory-related behaviours (Posar & Visconti, 2017). While male researchers Kanner and Asperger have widely been credited with discovering autism due to their work in the 1940s, female researcher Sukhareva's name remains in relative obscurity despite her findings being published in the 1920s. In the full century since then, definitions of autism have evolved.

Importantly, within the last decade there have even been changes to the diagnostic categories of autism. Kanner's observations in the 1940s included traits such as difficulties with communication, a need for sameness, and unusual speech patterns (Rosen et al, 2021). While Asperger's research did not initially gain the recognition and prominence that Kanner's did (Baron-Cohen, 2015), Asperger's work was later highlighted, and Asperger's Syndrome gained its own place in the DSM-4 and the ICD-10. At the time, Asperger's Syndrome connoted individuals who were able to communicate verbally but may have had difficulty interacting with peers or displayed restrictive interests or repetitive behaviours. The recognition of Asperger's Syndrome as a distinct condition, separate from autism, was later changed, with Asperger's Syndrome being subsumed in the umbrella of the autistic 'spectrum' of conditions.

By the 1980s, 'infantile autism' was introduced as a recognised condition in the Diagnostic and Statistical Manual's (DSM-III) third edition section on Pervasive Developmental Disorders (APA, 1980). The diagnostic criteria included early onset of difficulties in language development, and peculiar or rigid attachments to objects. By the 1987's update of the DSM (DMS-R), the autism diagnosis had been revised to acknowledge that it is a lifelong condition and is not confined to childhood, and the diagnostic criteria had been expanded to include three key domains: difficulties with

social interaction, social communication, and restricted or repetitive movements, interests, and behaviours (Rosen et al, 2021). While this development of criteria acknowledges the wide variance of presentations in autism and begins to clearly distinguish it from mental health conditions such as schizophrenia, the criteria for autism were still primarily framed in a deficit-centred model (Lee et al, 2023; Dinishak, 2016). By the time the DSM-V was published in 2013, autism was viewed as an umbrella term for a wide range of levels of ability, with Asperger's no longer being a separate diagnosis as it was absorbed into the wider diagnosis of autism. The diagnostic criteria for autism were also reduced from three categories down to two: difficulties with social communication, and restrictive/repetitive behaviours. The 'social interaction' and 'social communication' categories were combined into one category due to their inter-related nature.

1.1.4.2 Theoretical Frameworks

Although the diagnostic criteria for autism have evolved over the years, numerous theories have been proposed, and debates continue about its underlying causes. For example, several theorists, mostly focusing on the cognitive and information processing aspects of autism, have attempted to explain the occurrence of autistic characteristics with a wide range of theories. Research has proposed diverse cognitive and perceptual accounts of autism, including:

- Weak central coherence (Happé & Frith, 2006)
- Theory of mind deficits (Klin et al., 2003)

- Context blindness (Maxfield, 2019)
- Monotropism, emphasising focused attention strengths (Murray et al., 2005)
- Predictive processing differences (Constant et al., 2020)

Monotropism is notable for highlighting autistic strengths in sensory perception alongside processing differences (Lawson, 2024a, 2024b). Among influential developmental theories, Annette Karmiloff-Smith's neuroconstructivist approach is particularly relevant here. She proposed that cognitive development results from dynamic interactions between biology and environment, and that neurodevelopmental disorders should be understood as shaping adaptive developmental trajectories rather than solely as deficits. This perspective aligns with the current study's person-centred approach, recognising that individual differences—including sensory profiles—can be both strengths and vulnerabilities depending on context (Karmiloff-Smith, 1992, 1998).

1.1.4.3 Sensory and Interoceptive Differences

As understanding of autism continues to grow, there is increasing recognition of how differences in sensory processing and sensitivities significantly impact autistic individuals. Sensory sensitivities were highlighted in Sukhareva's research (Posar & Visconti, 2017), as well as Kanner's observations (Kanner, 1943). Sensory processing differences—especially interoceptive and exteroceptive sensitivities—are now recognised as core features of autism (Garfinkel et al., 2016). This recognition has grown in recent years, reflected in ICD-11's inclusion of full sensory processing as diagnostic criteria. Among these sensory domains, interoception—the sense of internal

bodily states—has emerged as a key area of research for understanding autistic experiences (Shah et al., 2016). Interoception is an aspect of sensory processing that is increasingly being researched, and which I will describe next.

1.1.5 Interoception as a Facet of Autistic Sensory Differences

Interoception is the process of perceiving, integrating, and interpreting physiological signals (Suksasilp & Garfinkel, 2022a). These processes are not only significant for homeostatic awareness and affect regulation, but are also closely linked to mental health—evidence shows that poorer interoceptive ability correlates with greater depression, anxiety, and alexithymia (Nord & Garfinkel, 2022; Nicholson et al., 2019). Atypical interoception has been extensively documented in autism, including findings of higher interoceptive attention alongside lower interoceptive accuracy in autistic individuals (Ben Hassen et al., 2023; Garfinkel et al., 2016). These interoceptive differences are associated with emotion dysregulation, sensory over-responsivity, and heightened anxiety (Ben Hassen et al., 2023). Given their importance to sensory experience and emotional well-being, interoceptive mechanisms require further, autism-informed investigation. While interoception research in autistic individuals suggests that their interoceptive abilities may be atypical (Garfinkel et al., 2016; Shah et al., 2016), it remains challenging to define the nature of these atypicalities. This may be in part due to the wide variance in autistic presentations. As there is not a homogeneity to the sensory profiles of autistic people (Garfinkel et al., 2016), this may be reflected in a wide variance in interoceptive ability between individuals.

Despite these challenges, many studies and reviews suggest that interoceptive processes are an important factor in understanding autism (Shah, 2016; Hatfield et al, 2019; Loureiro et al, 2024). For example, there is a higher prevalence of anxiety amongst autistic individuals (Jolliffe et al., 2023) and research has linked anxiety in autism to lower interoceptive accuracy. This gives an insight into the mechanism underlying the anxiety, which can help to inform appropriate interventions in response (Quadt et al., 2021a). Loureiro et al. (2024) suggested that how autistic people process and integrate interoceptive and exteroceptive information is a key contributor to core features of autism. More research is needed to understand what is involved in these processes for autistic individuals. To increase this understanding requires clearly defined parameters of what interoception is, and clear methodologies as to how we investigate its processes.

1.1.6 Interoception in Body and Mind: Difficulty Defining the Parameters of Interoception

While interoception is increasingly being acknowledged as having an important role in our everyday lives, there is much debate as to its definition, parameters, components, and how interoceptive processes function (Murphy, 2022; Suksasilp & Garfinkel, 2022a). Furthermore, there is much debate and controversy around how aspects of interoception can be measured and investigated (Murphy et al., 2019). In particular differences in interoception for autistic people may be critical in understanding their experiences, health needs, and mental health difficulties. Interoception has sometimes been described as the eighth sense (Mahler et al., 2015), but is a concept

that covers multidimensional signals in the body and brain (Suksasilp & Garfinkel, 2022a) and the parameters of how it should be defined has been the subject of much debate (Desmedt et al., 2022). Just as the term 'autism' was coined over a century ago, and the concepts attached to it have continued to evolve, interoception is a term that has been used for over a century (Sherrington, 1906), but its meaning has changed over time to account for increased understanding of, and research on, body signalling and regulation processes. In particular, there has been a significant increase in research into the area of interoception in the last two decades (Murphy et al., 2019).

Originally the term interoception focused on visceral sensations – signals from the digestive, cardiac, and respiratory systems (Sherrington, 1906; 1948) but has been broadened over time to include other sensory signals and pathways from within the body (Desmedt et al, 2023; Crucianelli & Ehrsson, 2022; Suksaslip & Garfinkel, 2022) such as pain signals and body temperature signals. As the conceptualisation of interoception has developed, there have been several definitions that have highlighted key aspects of interoceptive processes. One key feature of Cameron's (2001) definition was that it highlighted that interoceptive processes are connected to behaviour and thought, and that this can occur at both conscious and subconscious levels. Craig's (2002) re-definition of interoception to include any signals relating to the condition of the body acknowledged that interoceptive processes serve to allow the body to maintain homeostasis – the body's self-regulation process of maintaining stability in its internal environment (Libretti & Puckett, 2023). While there are still differing opinions as to what an accepted definition of interoception should include (Desmedt et al, 2023), in this thesis I will be taking a definition of interoception that is in line with Craig's (2002) broad

definition and also acknowledges the cognitive and behavioural aspects of interoceptive processes as highlighted by Cameron (2001). Ceunen et al.'s (2016) definition of interoception includes both these aspects and is considered an appropriate definition for this thesis. In using this definition, I am including sensations from the skin, such as pain (nociception) and temperature (thermoception). While this approach differs from Desmedt et al. (2024), who exclude most sensation from the skin, it is in line with Craig (2002), Ceunen et al. (2016), and with the more recent proposal highlighted by Crucianelli & Ehrsson (2022).

In this thesis, I adopt a broad definition of interoception aligned with Craig's (2002) account of signals concerning the condition of the body, and with Cameron's (2001) emphasis that such signals inform cognition and behaviour at conscious and non-conscious levels. Accordingly, I treat thermoception and nociception arising from the skin as interoceptive when they carry homeostatic information about the body state (Ceunen et al., 2016; Craig, 2002; Crucianelli & Ehrsson, 2022). Craig's (2002) reasoning for including skins sensations, such as affective touch from CT-fibres, in his definition was largely determined by the pathways and areas of the brain involve. While I am also including sensation from the skin, my reason for including the skin sensation in my definition is primarily functional, rather than determined by signal pathway. This stance contrasts with other definitions that exclude most cutaneous signals, but is consistent with contemporary rfameworks recognising interoception as multidimensional and distributed across body-brain pathways (Garfinkel et al., 2015; Murphy et al., 2019, Suksasilp & Garfinkel, 2022).

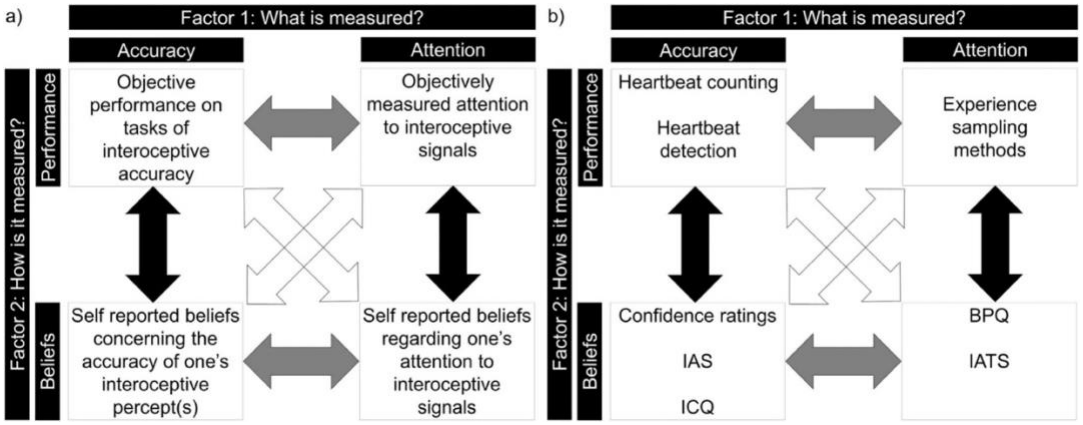
1.1.7 Interoception in Body and Mind: Frameworks for Understanding and Investigating Interoception

Becoming aware of internal body signals and sensations, interpreting them, and ascribing meaning to them is a complex process. Various frameworks conceptualise interoception as involving sensory signals, their perception and discernment, as well as the attention interpretation to these signals. In exploring how cognition relates to processes of interoception, Garfinkel et al. (2015) proposed a three-part model, comprised of interoceptive accuracy, interoceptive sensibility, and interoceptive awareness. Interoceptive Accuracy (IAcc) is the level of accuracy an individual can achieve in perceiving interoceptive signals (Garfinkel et al., 2015). Interoceptive Accuracy is often measured by asking participants to report on their perception of an internal body signal and comparing this to an objective measure of the body signal recorded at the same time. In particular, cardiac signals (i.e. the heartbeat) have often been used as a key interoceptive channel to measure interoceptive accuracy (Murphy, 2024; Kleckner et al., 2015) as heartrates can be objectively measured, and participants can also report on the frequency with which they perceive or believe their heart to be beating. Interoceptive sensibility (IS) was described by Garfinkel et al. (2015) as an individual's subjective self-reported beliefs regarding their own interoceptive abilities. Interoceptive Awareness (IAw) is the third component of Garfinkel et al. (2015) model of interoception. IAw is the interoceptive ability of an individual influenced by their IAcc and IS – an association between how accurately an individual perceives their interoceptive

signals, and their beliefs about their ability to perceive those signals accurately. In this model, IAcc is the central component of interoception, with IS relating to beliefs in one's interoceptive ability, and Interoceptive awareness being the metacognitive element of the model.

Building upon this model, Murphy et al. (2019) developed a 2x2 factor model (See Figure 1) that considers levels of awareness of interoceptive ability (Murphy et al., 2019). Specifically, the authors distinguished between the components of interoception and how they are currently measured via subjective and objective modes of measurement (see Fig. 1 from Murphy et al., 2019). The components of interoception that are focussed on in this model are Interoceptive Accuracy (IAcc), the aptitude for accurately perceiving interoceptive signals, and Interoceptive Attention (IAtt), the tendency of an individual to focus their attention on their interoceptive signals. In order to separately measures these components, Murphy et al. (2019) developed and validated subjective self-report measures that assess individual differences in beliefs regarding interoceptive attention (Gabriele et al., 2022) and interoceptive accuracy (Murphy et al., 2019).

Figure 1. Model of Interoceptive Ability: a 2x2 factorial model of organising the methodologies and components of interoceptive ability (from Murphy et al., 2019)



The processes of interoception involves more than just physiological signals, but also involve attention and interpretation, and these abilities can differ between individuals at any point in this process (Suksasilp & Garfinkel, 2022a). Suksasilp & Garfinkel (2022) conceptualised interoceptive pathways from the afferent signals arising within the body and travelling to the brain through stages of processing that range from preconscious to metacognitive awareness. There is growing recognition that even seemingly straightforward interoceptive tasks, such as detecting cardiac signals, involve considerable complexity (Murphy et al., 2018; Legrand et al., 2022), and that interoceptive processes do not just involve unidirectional signals, but includes bidirectional networks and processes (Berntson & Khalsa, 2021).

Investigating a complex and multidimensional process such as interoception is a challenging task that can involve a range of methodologies exploring interoception across different dimensions, including physiological signals, brain activity, behaviours, and beliefs. This current study will use Murphy et al. (2019) framework for conceptualising components of interoception and explore self-reported beliefs about

Interoceptive Accuracy as well as Interoceptive Attention. Objective measures of physiological signals are beyond the scope of this study. While this is a limitation, it is hoped that these findings will serve to inform and focus the design of further research including polysomnographic sleep studies, longitudinal studies, and other research involving objective physiological measures.

1.1.8 The Skin as a Key Organ in Thermal Interoception and Thermoregulation Processes

The skin serves a key interoceptive function in perception and regulation of body temperature (Crucianelli & Ehrsson, 2022) which in turn is an important to the process of falling asleep and staying asleep (Harding et al., 2019, 2020). The skin represents the boundary and limits of the body and the self, but it is also *part* of the body. The skin is the organ of the body with the greatest mass, and its large surface area is only exceeded by the surface area of the small intestine. As explained in the previous section, there have been differing opinions as to whether sensation from the skin should be considered as interoceptive (see Desmedt et al 2023; Crucianelli & Ehrsson, 2022). . Crucianelli & Ehrsson (2022) argued that the contribution of the skin to interoception remains understudied and merits further research. In this thesis I am taking the stance that the skin serves interoceptive functions and is a key contributor of interoceptive information regarding homeostasis of the body, in particular temperature. The skin can

provide information about the external world (exteroceptive) , but also important information about the body itself (interoceptive) (Crucianelli & Ehrsson, 2022). If I run my thumb along a plank of timber, I gain information about the texture of the timber, smooth or rough. If my thumb gets pierced by a splinter through this action, I feel pain which gives me information about my body, that a part of my skin has been injured. Even after breaking contact with the plank of timber, and removing a splinter, the pain remains, still updating me on the physiological state of my body as it heals. Skin interoception is underexplored in autistic populations, however a recent study found differences in itchiness in skin sensitivity in autistics vs allistics, where autistic individuals reported more profound and long-lasting discomfort uncorrelated with severity of dermatitis (Tackley et al., 2025). Greater understanding of autistic sensory experiences of temperature, discomfort, and pain can lead to more appropriate treatments.

Similarly to pain, temperature perception (thermoception) involves both exteroceptive and interoceptive functions from the skin. The skin is not only involved in thermoception, the sensing of temperature, it also has an active role in thermoregulation, the process by which the body controls its temperature in accordance with the body's needs, for example through sweating and releasing heat through the surface of the skin, particularly through the glabrous skin on the face, palms, and feet (Grahn et al., 2009). Thermoregulation takes place over conscious and unconscious levels, and requires circulatory, physiological and behavioural elements. Thermoregulation of the body is linked to circadian rhythms and occurs during sleep as

well as waking hours (Harding et al., 2019, 2020; Raymann et al., 2007), making it very relevant to the current study.

1.1.9 Thermoception and Thermoregulation Difficulties in Autism

Thermoregulation refers to the integrated physiological and behavioural processes that maintain body temperature within a viable range for ongoing metabolic needs. These processes are expressed across multiple timescales, through the day/night circadian phases, but also hour-to-hour and moment-to-moment. They also take place across multiple levels, such as autonomic responses like perspiration, variations in vascular capacity and flow. For example less blood flow to extremities, such as fingers/toes, would conserve core body temperature, or increased blood flow to the glabrous skin of the face, palms, or soles of feet would facilitate the release of heat and cool the body. In addition to autonomic responses, behavioural adjustments contribute to thermoregulation processes. Such behaviours include adjustment of clothing, or of the ambient temperature in the immediate environment. One such behaviour that is relevant to sleep is the creation of “skin microclimates” which influences sleep onset, sleep quality, and sleep maintenance (Harding et al., 2019, 2020; Raymann et al., 2005, 2007). Thermoception is a core component of thermoregulation and involves the perception of temperature in order to inform the need for responses and adjustments that serve to attain and maintain the optimal body temperature at any given time.

Many autistic people, as well as professionals, report observing hyposensitivity and hypersensitivity to temperature amongst autistic people. In twenty years of clinical practice, I have multitudes of anecdotal observations of autistic individuals who may have notable profiles in relation to temperature, some who might wear a winter coat in the middle of summer, and may not realise how hot they are getting, others who are highly sensitive to the cold and often decide to put heating on even on warm days. Despite many of these and other observations amongst autistic individuals and supporting practitioners, there is a lack of evidence of what thermoception is like for autistic people.

Williams et al. (2019) highlighted that anecdotal reports of autistic individuals being hyposensitive to temperature were commonplace, but when they compared warmth and coolness detection thresholds between a sample of autistic individuals (n=83) and a control group (n=59), no differences in detection thresholds were observed. However, there were significant differences between groups in self-report questionnaires focusing on sensory reactivity. There is a significant lack of research exploring these thermal sensory differences for autistic individuals and to my knowledge this has not been explored through the lens of interoception. Further research into this area may be of clinical relevance and provide strategies that are of benefit to autistic people in relation to comfort, and general quality of life. There may also be health and emotional regulation applications to advances in this area. One key area where thermoception research may benefit autistic people is in relation to sleep.

1.1.10 Sleep Processes in Body and Mind

Another key function that is dependent upon interoceptive processes is sleep (Arora et al., 2021; Bynum & Brindle, 2024; Wei & Van Someren, 2020). Sleep is a complex neurophysiological and behavioural state essential to human functioning. It is dependent upon interoceptive processes (Wei & Van Someren, 2020; Bynum & Brindle, 2024; Arora et al., 2021), which regulate bodily systems necessary for sleep onset, maintenance, and transitions between stages.

Rather than being a simple state of unconsciousness, sleep is now conceptualised as a reversible behavioural and physiological condition characterised by reduced responsiveness to external stimuli and altered patterns of brain activity. Carskadon and Dement (2011) define sleep as “a reversible behavioral state of perceptual disengagement from and unresponsiveness to the environment,” while also emphasising that it involves “a complex amalgam of physiologic and behavioral processes” (p. 16). Importantly, this definition highlights that sleep entails changes in sensory processing—including reductions in exteroceptive responsiveness—which may extend to interoceptive signals as well.

The necessity of this disengaged state, despite the evolutionary risk it presents, suggests that its core functions are critically important. Research indicates that sleep supports a range of essential functions, including memory consolidation (Diekelmann & Born, 2010), emotional regulation (Goldstein & Walker, 2014), synaptic homeostasis (Tononi & Cirelli, 2014), thermoregulation (Harding et al., 2020), and immune

functioning (Irwin, 2015). While these functions are primarily mediated by the brain, they rely on coordinated brain–body processes that involve widespread physiological systems.

As Hobson (2005) famously noted, “sleep is by the brain, of the brain, and for the brain,” suggesting that its purpose lies in neural maintenance and organisation. Yet, as Hirshkowitz (2004, p. 155) adds, “the body rests, but the brain sleeps”—acknowledging that while the central nervous system orchestrates sleep, it also induces changes throughout the body. These include shifts in heart rate, respiration, body temperature, and hormone secretion (Saper et al., 2005), all of which involve interoceptive signalling.

Although theories differ regarding the core evolutionary function of sleep, there is broad consensus regarding the architecture of sleep. Human sleep follows a cyclic structure comprising two major categories: non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep. NREM sleep includes stages 1 through 4, with stages 3 and 4 known as slow-wave sleep (SWS), considered the deepest stages of sleep. REM sleep is marked by distinct neural activity, heightened brain metabolism, and muscle atonia, and is typically associated with vivid dreaming (Carskadon & Dement, 2011; Hobson, 2005). Sleep architecture and sleep difficulties differ across the population by age and also by sex (Carskadon & Dement, 2011; McArdle et al., 2010; Zheng et al., 2018), and any research exploring sleep difficulties should consider these individual differences as variables in their analysis. Changes occur in the amount people sleep and their ability to fall back asleep as people age (Carskadon & Dement,

2011) and there is ample evidence the females experience sleep difficulties, including insomnis, more frequently than males with social, psychological, and hormonal factors being relevant (McArdle et al., 2010; Zheng et al., 2018).

Each night, sleep cycles through NREM and REM phases approximately every 90 minutes, with the relative time spent in each stage shifting across the night. These phases are accompanied by changes in autonomic function, thermoregulation, and sensory processing (Saper et al., 2005). Despite this, relatively little research has focused on how interoceptive processes specifically contribute to sleep architecture or regulation. The following section explores these relationships in more detail, examining the role of interoception and thermoregulation in the initiation and maintenance of sleep.

1.1.11 Sleep and Interoception

Sleep and interoception are both complex, integrative processes involving interplay between psychological, physiological, and neurocognitive systems. Each involves both conscious and unconscious components—for example, physiological signals such as heart rate or body temperature can influence sleep onset without entering full awareness, while subjective awareness of internal states can modulate affect and arousal levels that in turn influence sleep. Recent research has begun to examine the connections between these domains, although this remains an emerging field.

Initial evidence linking interoception and sleep comes from studies of cardiac interoception. For example, Wei et al. (2016) found that individuals with insomnia disorder had impairments in cardiac interoceptive accuracy, suggesting a potential mechanism through which bodily awareness may influence sleep initiation or quality. In a broader review, Wei and Van Someren (2020) proposed that multiple interoceptive domains—including thermoception, nociception, and the subjective appraisal of bodily signals—may be implicated in sleep regulation. These findings suggest that interoceptive processes may play diverse roles in the experience and regulation of sleep.

There are several theoretical pathways through which interoceptive differences may affect sleep. Sleep pressure, a homeostatic drive that accumulates with wakefulness, is likely experienced through interoceptive channels. If an individual has difficulty perceiving these internal cues—due to reduced interoceptive accuracy or disrupted attentional processing—they may fail to notice rising sleep pressure, making it harder to initiate pre-sleep routines or recognise the appropriate time to rest. Another connection between sleep and interoception is through emotion. Interoception is closely linked to affective states, emotional awareness, and self-regulation, including alexithymia (Brewer et al., 2016; Shah et al., 2016; Murphy et al., 2017). Difficulty interpreting or managing internal signals may impair an individual's capacity to downregulate arousal before sleep, contributing to prolonged sleep latency or fragmented sleep patterns. There is also evidence that interoception influences

subjective time perception (Pollatos et al., 2014; Di Lernia et al., 2018), which may in turn affect sleep behaviours—such as estimating how long one has been asleep, deciding whether to return to sleep, or interpreting time spent awake during the night.

Finally, interoception may be integral to thermoregulatory processes that support sleep onset and maintenance. Sleep requires precise regulation of core body temperature, and impairments in interoceptive awareness could compromise an individual's ability to initiate heat-dissipating behaviours or maintain thermal comfort during sleep.

These interoceptive mechanisms may be particularly relevant in autism. Research has shown that autistic individuals often experience differences in interoceptive attention and accuracy (Shah et al., 2016; Garfinkel et al., 2016), and may also experience co-occurring emotional regulation difficulties, heightened sensory sensitivity, and disrupted thermoregulation. Together, these differences could contribute to the distinct sleep challenges reported by many autistic people, including difficulties with recognising sleep cues, maintaining optimal body temperature, and managing physiological arousal in line with circadian rhythms.

While some sleep researchers have highlighted the potential relevance of interoception to autism (Bynum & Brindle, 2024), there remains a lack of empirical research directly investigating this relationship. To date, no published studies have explored how interoceptive processing relates to sleep difficulties in autistic adults, nor

how interoception, sleep, and autistic traits may be interrelated in the general population.

1.1.12 Sleep Relating to Thermoregulation

A significant body of evidence has demonstrated that sleep processes are highly dependent upon thermoregulation. Some researchers propose that brain thermoregulation is a fundamental function of sleep (Harding et al, 2019). Changes in temperature take place not only in the brain (Csernai et al, 2019), but throughout the body, from the core visceral organs to the distal limbs (Harding et al, 2019). These changes in temperature are managed partly by the circadian rhythms of the brains arousal system, and partly by human behaviour across conscious and unconscious levels of cognition. The temperature changes that happen to facilitate sleep occur during both pre-sleep and intra-sleep stages.

Pre-sleep temperature changes have been shown to influence sleep onset, as well as the length of ensuing slow-wave sleep stages (Harding et al, 2019; Zhang et al, 2019; Ting Cao et al, 2021). As part of the sleep onset process, core body temperature drops, and comes closer to the temperature of the distal limbs (Harding et al, 2019). Core body temperature starts to decrease in the 120 minutes before falling asleep and non-rapid eye movement sleep (NREM) usually occurs when this rate of cooling accelerates. In addition to this, humans play an active, allostatic role in

thermoregulations in advance of, and during sleep (Raymann et al., 2008). Part of this process involves pre-sleep preparatory actions which are not unique to humans. For example, many mammals create nests in order to maintain a temperature range during sleep, and humans do this too (Harding et al., 2019). Harding et al. (2020) refer to this practice as humans creating 'skin microclimates. They suggest that this is done in order to allow for keeping the body at a relatively stable temperature range, while minimising the energy expended to do so. Studies have shown that warming the skin prior to sleep, through bathing or showering can minimise sleep onset delays (Harding et al., 2019, 2020) by affecting circulation and bringing the temperature of limbs closer to that of the core body temperature.

This process is a complex one as warming the skin temperature serves to improve sleep onset, as it improves blood flow and actually slightly lowers the body's core temperature (Raymann et al., 2007, 2008). However, if a warm bath pre-sleep is too effective, it can actually have the effect of raising the core body temperature which would be detrimental to sleep (Raymann et al., 2007). This is one area where interoceptive awareness of temperature may have a role to play: if someone has difficulty assessing their own temperature, impaired thermoregulation pre-sleep can impinge upon the process of entering sleep. Poor interoception may lead to individuals failing to attain and maintain optimal body temperature for sleep, as they may not be aware of being too cold or hot. Not only could interoception have a role in facilitating sleep onset, but additionally it could affect sleep quality during each stage of sleep.

Once sleep has started, stable body temperature serves to allow progression of sleep. There is some evidence that rapid eye movement (REM) phases of sleep are negatively affected by poor thermoregulation, and poor NREM sleep is also linked to poor thermoregulation (Harding et al., 2019). During sleep, humans take action in order to maintain the body temperature that is optimal for sleep (Harding et al., 2019). This can involve manipulating blankets to retain or emit heat. Additionally, when overheating sleepers can extend their hands or feet out from blanket cover in order to cool. Interoception may have a role to play in facilitating this active process of maintaining temperature during sleep as the ability to interpret thermal body signals can inform what action is required to regulate temperature. This predictive aspect of thermal regulation aligns with allostatic processes, whereby individuals proactively adjust their environment or behaviour (e.g., removing covers or choosing lighter sleepwear) in anticipation of future thermal discomfort or physiological needs (Sterling, 2012; Schulkin & Sterling, 2019). To date there is limited exploration of how interoception may relate to these thermoregulatory processes, and to my knowledge no research exploring how interoception and thermoregulation might relate and influence sleep for autistic people.

1.1.15 Conclusion

The interoceptive ability to perceive body temperature may have an impact on someone's ability to attain and maintain a body temperature that facilitates sleep. This

perceptual ability allows the individual to recognise subtle internal cues—such as warmth, discomfort, or fluctuations in skin temperature—and respond adaptively. These responses can include behavioural actions like adjusting bedding, clothing, or room conditions to maintain thermal comfort during the sleep cycle. In individuals with impaired interoceptive processing, difficulties in identifying or responding to these cues could disrupt thermoregulation and hinder sleep initiation or maintenance. Exploring the interplay between interoceptive ability, thermoregulation, and sleep for autistic people may give greater insight into sleep difficulties, allowing for better-informed interventions and sleep improvement practices. Advances in research in the fields of interoception, sleep, mental health and autism present an opportunity to improve to lives of autistic people who are experiencing sleep difficulties. Understanding the role of interoception in autistic experiences, in sleep, and in thermoregulation may present avenues of research into clinical interventions that are helpful and relevant to this population. While research into the distinct topics of sleep, autism and interoception are growing, this specific research topic has not been the focus of any significant research effort, and therefore clinicians are left without findings to guide them. The interrelationships between sleep, interoception, and thermoregulation for autistic people present us with not only a gap in the literature, but also a pressing area of clinical need.

1.2 Systematic Literature Review: Sleep Difficulties in Autistic Adults

A systematic literature review was completed in order to provide a critical account of the published literature on autistic people's sleep difficulties and to examine the evidence for interventions aimed at improving sleep in this population. Preliminary searches failed to find studies explicitly linking all four core domains (autism, interoception, thermoregulation, and sleep). Therefore, the search framework focused on studies researching sleep in autistic adults. This enabled post hoc exploration of interoceptive and thermoregulatory content within sleep and autism literature. Given the lack of studies explicitly addressing all core domains, a post hoc coding process was applied to identify interoceptive or thermoregulatory elements in studies primarily focussed on sleep in autism. This decision was made to ensure inclusion of potentially relevant but non-indexed content. To understand what current research reveals about the relationship between sleep, interoception (including thermoregulation), and autistic traits, three research questions were developed. A primary question was designed to assess the breadth and nature of evidence regarding sleep difficulties in autistic adults. Given the variety of research methods used to investigate sleep, this question takes into consideration sleep studies across objective, subjective, and qualitative approaches. In recognition of the limited and fragmented nature of the literature relating to how these disparate domains might influence sleep for autistic adults, two additional research questions were formulated to explore: (1) what factors such as sensory, interoceptive

and thermoregulatory processes are proposed to contribute to these difficulties, and (2) whether existing interventions for sleep in autism consider these mechanisms. Given the emerging and interdisciplinary nature of this topic, this framework of research questions, combined with a search strategy examining sleep studies for autistic adults, allowed for a review of the literature within the limited evidence available.

1.2.1 Literature Review Questions:

To investigate the relationship between sleep, interoception (including thermoregulation), and autistic traits, a systematic literature review was conducted to address three questions. These questions were informed by clinical observations of autistic adults dealing with sleep difficulties and thermoregulation difficulties. They were developed after preliminary reading of the literature around autistic sleep difficulties. Preliminary searches found limited studies on sleep for autistic adults relative to those for autistic children, alongside evidence of thermoception issues in autism (Casterman et al., 2024), but not research relating this to sleep difficulties. Therefore, a PICO search framework was used to find papers relating to autistic adults and sleep, with a view to answering the following research questions:

Research Question 1:

- What is the nature and prevalence of sleep difficulties for autistic adults, as reported in the existing literature?

Research Question 2:

- To what extent do current studies explore sensory, interoceptive, and thermoregulatory processes in relation to sleep in autism?

Research Question 3:

- What evidence exists for interventions targeting sleep in autistic adults, and do these consider interoceptive or thermoregulatory processes?

The purpose of this review is to evaluate the extent and quality of current research on sleep in autistic adults, to identify whether interoception and thermoregulation have been considered as contributing mechanisms, and to assess the degree to which these factors are integrated into existing intervention research. The findings of this review directly inform the rationale for the present empirical study, which explores the relationships between sleep difficulties, interoceptive traits, thermoregulation, and autistic traits in the general population.

1.2.2 Search Strategy

Searches were limited to peer-reviewed, English-language articles, with no date restrictions. The literature search was conducted on the 2nd of November 2024. These searches were conducted using the EBSCOhost platform, utilising the following databases: APA PsycINFO, CINAHL Ultimate, MEDLINE Ultimate and APA

PsyARTICLES. Boolean operators were used to combine terms and search for research articles that included these terms in their titles (see Table 1). Synonyms were trialled but yielded no additional relevant results. Alternative keywords such as ‘circadian’, ‘insomnia’, ‘temperature regulation’, and ‘bodily awareness’ were tested alongside core terms (e.g., autism AND sleep AND interoception), but did not yield additional relevant results. This iterative refinement confirmed the specificity of the final Boolean search strategy. The search revealed N=320 articles after duplicates had been removed. Articles were screened through title and abstracts leaving 47 articles that were sought for retrieval. Full texts were found and screened again using the inclusion and exclusion criteria (discussed in the section below). All studies were assessed for methodological quality using the appropriate Critical Appraisal Skills Programme (CASP) checklists, including the CASP Qualitative Checklist, Cohort Study Checklist, Case-Control Checklist, and Randomised Controlled Trial Checklist, depending on the study design (Critical Appraisal Skills Programme, 2018). The included studies ranged in approaches from qualitative research, and cross-sectional surveys, to cohort studies and comparative observational studies. There was also one randomised pilot intervention study. Studies that failed to meet the minimum quality standards or lacked methodological clarity were excluded (N=2). The final sample included N=25 published studies. See Figure 1 in the Appendices for the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flowchart for further information on the selection process. Papers were reviewed following PRISMA guidelines (Page et al., 2021). See Table 2 for the final list of studies included in the review.

Table 1.
Literature Review Search Terms.

Topic	Search Terms
Sleep	Sleep OR insomnia
	AND
Autism	autism OR autistic
	NOT
Children	Adolescents OR teenagers OR children

Note: These were the search terms used in the final search.

1.2.3 Inclusion and Exclusion Criteria

Papers were screened to ensure they were fully published, peer-reviewed articles that focus on sleep and autism for adults. Participants in the included studies must all be adults aged 18 and above. Given the variance in sleep behaviours that take place over the course of child development (Carskadon & Dement, 2011; Chokroverty, 2017), it was decided to focus on studies that only included participants in adulthood and exclude all studies that included children. Caregivers of children also often play a role in management of the thermal environment around children, making it more difficult to explore the role of interoception in thermal sleep processes in childhood. Another reason for focusing on autistic adults and excluding sleep studies for existing children is the lack of research in this area that focussed on adult autistic sleep. Studies that explore the nature of sleep difficulties amongst autistic children and exmine the efficacy of interventions in this area far outnumber studies that explore these topics for adults. Animal studies and studies that use so-called ‘animal models of autism’ were also excluded.

Papers examining autistic traits in the general population were included, as their findings may be relevant to autistic individuals and highlight areas where further research is needed (Constantino & Todd, 2003; Limoges et al., 2005; Robinson et al., 2011; Ruzich et al., 2015). However, studies focusing solely on individuals with a learning disability who are also autistic were excluded, due to challenges in determining whether the findings are specific to autism or influenced by the learning disability in relation to sleep difficulties (Baker & Richdale, 2017). A summary of inclusion and exclusion criteria is provided below.

Inclusion Criteria:

- Peer-reviewed journal articles,
- English language articles,
- Participants aged 18 years and older,
- Focus on autistic individuals or autistic traits,
- Investigation of sleep-related variables.
- Both qualitative and quantitative studies, including quantitative studies that utilise objective and/or subjective measures.

Exclusion Criteria:

- Studies with child participants,
- Caregiver studies where the topic was the experience of a child's sleep difficulties (e.g. a parent's experience of caring for their autistic 8yo son who has insomnia),
- Animal studies or non-human models of autism,

- Reviews, opinion pieces, or editorials,
- Studies with unclear or unreported methodologies,
- Studies where all participants had a learning disability.

Table 2.
List of Studies Included in Review

Papers Reviewed

Authors (Year)	Focus of Study	Diagnosis of Participants (n)	Age Range (years)	Intervention y/n	Method	Questionnaires used
Baker & Richdale (2015)	Cross-sectional study sleep patterns	Autism (N=36) Control (N=36)	Autism (21-44) Control (22-43)	n	Actigraphy Self-Report Questionnaires	PSQI Sleep Diary
Quist et al. (2015)	Sleep hygiene psychoeducation Intervention for autistic male adults.	Autism (N=14)	20-55	y	Psychoeducation Intervention Pre and Post subjective measures	PIRS-20 Sleep Diary
Baker & Richdale (2017)	Behavioural sleep-wake rhythms and difficulties in autistic adults.	Autistic Adults without Intellectual Disability Autism (N=36) Control (N=36)	Autism (21-44) Control (22-43)	n	Actigraphy Self-Report Questionnaire Diagnostic Assessments	Autism Quotient WAIS ADOS-2 or autism diagnosis Composite Scale of Morningness Sleep Diary
Baker et al. (2019)	Employment status and sleep problems	Autism (N=36) Control (N=36)	21-44	n	Actigraphy Self-Report Questionnaires	PSQI Sleep-wake diary Epworth Sleepiness Scale (ESS) State-Trait Anxiety Inventory PHQ-8 Fatigue Frequency Scale (FFS)
Baker et al. (2019a)	Hyperarousal and insomnia in Autistic Adults	Autism (N=29) Control (N=29)	21-44	n	Actigraphy Self-Report Questionnaires Cortisol levels via saliva sampling	PSQI Sleep-wake diary Epworth Sleepiness Scale (ESS) State-Trait Anxiety Inventory PHQ-8 Fatigue Frequency Scale (FFS)
Benson et al. (2019)	Sleep Patterns and Activity levels. Comparative Study	Autism (N=15) Control (N=17)	18-35	n	Comparative Study Actigraphy BMI Self-Report Measures	Physical Activity Questionnaire (GSLTPAQ) PSQI Insomnia Screener STOP-Bang Sleep Apnoea Questionnaire

Deserno et al. (2019)	Sleep and QoL: Longitudinal Study	Autism (N=598)	-	n	Longitudinal Study Self-Report Measures	Autism Quotient Sensory Perception Quotient Insomnia Severity index
Hochard et al. (2020)	Sleep, suicidality and autistic traits	Autism (N=143) General population (N=507)	18-70	n	Online correlational study, self-report measures. General population recruitment, but additional step of asking participants with autism diagnosis to self-disclose.	AQ-10 PSQI Depression Severity Index-Suicide Subscale (DSI-SS) Specific yes/No questions of self-harm & suicidality (Mars et al 2014)
Stewart et al. (2020)	Sleep problems and mental health difficulties in older adults who endorse high autistic traits	Older adults with High autistic traits (N=187) Control Older Adults (N=6,740)	50-81	n	Cross-sectional online study Self -report measures Demographic	PROTECT Autistic Traits Measure (novel) St. Mary's Hospital Sleep Questionnaire (SMH-SQ, 8 items) PHQ-9 GAD-7
Gagnon et al. (2021)	EEG during REM sleep	Autism (N=17) Control (N=16)	18-38	n	Sleep study EEG	-
Halstead et al. (2021)	Impact of COVID-19 on sleep in autistic adults	Autism (N=95)	18-65	n	Longitudinal comparisons pre, at onset, and during lockdown.	PSQI PSAS (Pre-Sleep Arousal scale) Novel Survey questions related to wellbeing and experience of COVID-19 lockdown.
Halstead et al. (2021a)	Treatment of sleep problems for autistic adults, UK.	Autism (N=288)	18-65	y	Subjective measures	PSQI Indices of Multiple Deprivation (IMD) Novel survey questions relating to sleep problems, seeking help for those problems, and satisfaction with help received.
Leader et al. (2021)	QoL, gastrointestinal symptoms, sleep problems, social support, and social	Autism (N=107)	18-69	n	Subjective Measures	AQ-10 Multidimensional Scale of Perceived Social Support (MSPSS)

	functioning in autistic adults					Social Functioning Questionnaire (SFQ) Pittsburgh Sleep Quality Index (PSQI) Gastrointestinal Symptom Inventory World Health Organisation-Quality of Life (WHOQOL-BREF)
McLean et al. (2021)	Impact of sleep quality on quality of life for autistic adults	Autistic adults (N=40) Control (N=24)	18-55	n	Subjective Measures	PSQI Perceived Stress Scale WHOQOL-BREF Demographic variables
Reynaud et al. 2021	Differential effects of COVID-related lockdown on sleep-wake rhythms in autistic adults.	Autism (N=207) Control (N=1652)	<18	n	Cohort study, impact of lockdown. Pre- and during lockdown time-points for measures. Online survey Subjective Self-report measures	Novel/Experimental measure - 20 questions: 4 demographic 5 re: circadian rhythms 3 re: behaviours (screen time, daylight exposure, physical activity)
Sullivan et al. 2021	Anxiety, Insomnia, and Napping Predict Poorer Sleep Quality in an Autistic Adult Population	Autism (N=493) Self-diagnosed (N=85) Healthcare Diagnosis (N=408)	18-73	n	Online survey Validated subjective self-report measures	Demographic Questions (Incl. Socio-economic Status & Lifestyle) PSQI ESS (Epworth Sleepiness Scale)
Charlton et al. (2022)	Predictors of sleep quality for autistic people across adulthood	Autism (N=730)	18-78	n	Subjective self-report questionnaires	AQ-28 PSQI Perceived Stress Scale (PSS) GAD-7 PHQ-9
Lampinen et al. (2022)	Sleep disturbances relating to depressive symptoms in autistic young adults	Autism (N=304)	18-35	n	Subjective self-report questionnaires	BDI-II Sleep Questionnaire
Bishop et al. (2023)	Cardiovascular disease risk factors in autism: sleep and medications	Autism (N=545)	18-77	n	Correlational Study Subjective self-report measures	Autism Quotient (AQ-28) BMI Perceived Stress Scale PSQI
Gernert et al. (2023)	Stress in autism: sleep quality, sensory reactivity,	Autism (N=20)	18-65	n	Protocol Development study:	Culture Fair Intelligence Test 2 (CFT-20R)

	circadian rhythms	Control (N=20)			Sleep study (EEG wearable headbands) Sleep diary Self-report questionnaires	Sensory Perception Questionnaire (SPQ) Beck Depression Inventory (BDI-II) Autism Quotient (AQ-10) PSQI State-Trait Anxiety Inventory Perceived Stress Questionnaire
Harris & Carciofo (2023)	Chronotype (eveningness) relates to autistic traits. Mediating effects of depression and insomnia	General Population (N=163)	18-65	n	Subjective Measures	AQ-28 The Composite Scale of Morningness The Centre for Epidemiological Studies – Depression Scale Short (CES-D) Insomnia Severity Index (ISI)
Henderson et al. (2023)	Stronger Associations Between Sleep and Mental Health in Adults with Autism	Autism (N=220) Control (N=2200) Accelerometer study: Autism (N=83) Control (N=824)	37-73	n	UK Biobank study Accelerometer sleep study	-
Hidaka et al. (2023)	Exploring relationship between body temp, autistic traits, circadian rhythm, age.	General Population (N=2000)	20-79	n	Body temp monitoring at time points during day (participants self-administered and self-reported). Self-report questionnaires.	AQ-50 EQ-SQ CSM
Lawson et al. (2023)	ACT insomnia intervention for autistic adults (Pilot)	Autism (N=8)	18-70	y	Pilot study. ACT-i intervention for autistic adults Sleep study (actigraphy) Pre, post, and 2-month follow-up Sleep diaries Self-report measures	Insomnia Severity Index (ISI) Hospital Anxiety and Depression Scale (HADS) PSQI CORE-10 Brief Experiential Avoidance Questionnaire (BEAQ) Sleep Anticipatory Anxiety

						Questionnaire (SAAQ) Flinders Fatigue Scale (FFS) Social Validity
Nijhof et al. (2024)	Experiences of Insomnia and treatment preferences for autistic adults	Autism (N=12)	21-48	N	Qualitative Study Interpretative Phenomenological Analysis Insomnia Screening Questionnaires	Sleep Condition Indicator (insomnia screening measure)

Note. Table shows all papers included in the literature review (N=25). Table also details the focus of the study, sample size (and controls), participants age range, intervention (Y/N), methods and measures used.

1.2.4 Data Extraction

One researcher reviewed all the papers to extract data. This review considered the variety of methodological approaches, the findings and conclusions of these papers as well as the overall strengths and shortcomings of the body of knowledge available in considering the research questions (Levy & Ellis, 2006; vom Brocke, 2009). This involved noting areas of focus, methodologies, themes, similarities, and differences (Levy & Ellis, 2006). A second review of the papers was completed by this researcher in order to extract key quotes and confirm overarching themes. Given the wide range of approaches to studying sleep, this second reading also involved sorting papers by methodology and comparing papers with similar methodological approaches prior to synthesising findings in relation to the research questions (Levy & Ellis, 2006; vom Brocke, 2009).

1.2.5 Data Analysis & Synthesis

Preliminary synthesis was conducted to get an overview of similarities, differences, and gaps in the literature (Campbell et al., 2020). A preliminary synthesis involved reviewing each paper for the themes that were initially apparent. These themes were grouped into categories that showed commonality across all papers. Once these themes were clarified and collated, the literature was reviewed again to take broader perspective and review gaps in the current body of knowledge, and what methodologies had been used to explore this topic previously (Campbell et al., 2020). This gave a clear indication of areas where further research could be conducted (Aveyard, 2019).

1.2.6 Methodological Approaches

Of the 25 papers reviewed, 24 were quantitative papers, with only one qualitative study. Sleep research often includes a combination of subjective and objective measures, including self-report questionnaires, sleep diaries, actigraphic measurements and polysomnographic studies (Morgenthaler et al., 2007). The quantitative studies yielded by this search included a variety of approaches with combinations of these measures, which I will review in the following sections.

1.2.6.1 ***Objective Measures***

Sleep is a complex process that involves changes across physiological, neural, and cognitive domains. This process can be measured through many objective and subjective methods. Objective measures of sleep involve using technology to record

brain and body activity. From the 25 studies included in this review, 10 studies involved collecting data using objective measures, including polysomnography (Gagnon et al., 2021; Gernert et al., 2024), actigraphy (Baker, Richdale, & Hazi, 2019; Baker, Richdale, Hazi, et al., 2019; Baker & Richdale, 2015, 2017; Benson et al., 2019; Lawson et al., 2023), accelerometers (Henderson et al., 2023), and temperature measurement (Hidaka et al., 2023).

1.2.6.2 Polysomnography Studies

Polysomnography is an expensive and complex sleep study tool that captures brain activity via electroencephalography (EEG), eye movements, heart rate, as well as breathing, and blood oxygen levels (Gerstenslager & Slowik, 2025). This approach provides high-resolution, objective insights into the structure and quality of sleep. Although only two studies in this review include this approach, their findings contribute to Research Question 1 (RQ1) by illustrating potential differences in sleep architecture in autistic adults. These studies also provide a foundation for Research Question 2 (RQ2), which considers whether differences in physiological processes (including neural and arousal-related factors) might underlie autistic sleep difficulties. The foundation for RQ2, is provided by the findings of Gagnon et al. (2021), who found there are differences in neural activity during autistic sleep, but these differences are not yet fully understood. This study identified differences in REM sleep and sleep latency when compared to allistic controls (Gagnon et al, 2021). Differences in REM sleep suggest that some differences in brain activity during sleep are a part of autistic sleep

characteristics. However, the scarcity of polysomnographic studies with this population, and methodological challenges limit broader conclusions.

While polysomnography captures more accurate data of what is occurring during sleep compared to other objective measures such as actigraphy (Marino et al., 2013; McCall & McCall, 2012), it does require participants to sleep in a lab and to have wired sensors attached to their head and body. These changes in context and comfort can affect sleep quality and quantity, and therefore a single night's polysomnographic data should be interpreted with caution due to ecological validity issues. This literature search found only one article that involved polysomnographic data collection on autistic participants during sleep (Gagnon et al., 2021). The lack of polysomnography studies may be due in part to the limitations listed above and may also be due to the fact that polysomnography sensors may present difficulties for the sensory profiles of many autistic individuals. Gagnon et al. (2021) conducted a polysomnographic study over two nights. The first night allowed participants to become accustomed to the equipment and environment, and the second night was tailored for data collection. Participants in sleep studies may be disturbed in their sleep by the novelty and discomfort of having sensors attached to them. Studies that last longer that one night allow for participants to become more accustomed to wearing these items and therefore more accurate data can be collected in longer studies. While Gagnon's two-night experimental protocol may be preferable to a single night of data collection, it does not allow for the same level of adjustment that longer studies tend to – with some actigraphic studies lasting for seven, or even up to 14 days (Baker, Richdale, & Hazi, 2019; Baker, Richdale, Hazi, et al., 2019; Benson et al., 2019). It is worth noting that the focus of Gagnon et al. (2021)

study is unique when compared to others included in this review. Although it does explore sleep difficulties in autistic adults, the study's focus was primarily on exploring differences in neural activity between autistic and allistic adults during REM sleep. Participants were age-matched and IQ-matched, with 17 autistic adults and 15 allistic adults taking part. In terms of sleep difficulties, the study found differences between autistic and allistic sleep, with autistic people experiencing longer onset sleep latency, and less phases of REM sleep when compared to the control group. Importantly, there were correlations between characteristics noted in the Autism Diagnostic Interview (ADI-R) and electrical brain activity distribution during REM sleep. This may indicate that brain activity patterns during REM sleep are atypical and differ from neural activity during allistic REM sleep (Gagnon et al., 2021). While this study's findings contribute to the body of evidence regarding autistic sleep characteristics, they do not provide insights into sleep difficulties for autistic adults, nor do they give any indication of whether interoceptive or thermoregulatory processes are indicated as factors in autistic sleep difficulties. Although this study contributes valuable insights, its exploratory nature and narrow focus solely on REM-phase brain activity limit its clinical utility. The lack of replication across independent samples further highlights the need for more ecologically valid and mechanistically detailed sleep research in autistic populations. While they indicate there may be differences in sleep processes for autistic vs allistic individuals the lack of comparable studies highlights the need for further research in this area.

The only other paper included in this review that used polysomnography was a proof-of-concept protocol development study by Gernert et al. (2024), which gives some

indication of how researchers are trying to overcome some of the shortcomings of sleep research. The protocol involve participants using a wearable EEG headband that they wore for seven consecutive nights whilst they slept in their own home (Gernert et al., 2024). This technology may provide a way to mitigate some of the problems of novelty and environment that affect traditional polysomnography sleep studies. Another aspect of this study that shows a progression in this field is the inclusion of a consultation phase with autistic individuals, which ensured that their expertise and priorities were considered when designing the methodology of the planned study. This process involved a small sample of participants – some autistic, some allistic – who gave feedback and advice on the relevance and workability of the research focus and methods. Collaborative research approaches such as this increase the chances that findings will be meaningful and impactful on quality of life for autistic people (Fletcher-Watson et al., 2019).

Overall, polysomnographic evidence of sleep differences between autistic and allistic individuals is extremely limited. There is evidence of sleep difficulties, and well as indications that there are differences in brain activity during REM sleep stages. However, the exact nature of these sleep difficulties remains unclear, and there is no definitive evidence regarding their causes or underlying processes. Polysomnographic studies also provide no clear contribution to the requirements and efficacy of sleep interventions for autistic individuals, and therefore as of yet have little to contribute to Research Question 3 (RQ3). Other research approaches reviewed in this study may

provide further insight into the characteristics of autistic sleep difficulties and the factors that influence them.

1.2.6.3 Actigraphy

Actigraphy utilises sensors on wearable devices in order to collect data relating to behaviours, such as sleep, and physical activity. Actigraphy monitors are wearable, non-invasive devices, often similar to a small smartwatch or activity tracker wristband. These devices have movement sensors and can also collect physiological data such as heart rate, temperature, or oxygen levels. While actigraphy is generally accepted as a viable method for gaining objective sleep data (Marino et al., 2013), it has lower specificity than polysomnography (Hang Yuan et al., 2023; Schwab et al., 2018). Nonetheless, actigraphy is widely used in sleep studies as it is a practical and relatively cost-effective method of gaining data on sleep behaviour. Comparative studies have shown that, although polysomnography is more effective at accurately determining sleep stages, actigraphy can still provide valuable information as it can effectively measure sleep onset, sleep duration, and instances of night-time wakefulness (Schwab et al., 2018; Morgenthaler et al., 2007).

Using actigraphy in sleep studies offers provides ecologically valid, objective data on sleep-wake cycles and sleep duration (Marino et al., 2013). This can contribute rich insights into the prevalence and nature of sleep disturbance. These findings, although from limited sample size studies, indicate a clear prevalence of sleep difficulties in autistic adults, although there seems to be heterogeneity in the nature of these sleep

difficulties (RQ1). Several studies paired actigraphy with other physiological measures and/or subjective measures, e.g. (Baker, Richdale, Hazi, et al., 2019; Benson et al., 2019). These multimodal studies offer initial but limited indications of potential mechanisms for sleep difficulty (RQ2), such as hyperarousal, or attention switching difficulties (Baker, Richdale, Hazi, et al., 2019). Only one intervention study used actigraphy, offering preliminary evidence relevant to Research Question 3 (Lawson et al., 2023).

The present literature search identified six studies that used actigraphy to quantify sleep difficulties in autistic adults. The actigraphic studies in this review consistently found that autistic adults experience a higher rate of sleep difficulties than their allistic counterparts (Baker, Richdale, & Hazi, 2019; Baker, Richdale, Hazi, et al., 2019; Baker & Richdale, 2015; Benson et al., 2019) (see Table 2) a finding relevant to RQ1. These difficulties particularly related to prolonged sleep latency and lower sleep efficiency. Studies using actigraphy to explore relationships between sleep and quality of life found that sleep difficulty correlates with quality-of-life factors such as mental health and employment status. The pairing of actigraphy with subjective measures allowed for exploration of these relationships, however the small number of studies mean that insights into causal factors for autistic sleep difficulties are limited. This group of studies included only one intervention study – a pilot for Acceptance and Commitment Therapy for Insomnia (Lawson et al., 2023). Despite strong evidence from actigraphy that sleep difficulties are common and cause significant difficulty for autistic adults, these findings have yet to inform a substantial intervention research-base. Only

one study using actigraphy evaluated an intervention (Lawson et al., 2023). This highlights a serious gap in translational research between observational findings and treatment development. Overall, the actigraphy studies reviewed in this thesis highlight the prevalence and severity of autistic sleep difficulties, and how these relate to overall quality of life.

Baker and Richdale (2015) provided important evidence that autistic adults experience significant sleep difficulties. As with many of the objective measure studies in this review, Baker and Richdale (2015) collected subjective data as well as their objective actigraphic data. Actigraphic data was collected over 14 days and nights, allowing time for participants (autistic adults aged 21-44, N=36 and age-matched non-autistic adults, N=36) to become accustomed to wearing the devices. Actigraphic data indicated that autistic participants experienced longer sleep onset latency (SOL) and subjective self-report data (from sleep diaries and the Pittsburgh Sleep Quality Index (PSQI) compared to allistic participants. Subjective sleep data indicated that autistic participants felt less refreshed than allistic counterparts when waking up, and that their sleep quality and efficiency were poorer. While this well-designed study presents important data as to the sleep difficulties that autistic adults experience, it has a relatively small sample, and did not directly address the underlying reasons for autistic sleep difficulties. The authors highlight this shortcoming, as well as the need for further research around the causes of autistic sleep difficulties, how they occur across the lifespan, and how they may affect autistic symptomatology and activities of daily living (Baker & Richdale, 2015). In the decade since this study, there have been several other

studies that have added to the evidence for the prevalence of sleep difficulties amongst autistic individuals.

Benson et al.'s (2019) study utilised actigraphy technology in order to gain data on young autistic adults (N=15, 18-35 years), as well as collecting subjective self-report data on sleep and physical activity. Similar to Baker (2015), the fact that this study had age-matched controls is a strength of the study, as is the fact that participants wore the actigraphy monitor on their non-dominant wrist for 14 days. One potential limitation with this study is that some of the self-report subjective measures were not completed by participants, but by their caregivers, with these measures being more likely to capture the caregivers' perception rather than the participants' in some cases. Analysis of actigraphic data indicated that the autistic adults' sleep onset latency (SOL) was significantly longer than the control group (average of 36.5 minutes compared to 19.6 minutes). Notably no significant differences in night-time wakefulness were found between groups. While this study involved a small sample, the findings give an indication of the significant sleep difficulties that autistic adults experience. Additionally, this study takes into consideration many of the wide-ranging, physiological factors that can affect sleep, with inclusion of body mass index (BMI) data, as well as a subjective measure for sleep apnoea and physical activities. The use of actigraphy in tandem with the PSQI allows a wide variety of aspects of sleep to be examined.

Baker et al. (2019) took a similar methodological approach to Benson et al (2019) in utilising actigraphy monitors over a 14-day period in order to explore sleep difficulties

for autistic people. This research group recruited age-matched autistic (N=36, 21-44 years) and control samples (N=36, 21-44 years) to explore sleep and its relation to employment status. The authors found a higher prevalence of sleep difficulties amongst the autistic sample when compared to the controls. In fact, 20 of the 36 autistic participants had sleep difficulties to a level that would meet the criteria for a sleep disorder, whereas only four of the 36 participants in the control group had sleep difficulties to that level. This study also highlighted that participants from the autistic sample with a high level of sleep difficulties were more likely to be unemployed than those without.

Baker, Richdale, and Hazi's (2019) findings suggest a relationship between poor sleep and quality of life outcomes, such as employment status, in autistic populations. While sleep difficulties may have a significant impact upon employment and career prospects, there are also other factors that may impede an autistic person in accessing full-time employment, such as discrimination or lack of reasonable adjustments. Nonetheless, this research further adds to the evidence that sleep difficulties are more prevalent for autistic people than they are for the general population.

Another study by the same research group (Baker, Richdale, Hazi, et al., 2019) used actigraphy and self-report, while also collecting saliva samples from participants in order to examine cortisol levels. Notably this study found no significant differences between groups in Sleep Latency (SOL) or night-time wakefulness (WASO), or sleep efficiency (SE). Cortisol levels usually surge in the first hour of waking and then

gradually decrease throughout the day (Baker, Richdale, Hazi, et al., 2019), however this study found some indications of elevated evening cortisol levels in participants with more sleep difficulties in the autistic sample when compared to control. Subjective measures of arousal and objective cortisol measures suggested that dysregulation of arousal levels is a factor in sleep difficulties for autistic people. The researchers did cite some difficulty with saliva sampling timings methods in their limitations, and therefore excluded the cortisol levels from their final model. The difficulty they cited was that participants were required to collect a cortisol sample at their habitual time of going to sleep, and delay their actual time of going to sleep, which may have in turn influenced their sleep latency. This avenue of research that considers hormonal factors and physiological arousal is an important one but requires further research with larger sample sizes and increased cortisol sampling. Cortisol levels fluctuate throughout the sleep/wake cycle and facilitate changes in arousal levels. Larger studies would be required to gain insight as to whether this a factor contributing to the prevalence of sleep difficulties in autism.

A study that highlights contradictory evidence for sleep difficulty in autistic populations is by Henderson et al. (2023). The authors found no significant difference in subjective sleep measures; however, they did find some limited differences in objective measures. Autistic participants had on average lower sleep efficiency (Henderson et al., 2023), which was particularly prevalent amongst autistic females. Sex differences are not prominent in the other studies included in this review, even though sleep literature frequently highlights differences in sleep difficulties between

sexes (McArdle et al., 2020; Zheng et al., 2018). Henderson et al. (2023) initially analysed data from a large sample (N=2200) with subjective measures from the UK Biobank study, and then followed this up with an actigraphic study with autistic adults (N=220).

One particular strength of Henderson et al.'s (2023) study was the use of a range of measures for wellbeing and mental distress. The analysis of these measures in relation to sleep scores suggests that there is a stronger association between sleep difficulties and higher mental distress amongst autistic individuals than allistic individuals. Despite the correlational nature of the results, this highlights the need for further research and evidence-based interventions for autistic people in relation to their sleep.

While these studies all vary in their approaches, and each bring a perspective on the effects of autistic sleep difficulties, they do not shed light on the factors that contribute to autistic sleep difficulties compared to non-autistic individuals. Additionally, evidence for the efficacy of sleep interventions is sparse, with only one actigraphy study in this review evaluating a sleep intervention designed for autistic people. Lawson et al. (2023) developed a pilot study (N=8; 6 males, 2 females) for treating autistic adults affected by insomnia. The intervention used an Acceptance and Commitment Therapy treatment for insomnia (ACT-i) that had been developed with the needs of autistic people in mind. Acceptance and Commitment Therapy (ACT) is known as a third-wave cognitive therapy, that is associated with Relational Frame Theory and seeks to

promote psychological flexibility through mindfulness and acceptance processes, as well as commitment and behaviour change processes (Hayes et al., 2006; Öst, 2014). The results suggest that ACT-i can reduce insomnia and anxiety symptoms for autistic adults. This pilot study serves its purpose of proving this is an approach that merits further research and has promising clinical efficacy. One strength of this study is that it uses a wide variety of measures, including an ACT-related measure, the Brief Experiential Avoidance Questionnaire (Gamez et al., 2014), which would serve to indicate whether the intervention is affecting psychological flexibility. Measures for sleep (PSQI), anxiety and depression, as well as fatigue, insomnia severity, and sleep anticipatory anxiety were also included in the study. This wide-ranging combination of measures, combined with sleep diaries and actigraphic data allows for measurement of different factors that can affect sleep and the impact that sleep difficulties can have on a number of physical and mental health outcomes. In particular, the Sleep anticipatory questionnaire explores pre-sleep cognitions such as worries and negative thoughts, which may be particularly relevant for this population. Another strength of the design is that measures were taken at pre, post and 2-month follow-up stages of the intervention. Notwithstanding these methodological strengths, the study is underpowered and therefore the effectiveness of the intervention cannot be fully assessed. Future studies should implement similar methodologies using larger and more representative samples.

Overall, studies using actigraphy suggest that autistic adults have more sleep difficulties than allistic adults, however the evidence for the nature of the difficulty is varied. While Baker et al (2019) found a far higher percentage of autistic participant met

the criteria for a sleep disorder than control, Baker, Richdale, Hazi et al.'s (2019) research exploring the role of hyperarousal in sleep found no significant difference between groups in subjective measures for SOL, WASO, or even sleep efficiency. Actigraphic data indicated that autistic participants slept for a shorter amount of time than participants in the control condition. In this study, autistic participants also scored higher for overall sleep difficulties than participants in the control group on the PSQI subjective measure of sleep.

The differences in findings between studies in relation to chronotype and total sleep time also indicate that autistic sleep patterns differ from allistic sleep patterns, but that the heterogenous nature of autism means that there is huge variability in the autistic patterns across objective and subjective measures. Benson et al (2019) found the ASC group in their study had longer total sleep times than the allistic individuals. This finding differs from Baker, Richdale, Hazi et al.'s (2019) results which found shorter total sleep time in their ASC groups. Benson et al. (2019) observed earlier bedtimes among the ASC group, which contrasts with Nijhof et al.'s (2024) findings that autistic individuals prefer being awake late at night. This also challenges common stereotypes suggesting that an eveningness chronotype is more prevalent in autism. A greater number of actigraphic studies would be required in order to get a clearer understanding of whether there is a significant correlation between autism and chronotype. The current actigraphic studies demonstrate the presence of sleep difficulties for autistic adults, however this body of evidence does not provide insights into the factors contributing to these sleep difficulties.

1.2.6.4 Other Objective Measures

Some studies in this review involved additional objective measures that differ from actigraphic and polysomnographic approaches: alternative objective measures used were cortisol sampling (Baker, Richdale, Hazi, et al 2019) and body-temperature monitoring (Hidaka, 2023). These studies contribute to understanding underlying physiological processes that may explain autistic sleep difficulties, thereby informing Research Question 2. These studies offer limited but important steps toward exploring mechanisms such as arousal regulation and thermoregulation, although their findings have not yet translated into intervention development (RQ3). The temperature study (Hidaka, 2023) does not add to our understanding of autistic sleep difficulties; however, it tackles some hypothesis-related and methodology-related problems. Preliminary findings in cortisol-sampling suggest possible dysregulation in arousal systems, such as elevated evening cortisol being a factor in autistic sleep difficulties (Baker, Richdale, Hazi, et al. 2019). This may support a hyperarousal model of insomnia. However, research exploring interoceptive or thermoregulatory mechanisms are notably absent.

Baker, Richdale, Hazi, et al. (2019), as already mentioned, collected saliva samples alongside actigraphy data to explore arousal levels and test a hyperarousal hypothesis of autistic sleep difficulties. As cortisol relates to HPA axis regulation and cortisol levels fluctuate throughout the day, this approach is one that could give key objective insights into physiological arousal levels in the sleep-wake cycle of autistic individuals. Baker, Richdale, Hazi, et al. (2019) offer evidence supporting the

hyperarousal hypothesis of insomnia in autistic adults, highlighting a significant association between elevated cortisol levels and sleep disturbances. This pattern suggests dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis, a key neuroendocrine system involved in the regulation of stress and circadian rhythms (Baker, Richdale, Hazi, et al., 2019). Different factors may contribute to the dysregulation of the HPA axis. For example, prolonged or repeated exposure to stress can disrupt normal cortisol secretion patterns (Baker, Richdale, Hazi, et al., 2019; Diekelmann et al., 2011). Additionally, medical conditions and health factors (which are prevalent in autism) may also contribute to this dysregulation. Thus, research into the specific mechanisms of HPA axis function in autistic individuals is critical to developing tailored, biologically informed interventions for sleep disturbances in this population.

One notable limitation of this study concerns the methodology used for cortisol sampling. Specifically, samples were collected by participants themselves, and each participant provided only seven samples in total – five evening samples and two morning samples (Baker, Richdale, Hazi, et al., 2019). This relatively sparse sampling schedule may not adequately capture the full diurnal rhythm of cortisol. More frequent sampling at multiple time points during the day would likely yield a more comprehensive profile of cortisol fluctuations. In addition, self-collection of saliva samples introduces the possibility of procedural errors (e.g. incorrect timing, improper storage), all of which can compromise data validity. The study does not report in detail what systems or protocols were in place to ensure that participants followed collection procedures accurately.

Future research would benefit from implementing standardized collection protocols to enhance data reliability and reduce the risk of participant-related inconsistencies.

One of the strengths of the Baker, Richdale, Hazi et al. (2019) study was that as well as a control group, the study included two autism groups, one who were on medication that might affect sleep, and another who were not on medication. In both autism groups, evening cortisol levels were higher than expected for that point in the sleep-wake cycle. For the non-medicated autistic group, this elevated cortisol level was associated with increased night-time wakefulness (WASO) and lower sleep efficiency (SE%). For the autistic group who also took medication, the higher evening cortisol levels were associated with shorter total sleep duration (TST) and lower sleep efficiency (SE%) (Baker, Richdale, Hazi, et al., 2019). While these findings highlight some associations, unfortunately the authors could not develop an overall model that included cortisol levels in their analysis, and therefore this variable was excluded it from the final model. This further highlights the need for more research that explores how sleep, stress, physiological arousal, and processes of HPA axis regulation, relate for this population. In the context of issues of sleep difficulties in the general population, issues of arousal and regulation are important factors to consider. The findings of this study further highlight how it is worth exploring further how these factors are specifically relevant to autistic adults. However, the failure to model cortisol data due to methodological issues illustrates the critical importance of rigorous protocol design in sleep research.

Hidaka et al (2023) is the only paper included in this literature search that explores body temperature as a key factor associated with sleep difficulties in autism. This large-scale (N=2185) online study found no significant correlation between autistic traits and body temperature (Hidaka et al., 2023). Their hypothesis—that lower body temperatures at a population level are linked to increased autistic traits—was not supported by the evidence. The study did find an association between autistic traits and 'eveningness' chronotype, which is consistent with the findings of Harris & Carciofo (2023). Overall, this general population study does not provide further evidence of the nature of sleep difficulties for autistic adults, and although temperature was considered in this study, the relationship between thermoregulation and sleep was not explored.

A critical appraisal of this study highlighted some issues with its theoretical basis, as well as some methodological issues relating to the collection of data. From a theoretical standpoint, Hidaka et al. (2023) proposes that lower brain temperature is associated with higher autistic traits. Hidaka et al. (2023) presents two separate claims as the premise for this proposed association, and both claims are problematic. First, the authors claim that global decrease in human body temperature is possible causation for increased 'ASD-like characteristics and the number of clinical ASD diagnoses at a population level' (Hidaka et al., 2023, p. 2). There is no indication that these two facts have been analysed to determine their association over time. Second, Hidaka et al. (2023) refer to a study reporting that when autistic children had a fever, the frequency and severity of their observable autistic behaviours were reduced. A simpler explanation is that when children are ill and have a fever, they are less active, which naturally

reduces the frequency of their usual behaviours. This may be a conflation of autism with observable behaviours attributed to autism. There is no evidence that an autistic child who has a fever is any less autistic in their cognition, or in their experience of the world. An observer may see fewer notable behaviours that are generally associated with autism, but this is better explained as a change in behaviour due to other influencing factors (e.g. illness) rather than the child becoming less autistic. In terms of methodology, participants were asked to measure and record their own body temperature at time points during the day. While participants were asked to record the brand and model of their axillary thermometer, the area of the body where temperature was measured is not detailed in the article. An analysis of variance in accuracy between thermometers accounted for variability in readings from the devices.

To summarise, a small number of studies have collected objective data while focusing on sleep difficulties for autistic adults. The findings provide quantitative evidence that autistic adults experience a high level of sleep difficulties. However, there is considerable variation in the data regarding the specific nature of these difficulties. The objective measures also suggest some possible avenues for research into why autistic adults experience sleep difficulties Given the limited research on this population, it is difficult to determine why autistic individuals experience these difficulties or how they can be addressed. Studies that have employed subjective measures in their methodologies may add to what is known and give a clearer indication of future avenues for research. While objective measures provide quantifiable insights into sleep architecture, they often miss the lived, subjective experience of sleep. Subjective tools

fill this gap, offering data on perceived quality, restfulness, and the personal impact of sleep difficulties.

1.2.6.5 Subjective Measures

Subjective measures of sleep such as self-report questionnaires and sleep diaries are commonly used in sleep research (Bastien et al., 2001; Buysse et al., 1989). They are a cost effective and pragmatic way of getting large amounts of data regarding the sleep habits and experiences of individuals in their usual context and accounting for their lifestyle. Subjective measures such as these can be used in studies on their own, or else in tandem with objective physiological measures such as actigraphy and polysomnography. These subjective measures provide valuable insight into the lived experience of sleep among autistic adults. The studies in this section offer consistent evidence of widespread sleep difficulties (RQ1) and highlight mental health and sensory-related correlates that suggest possible causal mechanisms (RQ2). However, these suggestions are avenues for further research into sleep mechanisms rather than definitive findings. Some studies also provide participant perspectives on the limitations of existing treatment models, contributing insight relevant to Research Question 3.

The studies in this review that used subjective measures consistently report high levels of clinically significant sleep disturbance, including poor sleep quality and long sleep latency. The two most used validated self-report questionnaires used by studies included in this review were the Pittsburgh Sleep Quality Index (PSQI) and the Insomnia

Severity Index (ISI). Other studies used other validated measures, and some used novel survey measures with questions that have not been validated. Notwithstanding the richness of information that subjective measures may be able to provide, they may not fully capture the underlying physiological processes, or differences in sleep architecture.

1.2.6.6 Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index (PSQI) is the most commonly used self-report measure in the included studies (Buysse et al., 1989). It comprises of measure for a broad range of sleep difficulties such as subjective sleep quality, sleep onset latency, and night-time wakefulness. A higher global sleep score on the PSQI indicates higher levels of sleep difficulties. The PSQI differs from the Insomnia Severity Index (ISI) in that it does not focus solely on diagnosing insomnia but rather it assesses multiple aspects of sleep. The ISI was designed to be used as part of the diagnostic process for insomnia (Bastien et al., 2001). This gives the PSQI the advantage of gaining a broader insight into other aspects of sleep difficulty, whereas the ISI is specifically targeting the diagnostic criteria for insomnia. Studies using the PSQI make a strong contribution to Research Question 1 by consistently reporting high levels of sleep difficulty in autistic adults. These findings underscore the clinical need for tailored interventions (RQ3); however, they simply highlight the profound and pressing need for intervention research rather than providing evidence of treatments and efficacy. Most studies using the PSQI

give indication of different aspects of sleep difficulty for autistic people, but stop short of identifying underlying mechanisms, limiting their contribution to Research Question 2.

The PSQI was used in 14 of the studies included in this review. Of all those 14 studies, 13 had directly recruited autistic participants and one was a protocol development paper proposing a study that would recruit autistic participants (Gernert et al., 2024). Twelve of the thirteen studies using the PSQI found that autistic adults' experienced significant sleep difficulties: with their global sleep difficulty score being higher than the control group (Baker, Richdale, & Hazi, 2019; Baker, Richdale, Hazi, et al., 2019; Baker & Richdale, 2015; McLean et al., 2021). In studies where there was not a control group, the mean global sleep score for autistic adults was greater than 5, indicating a clinical level of sleep difficulty (Charlton et al., 2023; Halstead et al., 2021; Halstead et al., 2021; Lawson et al., 2023; Leader et al., 2021). These findings reveal a consistent pattern: the vast majority of autistic adults meet the clinical threshold for poor sleep. Across diverse samples and study designs, elevated global sleep scores reflect significant sleep difficulties, which may impact quality of life and mental health. This robust trend highlights the urgent need for tailored sleep interventions. While these studies establish high prevalence and severity of sleep difficulties through subjective reporting, they seldom move beyond symptom documentation to explore mechanistic or process-level explanations. This limits the utility of the data for informing autism-specific, individualised, or sensory-sensitive interventions. What the PSQI studies can provide us with, is greater detail on the subjective experiences of those sleep difficulties.

The PSQI global sleep is a composite score that is influenced by the scores in all sub-tests. It is a widely used subjective measures in sleep research and provides insight into this population by highlighting widespread sleep difficulties, including challenges with falling asleep (SOL), staying asleep, and sleep efficiency. While these global scores give us a broad overview of the prevalence of sleep difficulties for autistic adults, not every study showed significant differences in the global score (Benson et al., 2019), and a more detailed inspection of the sub-tests is required to gain insight into the range of sleep issues involved.

Notably, Benson et al. (2019) found no significant difference in global sleep scores between their autism group (M = 5.4 ± 3.8) and control group (M = 5.3 ± 2.4). This may be due to its small sample size (N=15), but some limitations in study design may also have contributed to this null result. For example, there is no mention in the paper that the control group was screened for autism. Additionally, two-thirds of the autistic sample could not complete the self-report measures and sleep diary themselves, and therefore a parent completed these on their behalf. This was not true of the control group and may represent a confounding factor in data collection. However, despite the lack of difference between groups on global sleep score, the scores for sleep onset latency (SOL) indicated that autistic participants took significantly longer to fall asleep (M = 53 minutes) than the control group (M = 11.8 minutes). Higher SOL scores are a risk factor for insomnia, and while insomnia was a risk factor in both groups, the data suggested that insomnia severity may be greater in the autistic group.

Several of these studies found that a high percentage (>85%) of autistic participants met the criteria for clinically poor sleep quality. This is derived from the PSQI global sleep score being greater than five. Charlton et al. (2022) found that 85.5% of the participants in their autism sample met the criteria, with this sample having a mean global sleep score of 9.49. Leader et al. (2021) found that 89% of participants in their autistic sample met the criteria for clinically poor sleep quality. Halstead et al. (2021) investigated treatment of sleep difficulties for autistic people and found that 89% of autistic participants met this threshold. In addition, they also noted that 58% of these individuals had not had any appointment with a healthcare professional to seek help regarding their sleep difficulties (Halstead et al, 2021). Furthermore, 80% of those with sleep difficulties reported that the approach of managing sleep problems by themselves was not effective.

While there is a relatively small number of papers investigating sleep difficulties for autistic adults, evidence from the PSQI studies alone demonstrate the significant clinical need for sleep interventions among this population. Additional subjective measures further support these findings.

1.2.6.7 Insomnia Severity Index

As previously mentioned, the Insomnia Severity Index (ISI) is a clinical subjective measure which is focussed on the diagnosis of insomnia, rather than examining any other aspects of sleep. Insomnia is a sleep-wake disorder that involves frequent and

persistent difficulties with getting to sleep or staying asleep such that the quality or quantity of sleep is unsatisfactory and affects quality of life. It is listed in both the DSM-V-TR (American Psychiatric Association, 2022) and the ICD-11 (World Health Organisation, 2019). The ISI is scored from 0 to 29, with 0-7 indicating no clinically significant symptoms, 8-14 indicating subthreshold insomnia, 15-21 clinical insomnia (moderate level), and 22-28 clinical insomnia (severe level) (Bastien et al., 2001; Morin et al., 2011). It is a well validated measure suitable for research and clinical contexts (Bastien et al., 2001; Morin et al., 2011). The ISI provides a focused assessment of insomnia symptoms and their severity. Studies using this tool confirm a high prevalence of insomnia in autistic populations (RQ1) and contribute to an understanding of how these difficulties affect quality of life. Findings from one intervention study using ISI are particularly relevant to Research Question 3 (Lawson et al., 2023) as it provides evidence of treatment efficacy and recovery rates in this pilot intervention study.

Three articles included in this review used the ISI in their studies (Deserno et al., 2019; Harris & Carciofo, 2023; Lawson et al., 2023). Lawson et al. (2023) adopted this measure in conjunction with the PSQI at three time-points in order to gain an understanding of whether their sleep intervention brought about clinically meaningful change. As previously mentioned, the data indicated that all six participants in this pilot study met the criteria for insomnia, with all of them showing some form of improvement. By the end of the intervention, 2 of the participants no longer met the criteria for insomnia according to the ISI, suggesting that ACT-i has potential to be an effective

insomnia intervention for autistic adults. This promising pilot study should be followed up with larger-scale research to establish a solid evidence-base for this intervention.

Harris and Carciofo (2023) used the ISI alongside the Autism Quotient Shortened version (AQ-28), the Composite Scale for Morningness (CSM), and the Centre for Epidemiological Studies –Depression Scale Short (CES-D) to examine the relationship between chronotype and autistic traits, as well as potential links between these traits, insomnia, and depression. It is important to note that this is a general population study and not a study that has recruited autistic participants. General population studies that explore autistic traits can produce helpful insights that might be relevant and beneficial to autistic people, however they should not-replace autism-specific research . Harris and Carciofo (2023) used the components of the AQ-28 to analyse whether specific traits related to chronotype. Morningness and eveningness chronotype are terms used to distinguish between trait-patterns of behaviour where some individuals tend to be more active in the evening and stay up later at night (eveningness chronotype) and others tend to get up earlier and be more active in the morning (morningness chronotype). Analysis of the component factors of the AQ-28 indicated that individuals who struggle with attention-switching were also likely to be associated with the eveningness chronotype. This suggests that difficulties with transitioning from daytime activities to a ‘wind-down’ state before sleep may contribute to a preference for later sleep times among autistic individuals. If this switching process takes longer, falling asleep later becomes more likely. The cross-sectional design of this study means conclusions cannot be drawn about causality, nor can conclusions be directly inferred

for autistic people, however these findings do give indications of relevant avenues for further research directly with autistic adults.

Deserno et al. (2019) took a more direct approach by recruiting a large sample of autistic adults (N=598). Importantly, this study is one of only two longitudinal studies included in this review. However, as an online study, it lacked the diagnostic validation seen in other studies that used ADOS-2 or ADI-R to confirm participants autism diagnoses. Deserno and colleagues (2019) found that sleep quality was a significant predictor of subjective quality of life in autistic adults. In fact, sleep problems were the most significant predictor of poor quality of life, with additional psychological conditions further compounding the effect of sleep difficulties. This suggests that sleep is a key factor in quality of life for autistic adults. The prominent role of sleep difficulty in the mental health of autistic adults highlights the importance of research into sleep interventions for this population.

1.2.6.8 Other Self Report Measures

Several articles included in this review used other self-report measures, including novel as well as validated measures. This section reviews validated and novel sleep measures beyond the PSQI and ISI. These tools support Research Question 1 by identifying high rates of sleep difficulty and highlighting contextual factors that may influence outcomes. Intervention and longitudinal studies using these tools also provide limited but valuable insight for Research Question 3. Nijhof et al. (2024) conducted a qualitative study with autistic adults affected by insomnia. They used the Sleep

Condition Indicator (SCI) as part of their selection process. The SCI is an 8 question clinical screener for insomnia (Espie et al., 2014) and was used to ensure all participants experienced sleep difficulties. Two other studies used validated sleep measures, with Quist et al. (2015) using the Pittsburgh Insomnia Rating Scale (PIRS) and Stewart et al. (2020) using Saint Mary's Hospital Sleep Questionnaire.

The Pittsburgh Insomnia Rating Scale (PIRS) is similar to the ISI and SCI in that its purpose is the detection and diagnosis of insomnia, whereas the PSQI takes a slightly broader view of multiple aspects of sleep. The PIRS is a validated and reliable measure for insomnia (Veqar et al., 2014). Quist et al.'s (2015) research was on a psychoeducation intervention for insomnia in autistic adults, so the use of the PIRS in this context is an appropriate measure. The intervention was a psychoeducation group meeting for six weekly one-hour sessions. The intervention involved homework tasks, sleep diaries, as well as psychoeducation about sleep difficulties and sleep hygiene strategies. While the PIRS measure did show promising outcomes in terms of sleep latency, there are some contextual factors that are relevant. This intervention took place in a specialist mental health inpatient unit for autistic adults. All participants were male (N=14), and they did not participate in the same group simultaneously, as data was collected over a two-year period (2011–2013). Measures were taken pre and post intervention without any follow-up measure. The context of the inpatient unit is important to consider, as it is a controlled and observable environment with professionals present at all times. The authors note that changes were made to the ward routines in order to promote healthy sleep, however more details are needed to determine the nature of

these changes and whether these may have influenced the observed improvements in PIRS outcomes. In addition to this, there was a small, single-gendered sample size, with each participant also affected by a mental health condition which they were receiving treatment for. Although the study showed improvement in insomnia symptoms, the absence of follow-up data makes it unclear whether these gains were sustained after discharge from the inpatient setting. This research suggests that psychoeducation sleep interventions may be helpful for autistic adults, however more studies are needed, using similar comparable measures, larger samples, and a design that includes more controls for confounding variables, such as changes in ward practices or environmental changes.

Stewart et al. (2020) used the Saint Mary's Hospital Sleep Questionnaire (SMH-SQ) in a general population correlational study to explore sleep difficulties and mental health problems in older adults who have a high level of autistic traits. The SMH-SQ is a validated self-report measure designed to be used by patients in medical contexts to report on their sleep quality (Charlton et al., 2023; Halstead et al., 2021; Leader et al., 2021). The overall online study involved a large sample (N=6,740), with 187 of those participants being considered to have a high level of autistic traits. However, the measure used to survey autistic traits was a novel one. While the authors state that is has similar validity to the AQ-10 or the RAADS-14, it is still a novel measure without sufficient reliability and validation data of its own. While this study is in an area with a significant need for further research, it is difficult to draw firm conclusions when a novel measure is used to assess autistic traits. Further research is needed to explore the

relationship between sleep difficulties and autistic traits in older adults using well-established measures.

In Charlton et al. (2022) study, autistic adults (n = 730, aged 18–78 years) were recruited for an online study exploring predictors of sleep quality across adulthood. This was an online survey asking about demographics, social supports, symptoms of anxiety and depression, health conditions, and sleep quality. Regression analyses explored the variables associated with sleep quality. Female sex, health, and self-reported anxiety symptoms significantly contributed to models for all aspects of sleep. Perceived stress contributed to models of overall and subjective sleep quality, and daytime dysfunction. Depression symptoms didn't contribute significantly to any of the models of sleep quality. However, utilising government support mechanisms (such as social security) contributed to the model of sleep efficiency. Age contributed little to models of sleep quality, whereas perceived stress and psychotropic medication use contributed to some but not all aspects of sleep. This study's consideration of socioeconomic factors is something that is not considered in other research is this review and gives insight into how societal factors may influence sleep difficulties.

Halstead et al. (2021a) took a different approach to investigating sleep difficulties in autistic adults by focusing on their experiences of treatment. They aimed to report the perspectives of autistic adults in the United Kingdom on treatment of their sleep problems. A total of 288 autistic adults living in the United Kingdom completed an online survey including assessments of their sleep quality using the Pittsburgh Sleep Quality

Index, reporting their experiences and preferences of sleep treatment with UK healthcare professionals and, their experiences of self-management of their sleep (Halstead et al., 2021a). This study found that participants who experienced sleep difficulties were more likely to have symptoms of depression or anxiety, regardless of their level of autistic traits. The group of older adults who measured high in autistic traits were more likely to have greater sleep difficulties, including difficulties with sleep onset, and poorer satisfaction with their sleep. Results also indicated that the 90% of participants met the criteria for poor sleep. The study also found that 60% of participants who attended medical appointments regarding their sleep difficulties were dissatisfied with the outcome. Self-management of sleep problems was not effective for 80% of participants.

Leader et al. (2021) investigated the relationship between sleep problems, gastrointestinal symptoms, social functioning, autism traits, and social support on quality of life (QoL) in 107 autistic adults. Questionnaires included the Autism Spectrum Quotient-10 (Adult), Multidimensional Scale of Perceived Social Support, Social Functioning Questionnaire, Pittsburgh Sleep Quality Index, Gastrointestinal Symptom Inventory, and World Health Organization Quality of Life-BREF. Greater sleep problems were correlated with poorer QoL in the physical health and environment domains. Specifically, the sleep problem of daytime dysfunction was correlated with poorer QoL in physical health. This research indicated that GI symptoms and sleep problems are common comorbid conditions in the adult ASD population. This paper expanded upon the existing literature by highlighting unexplored factors influencing QoL

in adults with ASD: Quality of life, gastrointestinal symptoms, sleep problems, social support, and social functioning in autistic adults.

1.2.6.9 Qualitative Research

The sole qualitative study included in this review (Nijhof et al., 2024) took an Interpretative Phenomenological Analysis approach (IPA; Smith et al., 2009). IPA is a qualitative approach intended to explore the complex experiences of participants, including embodied experience, and meaning-making. This approach is well-suited to exploring the unique experiences of an individual autistic person and this study makes a unique contribution to this review. This approach and this particular study are important in capturing the voices and experiences of autistic people, which in the past has been omitted from much of autism research. The qualitative study reviewed here offers unique, experiential insights into the nature and impact of sleep difficulties in autistic adults (RQ1). It also sheds light on potential mechanistic processes such as sensory sensitivity and interoceptive awareness (RQ2), and critiques the relevance of standard interventions, thereby informing Research Question 3.

Nijhof et al. (2024) highlight the importance of sleep for mental health and quality of life, as well as the prevalence of sleep difficulties amongst autistic people. They also note that there is currently no evidence-base for a Cognitive Behavioural Therapy for Insomnia (CBT-i) that has been adapted for, or used in, the treatment of autistic adults – a finding that is consistent with my literature review. This study took a collaborative

approach to autism research by consulting experts by experience in order to validate the need for research in this area. The researchers also asked for input from the experts by experience on the documentation used for the study and the methods to be used. Each participant self-reported that they had a diagnosis of autism, completed a self-report sleep scale – the Sleep Condition Indicator – and took part in individual interviews. Transcripts of these interviews were read and re-read by the lead researcher, following Smith's (2010) IPA steps of analysis. Two other researchers separately coded a transcript each to provide a comparison of codes and comments to improve the analytical process. Coding and comments were discussed by the entire research team to clarify themes and to agree upon Group Experiential Themes.

The two Group Experiential Themes (GET) that were identified in the process of analysis were "The Nighttime is Friendlier" and "It Doesn't Really Work for Me". The researchers highlighted in the GET "The Nighttime Is Friendlier" that the participants had experienced sleep difficulties throughout their lives and felt it was something they had to live with. Some direct quotes from participants refer to bodily and sensory experiences, such as increased sensitivity to noise when tired, and heightened awareness of interoceptive and proprioceptive discomfort. This GET also refers to the participants perceiving night as a time that is easier to navigate and has fewer social demands. Several participants also described not having a desire to go to sleep, even resenting having to sleep, or being surprised that for some people sleep is a desirable activity. It is possible that for some of these participants physiological sleep pressure signals – interoceptive signals – are not noticed or attended to until they are heightened,

but a conclusion cannot be reached from these data alone. Overall “The Night Is Friendlier” GET gives a rich description of autistic individuals’ sleep difficulties that is in line with differences in chronotype and difficulties with sleep onset reflected in other sleep and autism literature.

The second GET ‘It Doesn’t Really work For Me’ refers to the participants’ experiences of, and reflections on, advice and interventions they have received in relation to their sleep. In this theme, participants spoke about sleep guidance, self-help strategies, and sleep interventions not being individualised to their needs, or not taking their autistic profile into consideration. The idea that generic sleep advice and sleep interventions is ill-suited and ineffective in helping autistic people with their sleep difficulties is not only reflected in other research (Pavlopoulou, 2020), but is also something I have come across in multiple anecdotal reports from autistic clients and their clinicians – overall highlighting the urgency to tailor sleep interventions for autistic individuals, addressing their unique sensory needs, and moving beyond generic advice to improve outcomes.

1.2.7. *Synthesis*

This review evaluated 25 studies that investigated the relationship between sleep and autism. As highlighted throughout this review, the body of knowledge relating to sleep difficulties for autistic adults is extremely lacking. There has not been enough research in this area, and the broad range of methods used across studies limit

generalisability of findings. While there is a lack of comprehensive studies on adults, existing evidence—ranging from qualitative reports to self-reports and physiological data—clearly shows that sleep difficulties are prevalent in autistic adults.

Research Question 1:

- What is the nature and prevalence of sleep difficulties in autistic adults, as reported in existing literature?

Research indicates that sleep difficulties are more prevalent among autistic adults compared to their allistic counterparts. Several studies in this review suggest that these difficulties affect a significant portion of autistic adults (Charlton et al., 2023; Halstead et al., 2021; Leader et al., 2021). The majority of papers reviewed were quantitative studies, involving subjective and objective measures. The sleep difficulties highlighted include sleep latency difficulties, reduced sleep efficiency, increased night-time wakefulness, and non-restorative sleep. Both objective (actigraphy, EEG) and subjective (PSQI, ISI) measures corroborate these findings. Studies by Charlton et al. (2022), Leader et al. (2021), and Halstead et al. (2021) found that over 85% of autistic adults met the clinical threshold for poor sleep quality. Actigraphy studies further revealed significant delays in sleep onset latency and reduced total sleep time compared to allistic controls. However, considerable heterogeneity exists between studies, partly due to varying methodologies, sample characteristics, and inconsistent use of diagnostic confirmation. Importantly, longitudinal and lifespan data remain scarce. While the available evidence highlights the negative impact of sleep difficulties

on quality of life and other outcomes, there is limited understanding of the underlying causes of these difficulties for autistic individuals.

Research Question 2:

- To what extent do current studies explore sensory, interoceptive, and thermoregulatory processes in relation to sleep in autism?

While research shows that sleep difficulties are prevalent among autistic individuals, there is limited exploration of the underlying processes contributing to these difficulties. For example, while hyperarousal is explored in one study (Baker, Richdale, Hazi, et al., 2019), this review found no studies considering the role of atypical interoception or thermoregulation in autistic sleep difficulties. Baker, Richdale and Hazi et al. (2019) proposed a hyperarousal hypothesis that could be important for understanding sleep disturbances in this population.

This may be connected to issues of self-regulation and ability to transition between tasks (Baker, Richdale, Hazi, et al., 2019). Hyperarousal includes both physiological and attentional components, and recent work links arousal levels to interoceptive processing (Suksasilp & Garfinkel, 2022a; Suzuki & Yamamoto, 2023). Difficulties with self-regulating arousal may be influenced by interoceptive functioning (MacCormack et al., 2024; Suzuki & Yamamoto, 2023), which is often atypical in autism (Ben Hassen et al., 2023; Garfinkel et al., 2016; Shah et al., 2016). Likewise, autistic

individuals frequently report difficulty with cognitive and behavioural flexibility, including challenges transitioning between tasks (Garau et al., 2023; Hoekstra et al., 2011; Murray et al., 2005). These dual challenges – atypical interoception and reduced task-switching flexibility – may impair the ability to move from high-arousal daytime activities into the kind of low-arousal, sensory-calming routines typically required for sleep onset. Relatedly, Harris and Carciofo's (2023) study suggested that attention-switching difficulties may increase the likelihood of autistic individuals experiencing the eveningness chronotype, making it harder to regulate arousal levels for sleep onset. These arousal and attention-related factors are connected to interoception (MacCormack et al., 2024; Suksasilp & Garfinkel, 2022a; Suzuki & Yamamoto, 2023), yet no study explored the role of interoception in sleep difficulties in autistic individuals. Similarly, while thermoregulation's link to sleep is well-established (Harding et al., 2019, 2020; Raymann et al., 2008), no studies explored how thermoregulation challenges might contribute to sleep issues in autistic individuals, despite growing awareness of atypical sensory profiles and interoceptive abilities in this population.

Thermoception represents one of the most sleep-relevant domains of interoception, and its thermoregulatory behaviours may be disrupted by atypical interoceptive profiles. Evidence suggests that humans engage in specific behaviours to facilitate getting their body to the right temperature for falling asleep and staying asleep (Harding et al., 2019, 2020; Raymann et al., 2008). While the efficacy of these behaviours in supporting sleep is increasingly well-established, the extent to which they rely on interoceptive abilities remains underexplored. This gap is particularly pertinent to

autism research, as autistic individuals often present with atypical interoception profiles (Garfinkel et al., 2016), which may interfere with the recognition of internal cues that prompt thermoregulatory action. Consequently, atypical interoception profiles may influence the ability to execute thermoregulatory behaviours in order to better facilitate sleep onset, or sleep maintenance. Furthermore, cognitive functioning such as reduced attentional flexibility or difficulty with transitions may pose additional challenges to establishing consistent pre-sleep routines (Harris & Carciofo, 2023), including those aimed at thermoregulation. Despite these plausible mechanisms, no studies to date have empirically examined the intersection of interoception, thermoregulatory behaviour, and attentional control in relation to sleep in autism.

Research Question 3:

- What evidence exists for interventions targeting sleep in autistic adults, and do these consider interoceptive or thermoregulatory factors?

Only two intervention studies specifically targeting sleep in autistic adults were identified by the current literature review. Quist et al. (2015) evaluated a psychoeducational group in an inpatient unit, while Lawson et al. (2023) piloted an adapted Acceptance and Commitment Therapy protocol for insomnia (ACT-i). Although both studies reported promising improvements, sample sizes were very small (n=8–14), and methodological limitations (e.g., lack of follow-up, no control groups) limit

generalisability. Crucially, neither intervention study incorporated interoceptive assessment or addressed thermoregulation as part of the treatment model. Despite evidence suggesting that physiological and sensory regulation are relevant to autistic sleep, intervention design remains disconnected from these mechanisms.

While the research reviewed has made it clear there is a significant prevalence of sleep difficulties amongst autistic adults, and this review demonstrates the significant impact these difficulties have on this population, it stops short of formulating coherent explanatory models that could guide intervention. The absence of frameworks incorporating sensory regulation, interoceptive awareness, and chronotype variation leaves clinicians without evidence-based pathways for adapting sleep treatments. Notably, no studies have explored how sensory aspects of autism, such as interoception, contribute to sleep issues, even though they are closely linked to sleep regulation. Hyperarousal and somatic issues both relate to sleep and interoception as hyperarousal may prevent autistic individuals attending to physiological sleep pressure via interoceptive pathways. Therefore, the process of downregulation in the arousal system that needs to take place before sleep would be disrupted and delayed. Baker, Richdale, and Hazi's (2019) hyperarousal hypothesis, which links sleep disturbances to sensory processing, remains unexplored since its initial proposal. Additionally, there is no evidence that thermoregulation has been considered in sleep difficulties, despite established links between body temperature changes and sleep onset (Harding et al., 2019, 2020; Raymann et al., 2008).

The gap in research extends beyond identifying causes to include effective interventions. There are currently no published, peer-reviewed assessments of the efficacy of CBT for insomnia for autistic people. CBT is often described as an evidence-based approach, and despite CBT for insomnia (CBT-i) being the first-line treatment for insomnia in the general population, no peer-reviewed studies have assessed its efficacy for autistic individuals. While other CBT adaptations have been made for autistic people, there is no evidence yet on how CBT-i should be tailored for this population. This review also found some promising intervention studies, through their clinical utility is limited by small sample sizes and their status as standalone studies. One notable study, the Lawson et al. (2024) pilot study on Acceptance and Commitment Therapy treatment for insomnia, shows potential for treating insomnia in autistic individuals, though further research is necessary to validate its effectiveness.

1.2.8. *Conclusion*

Bringing together findings from subjective, objective, and qualitative methodologies, this review reveals not only the high prevalence of sleep difficulties in autistic adults, but also the consistent absence of mechanistic insight across study designs. The studies reviewed highlight that there is a problem, but give limited evidence of the underlying causes, or viable responses to this problem. This highlights a significant clinical need: sleep difficulties are both highly prevalent and under-treated amongst autistic adults. This significantly impacts quality of life for the individuals affected. Difficulties with sleep onset, night-time wakefulness, and a feeling of poor

sleep leave many autistic adults fatigued during the day. There is a need for research exploring the nature of autistic sleep difficulties across the lifespan and what factors are contributing to these difficulties. To explore these factors will require a comprehensive methodological approach including longitudinal studies, objective measure sleep studies, and subjective measures of sleep quality.

The lack of evidence regarding the processes underlying sleep difficulties in autism requires physiological objective data from sleep studies. Sleep studies are challenging and costly, so more evidence is needed to determine which aspects objective measure should focus on. Additional studies using subjective measure could help build evidence and identify key areas for future objective research. A stronger evidence-base and clearer hypotheses about autistic sleep difficulties will ultimately contribute to targeted, evidence-based interventions.

The need for research into interventions for sleep difficulties in autism is highlighted not only by the lack of published research, but also by the high prevalence of sleep difficulties, and the lack of success autistic people have had in finding suitable treatment. There is a need for randomised-controlled trials, with treatments that have been adapted for autistic people so that we identify suitable and effective interventions (Nijhof et al., 2024). Importantly, autistic individuals must be consulted in this process, as their input is crucial for the effective adaptation of any interventions (Fletcher-Watson et al., 2019). A collaborative approach is not only needed in the development of interventions, but also in the design and execution of research into autistic sleep

(Fletcher-Watson et al., 2019). This review found a lack of consultation and collaboration in the majority of the reports scrutinised. Autistic consultation and collaboration are key to conducting ethical, meaningful, and impactful research that relates to autistic individuals (Fletcher-Watson et al., 2019).

This review found that there is currently no published research that explores whether individual differences in interoceptive abilities are related to sleep difficulties for autistic people. This area has not been investigated despite the fact that interoception is a key process involved in sleep processes (Wei & Van Someren, 2020), and that interoception in autistic individuals is atypical (C. D. Butera et al., 2023). Given the clinical need within this population and the lack of interventions to address it, exploring the relationships between sleep difficulties, interoception, and autism is essential. Additionally, thermoception - a facet of interoception that has particular relevance to sleep – is another under-investigated process despite evidence of a link between thermoregulation and sleep (Harding et al., 2019, 2020). This additional focus on thermoregulation has not been explored in any of the research into autistic sleep difficulties and may be a factor of interoception that has a role to play in autistic sleep difficulties.

1.2.9. The Current Study

The current study explored the relationships between sleep difficulties, interoception and autistic traits, with a particular focus on whether thermoregulatory factors contribute to sleep difficulties.

1.2.9.1 Problem statement

Sleep difficulties are highly prevalent among autistic individuals, with challenges such as delayed sleep onset and frequent night-time awakenings commonly reported (Richdale & Schreck, 2009). These difficulties compound co-occurring mental health conditions and reduce the efficacy of therapeutic interventions. Despite this, existing sleep interventions are often designed for neurotypical populations and lack meaningful adaptation to the unique sensory, cognitive, and physiological profiles of autistic individuals. The potential role of interoception and its relationship with thermoregulation in contributing to sleep difficulties remains, to date, unexplored. Atypical interoceptive processing may impair an individual's ability to initiate or modulate temperature-related behaviours that facilitate sleep onset and continuity. However, the interrelationships between interoception, thermoregulation, and sleep in autism remain poorly understood. Without a clearer understanding of these mechanisms, the development of tailored, effective sleep interventions for autistic individuals remains a significant challenge.

1.2.9.2. Aims and Objectives of the Current Study

Given the lack of research in this area, this study will take the approach of exploring autistic traits in the general population. This study aims to explore the inter-

relationships between subjective sleep, interoception, thermoregulation variables, and autistic traits in the general population. While there is limited research in this area to inform my study, I formulated some tentative hypotheses to be considered during the study:

- Hypothesis 1: Greater sleep disturbance will be associated with higher autistic traits.
- Hypothesis 2: Greater interoceptive difficulties will be associated with greater sleep disturbance. Greater interoceptive difficulties may consist of lower inteoceptive accuracy, reducing one's capacity to accuracy perceive and attend to interoceptive signals. Interoceptive difficulties may also pertain to greater interoceptive attention, whereby participants could hypothetically be over-focussed on interoceptive signals and failed to downregulate, thus affecting sleep onset and sleep maintenance.
- Hypothesis 3: High Temperature sensitivity or individual differences in thermoregulation will account for unique variance in sleep difficulty after controlling for the effects of anxiety, age, and sex.

These hypotheses are tentative and their testing may serve to inform further research. The objective is to gain a better understanding of whether interoceptive and thermoregulation factors contribute to the sleep difficulties of individuals with high autistic traits. The ultimate goal of this study is to examine these relationships to inform the design of further studies that include autistic individuals and contribute to the

development of sleep interventions that are specifically tailored to the cognitive and sensory profiles of autistic individuals.

2. Methods

The literature review in the previous chapter highlighted the clinical need for greater understanding of the factors involved in the occurrence of sleep difficulties for autistic adults. This study focussed on the inter-relationships between sleep, autistic traits, interoception, and thermoregulation. This study took a quantitative approach, using validated measures, to contribute to the body of evidence available for the nature of sleep difficulties. The literature review found evidence for a high prevalence of sleep difficulties for autistic adults, however there is very limited investigation into possible contributing factors towards these sleep difficulties. In addition to this, there is scant evidence regarding the efficacy of sleep interventions for this population.

To my knowledge there are no studies exploring whether interoception issues or thermoregulation issues are a factor in sleep difficulties for autistic people. The purpose of this research is to explore these relationships so that findings can inform the development of more focussed research questions in future studies. These studies may involve the use of physiological data, and qualitative interviews that explore the rich subjective experiences of autistic people. This study took the approach of using validated subjective measures within a quantitative online survey. This method was chosen to allow for the collection of data from a larger sample, with the aim of

generating findings that could offer strong justification and clearer parameters for future studies that may involve more demanding methodologies or require greater resources to implement. While the clinical need highlighted during the literature review was for autistic adults, this study focused on autistic traits and recruited from the general population. Recognised observable autistic traits have been found to be distributed amongst the general population (Robinson et al., 2011; Ruzich et al., 2015). General population studies that measure these autistic traits can have findings that are relevant to and may help to inform further research with autistic people. While general population studies measuring autistic traits do not directly assess autism itself (Sasson & Bottema-Beutel, 2022), some participants who score highly may, in fact, be autistic, making the findings potentially relevant to autistic individuals. Research that measures autistic traits in the general population is an effective way of conducting initial research with larger sample sizes, and low-demands on participants, in fields where there has been limited research. In taking this approach, it is hoped that future research that recruits autistic people can have hypotheses that are focused, justified, and are an effective use of autistic participants' time and effort.

2.1 Ethical considerations

Ethical approval for this study was obtained through the University of Essex. Participants were informed about the nature of the study and were briefed about their right to withdraw during the study. They were given information about what the study's aims and also signposted to where they can get more information about supports

regarding sleep difficulties, or anxiety. For details of this information please see Appendix 2 - Participant Information Sheet. All data collection and processing adhered to General Data Protection Regulation (GDPR) and University of Essex ethical guidelines. The primary Qualtrics survey was fully anonymous and did not collect ant personally identifying information such as names, exact ages, or contact details. Participants were informed on the participant information sheet that their responses were anonymous and could not be traced back to them.

Data were stored securely on a password-protected University of Essex OneDrive account and University of Essex Box account, accessible only to the researchers and academic supervisors. Anonymous datasets were exported from Qualtrics and stored using encrypted file formats. A separate, unlinked Qualtrics survey was used to collect email addresses for the optional prize draw, ensuring no connection between participant identity and survey data.

Anonymised data will remain stored securely in line with University of Essex research data management policies. As this thesis constitutes a published piece of work, only fully anonymised and aggregate-level data (e.g., means, standard deviations, statistical outputs) have been included. No individual-level data or responses have been published or shared in any form that could allow participant identification. If anonymised data were to be made available to other researchers (e.g., through a university repository), this would only occur following additional ethical review and in accordance with participants' original consent and University of Essex data governance policies.

2.2 Design

This study employed a correlational design using a self-report online survey consisting of validated measures. The primary aim was to investigate the inter-relationships between individual differences at one time-point. This approach was chosen as an effective way of exploring cognitions around interoception and other individual difference amongst a large sample, while only requiring a short amount of time from participants. The survey included validated psychometric instruments measuring sleep, interoception, thermoception, autistic traits, and anxiety. Global Sleep Difficulty and Sleep Latency were the primary outcome variables.

2.2.1 Participants

Participants were recruited online from the general population. This study focused on autistic traits rather than exclusively recruiting autistic participants for two reasons: recruiting in the general population allowed for exploration of relationships between interoceptive differences, thermoregulation, and sleep difficulties across a broader spectrum of individual variation. Secondly, given the limited existing research in this area, studying autistic traits in the general population provides a pragmatic starting

point for generating hypotheses that can inform future studies involving formally diagnosed autistic individuals.

Autistic traits are understood to be continuously distributed within the general population (Robinson et al., 2011; Ruzich et al., 2015). Findings from studies that take this approach can still hold relevance for autistic individuals, particularly those who score high on trait measures, even if they do not have a formal diagnosis. This approach is often used in preliminary or exploratory research where representative and large samples are needed to identify patterns worth investigating further in clinical cohorts (Constantino & Todd, 2003). In addition to this, general population autistic trait studies are particularly suitable for exploratory research in relation to sleep. Objective sleep studies can be particularly demanding on participants, requiring a significant portion of their time, and often involving unusual equipment or environments which may cause sensory difficulties, such as the electroencephalographic (EEG) nodes attached to the scalp during EEG sleep studies, or temperature sensors attached to the skin during polysomnographic studies (Marino et al., 2013). Taking the approach of investigating autistic traits in the general population is a suitable approach in sleep research as it will allow for generation of preliminary findings in this area, which can serve to focus future objective sleep research studies involving autistic individuals.

2.2.2 Inclusion Criteria

Participants in the study were required to:

- Be at least 18 years of age or older.
- Be fluent in English.
- Provide informed consent to participate in the study.

2.2.3 Exclusion Criteria

Exclusion criteria were applied to minimise potential confounding effects on sleep outcomes. Participants were excluded if they:

- Were engaged in shift work, as this would impact circadian rhythms, sleep latency, and sleep quality.
- Had a diagnosed medical condition known to impact sleep (e.g., chronic fatigue syndrome, fibromyalgia).

2.2.4 Sample Size Determination

A priori power analysis was conducted using G*Power 3.1. For a hierarchical multiple regression with 9 predictors, an alpha of .05, power of .80, and medium effect size ($f^2 = 0.15$), a minimum sample size of 148 participants was required. The final sample exceeded this threshold.

2.2.5 Recruitment and Data Collection Procedure

This study was advertised on social media and in the University of Essex in order to recruit voluntary participants. Posts on social media platforms with a QR and link to the Qualtrics site for the study were shared. Social media posts also requested that others repost/retweet the advertisement in order to use the snowballing method to recruit a wider pool of participants. Posters were also place in the University of Essex on noticeboards and campus cafés. Posters contained a brief description of the research topic, a QR code linking to the survey, and a message saying that participants could have a chance to win a £50 voucher.

Data were collected between April and July 2024. Qualtrics was used to give participants information about the study, to obtain informed consent from participants, and to collect data using validated self-report measures. At the end of the survey was a link to a separate optional survey where participants could enter their email for a chance to win a £50 gift voucher. The reason the optional email was in a secondary survey was to ensure anonymity in the study – at no point were responses to the primary survey linked to emails submitted in the second study. After initial responses to the survey were completed a second round of recruitment was undertaken using Prolific – an online forum for recruiting participants. Responses were screened for completeness and attention to validity checks. Cases with incomplete data, or failed quality-check questions, were excluded from analysis during the data cleaning process.

2.3 Consultation with Autistic Individuals

This study recruited participants from the general population, but since the project's subject area pertains to autistic people, a public participatory inclusion (PPI) consultation was conducted prior to data collection. The PPI consultation was undertaken in line with guidance from the National Institute for Health and Care Research UK (Turk, 2022). This was in order to allow the autistic community to share their expertise to guide the design of the research (Fletcher-Watson et al., 2019). Ensuring that autistic individual's voices were included as part of this research process was an important part of the design process. The premise of the research question has developed through reviewing the literature as well as listening to the experiences of autistic people during my clinical practice over the last twenty years. However, as an allistic person, I did not want my observations, or my understanding of the literature to be the sole factors in the design of this study, as this would omit the perspectives of autistic individuals from research that is about their lives and intended to benefit them. Fletcher-Watson et al (2019) highlight how inclusive research practice is not only a moral obligation but is also a practical imperative, with insights from autistic people increasing the likelihood that research is meaningful and impactful.

The public participation process involved a consultation workshop prior to launching the online study. This was for four reasons: In order to ensure autistic people could give input into relevance of this research topic, to seek their opinions on the accessibility of the self-report measures used, to ask for guidance on the terminology to

be used throughout the study and write-up, and finally to check were there any additional factors or measures that should be considered within the study. This will ensure the research is relevant, impactful, and has been conducted in as neurodivergent affirming a way as possible within the time constraints of this project. There is increasing awareness of the importance of public involvement in research, particularly in relation to the autistic community.

An application was made to the University of Essex, School of Health and Social Care's Facilitating Research Fund in order compensate autistic contributors for their time and contribution. Contributors to these workshops were given a £25 Amazon gift voucher each for contributing to a one-hour workshop in line with the National Institute for Health and Care Research's guidance on remuneration for people contributing to research (*Payment Guidance for Researchers and Professionals | NIHR*, 2024). Contributors to the consultation process had the opportunity to give input in person during the workshop, and in writing via an anonymous Qualtrics survey after the workshop ended. The rationale for this dual approach for communication was to allow for input from contributors who may not have been comfortable speaking in the workshop, or who needed some time afterwards to reflect prior to giving feedback.

Six autistic adults attended one 60-minute in-person session at the University of Essex in order to give their input into the design of this study. Participants in the PPI consultation were aged 18-25 and were all students in the University of Essex. The sample consisted of two males, two females, and two non-binary participants. The

workshop started with a presentation explaining the premise of the study, and then participants were asked to give their opinions on:

- Terminology to be used in the study and write-up.
- The relevance of this research area to their experiences.
- Appropriateness and accessibility of the proposed self-report measures.
- Any other measures of factors that should be considered.

Contributors were free to give verbal or written feedback during or immediately following the consultation. Contributors also had the option to submit their feedback at a later date in writing. This was in order to give participants multiple options in terms of providing feedback in a way that suited them, while giving them time to reflect if required, and avoiding making public-speaking the only mode of communication available. The consultation was conducted in a spacious room on campus, with seating arranged so that participants could sit together, or apart from each other if preferred. ‘Fidget toy’ sensory items were available for use throughout the session, as were pens and paper.

Feedback from the consultation was that this is a topic that is highly relevant for autistic individuals. The contributors discussed how sleep is a very difficult issue, and difficulties can relate to body temperature, feeling physically tired at the right time, or ‘missing the window’ of tiredness and then later finding it difficult to get to sleep. When considering the measures be used in the study, contributors found most of the measures to be suitable, understandable, and accessible. Some contributors

highlighted a that some of the subscales in one measure were not directly relevant to the study, and had questions so specific they might not apply to everyone. These subscales were excluded. It was also highlighted that there was no measure for anxiety in the study, and that such a measure should be included. I was considering including a measure for trait anxiety, so once this was highlighted in the consultation a trait anxiety measure was included. Terminology was also discussed during the consultation, and it was agreed that the term ‘autistic person’ be used, although several participants said they would also find ‘person with autism’ acceptable.

2.4 Measures

2.4.1 Sleep Measure: Pittsburgh Sleep Quality Index

Subjective sleep data was collected from each participant using the Pittsburgh Sleep Quality Index (Buysse et al., 1989). The Pittsburgh Sleep Quality Index (PSQI) is a reliable and well validated measure of sleep for general population (Wang et al., 2022a) and has been widely used to research sleep in many different settings and populations. The PSQI is a 19-item measure that assesses seven aspects of sleep with its seven subscales. The subscales are subjective sleep quality, sleep latency – also

referred to as sleep onset or sleep onset latency (SOL), sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. The PSQI questions are in Appendix 6. The subscale scores contribute to a global sleep score that can range from 0 to 21, with a higher score indicating greater sleep difficulties, and a score greater than 5 indicating a clinical level of sleep difficulty, such as insomnia (Wang et al., 2022a).

In terms of reliability and validity, the PSQI has been shown to have good test re-test reliability, internal consistency, and construct validity. Backhaus et al. (2002) found that the PSQI had high test-retest reliability over a 48-hour interval ($r = .90$ for global sleep score) and also was found to have good validity compared to sleep log data concurrently collected. The sleep log data and PSQI data were significantly correlated ($r = .81$, for sleep duration, also $r = .71$ for sleep onset latency) (Backhaus et al., 2002), indicating the PSQI's validity.

In terms of internal consistency, the PSQI has demonstrated strong internal consistency in multiple studies conducted in different populations, at various lifespans stages including studies finding Cronbach's α coefficient for internal consistency between 0.70 and 0.85 (Wang et al., 2022b).

In a recent review, Fabbri et al. (2023) also found that the PSQI had acceptable internal consistency with Cronbach's α values typically ranging between .70 and .83 across studies. The authors also concluded that the PSQI demonstrates good construct validity, convergent validity with other sleep measures, and diagnostic validity in distinguishing between clinical and non-clinical populations. However, the authors also cautioned that there were some variations in factor structure between studies. This

variation is in part due to the change from a two-factor model to a three-factor one. Cole et al. (2006) examined validation of a three factor model and it was found to have validity. Several studies have highlighted the sensitivity and specificity of this measure (Backhaus et al., 2002; Mollayeva et al., 2016; Sohn et al., 2012) finding it to be a suitable measure for distinguishing between clinical and non-clinical levels of sleep difficulty.

The PSQI has also been shown to be suitable for use with clinical and non-clinical populations (Mollayeva et al., 2016) and in the literature review in the previous chapter it was found to be the most commonly used scale in sleep research with autistic adults. In addition to having demonstrated strong internal consistency in general population studies, the PSQI has been found to have good internal consistency in studies with autistic adults, with a Cronbach's α coefficient of 0.68 (Baker & Richdale, 2015). While this current study recruited from the general population, the research topic concerns autism, so suitability of this measure for autistic people was an important consideration.

Given that the PSQI measures multiple aspects of sleep, this questionnaire is more suitable than a specifically insomnia-focussed measure such as the ISI. The broader scope of the PSQI allows for a systematic examination of a broad range of sleep difficulties, including insomnia (Mollayeva et al., 2016), but also open to the possibility that autistic sleep difficulties could fall outside the parameters of the diagnostic criteria for insomnia. The ISI is designed to be sensitive to the DSM-V's specific criteria for insomnia (Bastien et al., 2001). The sub-scales within the PSQI that measure certain aspects of sleep will allow for the examination of distinct aspects of

sleep difficulty. Employed alongside other measures, the PSQI allowed for exploration of how individual differences might relate to sleep difficulties amongst the general population.

2.4.2 Measures of Interoception

The research community has provided various conceptualisations of interoception, which have led to the development of several measures, each tapping on different dimensions (e.g. interoceptive accuracy, interoceptive attention) and channels of interoception (e.g. cardiac, respiratory, gastric) (for reviews see Suksasilp & Garfinkel, 2021; Nord & Garfinkel, 2022). As already described in Chapter 1 interoception comprises stages in a process of information transfer from signals in nerves, through to conscious thoughts, beliefs, and behaviours (Suksasilp & Garfinkel, 2022b). For the purpose of the present study, I focused the investigation of interoception on self-reported measures of interoception. The reason for this focus was threefold: Firstly, in order to explore aspects of interoception that relate to attention and cognition. Autistic presentations can involve highly focussed attention on some things, while being inattentive to, or unaware of other things happening. Subjective measures of the thoughts and beliefs around interoception may give some indication whether this highly focussed, yet blinkered cognitive style is a factor autistic interoception processes. The second reason for taking this approach was that sleep studies that collect objective data can be a demanding experience for participants and involve various sensory

experiences that may present difficulties for autistic individuals. Given the lack of research in this area, I decided it was more appropriate to use self-report measures of interoception in this study, so that future studies can be better informed as to what approach may be appropriate for objective sleep studies. Thirdly, using self-report measures in an online study is an efficient way to collect a large dataset in order to explore individual differences.

There are a number of self-report questionnaires available in the literature that tap into interoception. The most widely used questionnaires in interoception research are Porges' Body Awareness questionnaire (Cabrera et al., 2018), the Multidimensional Assessment of Interoceptive Awareness (MAIA-2) (Eggart et al., 2021), and Murphy's Interoceptive Attention Scale (Gabriele et al., 2022a) and Interoceptive Accuracy Scale (Murphy, 2020). Porges' Body Awareness questionnaire (Cabrera et al., 2018) is designed to explore individual differences in subjective perceptions of body signals. While it does measure for interoceptive sensibility, and has been used in research with autistic adults (Quadt et al., 2021b), it has only been used to a limited extent with this population, and its focus is on interoceptive sensibility, not on interoceptive attention, or self-beliefs regarding interoceptive accuracy.

The MAIA measures interoceptive awareness (IA), but breaks down aspects of IA into eight domains. The MAIA-2 is one of the most widely used subjective measures of interoceptive awareness and has been employed in studies autistic adults (Solano Durán et al., 2024). It has good validation for the general population (Eggart et al.,

2021). The MAIA-2 has eight aspects to interoception that it measures in order to gain insight into a person's interoceptive awareness. These eight aspects are Noticing, Not Distracting, Not Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body-Listening, and Trusting. Interoception involves a broad spectrum of internal sensory signals, and the MAIA-2 is designed with this in mind. In their review of use of the MAIA-2 with clinical populations, Durán et al found that this measure has clinical utility for autistic people, but that the subscale scores may be more useful than the overall global scores.

While MAIA includes the phrase 'Interoceptive Awareness' in its title, its focus is on interoceptive sensibility (Desmedt et al., 2022), which differs slightly from the concept of interoceptive sensibility as proposed by Garfinkel et al (Garfinkel et al., 2015) which is about one's self-perception sensitivity to interoceptive signals. The MAIA-2's focus is purely on the subjective experience of interoception and does not have a focus on aspects of interoception that relate to accuracy.

More recently, Murphy and colleagues (Murphy, 2022; Murphy et al., 2019) presented an alternative to prior theories of interoception by proposing a matrices of interoceptive attention and interoceptive accuracy as described in Chapter 1. The Interoceptive Attention Scale (IATS) and Interoceptive Accuracy Scale (IAS) were developed in line with this framework as self-report measures for researching these constructs. The IATS and the IAS both are 21-item measures. These scales have corresponding items, but the IAS explores an individual's beliefs about their own

interoceptive accuracy, whereas the IATS is a self-report measure that explores how much an individual's attention is occupied with interoceptive signals. An advantage of using these two self-report measures is that they can be used together to explore different aspects of the metacognitive level of interoception, beliefs regarding interoceptive accuracy, and interoceptive attention. Given that the IATS and IAS measures are interrelated, and they both fit into a theoretical construct of interoception that is broader than the construct employed in the MAIA or the BPQ, they have been selected as sufficiently valid, reliable, and appropriate measures for this study. Murphy et al's (Murphy et al., 2019) distinction between interoceptive attention and beliefs regarding interoceptive accuracy as aspects of interoceptive awareness, provide a way of considering individual differences that may yield further insight into atypicalities in autistic sensory awareness. Using the IATS and IAS in conjunction with each other should yield a more detailed insights than the MAIA-2 or BPQ alone could reveal, as they may show indicate whether interoceptive differences on autistic individuals occur at the level of attention, or in beliefs regarding accuracy (Murphy et al., 2019). Gabriele et al's (2022a) study provides evidence that is in line with Murphy et al. (2020) distinction between interoceptive attention and beliefs about interoceptive accuracy. This study also highlights how the IATS and IAS used in conjunction measures clearer constructs than the BPQ (Gabriele et al., 2022a).

The IATS and IAS both have a question relating to feeling too hot/cold (Item 11 on both) which may give some indication of thermoregulatory interoception, but would be insufficient on its own to draw conclusions regarding thermoception. For this reason,

another self-report measure for thermoregulation was included in addition to the IATS and IAS (the IAS is in Appendix 3, the IATS is Appendix 4).

2.4.3 Body Temperature and Thermoregulation

Subjective self-report measures of body temperature perception and thermoregulation behaviours are limited, and finding a suitably validated one presented a difficulty. The Social Thermoregulation and Risk Avoidance Questionnaire (STRAQ-1) (Vergara et al., 2019) is a self-report measure that was developed to explore relationships between social attachments, subjective experiences of safe and secure relationships, and individual experience of thermoregulation in this wider social context. The measure was validated with a large sample of adult participants (*N=1510*) across 12 different nations including the UK and USA. The factor analysis of their findings produced 4 distinct subscales – social thermoregulation (*omega = 0.83*), high temperature sensitivity (*0.83*), Solitary thermoregulation (*0.77*), and risk avoidance (*0.57*). The constructs measured in these subscales were explained by Vergara et al. as:

- High Temperature Sensitivity: Sensitivity to comfort and discomfort in relation to high ambient temperature. Higher scores suggesting greater discomfort at higher temperatures, and preference for cold environments.

- Social Thermoregulation: Preference for warmth-seeking behaviours by being physically close to another person when experiencing distress, or feeling cold.
- Solitary Thermoregulation: Preference for warmth-seeking behaviours that do not involve others when experiencing distress, or feeling cold.
- Risk Avoidance: Preference for avoiding novel or unknown social situations.

As this is measure is a relatively novel one and is not widely used, and to my knowledge has not been used in studies with autistic adults, the scale was presented to autistic individuals who gave feedback and advice at the design stage of the study during a consultation process. The consultation group felt that some items in the Social Thermoregulation and Risk Avoidance subscales were unclear, but that the items in the Solitary thermoregulation (SOLT) and high temperature sensitivity (HTS) subscales were appropriate, understandable, and relevant to the study.

It was decided to include only the SOLT and HTS subscales in the study for four reasons: These two subscales were the ones primarily relevant to the focus of our study, the consultation process highlighted these measures as appropriate and understandable, the social thermoregulation and risk avoidance subscales focus on levels of social interaction that may present difficulties for many autistic individuals, and finally, Vergara's validation study and factorial analysis found the SOLT and HTS measures to be robust, whereas the risk avoidance subscale was a relatively weak subscale in the study (Vergara et al., 2019). The SOLT and HTS STRAQ-1 subscales

were selected to be used alongside the IATS and IAS interoceptive scales in order to be able to collect data on the subjective experience of interoceptive temperature issues. . The HTS subscales questions are in Appendix 7. The SOLT subscale questions are listed in Appendix 8.

2.4.3 Autistic Traits

In order to measure autistic traits amongst participants The Autism Spectrum Quotient Scale (AQ) (short version) was used. The AQ is designed to be descriptive rather than diagnostic (Ruzich et al., 2015) and therefore it is usually employed to assess autistic traits, rather than to determine a diagnosis. It is a widely used and well validated measure that is suitable for use in populations with and without Autism Spectrum Condition diagnoses (Ruzich et al., 2015). The Autism Quotient measure was originally developed as a 50-item measure, and a more recent 28-item abridged version (Hoekstra et al., 2011) was developed which maintained a good the factor structure and high-level of validity (Hoekstra et al., 2011).

The 28-item version of the AQ was chosen for this study as it is well-validated and provides more detail than the briefer 10-item version, and yet takes less time to complete than the full 50-item AQ questionnaire. The AQ-28 demonstrated acceptable internal consistency (α =*. .79*) with the social behaviours factor having an score between 0.79 and 0.86, and the (fascination with) numbers/patterns factor having a Cronbach's alpha score between 0.67 and 0.73 (Hoekstra et al., 2011). The AQ-28 is

also suitable for use on clinical and non-clinical populations such as general population studies (Ruzich et al., 2015), and has been studied across multiple cultures and nations (Chee et al., 2024). Another measure considered was the Ritvo Autism Asperger Diagnostic Scale – Revised (RAADS-R) (Ritvo et al., 2011). While the RAADS-R is also well-validated, it involves much more items than the AQ-28. Measures that take longer to complete, increase the likelihood of less participants completing every measure, so a decision was taken to use the AQ-28 as a moderate-length, well-validated item, in order to allow for inclusion of a thermoregulation measure while still keeping the overall survey shorter than 30 minutes. The AQ-28 questions are listed in Appendix 5.

2.4.4 Trait Anxiety

There is a well-established relationship between sleep difficulties and anxiety. In order to give consideration to the presence of trait anxiety in the sample, the Generalised Anxiety Disorder-7 measure (GAD-7) was included. The GAD-7 is a widely used measure of trait anxiety within clinical and non-clinical contexts (Löwe et al., 2008). The GAD-7 is a 7-item measure that was developed as a screener for generalised anxiety disorder in clinical contexts, but has been found to be effective as a measure of trait anxiety in the general population (Johnson et al., 2019). The measure has been shown in several studies to have a single-factor structure (Beard & Björgvinsson, 2014; Johnson et al., 2019). It has also demonstrated good sensitivity and specificity (Beard & Björgvinsson, 2014). Each item is scored on a Likert-type scale from 0 to 3, with 3 indicating higher tendency for anxiety and 0 indicating lower

tendency for anxiety. The scale asks participants to consider the frequency of their experience of aspects of anxiety over the past two weeks.

From a pragmatic point of view the GAD-7 only takes one or two minutes to complete and therefore leaves time within the online study for other measures while still providing a reliable and validated measure of anxiety. The GAD-7 was found to have good internal consistency across the general population with a Cronbach's alpha of 0.89 (Löwe et al., 2008b).The GAD-7 was chosen over other measures for this study due to its high level of validity and reliability with multiple populations, its ease of use, and the short time required to complete it. The. GAD-7 questions are listed in Appendix 9.

2.4.5 General Demographic Information

General demographic data on age, sex, profession, were also collected. This was to further explore whether issues such as shiftwork, having young children who wake during the night, or other factors affecting sleep. One optional question on the study will ask whether the participants have any conditions or diagnoses. This was to allow people to report conditions such as chronic pain, anxiety disorders, health issues, or mental health issues that may also affect sleep. Any conditions that were considered significant factors in sleep disturbance were excluded. This exclusion was applied to reduce the potential confounding effects that these conditions can have on sleep outcomes. This will help to ensure less chance of health conditions distorting any observed associations between sleep, interoception, and autistic traits. Similar

exclusion criteria have been used in prior research investigating sleep in autistic populations, for example Baker & Richdale (2015).

2.5 Analysis

Data collected on the Qualtrics platform were analysed in order to explore the interrelationships between autistic traits, aspects of sleep, and aspects of interoceptive ability and the other individual difference via the validated measures detailed above. Data were input into SPSS (IBM SPSS Statistics, version 27 for Mac). Responses were first screened for completeness and for validity-check failures. Incomplete entries, duplicate submissions, and cases that failed attention checks were removed during the data cleaning process.

Descriptive statistics, including standard deviations, means, and frequency distributions, were computed for the variables in order to gain an understanding of the sample and how the measured constructs appear within this sample. Group difference tests were used to explore how variables relate to biological sex, and age. Independent t-tests were conducted to explore sex differences. One-way ANOVAs were used to examine age group differences across variables.

Bivariate correlations were calculated in order to explore simple relationships between variables and also to guide selection of variables for inclusion in hierarchical

regression models ($p < .2$) (Crucianelli et al., 2019). Pearson's r was used for all normally distributed data, whereas Spearman's rho was used for non-normal variables. To reduce the risk of Type I error in multiple comparisons (correlations, *t*-tests, and ANOVAs), False Discovery Rate (FDR) correction was applied using the Benjamini-Hochberg procedure (Benjamini & Hochberg, 1995).

Multiple regression analyses were conducted to assess the dynamics between the continuous variables and the variables of interest: Global Sleep Difficulty, and Sleep Latency. Specifically, two hierarchical multiple regressions were conducted. Regression Model A predicted Global Sleep Difficulty. Regression Model B predicted Sleep Latency. This approach allowed for the sequential entry of variables (age, sex, and trait anxiety) before adding the interoceptive and psychological variables of interest. The reason for placing age, sex, and trait anxiety at step one in the model was that there is already evidence in the literature of their relationship to sleep (Chokroverty, 2017; Sullivan et al., 2021; Zheng et al., 2018). Entering known covariates first provides a conservative estimate of the unique contribution of the Step-2 variables and reduces confounding; results are interpreted as variance unique to those predictors over and above age, sex, and anxiety. Because age, sex, and anxiety are well-established correlates of sleep disturbance, they were entered in Step 1 as covariates. The variables of primary interest (thermoregulatory measures, autistic traits, and interoceptive indices) were then entered in Step 2 to test their incremental predictive value beyond Step 1. This hierarchical approach allows us to evaluate the change in explained variance (ΔR^2) and the

associated *F* change test, indicating whether adding the Step-2 block significantly improves model fit after controlling for age, sex, and anxiety.

Data were tested to ascertain whether the assumptions were met in order to conduct a hierarchical regression. P-P plots were checked to test for multivariate normality, Data was also checked for homoscedasticity, independence of errors, and linearity. The hierarchical regression analysis was then completed using SPSS to determine if there was a relationship between sleep difficulties, interoceptive abilities, thermoregulation and autistic traits when controlling for differences relating to trait anxiety, gender or age. These variables were included and controlled for as possible confounding variables since there is evidence in the literature of these individual differences relating to sleep difficulty (Carskadon & Dement, 2011; Hirshkowitz, 2004; Zheng et al., 2018).

2.6 Conclusion

This correlational online study aimed to explore how sleep difficulties relate to individual differences. The survey included validated psychometric instruments measuring sleep, interoception, thermoception, autistic traits, and trait anxiety. Global Sleep Difficulty and Sleep Latency were the primary outcome variables. Statistical analysis involved bivariate correlations, analyses of variance, independent t-tests, and hierarchical regressions in order to examine the data. The next chapter will report the results of these analyses.

3. Results

3.1 Introduction

Sleep difficulties are highly prevalent amongst autistic individuals, and yet research into the contributing factors of these difficulties is sparse. In particular, autistic adults lack access to evidence-based sleep interventions that are tailored to their needs and informed by the causes of their sleep difficulties. Individual differences in interoceptive abilities are part of many autistic individuals' experiences (Shah et al., 2016), and interoceptive processes have been linked to sleep difficulties (Wei & Van Someren, 2020). Yet to my knowledge, no published research has investigated the relationship between interoception and autistic sleep difficulties. Importantly, thermoception is increasingly being recognized as an under-investigated aspect of interoception (Crucianelli & Ehrsson, 2022), and there is a wealth of evidence demonstrating the temperature-dependent nature of sleep (Harding et al., 2019, 2020). For example, body temperature changes are a key factor in sleep onset (Raymann et al., 2007) and stability of body temperature is important to maintain sleep (Heinze & Golz, 2019; Raymann et al., 2008). This study set out to investigate whether individual differences in interoception, and particularly thermoceptive differences, may merit further investigation in order to benefit autistic individuals who struggle to get a good night's sleep.

3.2 Demographic Information

Of the 239 sample that completed all measures, 108 were assigned female at birth (*45.2%*), and 126 were assigned male (*52.7%*). The remaining 2.1% of participants expressed that they preferred not to say what their sex was (*N=5*). Participants were also asked which of six age categories they belonged: 18-24, 25-34, 35-44, 45-54, 55-64, and 65+ years. The distribution of participants in age categories and Sex is detailed in Table 1. Participants were distributed across all age categories, with the largest group falling within the 35-44 age range (*N=64*). The two smallest groups were the youngest (18-24yrs, *N=24*) and the oldest (65+yrs, *N=20*) age categories. The 2.1% of cases who chose not to share their age category were the same *N=5* case who also did not disclose their sex.

During data quality checks and screening, 23 cases were excluded. Of the 23 exclusions, 7 failed inattention or quality checks, 10 did not complete all the measures, and 6 cases self-reported diagnosed conditions that met the study's exclusion criteria (chronic fatigue syndrome, Parkinson's disease, and chronic pain syndrome). After excluding these cases the final analysed sample comprised N=239. Table 1 presents demographic details for the analysed sample.

Table 1.
Frequencies and Percentages for Participant Demographics (N = 239)

Variable	Category	n	%
Sex	Male	126	52.7%
	Female	108	45.2%
	Prefer Not to Say	5	2.1%
Age Group	18–24	24	10.0%
	25–34	62	25.9%

	35–44	64	26.7%
	45–54	39	16.3%
	55–64	25	10.5%
	65+	20	8.4%
	Prefer Not to Say	5	2.1%

N.B. Percentages are based on valid cases

3.2.1 Descriptive Analysis

Frequency analyses and Descriptive statistics were calculated in SPSS using the key variables prior to running more complex analyses. Table 2 displays the means, standard deviations, and the sample sizes for continuous variables on all valid cases where data on age and sex were also available. GSD, the composite total score from the PSQI, had a *mean of 6.55* (*SD = 3.56*). The PSQI's GSD score ranges from 0-21, with scores above 5 indicating poor sleep quality, and higher scores reflecting greater sleep difficulties. A *mean of 6.55* may suggest that individuals who have sleep difficulties are well represented in this sample. Sleep duration (minutes) had a *mean of 412.58* (*SD = 70.28*). This represents a *mean* sleep duration time of 6 hours and 53 minutes, however, the *standard deviation* of over 1 hour and 10 minutes indicates a wide variance in total sleep time in the sample.

Further analysis of the sample in relation to clinical cut-offs found that 52% of participants scored above the clinical threshold for GSD on the PSQI. In relation to the AQ28, 10% of participants in this general population sample scored 19 or above,

meeting the screening tools clinical threshold for high levels of autistic traits (Hoekstra et al., 2011). In this sample of 239 participants, n=19 reported that they had a formal diagnosis of autism, n=3 declared they were self-diagnosed as autistic. This aligns with the 10% of participants who scored above the clinical cutoff for autism. In relation to trait anxiety, 35% of participants scored 9 or above in the GAD-7, indicating moderate to severe levels of anxiety (Johnson et al., 2019).

Table 2.
Descriptive Statistics for Continuous Variables

Variable	Mean	SD	N
GSD	6.55	3.56	234
Sleep Quality	1.23	0.75	234
SOL (mins)	27.41	29.03	234
Sleep Duration (mins)	412.58	70.28	234
Interoceptive attention	51.38	13.58	234
Interoceptive accuracy	81.05	10.96	234
Trait anxiety	6.79	4.83	234
Thermoregulation	21.6	5.59	234

Note: Descriptives for cases where all measures had been completed, including Sex & Age.

3.2.2 Assumptions and Preliminary Checks

Data were screened for missing values prior to analysis to assess normality and statistical outliers. Skewness and kurtosis values were calculated and analysed to

assess the data distribution for each continuous variable. The majority of variables were normally distributed and were within acceptable range for skewness, however SOL (mins) was skewed (*skewness 3.38, kurtosis 16.4*) and therefore not normally distributed. Given its skewed distribution, boxplots were produced in order to examine the presence of outliers in the SOL data. Mild outliers (112mins, 141mins) were identified as well as more significant outliers (207mins, 229 mins, 240mins). The majority of other values fell within the range of zero to 50 minutes for SOL (*mean 27.41mins, SD 29.03mins*). Outliers in reported sleep latency were further examined in relation to participants' estimated total sleep time, time of going to bed, and time of waking, to determine whether these values reflected genuine difficulty with sleep onset or were more likely due to erroneous data entry. Where inputs appeared accurate, sleep latency estimates were cross-validated by triangulating them with the other reported sleep variables. Given the context of the other data provided, it was decided that these outliers were not erroneous inputs, but were more likely to be valid and meaningful cases where individuals had extreme difficulty with sleep onset, and may be suffering from insomnia. For these reasons, the identified outliers for SOL were included, and non-parametric analyses were employed. Pearson's *r* and Spearman's *rho* were calculated to assess correlations, with Spearman's *rho* include to account for non-normality amongst variables: namely SOL. Sex and age category were included as additional variables in the correlation matrix in order to explore any associations between the demographic factors and the key variables under analysis.

3.3.1 Correlational Analysis

Bivariate correlations were conducted to guide variable selection for regression analyses. Any variable showing a correlation with key sleep factors at $p < .20$ was included in further regression analyses. The key sleep outcome variables that this study focused on are: Global Sleep Difficulty (GSD), and Sleep Latency (minutes) (SOL). Pearson correlations were used for normally distributed variables. Given the positive skew of SOL, Spearman's rho was used for correlations involving SOL. Correlations between GSD and its component variables, and between total autistic traits score and its component subscales, were not reported, as they are inherent to the construction of those composite variables. Given the number of comparisons, a false discovery rate (FDR) correction was applied to control for Type I error (Benjamini & Hochberg, 1995). Only associations that remained significant after FDR correction are reported here; full correlation coefficients and uncorrected p-values are presented in Tables 3 and 4.

Autistic traits were significantly correlated with interoceptive attention *r(237) =.211, p=.001, FDR-corrected p = .010)*, interoceptive accuracy *r(237) = –.243, p<.001, FDR-corrected p = .006)*, high temperature sensitivity, *r(237) =.379, p<.001, FDR-corrected p = .003*, and trait anxiety *r(237) =.353, p<.001, FDR-corrected p= .006)*. GSD was positively correlated with interoceptive attention *r(237) =.195, p=.003, FDR-corrected p = .019*, high temperature sensitivity *r(237) = .227, p<.001, FDR-corrected p = .022)*, and Trait anxiety *r(237) =.436, p<.001, FDR-corrected p<.001)*, and negatively correlated with interoceptive accuracy *r(237) = –.178, p=.006, FDR-corrected p= .028)*.

No significant correlations with SOL remained after correcting for multiple comparisons.

All other associations are reported in Tables 3 and 4.

Table 3.
Pearson Correlation Matrix (GSD)

		GSD	*Interoceptive attention*	*Interoceptive accuracy*	*Autistic traits*	*Numbers/patterns*	*Social Behaviour*	*Social skills*	*Routine*	*Switching*	*Imagination*	*High Temp Sensitivity*	*Thermoregulation*	*Trait anxiety*	*Age*	*Sex*
GSD	Correlation	1	**.195****	**-.178****	**.131***	**0.104**	**0.112**	**.149***	0.03	**0.117**	0.035	**.227****	0.051	**.436****	**0.09**	0.069
	Sig. (2-tailed)		**0.003**	**0.006**	**0.042**	**0.108**	**0.085**	**0.022**	0.645	**0.071**	0.587	**<.001**	0.432	**<.001**	**0.168**	0.291
Interoceptive attention	Correlation	**.195****	1	0.004	.211**	.222**	.161*	.129*	.206**	.137*	0.068	.210**	0.113	.280**	-.208**	-0.108
	Sig. (2-tailed)	**0.003**		0.948	0.001	<.001	0.013	0.047	0.001	0.034	0.298	0.001	0.08	<.001	0.001	0.095
Interoceptive accuracy	Pearson Correlation	**-.178****	0.004	1	-.243**	0.043	-.286**	-.212**	-.164*	-.229**	-.259**	-.184**	-0.01	-.199**	0.046	-0.015
	Sig. (2-tailed)	**0.006**	0.948		<.001	0.509	<.001	<.001	0.011	<.001	<.001	0.004	0.873	0.002	0.486	0.813
Autistic traits	Pearson Correlation	**.131***	.211**	-.243**	1	.477**	.955**	.778**	.719**	.704**	.734**	.379**	-0.027	.353**	-.178**	0.004
	Sig. (2-tailed)	**0.042**	0.001	<.001		<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.681	<.001	0.006	0.945
Numbers/patterns	Pearson Correlation	**0.104**	.222**	0.043	.477**	1	.195**	0.11	.186**	.142*	.181**	.222**	-0.054	.159*	-.188**	-.196**
	Sig. (2-tailed)	**0.108**	<.001	0.509	<.001		0.002	0.091	0.004	0.028	0.005	<.001	0.404	0.014	0.004	0.002
Social Behaviour	Pearson Correlation	**0.112**	.161*	-.286**	.955**	.195**	1	.831**	.739**	.738**	.759**	.349**	-0.012	.341**	-.135*	0.071
	Sig. (2-tailed)	**0.085**	0.013	<.001	<.001	0.002		<.001	<.001	<.001	<.001	<.001	0.859	<.001	0.039	0.274
Social skills	Pearson Correlation	**.149***	.129*	-.212**	.778**	0.11	.831**	1	.547**	.510**	.401**	.373**	-0.035	.310**	-0.043	0.071
	Sig. (2-tailed)	**0.022**	0.047	<.001	<.001	0.091	<.001		<.001	<.001	<.001	<.001	0.594	<.001	0.512	0.274
Routine	Pearson Correlation	0.03	.206**	-.164*	.719**	.186**	.739**	.547**	1	.530**	.386**	.269**	0.095	.317**	-0.113	0.11
	Sig. (2-tailed)	0.645	0.001	0.011	<.001	0.004	<.001	<.001		<.001	<.001	<.001	0.143	<.001	0.086	0.09
Switching	Pearson Correlation	**0.117**	.137*	-.229**	.704**	.142*	.738**	.510**	.530**	1	.413**	.290**	0.035	.323**	-0.099	0.06
	Sig. (2-tailed)	**0.071**	0.034	<.001	<.001	0.028	<.001	<.001	<.001		<.001	<.001	0.589	<.001	0.129	0.359
Imagination	Pearson Correlation	0.035	0.068	-.259**	.734**	.181**	.759**	.401**	.386**	.413**	1	.151*	-0.066	.152*	-.169**	0.005
	Sig. (2-tailed)	0.587	0.298	<.001	<.001	0.005	<.001	<.001	<.001	<.001		0.02	0.31	0.018	0.01	0.943
High Temp Sensitivity	Pearson Correlation	.227**	.210**	-.184**	.379**	.222**	.349**	.373**	.269**	.290**	.151*	1	0.007	.288**	-0.047	-0.043
	Sig. (2-tailed)	<.001	0.001	0.004	<.001	<.001	<.001	<.001	<.001	<.001	0.02		0.917	<.001	0.471	0.505
Thermoregulation	Pearson Correlation	0.051	0.113	-0.01	-0.027	-0.054	-0.012	-0.035	0.095	0.035	-0.066	0.007	1	.155*	-0.004	.188**
	Sig. (2-tailed)	0.432	0.08	0.873	0.681	0.404	0.859	0.594	0.143	0.589	0.31	0.917		0.016	0.957	0.004
Trait anxiety	Pearson Correlation	**.436****	.280**	-.199**	.353**	.159*	.341**	.310**	.317**	.323**	.152*	.288**	.155*	1	-.290**	-0.007
	Sig. (2-tailed)	**<.001**	<.001	0.002	<.001	0.014	<.001	<.001	<.001	<.001	0.018	<.001	0.016		<.001	0.911
Age	Pearson Correlation	**0.09**	-.208**	0.046	-.178**	-.188**	-.135*	-0.043	-0.113	-0.099	-.169**	-0.047	-0.004	-.290**	1	.296**
	Sig. (2-tailed)	**0.168**	0.001	0.486	0.006	0.004	0.039	0.512	0.086	0.129	0.01	0.471	0.957	<.001		<.001
Sex	Pearson Correlation	0.069	-0.108	-0.015	0.004	-.196**	0.071	0.071	0.11	0.06	0.005	-0.043	.188**	-0.007	.296**	1
	Sig. (2-tailed)	0.291	0.095	0.813	0.945	0.002	0.274	0.274	0.09	0.359	0.943	0.505	0.004	0.911	<.001	

Note: * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed). All correlations reported in the Table display uncorrected p-values. Statistics in bold indicate a correlation of p<0.2 with Global Sleep Difficulty (GSD) and therefore those variables were included in GSD Regression Model.

Table 4.
Spearman Correlation Matrix (SOL)

VARIABLE		SOL	INTEROCEPTIVE ATTENTION	INTEROCEPTIVE ACCURACY	AUTISTIC TRAITS	NUMBERS/PATTERNS	SOCIAL BEHAVIOUR	SOCIAL SKILLS	ROUTINE	SWITCHING	IMAGINATION	HIGH TEMP SENSITIVITY	THERMOREGULATION	TRAIT ANXIETY	AGE	SEX
SOL	Correlation Coefficient	1	**.129***	-0.052	0.043	-0.018	0.051	0.073	-0.014	0.016	0.079	**0.094**	0.001	**.214****	-0.006	0.052
	Sig. (2-tailed)	.	**0.046**	0.425	0.506	0.784	0.428	0.26	0.825	0.806	0.221	**0.149**	0.986	**<.001**	0.922	0.426

Note: * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed). All correlations reported in the Table display uncorrected p-values. Statistics in **bold** indicate a correlation of $p<0.2$ with SOL and therefore those variables will be included in SOL Regression Model. During assumption checks SOL was found to be non-normally distributed therefore Spearman's rho was used for bivariate correlations that included this variable.

3.3.4 Sex Group Differences

Independent samples t-tests were conducted to examine sex differences in the 14 continuous variables: GSD, SOL, interoceptive attention, interoceptive accuracy, autistic traits (AQ28 total score), all AQ28 subtraits (numbers/patterns, social behaviour, social skills, routine, switching, imagination), as well as high temperature sensitivity, thermoregulation, and trait anxiety. In this section 'males', 'females', and 'sex' refer to sex assigned at birth as reported by participants in the study. Effect sizes are reported using Cohen's *d*. False Discovery Rate (FDR) correction was applied to account for multiple comparisons.

A significant difference in interoceptive attention did not survive FDR-correction, *t(231.6) = 1.99, p =.047, FDR corrected p=0.261, d =.26*, with males *(M = 52.98, SD = 14.64)* tending to score higher than females *(M = 49.51, SD = 12.02)*, although with a small effect size, *d =.26*. There was no significant difference in interoceptive accuracy between males and females, *t(231.60) = 0.77, p = .441, FDR-corrected p=0.641, d = 0.10*.

Significant differences between sexes were observed in thermoregulation, *t(232) = -3.83, p<.001, FDR-corrected p=<.001, d = -.50*, with females reporting higher scores (*M = 23.07, SD = 5.94*) than males (*M = 20.34, 4.96*). No significant sex differences were found in high temperature sensitivity, *t(199.07) = 0.28, p = .782, FDR-corrected p=.791, d = 0.04*.

For GSD, there were no significant sex differences, *t(212.61) = –1.09, p = .277, FDR-corrected p=0.554, d = –0.15*. There was no significant difference in sleep quality, *t(211.75) = 0.83, p = .405, FDR-corrected p=0.640, d = 0.11*. There was no significant difference in SOL (mins), *t(164.57) = –1.60, p = .098, FDR-corrected p=.260, d = –0.22*, or sleep duration (mins), *t(224.17) = –1.79, p = .076, FDR-corrected p=.261, d = –0.23*.

There were no significant sex differences in autistic traits (total score), *t(180.64) = 0.26, p = .791, FDR-corrected p=.791, d = 0.03*, nor were there significant differences by sex for the subscales social behaviour, *t(192.87) = –0.89, p = .375, FDR-corrected p=.640, d = –0.12*, social skills, *t(212.16) = –1.22, p = .223, FDR-corrected p=.510, d = –0.16*, and switching, *t(188.25) = –0.60, p = .547, FDR-corrected p=.716, d = –0.08.* The only autistic trait subscale to showed a significant difference between sexes was numbers/patterns, with males scoring higher than females, *t(208.7) = 3.65, p <.001, FDR-corrected p<.001, d = 0.49*.

Overall, the independent t-tests found statistically significant differences between sexes in interoceptive attention, numbers/patterns, and in thermoregulation. The effect sizes for these differences were in the small-to-medium range. Among the variables examined, only sex differences in thermoregulation and the numbers/patterns subscale of autistic traits remained significant after FDR correction.

3.3.5 Age Group Differences

Ten one-way ANOVAs were conducted to test for group differences by age category on each continuous variable. A significant effect of age was found for interoceptive attention, *F(5, 228) = 3.84, p = .002, η² = .078*, and trait anxiety*, F(5, 228) = 5.36, p < .001, partial η² = .105*. Post hoc (Tukey HSD) comparisons revealed that participants aged 18–24 reported significantly higher interoceptive attention than those aged 45–54 (p = .002) and aged 55–64 (*p = .030*). The 25-34 age group also scored significantly higher than the 45-54 group (*p =.042)*. There was no significant effect of age on interoceptive accuracy *F(5, 228) = 0.91, p = .475, η² = .020*.
Like interoceptive attention, trait anxiety was significantly higher among younger participants. Participants in the 18–24, 25–34, and 35–44 age groups all reported higher anxiety levels than those in the 55–64 age group (*all p = .002*). These results suggest a general decline in interoceptive attention and anxiety with increasing age. These trends are shown visually in Figures 1-3. Figure 1 charts interoceptive attention by age group. Figure 2 shows interoceptive accuracy by age group (included for the purpose of comparison with Figure 1). Figure 3 shows Anxiety by age group. All of the significant ANOVA results remained significant following FDR correction.

None of the included sleep variables were found to be significant in the age category ANOVAs. GSD, *F(5, 228) = 1.23, p = .296, η² = .026*, and sleep quality did not vary significantly by age group, *F(5, 227) = 0.55, p = .738, η² = .012*. There was no significant effect of age on SOL (mins), *F(5, 228) = 0.65, p = .659, η² = .014*, or on Sleep Duration (mins), *F(5, 228) = 1.13, p = .344, η² = .024*.

No other variables were found to significantly vary by age. The effect of age on autistic traits $F(5, 228) = 1.98$, $p = .082$, $\eta^2 = .042$, was not statistically significant. No significant age differences were found for high temperature sensitivity, $F(5, 228) = 0.88$, $p = .499$, $\eta^2 = .019$, or thermoregulation, $F(5, 228) = 0.72$, $p = .610$, $\eta^2 = .015$. In summary, the analysis of variance and post hoc tests indicate that age had a moderate effect on interoceptive attention and trait anxiety, with older individuals in this study reporting lower levels of trait anxiety and interoceptive attention scores. No significant age-related differences were observed for the included aspects of sleep, for interoceptive accuracy, or autistic traits.

Figure 1.
Interoceptive attention by Age Group.

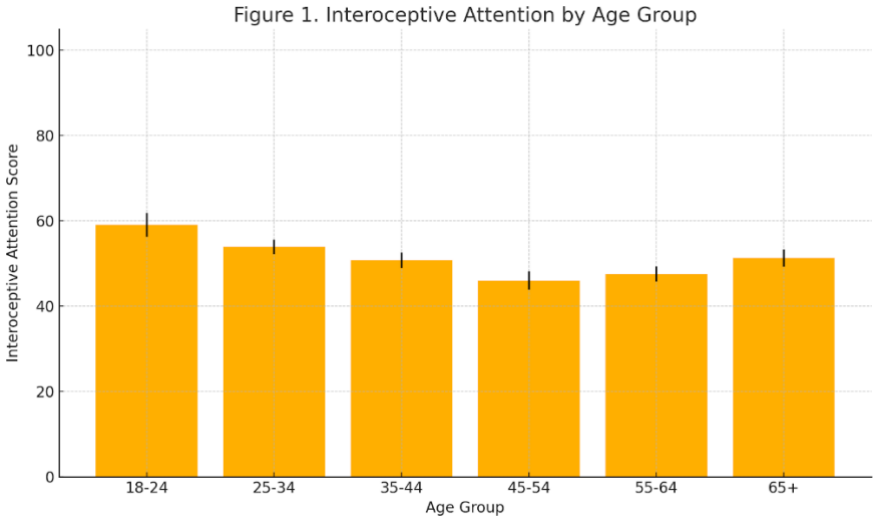


Figure 2.
Interoceptive accuracy by Age Group.

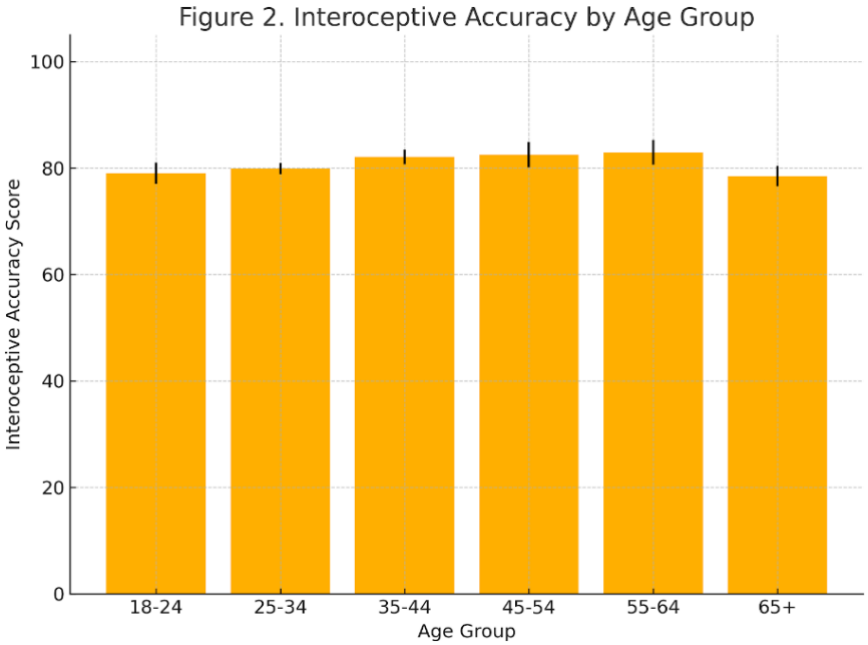
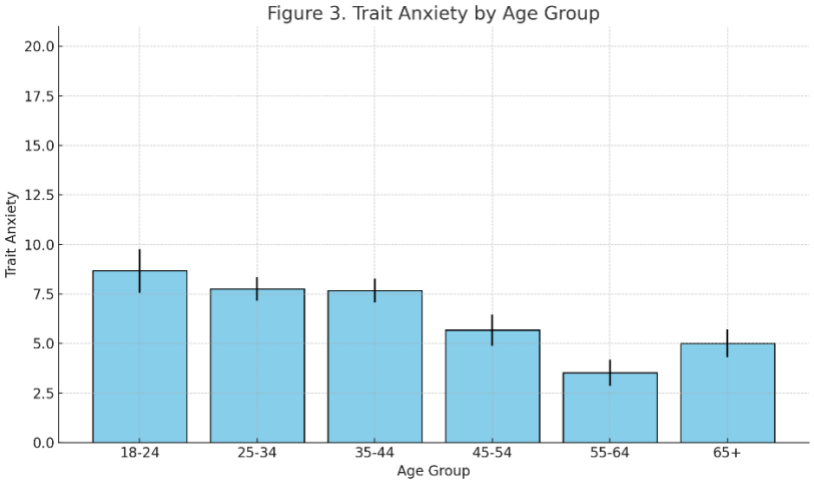


Figure 3.
Trait anxiety by Age Group



3.4 Primary analyses and results

We ran regression models in order to examine whether our variables of interest predicted sleep difficulties. The outcome variables selected for the first regression model was GSD, i.e. the composite score from the PSQI. For the second regression model, SOL was selected as the outcome variable, in order to explore whether our variables of interest had a specific role in predicting SOL.

3.4.1 Regression Model A: GSD

The first hierarchical regression focused on the role of our key variables in predicting overall sleep difficulty. Based on the initial correlational analyses, only variables associated with GSD at a *p* value < *.2* were included in the regression model (Crucianelli et al., 2018). Other sleep variables were not included in the model as these variables already contribute to the GSD score. The predictors were entered in two blocks. Step 1 included age (category), Sex (1 = male, 2 = female), and trait anxiety (GAD-7). The reason for entering these variables in Step 1 is that there are established differences in sleep behaviours and experience of sleep difficulty in relation to these variables (Carskadon & Dement, 2011; Chokroverty, 2017; Zheng et al., 2018). Step 2 added our main variables of interest, hypothesized to relate to sleep difficulty: the social skills and switching subscales of autistic traits (AQ28), interoceptive attention, interoceptive accuracy, high temperature sensitivity, and thermoregulation.

3.4.2 Regression Model A: Assumption Checks

The assumptions required for multiple regressions were evaluated prior to examining the model results. Independence of errors was supported by a *Durbin–Watson* statistic of *2.03*, indicating residuals were not significantly autocorrelated. Multicollinearity was not a concern: all variance inflation factors were well below the common threshold of 10 (highest *VIF = 1.54*) and tolerance values were all above *0.65*. This suggests the predictors had minimal overlap and each contributed unique variance.

Checks for outliers found no significant issues. Cook's distance values were all low (with a maximum = *0.05*). All cases (*N=234*) were retained in the analysis. The normality assumption was evaluated via histogram and P-P plots. Examination of the histogram indicated a normal distribution with no severe skew. In summary, all the assumptions for regression were adequately met. Table 5 shows the model for Regression A, detailing the structure. This model excluded PSQI component sleep scores in order to avoid the overlap in scores skewing the statistical analysis. Total scores for the autistic traits measure (AQ28) and its component factor social behaviours were also excluded from the model, to avoid issues of collinearity with their component subscales. Only the subscales factors indicated as relevant (bivariate correlation of $p < .2$) were included.

Table 5.
Regression Model A

Step	Variable
Predicted Outcome Variable	GSD Score (PSQI)
Step 1	Age (Categories)
	Sex (1=male, 2=female)
	Trait anxiety (GAD-7)
Step 2	

	Interoceptive attention
	Interoceptive accuracy
	Social skills (AQ28 subscale)
	Switching (AQ28 subscale)
	High temperature sensitivity
	Thermoregulation

Note. Component Sleep Scores exclude from model as they already contribute to composite Global Sleep Score. Additionally, overall autistic traits score excluded from model, only the significant ($p < 0.2$) subscales included.

3.4.3 Regression A: Results

Step 1 of the model was statistically significant, $F\ (3,230) = 24.58,\ p< .001$. The Step 1 predictors (age, sex, and trait anxiety) together accounted for 24.3% of the variance in sleep difficulty ($R^2= 0.24$). Both age and trait anxiety were highlighted as significant predictors of GSD. Older age was associated with higher GSD ($B = 0.58,\ \beta = 0.23,\ p < .001$), whilst higher trait anxiety was also associated with greater GSD ($B = 0.36,\ \beta = 0.49,\ p < .001$).

Step 2 of the model was also significant, $F\ (9,224) = 9.39,\ p< .001$. The R^2 value increased to *0.27*, indicating that approximately *27%* of the variance in GSD was predicted by the variables in this step of the model. This represents a *0.03* increase in R^2, which is not a statistically significant change. Full coefficients for the final step of Model A are presented in Table 6.

Table 6.
Hierarchical Regression Co-efficients (predicting GSD)

Predictor	B	SE B	β	t	p	95% CI for B
Age	.600	.158	.239	3.801	<.001	[0.29, 0.91]
Sex	.285	.446	.040	.639	.524	[−0.59, 1.16]
Trait Anxiety (GAD-7)	.341	.049	.463	6.891	<.001	[0.25, 0.44]
Social Skills (AQ28)	-.016	.054	-.020	-.288	.773	[−0.12, 0.09]
Switching (AQ28)	-.086	.096	-.062	-.903	.368	[−0.27, 0.10]
Interoceptive Attention	.032	.016	.121	1.964	.051	[0.00, 0.06]
Interoceptive Accuracy	-.032	.019	-.100	-1.664	.098	[−0.07, 0.01]
High Temperature Sensitivity	.055	.043	.082	1.271	.205	[−0.03, 0.14]
Thermoregulation	-.028	.039	-.045	-.737	.462	[−0.10, 0.05]

Note: Regression co-efficients from regression model A predicting Global Sleep Difficulty (GSD).

In the overall model for Regression A (including all predictors), age and trait anxiety remained the only significant predictors of GSD, explaining *24.3%* of the variance. Adding interoceptive and thermoceptive variables did not significantly improve the model. Age continued to show a positive association with sleep difficulty (*B = 0.60, β = 0.24, t = 3.80, p < .001*). Trait anxiety also remained a strong positive predictor in Step 2 (*B = 0.34, β = 0.46, t = 6.89, p < .001*). These results suggest that older individuals and those with higher trait anxiety tend to report greater global sleep difficulties, even after accounting for all other predictors in the model.

3.5 Regression Model B: SOL

A hierarchical multiple regression was conducted to examine predictors of SOL. For this variable, the SOL in minutes were used as the predicted outcome variable rather than the converted PSQI subscale scores ranging from 0-3. This was done in order to get a more accurate analysis of the relationships between sleep onset difficulties and our key predictor variables. As with Regression Model A, based on the initial correlational analyses, only variables associated with SOL at a *p value* < *.2* were included in the regression model (Crucianelli et al., 2018). Other sleep variables were not included in the model as these variables may create collinearity issues. The predictors were entered in two blocks. Step 1 included trait anxiety (GAD-7), sex, and age (Categories). Step 2 added the variables interoceptive attention, interoceptive accuracy, social skills (AQ28 subscale), switching (AQ28 subscale), high temperature sensitivity, and thermoregulation. Table 7 shows the model structure.

Table 7.
Regression Model B

Step	Variable
Predicted Outcome Variable	SOL (SOL - in minutes)
Step 1	Age (Categories)
	Sex
	Trait anxiety (GAD-7)
Step 2	
	Interoceptive attention
	Interoceptive accuracy
	Social skills (AQ28 subscale)
	Switching (AQ28 subscale)
	High temperature sensitivity

Note: Component Sleep Scores exclude from model to avoid issues of collinearity. Global score for AQ28 also excluded to avoid overlap causing issues of collinearity

3.5.1 Assumption Checks

The assumptions of the regression (linearity, independence, homoscedasticity, normality, and collinearity) were examined and found to be met. Residuals of the regression were normally distributed. trait anxiety was the only predictor with a significant effect in the model, so the residual distribution closely mirrored that of SOL itself. Examination of the regression residuals histogram suggested that they are normally distributed, supported by the bell-shaped histogram. Examination of the *P-P plot* confirmed normality. The scatterplot confirmed linearity and homoscedasticity. Residuals were randomly scattered around zero. No issues with multicollinearity were detected. All predictors had tolerance values > *.1* and *VIF* < *10*. The *Durbin–Watson* statistic was *2.19*, suggesting independence of residuals.

3.5.2 Regression Model B Results

Step 1 of the model was significant, ($\Delta R^2 = .031, F \approx 3.66, p = .027$) accounting for *3.1%* of the variance. trait anxiety (GAD-7) was the only significant predictor.

The additional Step in the model included interoceptive variables, high temperature sensitivity, and autistic trait subscales (social skills, switching). Step 2 overall was not significant ($F(7, 226) = 1.15, p = .336, R^2 = .034$), with a R^2 change of *0.004* to the model from Step 1 ($p = .975$). Table 8 shows full details of the coefficients for each predictor variable.

Table 8.
Hierarchical Regression Co-efficients (predicting SOL in minutes)

Predictor	B	SE B	β	t	p	95% CI for B
Age (Categories)	0.91	1.41	.05	0.65	.518	[-1.87, 3.70]
Sex	~0.00	1.40	~.00	0.01	.995	[-2.75, 2.77]
Trait anxiety (GAD-7)	1.02*	0.46	.17	2.22	.027	[0.12, 1.91]
Interoceptive attention	0.12	0.15	.05	0.78	.436	[-0.17, 0.41]
Interoceptive accuracy	-0.05	0.18	-.02	-0.28	.781	[-0.41, 0.31]
Social skills (AQ28 subscale)	0.04	0.50	.01	0.08	.935	[-0.94, 1.02]
Switching (AQ28 subscale)	-0.33	0.90	-.03	-0.37	.713	[-2.10, 1.43]
High temperature sensitivity	0.06	0.40	0.01	0.16	.876	[-0.73, 0.85]

Note: Regression co-efficients from regression model B predicting sleep onset latency (SOL).

Overall, this final model for Regression B indicated that trait anxiety was the only included variable that significantly predicted SOL.

3.6 Summary of Results

The range of analyses conducted and reported in this chapter each give an insight into the sample and how each variable relates to each other. Descriptive statistics were examined, as well as independent t-tests, analyses of variance, and bivariate correlations were conducted prior to two hierarchical regression models being employed.

Descriptive statistics revealed the sample had a good balance of biological sex and a wide age range. Further exploration of group differences revealed sex differences in, numbers/patterns (autistic trait subscale), and in thermoregulation. Males reported higher scores on numbers/patterns. Females scored higher on thermoregulation. No other variables showed significant differences by sex.

Analysis of variance found significant differences across age categories in interoceptive attention and trait anxiety. In both of these variables younger adults reported higher scores, with scores gradually reducing across middle years and starting to rise again in older adults. No other variables had significant age category differences. False Discovery Rate (FDR) correction was applied to the t-tests, ANOVAs, and correlation analyses to control for multiple comparisons. Only the significant t-tests and ANOVA results mentioned here remained significant following correction.

Bivariate correlations were used to select variables to be included in regression models ($p < .2$), but also identified multiple statistically significant ($p < .05$) relationships between variables. GSD was positively correlated with trait anxiety. GSD was also positively correlated with interoceptive attention and high temperature sensitivity. GSD was negatively correlated with interoceptive accuracy. Autistic traits were positively correlated with interoceptive attention and negatively correlated with interoceptive accuracy. Autistic traits were also positively correlated with high temperature sensitivity. In addition, high temperature sensitivity was positively correlated with interoceptive attention and negatively correlated with interoceptive accuracy. After applying FDR correction for multiple comparisons, all of the GSD correlations survived the correction apart from the correlation with autistic. traits,

which did not survive FDR correction. However, no correlations with SOL survived the multiple comparisons correction.

Hierarchical regression modelling allowed for more complex examination of the relationship between variables. Regression A predicted GSD. The final model showed that trait anxiety and age were the only significant predictors, with trait anxiety being the strongest predictor. Regression B predicted SOL. This regression model found that trait anxiety was the only significant predictor of SOL. Further consideration of the possible implications of these analyses in light of current literature will be considered in the next chapter.

4. Discussion

4.1 Introduction

This chapter will consider the implications and significance of the results of the present study in the context of existing published literature. We investigated the relationship between sleep difficulties, autistic traits, and interoceptive processes, with particular attention to thermoregulation. Sleep difficulties are highly prevalent among autistic individuals (Halstead et al., 2021), yet there remains limited research into the mechanisms that contribute to these difficulties. Crucially, autistic adults currently lack access to evidence-based sleep interventions that are both adapted to their needs and informed by causal pathways (Nijhof et al., 2024).

Interoceptive differences are increasingly recognised as core features of many autistic people's experiences (Shah et al., 2016), and interoceptive processing has been linked to sleep regulation (Wei & Van Someren, 2020; Bynum & Briindle, 2024). Despite this, no published studies to date have directly investigated the role of interoception or thermoregulation in autistic sleep, even though this relationship may have important implications for clinical understanding and intervention design.

Perception of body temperature, as a specific domain of interoception, is a growing focus in the literature (Crucianelli & Ehrsson, 2022). Sleep itself is a process highly dependent on thermoregulation, with changes in body temperature playing a critical role in sleep onset (Raymann et al., 2007) and thermal stability supporting sleep maintenance (Heinze & Golz, 2019; Raymann et al., 2008). Taken together, this theoretical groundwork

suggests that interoceptive and thermoceptive differences may contribute to sleep disturbances in individuals with high autistic traits.

The aim of this study was to explore whether self-reported interoceptive and thermoregulatory traits are associated with sleep difficulties in a general population sample. Using validated self-report measures in an online survey, this study examined correlations among sleep variables (Buysse et al., 1989), interoception (Gabriele et al., 2022; Murphy, 2020), thermoregulation. (Vergara et al., 2019), autistic traits (Hoekstra et al., 2011), and anxiety (Löwe et al., 2008). This exploratory approach aims to lay the groundwork for more targeted future research, including physiological investigations and clinical trials that directly involve autistic participants.

4.1 Findings

This was an online correlational study utilizing validated, subjective, self-report measures to explore relationships between autistic traits, interoceptive differences, sleep difficulties, and temperature sensitivity in the general, adult population. Data were analysed to explore descriptive statistics, bivariate correlations, and two separate hierarchical regressions predicting global sleep difficulty (GSD) and sleep latency (SOL), respectively. GSD is a global score calculated using the PSQI which is comprised of several component scores for aspects of sleep difficulty. Higher GSD scores mean greater sleep difficulty. SOL is the estimated time (in minutes) that it usually takes someone to fall asleep, as reported by participants when completing the PSQI. Higher SOL scores indicate longer time taken to fall asleep and higher SOL scores are a key indicator for insomnia.

4.1.1 Demographic Factors: Age Categories and Sex

There were notable differences across ages for trait anxiety and for interoceptive attention. T-test analyses revealed that trait anxiety was highest for the 18-24 age category, and gradually reduced for each ensuing age category until it reached its lowest point for the 55-64 years category, before increasing again for the 65+ category (See Figure 3, Chapter 3). These findings are in line with previous research showing that trait anxiety tends to decrease as people age (Spalding et al., 2021). However, these differences may be due to other unmeasured confounding variables such as changes in lifestyle and socioeconomic factors affecting individuals across age categories differently (Booth et al., 2016; Twenge, 2000). While a correlational study such as this one cannot shed light on the causation of this pattern, the existing literature suggests that both the process of ageing and differing generational conditions are a factor.

Interestingly, a similar pattern of gradual reduction and then late resurgence across age categories was found for interoceptive attention. Interoceptive attention was at its highest amongst 18-24-year-olds, and gradually declined across age categories, reaching its lowest point in the 45-54 category, before starting to ascend again for 55–64-year-olds and 65+. This U pattern may also be suggestive of changes across the lifespan. Interoceptive attention appears to peak in younger adults, decline through midlife, and then increase again in later years. This resurgence may reflect older adults' increased sensitivity to pain or bodily discomfort (Spalding et al., 2021). This may relate to physical ageing and people becoming more attentive to the sensations of pain and loss of strength in their ageing bodies (Spalding et al., 2021). These age-related trends align with previous research showing that anxiety and interoceptive attention both tend to decline with age (Spalding et al., 2021; Murphy et al., 2017; Dobrushino et al, 2022). Speculative explanations for this could include improved

emotional regulation with age, sensory attenuation, or changes in the relevance and salience of bodily cues across the lifespan (Booth et al., 2016; Pfeifer & Cawkwell, 2025).

Importantly, younger adults in this study reported higher interoceptive attention, but this was not accompanied by greater interoceptive accuracy. Interoceptive attention and accuracy are distinct dimensions that can be measured independently (Gabriele et al., 2022; Murphy, 2020). While interoceptive attention showed clear variation across age groups, interoceptive accuracy displayed only a small positive correlation with age and a more subtle pattern of change. This distinction reinforces that attending more to internal signals does not necessarily mean interpreting them correctly.

This aligns with Trevisan et al. (2023), who found that individuals with high interoceptive attention but low accuracy were more likely to report health anxiety—suggesting that heightened attention without accurate interpretation may reflect hypervigilance or worry rather than beneficial bodily awareness. In the present study, younger participants reported both higher trait anxiety and greater attention to bodily sensations, potentially reflecting a similar form of maladaptive monitoring.

Although interoceptive attention displayed clear age-related trends, this study did not find convincing evidence for parallel developmental changes in interoceptive accuracy. Scores for accuracy showed a gradual increase from ages 18 to 64, followed by a decline in the 65+ group, resulting in a non-linear trajectory across the lifespan. This mirrors findings from Brennan et al. (2023) and Pfeifer et al. (2024), which suggest that age-related changes in interoception do not follow a simple linear pattern. For example, Brennan et al. (2023) reported that interoceptive accuracy tends to increase with age, while attention decreases—a general trend also observed in the current study.

Changes in both interoceptive attention and interoceptive accuracy across the lifespan remain underexplored and warrant further research. These factors should also be considered by clinicians working with ageing populations. Murphy et al. (2017) investigated the effects of ageing on interoceptive accuracy and interoceptive attention, finding that although interoceptive abilities declined with age, factors such as BMI helped explain individual differences in these trajectories. This current study did not collect data on BMI or other physiological measures, so it remains unclear whether BMI played a role in interoceptive changes within this sample. Together, these results support the idea that some components of interoception may change across the lifespan in complex ways (Brennan et al., 2023; Murphy et al., 2018; Pearson & Pfeifer, 2022). Interoceptive attention may reduce with age, possibly due to improved regulation or changing bodily priorities, while interoceptive accuracy may improve, perhaps due to accumulated experience and learning. However, the trajectory is not linear, and further research is needed to explore how interoception develops over time and relates to age-related factors such as hormonal changes, health status, and emotion regulation.

One significant open question that should be accounted for in future research in this area concerns the role of biological sex in relation to thermoception and interoceptive processes. In the present study, sex was significantly associated with thermoregulation. Interestingly, evidence demonstrates that females experience body temperature changes as part of their menstrual cycle (Alzueta et al., 2022; Baker et al., 2020; Shilaih et al., 2018), and during perimenopause and menopause (Deecher & Dorries, 2007; Zhang et al., 2021). As the present study did not collect data on participants' menstrual cycle status or their perimenopausal or menopausal stage, I was unable to assess the potential influence of hormonal fluctuations on interoceptive measures. Given the limited research on menstrual cycle phases, perimenopause, and menopause in autistic females, future studies should

prioritise exploring how these physiological transitions impact thermoception, interoception, and sleep within this underrepresented cohort.

In addition to age-related differences, a significant sex difference was found in thermoregulation, with females reporting higher levels than males. This finding aligns with prior research suggesting that females may experience more thermoregulatory disruption, particularly in relation to hormonal fluctuations across the menstrual cycle, perimenopause, and menopause (Alzueta et al., 2022; Baker et al., 2020; Shilaih et al., 2018; Deecher & Dorries, 2007; Zhang et al., 2021). These physiological processes can influence thermal perception, vasodilation, and temperature regulation — all of which may impact sleep quality and comfort. Although the present study did not assess hormonal status, it is likely that fluctuations in sex hormones contributed to the observed differences. This supports the call for future research to explicitly examine sex and gender-related biological factors when studying thermoregulation, interoception, and sleep. Given the growing evidence of menopause-related sleep and thermal disruption, especially among neurodivergent populations, clinicians should be attentive to these sex-specific factors when working with autistic women and other individuals affected by hormonal change.

4.1.2 Correlations

Several bivariate correlations were found between sleep difficulty and psychological, sensory, and autistic trait variables. These results are interpreted below in relation to prior literature, with a focus on the role of anxiety, interoception, and temperature sensitivity in sleep outcomes. I will first consider the variables significantly correlated with global sleep difficulty (GSD) before moving on to interoceptive correlations and exploring the dynamics observed in how interoceptive accuracy and attention correlate with other variables

differently. Following this, I will consider correlations with anxiety, thermoregulation variables, and autistic traits.

4.1.2.1 Global Sleep Difficulty

GSD was positively correlated with higher levels of trait anxiety, greater interoceptive attention and high temperature sensitivity. In relation to the body temperature measures, GSD was positively correlated with high temperature sensitivity (HST) but not with solitary thermoregulation. HTS is a self-reported sensitivity to higher temperatures, with higher scores indicating greater discomfort at higher temperatures. Solitary thermoregulation, on the other hand, measures a more complex construct of behavioural preference for warmth-seeking behaviours when experiencing colder temperatures or experiencing emotional distress. This correlation between HST and GSD fits with the wide range of literature linking the importance of body temperature to sleep processes (Alzueta et al., 2022; Harding et al., 2019, 2020; Raymann et al., 2008). The current literature highlights how sleep is facilitated by temperature changes in the body and how thermoregulation behaviours facilitate sleep and promote better sleep. These findings contribute to existing evidence by examining individual differences in temperature sensitivity in relation to sleep. I found that individuals who are more sensitive to high temperatures and more prone to experience discomfort at higher temperatures, are more likely to experience GSD.

GSD show a strong correlation with trait anxiety. Participants who reported higher levels of trait anxiety also reported greater sleep difficulties. This finding supports the opening premise of Chapter one: that sleep and mental health are linked in a bidirectional relationship with significant clinical relevance. This correlation aligns with an extensive body of research demonstrating that trait anxiety is a robust predictor of poor sleep quality, night-time wakefulness, and difficulties with sleep onset (Alfano et al., 2009; Buysse et al., 2008; Chokroverty, 2017; Cole et al., 2006; Henderson et al., 2023). Harvey's (2002) cognitive model of insomnia suggests that anxiety elevates pre-sleep cognitive and physiological

arousal, disrupts relaxation, and interferes with sleep onset and maintenance. This model fits well with the current findings, affirming that cognitive-affective factors play a substantial role in sleep disruption. However, additional correlations found in the present study suggest that sleep problems also involve broader perceptual and physiological factors which align with broader models of insomnia that consider both psychological and physiological contributors—such as Riemann et al.'s (2010) hyperarousal model.

In the present study, GSD was positively correlated with interoceptive attention and negatively correlated with interoceptive accuracy. While these correlations are consistent with the "Attentive-Inaccurate" profile described by Bynum and Brindle (2024), I cannot conclude that this specific phenotype is present in individual participants. Correlation does not imply that both features (high attention and low accuracy) necessarily co-occur within the same individuals. It is possible that some individuals in this sample had higher interoceptive attention, while others had low accuracy, without both traits overlapping in the same cases. Nevertheless, the pattern observed here—high attention and low accuracy both associated with sleep difficulties—mirrors prior findings and strengthens the case for further research into the role of interoception in sleep.

This attention/accuracy pattern may reflect differing mechanisms contributing to sleep problems. High interoceptive attention could indicate anxiety-driven hypervigilance, while low interoceptive accuracy may signal difficulty interpreting bodily cues needed for effective arousal regulation. Together, these traits may interfere with sleep-promoting behaviours. However, the data from this study are multiple simple correlations, not results from a multivariate or interaction model, which limits conclusions about profiles, and do not permit conclusions about directionality. It may be that sleep difficulties impair interoceptive functioning, that impaired interoception exacerbates sleep problems, or that both effects occur bidirectionally.

The present findings are consistent with theoretical models proposing that interoceptive processing is central to sleep regulation. Wei & Van Someren (2020) suggested that interoceptive ability—across multiple domains including cardiac, thermal, and nociceptive signals—plays a key role in sleep disturbances. The current data extend this framework by highlighting associations between global sleep difficulty and both heightened attention to, and reduced accuracy of, interoceptive signals.

These results should not be over-interpreted as identifying a singular interoceptive profile. Instead, they suggest that interoception plays a meaningful role in sleep experiences, potentially in distinct ways for different individuals. Some participants may present with high attention, others with low accuracy, and some with both. This underscores the clinical value of understanding a person's interoceptive profile when addressing sleep problems. Although more research is needed, especially with physiological or longitudinal data, these findings reinforce the transdiagnostic importance of interoception in mental health and sleep outcomes.

4.1.2.2 Interoceptive Attention and Accuracy

A consistent pattern emerged in this study's correlational findings: Global Sleep Difficulty (GSD), trait anxiety, high temperature sensitivity, and autistic traits were all positively correlated with interoceptive attention and negatively correlated with interoceptive accuracy. This pattern is notable as it highlights the importance of individual differences in interoception across multiple aspects of human experience, including sleep, physical. comfort, affect, neurodivergence, and mental health. Prior research showing that interoceptive attention and accuracy are dissociable constructs (Gabriele et al., 2022; Murphy, 2020; Suksasilp & Garfinkel, 2022) and understanding how these components of

interoception vary amongst individuals may help to guide clinical approaches in a broad range of clinical conditions. Interoceptive attention refers to the tendency to focus on bodily signals, while interoceptive accuracy reflects the ability to correctly interpret these signals. The observed pattern in this sample, highlights the clinical importance of individual differences in interoception across issues of sleep, anxiety, and sensory difficulties. Based on simple correlations alone, it is not statistically valid to treat the co-occurrence of high attention and low accuracy as a unified construct or to make inferences about its relationship with other variables. However, the importance of these correlational findings is that interoceptive attention and interoceptive accuracy are both separately indicated as being correlated with our key variables of interest. Therefore it is important to consider both these components of interoception in further research, clinical assessments, and treatment. Further research is needed to explore whether the specific the attentive-inaccurate profile indicated by other research (Bynum & Brindle, 2024; Trevisan et al., 2023) is relevant to thermoregulation, sleep, and autistic traits.

In relation to sleep, this was particularly evident: GSD was positively associated with interoceptive attention and negatively associated with interoceptive accuracy. These findings are consistent with those of Bynum and Brindle (2024), who reported similar correlations in two large general population studies, linking poor sleep quality to higher attention and lower confidence in interoceptive accuracy. While our study cannot identify causality or confirm whether these patterns represent a distinct interoceptive profile within individuals, they may reflect different contributing mechanisms. For example, greater interoceptive attention may reflect heightened awareness or vigilance to bodily states, possibly linked to anxiety or hyperarousal, while lower interoceptive accuracy may signal impaired ability to interpret these signals and downregulate arousal. Both could interfere with sleep onset and maintenance. These findings support Wei and Van Someren's (2020) model, which argues

that impairments in interoception across multiple domains (e.g. thermal, nociceptive, cardiac) are implicated in sleep disturbances.

Similar correlations were observed for trait anxiety: participants reporting higher anxiety showed greater interoceptive attention and lower interoceptive accuracy. This echoes the findings of Trevisan et al. (2023), who proposed that a combination of high attention and low accuracy may contribute to health anxiety. In our study, these correlations suggest that interoceptive processing may be an important factor in understanding how anxiety disrupts sleep. If individuals are highly attuned to their bodily states but lack clarity in interpreting them, this could heighten anxious arousal and make it more difficult to relax before sleep. The interplay between anxiety, hypervigilance, and uncertainty in bodily awareness may be particularly disruptive in pre-sleep contexts.

Autistic traits were also associated with this same pattern of correlations: a positive relationship with interoceptive attention and a negative relationship with accuracy. Although this study recruited from the general population rather than a clinically diagnosed autistic sample, the findings align with prior literature suggesting that interoceptive differences are relevant to autism (Shah et al., 2016; DuBois et al., 2016; C. Butera et al., 2023). The present data suggest that individuals with higher levels of autistic traits tend to focus more on bodily signals but may experience greater difficulty interpreting them accurately. This may contribute to emotion regulation difficulties and sensory sensitivities commonly reported in autistic populations (Garfinkel et al., 2016; Rodgers & Ofield, 2018).

These findings may be helpfully interpreted through monotropism theory (Murray et al., 2005), which proposes that autistic individuals often focus intensely on a narrow range of stimuli, sometimes to the exclusion of other relevant information. This attentional style could shape how interoceptive signals are processed—enhancing sensitivity in some domains

while limiting integration across sensory systems (Garau et al., 2023; Lawson, 2024a, 2024b). While speculative, future research may investigate whether interoceptive attention in autism is influenced by monotropic attentional patterns, and whether this helps explain sensory overload or difficulties with physiological self-regulation. Further research is also needed on thermal aspects of interoception.

High Temperature Sensitivity (HTS) also showed the same pattern of correlations: positive with interoceptive attention and negative with accuracy. This suggests that individuals who are more sensitive to thermal discomfort also tend to report heightened attention to their internal states, yet may struggle to interpret them precisely. This adds to emerging evidence that thermal interoception is a core component of broader interoceptive functioning (Crucianelli & Ehrsson, 2022). Thermoregulation is central to sleep initiation and maintenance (Harding et al., 2019), and dysregulated thermal awareness may exacerbate sleep problems. While our data do not confirm an "attentive-inaccurate" thermal interoceptive profile in individual participants, the pattern of correlations suggests that discomfort with temperature may be linked to broader interoceptive processing differences.

In summary, the pattern of positive correlations between interoceptive attention and key study variables (GSD, anxiety, autistic traits, HTS), alongside negative correlations with interoceptive accuracy, highlights the relevance of interoceptive processing across domains of sleep, emotion, and sensory experience. While we cannot determine whether a specific attentive-inaccurate interoceptive profile exists in individual participants, this consistent pattern of correlations suggests that interoception may function as a transdiagnostic factor relevant to a range of mental health and neurodevelopmental presentations. Future research should investigate whether different interoceptive profiles exist and explore how they might relate to treatment responsiveness—for example, whether those with low interoceptive accuracy benefit from different interventions than those with heightened attention. Clinically,

these findings underscore the value of incorporating interoceptive assessment into formulation, especially for individuals presenting with sleep, anxiety, or sensory difficulties.

4.1.2.3 Thermoregulation Correlations

In addition to the correlations found in relation to GSD and in relation to interoceptive variables, there were notable correlations across the two thermoregulation STRAQ-1 subscales. In addition to HTS being correlated with the higher attention and lower accuracy interoception pattern, a significant correlation was found between autistic traits and HST. This indicates individuals in the general population with higher autistic traits are more likely to experience discomfort when they perceive themselves experiencing higher temperatures. This finding has relevance for autistic people and may be an indication of a difference in some thermoceptive aspects of interoception in relation to autism. It is worth noting that the HTS scale is not about accuracy of temperature perception, but is primarily about discomfort with heat (Vergara et al., 2019). This finding warrants further exploration in autistic populations, given the variability in thermal comfort and sensory processing reported among individuals. In my clinical work I have come across multiple anecdotal reports of autistic individuals having notably atypical experiences of temperature (e.g. individuals turning the thermostat up extremely high in summer, or another individual reporting being very sensitive to cold even on a mild day). A recent review has shown mixed evidence regarding the nature of thermoceptive differences amongst autistic people (Casterman et al., 2024). Casterman et al. (2024) found some evidence of hyposensitivity to warm and cool stimuli, but also some evidence of no significant differences in thermal detection thresholds between autistic vs allistic groups (Casterman et al., 2024). This mix of evidence suggests that there is a difference in how autistic individuals process thermal interoceptive information, but this is not homogeneous across all autistic individuals (Casterman et al., 2024), with differences in thermoception being part of the sensory variance of individual differences on the autistic

spectrum. The correlation between autistic traits and HTS is noteworthy in the context of the mixed evidence available, and further research into thermoception and thermoregulation issues for this population is merited.

HTS was also positively correlated with trait anxiety. This indicates that individuals who report a higher tendency to feel anxious are also more likely to experience discomfort at higher temperatures. This may be related to the physiological aspects of affect and how body temperature changes are linked to various emotional experiences (Fischer et al., 2021; Sel et al., 2020), and emotions have physiological attributes, such as anxiety involving clammy hands, feeling too hot, or sweating (Fischer et al., 2021).

Solitary thermoregulation (STRAQ-1 subscale) was the least correlated variable of interest in this study. This variable was correlated positively with trait anxiety, as well as with sex. The correlation with trait anxiety indicates that individuals who have a higher tendency to be anxious also tend to engage in warmth-seeking behaviours when feeling distressed or cold. This fits with the affect-thermoregulation link proposed by the developers of the STRAQ-1 (Vergara et al., 2019). However, it does raise questions in light of the HTS-anxiety correlation discussed in the previous paragraph. How can higher trait anxiety correlate with both greater discomfort at high temperatures and increased warmth-seeking behaviours during emotional distress? These associations may reflect distinct sensory response profiles present in different individuals within the sample. As already specified, these are multiple simple correlations, not results from a multivariate or interaction model, which limits conclusions about profiles. However, it is also possible that these seemingly contradictory tendencies co-occur in some individuals under different physiological or contextual conditions. Referring to the literature can help us to parse the subtleties between these dynamics and provide understanding of the dynamic involved. There is evidence that thermoregulation is linked to anxiety (Fischer et al., 2021; Oka, 2015) and the evidence I

have found in our current study fits with these links. Changes in body temperature occur during anxiety, but the nature of these are affected by the intensity and timing of the affect, as well as individual thermoregulatory differences. During moments of acute anxiety, such as a panic attack, body temperature spikes (Sel et al., 2020), in some cases this can result in a 'psychogenic fever' where core body temperature can reach up to 41 degrees Celsius (Oka, 2015). After these initial periods body temperature drops (possibly due to sweating, and changes in heart-rate), which would then be a logical time for individuals seek warmth for comfort (perhaps a hot beverage, a blanket etc.) in response to this temperature drop. Repeated, or ongoing stress does not result in these spikes but induces an ongoing but slight elevation in body temperature throughout the day (Oka, 2015). There are specific profiles of thermoregulatory responses to various forms of anxiety, such as social anxiety, phobias, and panic disorders (Fischer et al., 2021). The findings of this study show a link between anxiety and thermoregulation that is consistent with the literature. However, more research is needed to clarify whether thermoregulatory profiles for anxiety differ, or are experienced differently, by autistic people. There is mixed evidence of differences in thermoception for autistic people (Casterman et al., 2024), but there is evidence that anxiety is more prevalent amongst autistic individuals (Jolliffe et al., 2023) and experienced differently, requiring adapted treatment (Jolliffe et al., 2023; Rodgers & Ofield, 2018).

4.1.2.4 Correlation Summary

These bivariate correlations highlight the complexity of how sleep difficulties relate to individual differences in interoception, temperature sensitivity, anxiety, and autistic traits. In particular, a consistent pattern emerged across several variables: higher global sleep difficulty was associated with greater interoceptive attention and lower interoceptive accuracy. While I cannot infer the presence of a specific interoceptive profile from these data, this pattern is theoretically meaningful and consistent with previous research linking interoceptive dissociation to sleep and anxiety difficulties (Bynum & Brindle, 2024; Trevisan

et al., 2023). Rather than representing a single unified trait profile across individuals, these associations likely reflect overlapping but distinct pathways through which interoceptive processes contribute to sleep disturbance. These findings also extend beyond the cognitive mechanisms proposed by Harvey's (2002) model of insomnia by suggesting that perceptual and physiological processes—including interoception and thermosensitivity—may also play a significant role in sleep difficulty (Wei & Van Someren, 2020; Riemann et al., 2010). Finally, given the high intercorrelation between several key variables, hierarchical regression analysis was a suitable approach to explore the relative contribution of these factors in predicting global sleep difficulty (GSD) and sleep latency (SOL), while accounting for well-established predictors such as age, sex, and anxiety.

4.2 Main Analysis A: Predicting Global Sleep Difficulty

While the previously mentioned bivariate correlations indicated connections between several pairs of variables in individual difference relevant to GSD, further analysis is required in order to understand to what extent each of these elements plays a role in GSD. This hierarchical regression offered further insight in the roles of anxiety, interoceptive factors, and autistic traits. The outcome variable for this model was GSD. Step 1 included age (category), sex, and trait anxiety. Step 2 introduced interoceptive accuracy, interoceptive attention, HTS, Solitary thermoregulation, and two subscales of autistic traits: social skills and switching.

The first step accounted for 24% of the variance in global sleep difficulty. Notably both age category and trait anxiety were found to be significant predictors of GSD. In Step 2, interoceptive variables, thermoception variables, and autistic traits were added to the model; although the full model remained significant, this step did not significantly improve model fit.

In the final model, age category and trait anxiety continued to significantly predict Global sleep difficulty. None of the interoceptive or temperature-related variables made a significant contribution when these control variables were included.

As expected, trait anxiety was a prominent predictor of global sleep difficulty and remained the most significant predictor of sleep difficulty in the model even after accounting for interoceptive and thermoceptive factors. The positive association between trait anxiety and sleep difficulty is consistent with existing evidence on the bidirectional relationship between sleep and mental health (Becker et al., 2018; Maddox et al., 2020). This finding further emphasises how important an understanding of sleep difficulties is to mental health care.

While other individual difference factors—such as interoceptive abilities and thermosensitivity—were implicated in the bivariate correlations, trait anxiety emerged as the most robust and consistent predictor of sleep difficulties. This central role of anxiety is in line with a substantial body of research demonstrating its impact on sleep quality and sleep onset latency (Alfano et al., 2009; Buysse et al., 2008; Chokroverty, 2017). It also aligns with Harvey's (2002) cognitive model of insomnia, which posits that worry-driven cognitive processes sustain hyperarousal and interfere with the initiation and maintenance of sleep.

However, anxiety is not purely a cognitive phenomenon—it also involves physiological arousal and autonomic dysregulation (Fischer et al., 2021; Sel et al., 2020). The Riemann et al. (2010) hyperarousal model of insomnia acknowledges this broader scope by integrating cortical, cognitive, and physiological activation pathways. The current study's findings suggest that interoceptive processing, and thermal interoception, in particular, may act as a subjective bridge between the physiological and cognitive elements of anxiety. Interoception may thus play a key role in how individuals experience and interpret the bodily arousal associated with anxious states (Palser et al., 2018; Quadt et al., 2021a;

Trevisan et al., 2023), which in turn may influence sleep onset and maintenance. In this way, interoceptive variables enhance Riemann's model by linking bodily arousal to conscious anxious cognition through perceptual pathways. While anxiety should remain a primary treatment target, these findings highlight the value of also considering sensory and interoceptive processes—particularly in populations with known interoceptive differences, such as autistic individuals. This finding is relevant for autistic adults. While we did not find that autistic traits predicted GSD, the correlation analyses highlighted a significant positive association between autistic traits and trait anxiety. Indeed, anxiety is more prevalent amongst autistic individuals than the general population (Jolliffe et al., 2023) and autistic people may find some experiences more stressful than an allistic individual might (Gillott & Standen, 2007). Anxiety symptoms can present differently in autistic individuals and approaches to treatment, such as cognitive behavioural therapy (CBT), can require specific adaptations for this population (Rodgers and Ofield, 2018). The evidence of a link between trait anxiety and autistic traits, together with a significant role of trait anxiety in predicting global sleep difficulty in this study, further highlights the need for clear clinical guidelines as to how to adapt treatments for this population. The NICE guidelines currently recommend CBT-i as the primary mental health treatment for insomnia and other sleep difficulties (*NICE Guidelines CKS*, 2024), and yet to my knowledge there is no evidence-base for its efficacy with this population, with no published research examining either generic or modified CBT-i treatments for autistic adults. There is a need for individualization of treatment informed by affective, interoceptive, and thermoregulatory factors to assist with treating anxiety and insomnia. There is evidence that interoceptive processes are linked to affect, to mental health, and psychopathology. While trait anxiety is the most prominent predictor of GSD, interoceptive and thermoregulatory processes are part of the psychophysiological affective mechanisms (Feldman et al., 2024; Harrison et al., 2021; Khoury et al., 2018; Murphy et al., 2018; Shah et al., 2016; Trevisan et al., 2023). A greater understanding of how these processes differ and are experienced by autistic individuals (Ben Hassen et al., 2023; C.

Butera et al., 2023; Garfinkel et al., 2016) will help to inform interventions targeting anxiety and sleep with this population.

4.3 Main Analysis B: Predicting Sleep Latency

In order to better understand the factors at play in difficulties falling asleep, a second hierarchical regression model was run with sleep latency as the outcome variable. Difficulty falling asleep is a key criteria for insomnia and is the most common symptom (Bootzin & Epstein, 2011*)*. Factors contributing to sleep latency may have important clinical applications. For this regression model, Step 1 included Age Category and Trait anxiety. Step 2 included interoceptive attention, interoceptive accuracy, high temperature sensitivity, social skills, and switching.

In Step 1, the model significantly predicted Sleep latency, explaining 3.1% of the variance. Only trait anxiety significantly predicted the model. The addition of variables in Step 2 did not result in a statistically significant improvement to the model. None of the interoceptive or thermoregulatory variables significantly predicted sleep latency, suggesting that pre-sleep arousal associated with anxiety may be the primary factor influencing time taken to fall asleep. These results reinforce anxiety's central role in both general and specific aspects of sleep difficulty.

Generally, the environmental context for sleep involves a reduction in external stimuli and decreased interaction with the environment. As exteroceptive input becomes less salient, internal experiences such as perseverative cognition and interoceptive sensations may become more prominent. We might hypothesise that during pre-sleep routines—when social demands and external tasks are reduced—any internal discomfort or emotional

distress is more likely to rise to conscious awareness. As Blaise Pascal (2005) observed, “All of humanity's problems stem from man's inability to sit quietly in a room alone.” Heightened anxiety or physiological hypervigilance may be particularly noticeable during these quieter moments, contributing to delayed sleep onset. In this context, interoceptive attention and accuracy may play a key role in how internal states are monitored, interpreted, and emotionally regulated.

Existing literature shows that perseverative cognition, including mind-wandering, is associated with poor sleep outcomes (Cárdenas-Egúsquiza & Berntsen, 2022; Fell, 2024). A recent preprint by Banellis et al. (2024) extends this work by introducing the concept of “body-wandering”—a form of mind-wandering centred on bodily sensations. Although still undergoing peer review, their initial findings suggest that body-wandering is associated with heightened physiological arousal and increased negative affect. These results are particularly relevant to the present study’s findings on the relationships between sleep difficulties, anxiety, and interoceptive attention. Together, this research points to the importance of attentional focus, affect regulation, and bodily awareness in shaping sleep quality. Future research should explore whether body-wandering contributes to delayed sleep onset and whether interventions that target attentional flexibility or interoceptive skills may help mitigate these effects.

4.3 Summary of Statistical Findings

This study sought to explore the relationships between sleep difficulties, interoception, thermoregulation and autistic traits. The goal in exploring this area was to establish a greater understanding of the directions for future research into sleep difficulties for autistic adults. The correlational online study recruited from the general population. Using validated self-report measures, we took the unique approach of exploring individual

differences across thermoregulation, interoceptive, autistic traits, anxiety, and sleep domains. In addition to finding interesting demographic patterns across age and sex, and multiple correlational patterns which shed light on these relationships, hierarchical regressions explored how these variables might predict GSD and SOL. In considering all these findings we will first look at anxiety's role in sleep difficulties, then interoceptive and thermoregulation factors, before finally considering what the findings indicate regarding autistic traits and how this may be relevant for autistic individuals.

The findings from this study suggest that trait anxiety plays a central role in sleep difficulties. Across all analyses, trait anxiety consistently emerged as the most robust predictor of sleep outcomes. As well as being correlated with GSD it was indicated as a correlate of SOL prior to FDR correction. Trait anxiety was the most prominent predictor in both regression models, and the only significant predictor of SOL. These findings are consistent with longstanding evidence linking anxiety to sleep onset delay, reduced sleep quality, and nocturnal arousal (Alfano et al., 2009; Buysse et al., 2008). This highlights the disruptive effects of anxiety on sleep through mechanisms such as heightened physiological arousal, worry, and impaired pre-sleep cognitive disengagement (Harvey, 2002; Alfano et al., 2009). These findings further support models that place anxiety as a transdiagnostic risk factor for sleep disturbance and reinforce the prioritisation of CBT for insomnia (CBT-I), particularly where anxiety is elevated (NICE, 2024). Notably, younger participants in our study reported significantly higher trait anxiety levels, mirroring population-level trends and suggesting potential developmental differences in affective regulation (Murphy et al., 2017). The age-related increase in interoceptive accuracy seen in our data may also play a role here, potentially helping older adults manage bodily arousal and emotional distress more effectively than younger counterparts.

While anxiety explained the greatest variance in sleep outcomes, several interoceptive and thermoregulatory variables also showed significant bivariate associations with GSD. Specifically, interoceptive attention was positively correlated with GSD, while interoceptive accuracy showed a negative correlation. This pattern suggests that greater attentiveness to internal bodily sensations tends to co-occur with poorer sleep, while greater interoceptive accuracy tends to co-occur with better sleep. Previous research has linked such mismatches between attention and accuracy to elevated anxiety and hypervigilance (Gabriele et al., 2022; Trevisan et al., 2023), and Bynum et al. (2024) also found that disrupted sleep was associated with this general pattern. These findings contribute to emerging understandings of interoceptive dysregulation, in which heightened bodily awareness without clarity may interfere with arousal downregulation—particularly relevant in contexts like sleep.

Given the strong link between anxiety and sleep difficulties, and the role of interoception in shaping how anxiety is experienced and regulated (Harrison et al., 2021; Sugawara et al., 2020), clinicians should consider interoceptive functioning as a relevant factor in both formulation and intervention. Interoceptive processes influence how individuals detect, interpret, and respond to physiological arousal, making them a potentially important mechanism in the development and maintenance of anxiety-related sleep problems. Assessing interoceptive attention and accuracy in clinical practice could help identify whether these perceptual processes contribute to heightened arousal or misinterpretation of bodily cues, informing more tailored and effective treatment approaches.

High Temperature Sensitivity (HTS) followed a similar pattern, correlating positively with interoceptive attention and negatively with accuracy. HTS was also significantly associated with GSD, although it did not remain predictive in the regression model. The literature on thermal interoception—particularly the work of Crucianelli and colleagues

(Crucianelli & Ehrsson, 2022)—frames temperature sensitivity as a key interoceptive modality, especially relevant to homeostasis and sleep onset. The failure of HTS to remain significant in the regression may suggest that its effect on sleep is mediated through general anxiety or discomfort. However, its role should not be discounted, especially for individuals reporting sleep disruption linked to temperature discomfort, as these may benefit from targeted sensory interventions. This current study's findings were in line with this established connection between thermoregulation and anxiety, with anxiety being correlated with HTS, and with Solitary thermoregulation. Importantly, there is evidence that anxiety has thermoregulatory aspects, with differing anxious presentations having their own thermoregulatory profile (Fischer et al., 2021). Anxiety can cause spikes in body temperature but can also disturb the natural changes of thermoregulation that occur in a body over the sleep/wake cycle. Again, our study cannot infer causality, but I speculate that thermoregulation's role in sleep disturbance may be a contributor to how sleep difficulties are affected by anxiety. This suggests a broader model of insomnia than Harvey's (2002) model that is not limited to cognition, but spans affective, interoceptive and thermoregulatory domains.

Given that both trait anxiety and interoceptive variables were significantly associated with sleep difficulties, the interplay between autistic traits, anxiety, and interoception may be clinically meaningful—even if autistic traits themselves were not direct predictors in the regression models. Autistic individuals frequently report difficulties with emotional regulation, sensory processing, and sleep, all of which may be influenced by interoceptive mechanisms. Henderson et al. (2023) suggested that the bidirectional relationship between sleep difficulties and mental health may be stronger for autistic people than for allistics.

In this study, higher autistic traits were correlated with higher interoceptive attention and also correlated with lower interoceptive accuracy—a pattern also observed for GSD, trait

anxiety and higher temperature sensitivity. While these associations do not confirm that this attentional-accuracy mismatch co-occurs in individuals, they suggest that such interoceptive dynamics may be relevant across multiple domains. These findings reinforce the need to move beyond using autism diagnosis as a standalone explanatory factor and instead examine the multiple factors contributing to sleep, such as anxiety, interoception, and sensory sensitivity. Identifying and addressing these underlying processes may support more targeted and effective interventions for autistic individuals experiencing sleep difficulties.

4.4 Limitations and Strengths

While this study has several limitations, it also offers important strengths that contribute novel insights to the literature on sleep in autism. This was one of the first studies to explore the intersection of sleep difficulties, interoception, thermoregulation, anxiety, and autistic traits in an integrated framework. By examining these domains together—rather than in isolation—the study provides a more nuanced understanding of the potential mechanisms underlying sleep disruption, particularly in relation to interoceptive mismatches and sensory sensitivity. The use of validated measures and a relatively large general population sample allowed for the identification of meaningful patterns that are both theoretically novel and broadly consistent with existing literature. Importantly, the study design was informed by patient and public involvement (PPI) consultation at the planning stage, ensuring that the research questions addressed issues of lived relevance and clinical importance. These strengths provide a strong foundation for future research while also helping to interpret the limitations outlined below.

Several limitations should be considered when interpreting the findings of this study. Firstly, the cross-sectional design means that we cannot draw any conclusions about causality. Although associations were found between anxiety, temperature sensitivity, and sleep difficulties, we cannot determine the direction of these relationships. For example, while anxiety may contribute to poor sleep, chronic sleep disruption and fatigue may also exacerbate anxiety symptoms. Longitudinal or experimental studies are needed to clarify these causal pathways.

Secondly, the use of a general population sample limits the generalisability of the findings to clinically diagnosed autistic individuals. Although the inclusion of autistic trait measures allows for exploration of dimensional associations, the range of autistic traits may have been restricted, and subclinical traits may manifest differently from those in formal autism diagnoses. This approach is a pragmatic one, allowing for recruitment of a large sample, and enabling exploration of individual difference variables on a novel topic without placing too high demands on autistic participants. The interpretation of its findings must be viewed in that context and with the hope that these findings can guide future research that will include autistic people in order to improve their quality of life. This limits the extent to which findings can be applied to autistic individuals. However, the associations found can serve to inform the direction of future research. Future studies using clinically diagnosed samples are needed to determine whether the observed patterns hold in autistic populations.

Thirdly, this study relied entirely upon the use of self-report measures, which introduces potential biases related to self-perception and accuracy. While the questionnaires used are well-validated, they may not fully capture the complexity of interoceptive or thermoregulatory processes. The inclusion of objective physiological measures—such as core body temperature, heart rate variability, or polysomnographic sleep data—would improve the precision and ecological validity of future research.

Fourth, although sleep latency was included as a separate outcome variable, it was measured through a single self-reported item. This item asked participants on average how long it had taken them to get to sleep in the past month. This limited the scope of analysis possible in terms of understanding the dynamics at involved with sleep latency. A more nuanced or multi-item assessment of sleep latency and pre-sleep arousal, paired with physiological measures could allow for data that would give clearer understanding of sleep latency difficulties.

In addition to these limitations, mental health measures beyond anxiety were not included in this study. For example, depression which has strong links to sleep difficulties, was not factored into the design and therefore cannot be accounted for in this sample. The reason for prioritizing anxiety, and not including a measure for depression was influenced by pragmatic factors: the need to limit the amount of items in the survey, and by the PPI consultation guidance: which specifically name anxiety as a key mental health factor that should be included. Future work should include validated measures for depression.

Finally, the study did not assess hormonal status or menstrual cycle phase, which may have influenced interoceptive and thermoregulatory responses, particularly among female participants. This omission limits interpretation of sex-related findings and highlights the importance of considering biological rhythms in future interoception and sleep research. This limitation is particularly relevant for autistic females, given that autistic experiences of puberty, menstruation, as well as perimenopause and menopause are emerging areas of research. While the sex-balanced sample in this study is a strength of the current study, further consideration during research design would help to improve the exploration of how sex relates sleep, thermoregulation, interoception and autistic traits.

4.5 Implications for Future Research

To my knowledge, this research is the first to explore the interplay of autistic traits, sleep difficulties, interoception and thermoregulation. This initial correlational study gives an indication of several avenues of further research that could be explored. While interoceptive and thermoceptive factors did not significantly predict sleep difficulty or latency in the final regression models, their significant bivariate correlations with sleep measures suggest they may nonetheless play a meaningful role—possibly as moderators, mediators, or components of broader neuro-biopsychosocial models of sleep. The aforementioned limitations of the current study highlight areas of focus for future studies: the collection of physiological data and longitudinal approaches, the recruitment of autistic participants in studies and inclusion in their design, and longitudinal approaches.

Collection of objective data is a key next step in exploring the role of interoception in autistic sleep difficulties. In addition to lab-based sleep studies, there are actigraphic and smartwatch-based approaches that could allow for insights into aspects of sleep (Girschik et al., 2012; Marino et al., 2013), as well as aspect of interoception (such as objective interoceptive accuracy e.g. heartbeat detection). Clearer insights into sleep latency difficulties, as well as night-time wakefulness and sleep-cycles could be explored alongside changes in temperature, thermoregulatory behaviours, and heart-rate changes. The heterogenous nature of autistic presentations and sensory profiles may be easier to understand when objective data can be collected on individuals, helping us to understand a wide range of complex sensory profiles in relation to sleep behaviours. The study protocol published by Gernert et al. (2024) in advance of their ‘STREAM: Stress in Autism’ study appears to be a promising avenue of research in this area, as it intends to collect

physiological data considering several of the factors highlighted in this study: sleep quality, sensory reactivity, and stress.

Future studies should consult and collaborate with autistic individuals in their development (Fletcher-Watson et al., 2019). There is a need to recruit autistic participants in order to get an accurate insight into the factors relevant for autistic individuals. Sleep studies, qualitative interviews, and self-report measures with autistic adults will all be able to contribute to a clearer picture of the factors involved in autistic sleep difficulties. Longitudinal studies would also be a beneficial approach in order to understand how autistic sleep difficulties change over the lifespan. This is particularly relevant given evidence of changes to interoceptive and trait anxiety variables across adulthood highlighted in this study. Age category was also found to be a significant predictor of sleep difficulty in the primary regression model, which adds to the importance of taking longitudinal approaches. Longitudinal studies could further add to the work by Charlton et al. (2023), and Halstead et al. (2021) in this area.

Another key implication of this study is the importance of considering trait anxiety in future sleep research**.** Across both regression models, trait anxiety emerged as the most robust predictor of Global sleep difficulty, consistent with established research in non-autistic populations. Given the elevated rates of anxiety among autistic adults (Jolliffe et al., 2023; Rodgers & Ofield, 2018), future research should explore how anxiety relates to interoception and sensory sensitivity to influence sleep. Investigating how alexithymia—a common co-occurring trait in autism (Ben Hassen et al., 2023)—relates to interoceptive difficulties and sleep disturbance may also be worthwhile, as it could provide an explanatory bridge between affective dysregulation and physiological dysregulation during sleep difficulty. The link between interoception and alexithymia has been explored before (Brewer et al., 2016; Murphy et al., 2018) and considered in the context of autism (Ben Hassen et al., 2023; Bird

& Cook, 2013; C. D. Butera et al., 2023; Shah et al., 2016). Given the interplay of affect, interoception, and autistic traits highlighted in this current study, alexithymia may have a role on sleep difficulties for autistic individuals, and further research should consider this as a variable to be included.

Future research should also include mental health measure beyond anxiety. This current study was limited to measure anxiety and therefore could not make inferences regarding the role of other mental health conditions in relation to sleep. Given the well-established connection between depression and sleep (Alfano et al., 2009; Buysse et al., 2008), future research should also collect validated depression measures.

In addition to the promising directions of research highlighted by the findings in the current study the literature review also found some additional gaps in research in this area. To my knowledge, there are currently no studies exploring CBT for insomnia (CBT-i) treatments for autistic adults, despite NICE guidelines recommending CBT-i as the primary treatment for insomnia in adults. The findings of the current study suggest that anxiety is an important component of autistic sleep difficulty, so CBT-i may indeed be helpful, but it would need to be appropriately adapted for autistic adults, and the efficacy of this adaptation would need to be supported by empirical research (Rodgers and Ofield, 2018). Acceptance and Commitment Therapy for Insomnia (ACT-i) showed promising initial results in a small pilot study (Lawson et al., 2023), but larger trials are needed to establish an evidence base. ACT-i is an approach that utilises mindfulness and promotes psychological flexibility which can be helpful in dealing with uncomfortable emotions such as anxiety, so could be a promising approach given the prominence of anxiety in the current study's statistical models. Future research could build on cognitive models of insomnia, such as Harvey's (2002) cognitive–attentional model, by incorporating individual differences in interoception (Bynum & Brindle, 2024; Wei & Van Someren, 2020) and thermoregulation. Anxiety emerged as the most

robust predictor of sleep difficulty, but anxiety is itself closely tied to interoceptive and thermoregulatory processing. Investigating how these factors relate, particularly in relation to sleep onset and hyperarousal, could help refine theoretical models of insomnia, with relevance to both neurotypical and neurodivergent populations.

Further intervention studies could be developed in collaboration with autistic contributors, and therapeutic frameworks, such as CBT-i or ACT-i should be adapted ina highly individualised manner that suits the individual receiving treatment. To adapt interventions in an autism-informed, and neuro-affirmative way, modifications could be made across these four domains:

- Openness to understanding. Clinicians would need to take time to develop greater understanding of the individual autistic experiences and viewpoints.
- Language and Metaphors. Interventions should ensure language and metaphors used are clear, understood as intended, and unambiguous.
- Sensory Profiles. Interventions should start with assessment of the individual's sensory and interoceptive profile. This can inform whether interoceptive training, attentional training, or environmental adaptations may be beneficial.
- Interventions should take into account an autistic individual's interests and preferences. Adapting to these individual characteristics may enhance engagement with therapy and remove barriers to progress.

Research involving sleep interventions with and without these adaptations will provide further evidence as to what interventions are effective for autistic individuals.

Delphi studies of professionals who have experience treating autistic adults for insomnia, may be a first step in developing appropriately adapted approaches as there is a

need to gain further insight into current practices in this area as highlighted by Halstead et al. (2021) in a UK context. Further qualitative studies of autistic patients in sleep clinics could give insight into what does or does not work, building upon the work of Nijhof et al. (2024) and Pavlopoulou (2020).

This current study had a relatively well-balanced sex representation in its sample. Correlations were found between sex and solitary thermoregulation. There is evidence that thermoregulation changes alongside hormonal changes in females (Alzueta et al., 2022; Baker et al., 2020; Deecher & Dorries, 2007; Shilaih et al., 2018). Female-focused sleep studies are needed to explore how hormonal changes across the lifespan affect sleep, particularly through interoceptive and thermoregulatory pathways. The omission of menstrual cycle, hormonal status, and menopause data was a limitation of the present study. Given that female participants reported higher thermoregulation scores, future research should investigate how thermal and interoceptive variability across hormonal stages influences sleep outcomes.

Lastly, once further sleep studies have given a greater sense of the role of interoception and temperature in autistic sleep difficulties, tailored interventions could be developed as a response. There is clear evidence that interoceptive training can help improve interoceptive abilities (Quadt et al., 2021a; Sugawara et al., 2020, 2024). A similar approach could be developed in improving attuning to physiological signals of sleep pressure, although consideration would need to be given to what aspect of interoception is being targeted. This study found a positive correlation between interoceptive attention and sleep difficulty, and a negative correlation between interoceptive accuracy and sleep difficulty. Attentional training, or mindfulness interventions that do not focus on the body could be explored as a method of reducing interoceptive attention to facilitate sleep onset. Future research should explore the intersection of anxiety, interoception, and

thermoregulation in autism. The current study found a consistent mismatch between interoceptive attention and accuracy in individuals with higher anxiety, GSD, and autistic traits. In autistic populations—where sensory sensitivity (Lawson, 2024; Shah et al., 2016) and autonomic dysregulation are common (Butera et al., 2023; Shah et al., 2016)—this mismatch could be especially pronounced (Garfinkel et al., 2016). Investigating how this pattern relates to sleep regulation and emotional functioning could help identify transdiagnostic pathways relevant to clinical care.

4.6 Clinical Implications

While further research is needed to support clinicians in working with autistic adults experiencing sleep difficulties, this study offers several useful principles that can inform current practice. Firstly, clinicians should be mindful of the heterogeneity of autistic presentations (Adams & Young, 2021). Each client has a unique sensory profile, with their own needs and experiences (Lawson, 2024; Rodgers & Ofield, 2018). The literature review highlighted the high prevalence of sleep problems among autistic adults, and clinicians should routinely ask about sleep in their assessments. Secondly, this study's analysis shows that factors such as sensory sensitivity, interoceptive traits, and anxiety change with age. This means that the needs of clients may shift across the lifespan, especially in later adulthood.

In addition to this, the correlational findings showed that multiple factors may contribute to sleep difficulty, including temperature sensitivity, interoceptive attention and accuracy, autistic traits, and trait anxiety. Clinicians should consider these variables in an individualised, formulation-driven approach and identify which factors are most relevant for the person in front of them. Interventions can then be tailored accordingly—whether through

cognitive strategies, sensory/environmental changes, or behavioural techniques (Adams & Young, 2021; Lawson, 2024; Quadt et al., 2021a; Rodgers & Ofield, 2018).

The interoceptive pattern found in this study—marked by high attention but low accuracy—was linked with anxiety, sensory sensitivity, and sleep difficulty. This suggests that interoceptive training may have value as a transdiagnostic intervention (Quadt et al., 2021a; Sugawara et al., 2020, 2024). Improving interoceptive accuracy or reducing unhelpful attentional focus could be beneficial not only for sleep but also for anxiety and other regulation difficulties (Quadt et al., 2021a; Sugawara et al., 2020). Meanwhile, the observed relationship between anxiety, temperature sensitivity, and thermoregulation points to an additional clinical opportunity: temperature-based interventions for anxiety and arousal regulation. Given the different thermoregulatory profiles observed across mental health conditions (Fischer et al., 2021; Sel et al., 2020), these interventions may serve as useful complements to psychological therapies. For example, Dialectical Behaviour Therapy (DBT) already includes elements of this in the TIPP skill (Temperature, Intense Exercise, Paced Breathing, Progressive Muscle Relaxation) (Linehan, 2015), which uses cold temperatures to reduce acute emotional intensity. Further adaptation and expansion of such techniques may support clients with heightened thermal reactivity or difficulty downregulating before sleep.

These findings also highlight the importance of a multidisciplinary team (MDT) approach. While psychologists and talking therapists are trained to address cognitive aspects of anxiety (Rodgers & Ofield, 2018; Spain & Happé, 2020), occupational therapists bring valuable expertise in managing sensory and interoceptive issues that may be beyond the scope of standard talking therapy. A collaborative approach is essential to fully address the range of physiological, behavioural, and emotional factors contributing to sleep disturbance in autistic clients (Adams & Young, 2021; Lai et al., 2019; Mandy, 2022).

Finally, the most consistent predictor of both global sleep difficulty and sleep latency in this study was trait anxiety. Encouragingly, this is a factor that clinicians are often well equipped to address. Supporting clients in reducing anxiety is likely to have a positive impact on sleep outcomes. However, anxiety is not just cognitive—it also has affective, sensory, thermoregulatory, and physiological dimensions (Fischer et al., 2021; Harrison et al., 2021; Jolliffe et al., 2023; Sugawara et al., 2020). Effective treatment must reflect this complexity.

Future studies should explore the complexity of these contributing factors for autistic people, as well as investigating viable interventions that target cognitive, affective, sensory, thermoregulatory, and physiological domains. Speculatively, I would suggest a possible model whereby differences in interoception contribute, not only to difficulties attaining/maintaining optimal body temperature for sleep, but that interoceptive atypicalities contribute to the effect anxiety has on arousal systems and sleep onset processes. Interoceptive attention and interoceptive accuracy, and thermal sensitivity may each play mediating or moderating roles in how anxiety influences both sleep onset and sleep quality. This speculative model could be tested in experimental research.

Sleep studies could combine qualitative and quantitative measures. For example, using the PSQI and the interoceptive measures from the current study alongside actigraphy or polysomnographic measures. Ambient, and body temperature data could also be monitored in parallel with movement during sleep, and STRAQ-1 thermoregulation, and mental health (e.g. depression and anxiety) self-report measures. Data from these methods could be analysed to test hypotheses relating to interoceptive and thermoregulatory roles mediating between affective states and sleep difficulty. Once there is further evidence and clarity for such model, intervention studies could explore the viability and efficacy of interventions across interoceptive, thermal, environmental, and arousal domains.

This thesis began by describing the bidirectional relationship between mental health and sleep: when one suffers, so does the other (Arora et al., 2021; Gernert et al., 2024; Henderson et al., 2023). The principle for clinicians to remember is simple: improving one domain may improve the other. But because both sleep and mental health involve more than cognition, our formulations and interventions should likewise reach beyond purely cognitive approaches.

Taken together, these clinical insights reinforce the complexity of sleep difficulties in general and autistic populations (Richdale & Schreck, 2009; Wei & Van Someren, 2020), and the need for multifaceted, individualised approaches. While this study offers a preliminary framework for understanding the interplay of anxiety, interoception, and sensory processing in sleep, further work is needed to refine interventions and translate findings into routine clinical care. The conclusion below summarises the key contributions of this study and their significance for future research and practice.

4.7 Conclusion

The goal of this study was to explore the inter-relationships between interoception, sleep difficulties, autistic traits, and thermoregulation. This work was informed by emerging evidence linking interoception to autism (Butera et al., 2023), research showing thermoregulation's role in sleep (Harding et al., 2020), and the well-documented sleep difficulties experienced by autistic adults (Charlton et al., 2023; Halstead et al., 2021; Pavlopoulou, 2020) —who often find standard interventions inadequate. Using validated self-report measures in a general population sample, this study examined how anxiety, temperature sensitivity, interoceptive traits, and autistic traits relate to global sleep difficulty and sleep latency.

Trait anxiety emerged as the most robust and consistent predictor of sleep difficulties, significantly predicting both global sleep difficulty and sleep latency. Age was also a significant predictor of global sleep difficulty, with younger adults reporting greater difficulties. Interoceptive attention and high temperature sensitivity were positively correlated with sleep difficulty, while interoceptive accuracy was negatively correlated—indicating a pattern of high awareness but low precision. Although these interoceptive and thermoregulatory traits did not remain significant predictors in regression models, their relationships with anxiety and autistic traits suggest they may contribute indirectly to sleep outcomes, perhaps through heightened arousal or sensory dysregulation.

These findings highlight the complexity of sleep difficulties and the relevance of emotional, sensory, and physiological mechanisms—particularly for autistic individuals. The 'attentive-yet-inaccurate' pattern of high interoceptive attention and low accuracy across several domains suggests a potentially meaningful transdiagnostic marker that warrants further investigation.

Future research should incorporate objective physiological measures, longitudinal designs, and direct involvement of autistic individuals to better understand and support sleep in this population. There is also a pressing need to develop and evaluate adapted sleep interventions for autistic adults, so that effective, evidence-based support becomes accessible to all who need it.

5. References

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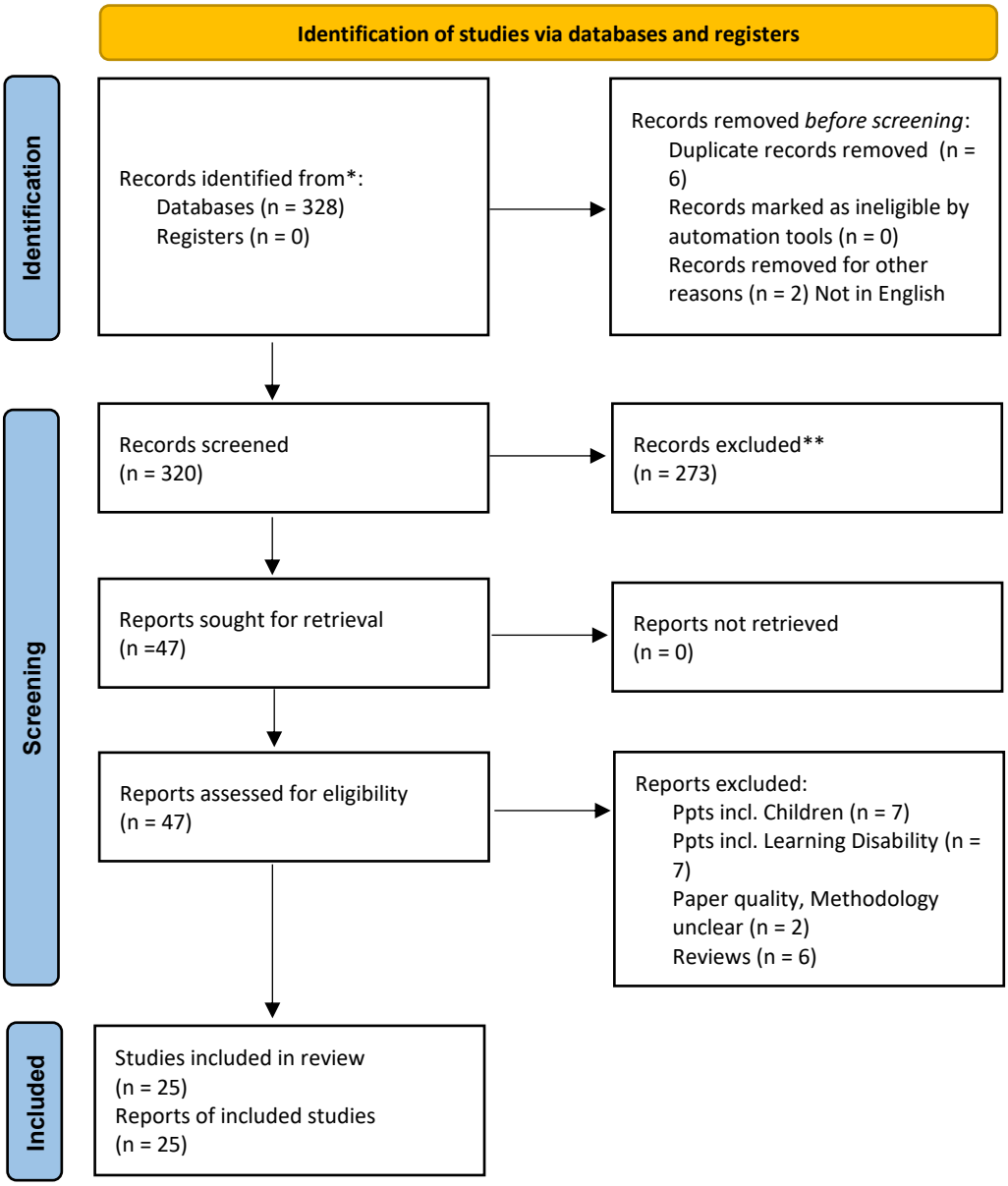
6. Appendices

Appendix 1. PRISMA Diagram



Appendix 2. Participant Information Sheet (in Methods, Ethics)

Invitation to our study

This is a study exploring how attention and interpretation of body signals are linked to sleep in different people. I would like to invite you to participate in this research project. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, it is important for you to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or you would like more information (contact details below).

Can I take part?

You must be 18 years or older to take part in this study.

The study

With this project, we want to better understand the association between individuals' attention and interpretation of internal body signals (an ability known as interoception) and sleep quality in different individuals. Participation is voluntary and you may choose to end the survey at any time. Choosing not to take part will not disadvantage you in any way.

As well as some questions about your sleep and your experience of body signals, we will also be asking general questions about lifestyle, personality and circumstances in order to explore the relationship between sleep and individual differences. Some of the questions will tap into autistic traits, because we are interested in whether there might be an association between autism and interoception.

The questionnaires will take approximately **30-40** minutes to complete. Feel free to complete the questionnaires on your phone, tablet or computer.

You have the right to withdraw at any point during the study, for any reason, and without any prejudice. However, please note that any data collected up to the point of your withdrawal will be retained and used in the study because we will not be able to identify your data.

What are the possible benefits of taking part?

This study is a novel exploration of how sleep quality is linked to attention and interpretation of body signals and body temperature. The findings could contribute to further research and lead to improved sleep interventions. If we can better understand the processes involved in good sleep, interventions that improve sleep can be designed to be more effective. Improving sleep quality is a key step in improving quality of life, and has been shown to improve mental health. It is hoped that this research will lead to better sleep quality, especially in autistic individuals or individuals with autistic traits.

Upon completion of the survey, you will have the chance to provide your email address for a chance to win a voucher as a thank you for giving your time to the survey.

What are the possible risks of taking part?
There are some questions below which are sensitive in nature, and it might be that you find these upsetting or difficult to answer. If you are unhappy completing questions, then please be aware that you can quit the survey at any point by simply clicking the 'Exit' tab on your screen.

If this questionnaire does elicit any worry or unwanted negative feelings and you would like to talk to somebody about it, please feel free to contact one of the organisations below:

Samaritans

Free listening services

These services offer confidential support from trained volunteers. You can talk about anything that's troubling you, no matter how difficult:

- Call 116 123 to talk to Samaritans, or email: jo@samaritans.org for a reply within 24 hours
- Text "SHOUT" to 85258 to contact the Shout Crisis Text Line, or text "YM" if you're under 19

If you're under 19, you can also call 0800 1111 to talk to Childline. The number will not appear on your phone bill.

NHS

Call 111 or contact your local GP.

National Autistic Society

https://www.autism.org.uk/

For Further information please see below links:

Sleep
https://www.nhs.uk/every-mind-matters/mental-health-issues/sleep/
https://www.nhs.uk/live-well/sleep-and-tiredness/
https://www.nhs.uk/every-mind-matters/mental-wellbeing-tips/how-to-fall-asleep-faster-and-sleep-better/

Autism
https://www.nhs.uk/conditions/autism/

https://www.autism.org.uk/

If you have any concerns about sleep difficulties, or anything else that has been mentioned in this study then you could contact your GP to discuss the best thing to do.

Ethics approval

This project has been reviewed on behalf of the University of Essex Science and Health Ethics Sub-committee, and had been given approval with the following Application ID: ETH2223-1585

Data gathered

- We will collect the following data from each participant: demographics information, your experience of sleep, your experience of different body sensations (e.g. heartbeat, temperature, hunger, etc) and information about autistic traits.
- Your experimental data will be fully anonymous, so that it is not possible to identify you from our stored data. If you decide to give us your email address, this will not be stored with your data.
- We are using your data to better understand sleep, body signals, perception of body temperature, and how these might relate to individual differences in autistic traits.
- Your data will be gathered by Peter Ryan and Dr Maria Laura Filippetti.
- Your anonymous data may be published in scientific journal articles, and shared in permanent, publicly accessible archives accessible from any country.

Concerns and complaints

If you have any concerns about any aspect of the study or you have a complaint, in the first instance please contact the Principal Investigators of the project (see contact details below). If you are still concerned or you think your complaint has not been addressed to your satisfaction, please contact the Director of Research in the Principal Investigator's department (see below). If you are still not satisfied, please contact the University's Research Governance and Planning Manager

Appendix 3.

Interoceptive Accuracy Scale

Below are several statements regarding how accurately you perceive specific bodily sensations. Please rate on the scale how well oyu believe you can perceive each specific signal. For example, if you often feel you need to urinate and then realise you do not need to when you go to the toilet you would rate your accuracy perceiving this bodily signal as low.

Please only rate how well you can perceive these signals without using external cues, for example, if you can only perceive how fast your heart is beating when you measure it by taking your pulse this would not count as internal perception.

1. I can always accurately perceive when my heart is beating fast
2. I can always accurately perceive when I am hungry
3. I can always accurately perceive when I am breathing fast
4. I can always accurately perceive when I am thirsty
5. I can always accurately perceive when I need to urinate
6. I can always accurately perceive when I need to defecate
7. I can always accurately perceive when I encounter different tastes
8. I can always accurately perceive when I am going to vomit
9. I can always accurately perceive when I am going to sneeze
10. I can always accurately perceive when I am going to cough
11. I can always accurately perceive when I am hot/cold
12. I can always accurately perceive when I am sexually aroused
13. I can always accurately perceive when I am going to pass wind
14. I can always accurately perceive when I am going to burp

15. I can always accurately perceive when my muscles are tired/sore
16. I can always accurately perceive when I am going to get a bruise
17. I can always accurately perceive when I am in pain
18. I can always accurately perceive when my blood sugar is low
19. I can always accurately perceive when someone is touching me non-affectionately
20. I can always accurately perceive when something is going to be ticklish
21. I can always accurately perceive when something is going to be itchy

Scale: Strongly Sgree (5), Agree (4), Neither agree nor disagree (3), Disagree (2), Strongly Disagree (1)

Appendix 4.

Interoceptive Attention Scale

Below are several statements regarding how much attention you pay to specific bodily sensations. Please rate on the scale how much attention you think you pay to each specific sensation. Think about how you feel during most situations in your daily life, rather than at a specific point in time. For example, if you often think about your heart beating, feeling hungry or needing the toilet then you would rate your attention to these sensations as high. In contrast, if you don't often think about your heart rate, how hungry you are or whether you need the toilet then you would rate your attention to these sensations as low.

Please only rate how much **attention** you pay to these sensations **regardless of how well you think you can perceive them**. For example, if you often feel you need the toilet but when you go to the toilet you realise you don't need to you should still rate your attention to this signal as high. Do not worry about how often you think the sensation is **truly** happening inside your body – we would like to know how much of the time you pay attention to these sensations.

The questions ask about your attention to feelings coming from **inside** your body. For example, if the question asks about temperature, it is referring to sensations you notice internally without using your hand to feel how warm your skin is, and if it asks about your heartbeat, it is referring to feelings you notice inside your body without taking your pulse.

1. Most of the time my attention is focused on whether my heart is beating fast
2. Most of the time my attention is focused on whether I am hungry
3. Most of the time my attention is focused on whether I am breathing fast
4. Most of the time my attention is focused on whether I am thirsty or dehydrated
5. Most of the time my attention is focused on whether I need to urinate
6. Most of the time my attention is focused on whether I need to defecate
7. Most of the time when I am eating, my attention is focused on different tastes

8. Most of the time my attention is focused on whether I am nauseated or need to vomit
9. Most of the time my attention is focused on whether I need to sneeze
10. Most of the time my attention is focused on whether I need to cough
11. Most of the time my attention is focused on the temperature of my body (feeling hot or cold)
12. Most of the time my attention is focused on whether I am sexually aroused
13. Most of the time my attention is focused on whether I need to pass wind
14. Most of the time my attention is focussed on whether I need to burp
15. Most of the time my attention is focussed on whether my muscles are tired or sore
16. Most of the time my attention is focused on whether I am in pain after I am hurt or injured
17. Most of the time my attention is focused on whether I am in pain (that is not caused by injury)
18. Most of the time my attention is focused on whether my blood sugar is low
19. Most of the time when someone is touching me, my attention is focussed on whether it is pleasant/affectionate
20. Most of the time my attention is focused on whether touch or materials feel ticklish on my body
21. Most of the time my attention is focused on whether my body feels itchy

Scale: Strongly Agree (5), Agree (4), Neither agree nor disagree (3), Disagree (2), Strongly Disagree (1)

Appendix 5.

Autism Quotient Scale (Abridged 28-item version: AQ28)

Below are a list of statements. Please read each statement and indicate how strongly you agree or disagree with it. Try not to spend too much time on any one statement. There are no right or wrong answers.

Participants respond using a 4-point Likert scale:

- Definitely agree
- Slightly agree
- Slightly disagree
- Definitely disagree

1. I prefer to do things with others rather than on my own
2. I prefer to do things the same way over and over again
3. If I try to imagine something, I find it very easy to create a picture in my mind
4. I frequently get so strongly absorbed in one thing that I lose sight of other things
5. *I usually notice car number plates or similar strings of information*
6. When I'm reading a story, I can easily imagine what the characters might look like
7. *I am fascinated by dates*

8. In a social group, I can easily keep track of several different people's conversations

9. I find social situations easy

10. I would rather go to a library than a party

11. I find making up stories easy

12. I find myself drawn more strongly to people than to things

13. I am fascinated by numbers

14. When I'm reading a story, I find it difficult to work out the characters' intentions

15. I find it hard to make new friends

16. I notice patterns in things all the time

17. It does not upset me if my daily routine is disturbed

18. I find it easy to do more than one thing at once

19. I enjoy doing things spontaneously

20. I find it easy to work out what someone is thinking or feeling just by looking at their face

21. If there is an interruption, I can switch back to what I was doing very quickly

22. I like to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant, etc.)

23. I find it difficult to imagine what it would be like to be someone else

24. I enjoy social occasions

25. I find it difficult to work out people's intentions

26. New situations make me anxious

27. I enjoy meeting new people

28. I find it very easy to play games with children that involve pretending

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Appendix 6.

Pittsburgh Sleep Quality Index

1. **During the past month, what time have you usually gone to bed at night?**
2. **During the past month, how long (in minutes) has it usually taken you to fall asleep each night?**
3. **During the past month, what time have you usually gotten up in the morning?**
4. **During the past month, how many hours of actual sleep did you get at night?**

(This may be different than the number of hours you spent in bed.)

5. **During the past month, how often have you had trouble sleeping because you:**
    - a. Cannot get to sleep within 30 minutes
    - b. Wake up in the middle of the night or early morning
    - c. Have to get up to use the bathroom
    - d. Cannot breathe comfortably
    - e. Cough or snore loudly

- f. Feel too cold
- g. Feel too hot
- h. Have bad dreams
- i. Have pain
- j. Other reason(s), please describe: _____

6. **During the past month, how often have you taken medicine (prescribed or over-the-counter) to help you sleep?**
7. **During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?**
8. **During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?**
9. **During the past month, how would you rate your sleep quality overall?**
10. **Do you have a bed partner or roommate?**

    If yes, ask them how often in the past month you have had:

- a. Loud snoring
- b. Long pauses between breaths while asleep
- c. Legs twitching or jerking while you sleep
- d. Episodes of disorientation or confusion during sleep
- e. Other restlessness while you sleep, please describe: _____

Appendix 7.
High Temperature Sensitivity (STRAQ-1 Subscale)

Participants rate each item using a **5-point Likert scale** with the following options:

- 1 = **Strongly Disagree**

- 2 = **Disagree**
- 3 = **Neither Agree nor Disagree**
- 4 = **Agree**
- 5 = **Strongly Agree**

Items:

1. I easily get uncomfortably hot.
2. I feel distressed when I am too warm.
3. I find it hard to fall asleep when it is too warm.
4. I have difficulty concentrating when I feel warm.
5. I often feel tired or drowsy when I am too warm.
6. I usually wake up because I feel too warm.

Appendix 8.
Solitary Thermoregulation (STRAQ-1 Subscale)
Participants rate each item using a **5-point Likert scale** with the following options:

- 1 = **Strongly Disagree**
- 2 = **Disagree**
- 3 = **Neither Agree nor Disagree**
- 4 = **Agree**
- 5 = **Strongly Agree**

Items:

1. When it is cold, I wear more clothing than others.

2. When it is cold, I more quickly turn up the heater than others.

3. When I am troubled I like to take a long warm shower to clear up my thoughts.

4. If I am feeling distressed I seek a warm place to calm down.

5. A warm beverage always helps me relax when I am down.

6. When I feel cold I don't turn on the heater. (reverse scored)

Appendix 9.

Generalised Anxiety Disorder Scale (Seven item version: GAD-7)

The GAD-7 (Generalized Anxiety Disorder 7-item scale) consists of the following questions. Each item is rated on a 4-point scale: **0 = Not at all**, **1 = Several days**, **2 = More than half the days**, **3 = Nearly every day**, based on the past two weeks.

Here are the 7 items:

1. **Feeling nervous, anxious, or on edge**
2. **Not being able to stop or control worrying**
3. **Worrying too much about different things**
4. **Trouble relaxing**
5. **Being so restless that it is hard to sit still**
6. **Becoming easily annoyed or irritable**
7. **Feeling afraid as if something awful might happen**